AMERICAN UNIVERSITY OF NIGERIA

VOL. 1

1ST AUN INTERNATIONAL CONFERENCE PROCEEDINGS

Research: A Tool For National Development And Innovation In The 21st Century

Chief Editors

Abubakar Sadiq Hussaini, PhD
Adewale James, PhD
Raed A. Abd-Alhameed, PhD
Rabiu Ibrahim, PhD

Conference Dates
14th – 15th November, 2023

www.aun.edu.ng/aunic2023

AMERICAN UNIVERSITY OF NIGERIA

AUNIC 2023

CONFERENCE HOSTS

DR. DEWAYNE FRAZIER

President,

American University of Nigeria, Yola, Adamawa State, Nigeria

- Chief Host

DR. ATTAHIR YUSUF

Provost,

American University of Nigeria, Yola, Adamawa State, Nigeria

- Co-Host

CONFERENCE CHAIR

Abubakar Sadiq Hussaini, PhD

Conference Chairman

Adewale James, PhD

Conference Co-Chair

Raed A. Abd-Alhameed, PhD

Conference Co-Chair

Rabiu Ibrahim, PhD

Conference Co-Chair

KEYNOTE SPEAKERS

Jimmy A. Reyes ***PH.D., DNP, AGNP, RN, FRE***

Department of Nursing and Public Health
University of Northern Iowa, United States

Keynote Title:
Facilitating International Community-Engaged Research and Collaboration across Disciplines

Amed Demirhan ***MLIS., MADR***

General Manager/Director,
Barzani National Memorial,
Kurdistan Federal Region - Iraq

Keynote Title:
Research: A Tool for National Development and Innovation In The 21st Century Sciences

Prof. Odekunle Mathew Remilekun

Modibbo Adama University,
Yola, Adamawa State

Keynote Title:
Choice, The Greatest Challenge To The Universality of Mathematical Research Results

Özcan Asilkan ***PROFESSOR & DEAN***

School of IT & Computing (SITC) American University of Nigeria (AUN), Yola

Keynote Title:
How To Realize An Effective Digital Transformation

TECHNICAL SUPPORT

e-ISSN: 3027-0650

www.aun.edu.ng/aunic2023

e-ISSN: 3027-0650
November 13-16, 2023

American University of Nigeria 1st International Conference (AUNIC2023)

AUN's goal is to create a platform for experts, academics, and practitioners to collectively address the role of research in driving innovation and development.

Research plays a vital role in shaping public policies and decision-making processes. The conference aims to provide policymakers with evidence-based insights and data-driven recommendations, enabling them to make informed choices that benefit the nation as a whole. Whether it's developing sustainable infrastructure, improving education systems, or tackling social issues, research provides the foundation upon which effective policies can be built. Research encourages scientists, researchers, and experts from different fields to come together, exchange ideas, and work towards common goals. Research is not just a tool for national development and innovation in the 21st century—it's the catalyst that drives progress, shapes our future, and unlocks our potential. By investing in research, we invest in our collective growth, prosperity, and well-being. The keynote speakers will share their invaluable insights, experiences, and success stories, inspiring us to embrace the power of research and its potential to transform our world. - ***Abubakar Sadiq Hussaini, PhD (Conference Chair)***

Conference Chair

Abubakar Sadiq Hussaini, PhD - Chairman
Dr. Adewale James - Co-chair
Prof. Raed A. Abd-Alhameed - Co-chair
Dr. Rabiu Ibrahim - Co-chair

Organizing Committee

Abubakar Sadiq Hussaini, PhD - Chairman
Dr. Adewale James - Co-chair
Prof. Raed A. Abd-Alhameed - Co-chair
Dr. Rabiu Ibrahim - Co-chair
Prof. DeWayne Frazier, President, AUN
Prof. Attahir B. Yusuf, Provost, AUN
Prof. Chris Mbah, Dean, School of Graduate Studies
Prof. Abdulmumin Sa'ad, Director, Academic Planning
Prof. Mohammed Yusuf Yusuf, Dean, School of Law
Dr. Patrick Fay, Dean, School of Arts & Sciences
Prof. Ozcan Asilkan, Dean, School of IT & Computing
Prof. Jonathan Rodriquez, IT, Aveiro University, Portugal
Dr. Issa Elfergani, Instituto de Telecomunicações, Aveiro, Portugal
Dr. Rana Zubo, Northern Technical University (NTU), Iraq
Mr. Benson Ali, University Librarian
Mr. Byron Bullock, Dean, Student Affairs
Mr. Anthony E. Fadaka, Registrar
Ms. Nnenna Mosugu, Head of Finance
Ms. Faizatu Ahmed Abubakar, Head of Human Resources
Dr. Ahmad M. Aliyu, Head of Sponsorship CMTE
Mr. Usoh Usoh, Head of Event and Venue
Mr. Dan Okereke, Head of Communications and Publicity
Mr. Mustapha Atiku Abubakar, Head of Logistics
Mr. Francis Chaming, Head of IT
Ms. Ndifreke Clinton, Head of Facilities
Mr. Yusuf Mohammed, Senior Director Public Affairs
Mr Noel Sashi, DD, Digital Resources
Ms. Emilienne Akpan, Head of Writing Center
Ms. Ogechi Danokereke, Head of Welfare CMTE
Dr. Lionel Rawlins, Head of Security
Mr. Daniel Ishaku, University Webmaster

Technical Program Committee

Prof. DeWayne Frazier, American University of Nigeria
Prof. Attahir B. Yusuf, American University of Nigeria
Prof. Chris Mbah, American University of Nigeria
Prof. Abdulmumin Sa'ad, American University of Nigeria
Prof. Mohammed Yusuf Yusuf, American University of Nigeria
Dr. Patrick Fay, American University of Nigeria
Prof. Ozcan Asilkan, American University of Nigeria
Prof. Sakah Saidu Mahmud, American University of Nigeria
Prof. (Mrs) Fadipe-Joseph, University of Ilorin, Nigeria
Prof. Raed A. Abd-Alhameed, University of Bradford, UK
Prof. Jonathan Rodriquez, IT, Aveiro University, Portugal
Dr. Issa Elfergani, Instituto de Telecomunicações, Aveiro, Portugal
Dr. Rana Zubo, Northern Technical University (NTU), Iraq
Prof. Umar Hamman Diram, American University of Nigeria
Prof. Suleyman BASTÜRK, Altınbaş University, Istanbul, Turkey
Prof. Joseph Sule Rishante, American University of Nigeria
Prof. M. B. Hammawa, University of Abuja, Nigeria
Dr. Abubakar Sadiq Hussain, American University of Nigeria
Dr. Adewale James, American University of Nigeria
Dr. Rabiu Ibrahim, American University of Nigeria
Prof. A. D Usman, Ahmadu Bello University Zaria, Nigeria

Prof. Maryam Ishaku Gwangudi, American University of Nigeria
Prof. Walid A. Al-Hussaibi, Southern Technical University, Iraq
Dr. Bello Magaji, American University of Nigeria
Dr. Abdulahi Momoh, Moddibbo Adama Fed. Uni. Nigeria
Prof. Leo U. Ukpong, American University of Nigeria
Prof. Peter A. Ocheme, American University of Nigeria
Prof. Mohamed Lashab, Université Larbi Ben M'hidiOum El-bouaghi, Algeria
Prof. Badeniyi Tosin, Durban University of Technology, SA
Dr. Ahmad M. Aliyu, American University of Nigeria
Dr. Oguz ATA, Altınbaş University, Istanbul, Turkey
Dr. Bolade Agboola, American University of Nigeria
Prof. Ibrahim Danjuma, American University of Nigeria
Prof. Olusola Ladokun, Lead City University Ibadan, Nigeria
Dr. Hayatu Raji, American University of Nigeria
Dr. Haruna Isa Mohammad, American University of Nigeria
Dr. Zuhairiah Zainal Abidin, Universiti Tun Hussein Onn Malaysia (UTHM))
Dr. Agatha Ukata, American University of Nigeria
Prof. Remilekun Odekunle, Moddibbo Adama Fed. Uni. Nigeria
Dr. Malachy Ifeanyi Okeke, American University of Nigeria
Prof. Ike Mowete, University of Lagos, Nigeria
Dr. Abdullahi Iliyasu, American University of Nigeria
Prof. Rajesh Prasad, African University of Science & Technology, Abuja, Nigeria
Prof. Yusuf Aboki, American University of Nigeria
Dr. Genger Peter, American University of Nigeria
Prof. Sam Musa, Moddibbo Adama Fed. Uni. Nigeria
Dr. Loveday N. Gbara, American University of Nigeria
Dr. Charles Nche, American University of Nigeria
Prof. S. S. Adamu, Bayero University Kano, Nigeria
Dr. Aamo Iorliam, American University of Nigeria
Prof. James Katende, Namibia University of Science & Technology,
Windhoek)
Dr. Yusuf Kani, American University of Nigeria
Prof. Oladipo Salami, American University of Nigeria
Dr. Hussein N. Fadhel, Northern Technical University (NTU), Iraq
Dr. Jennifer Tyndall, American University of Nigeria)
Prof. Yakunbu Bila, Tafawa Balewa federal University Bauchi
Dr. Samuel Utulu, American University of Nigeria
Dr. Olusegun Ogundapo, American University of Nigeria
Prof. Magaji Nurundeen, Bayero University Kano, Nigeria
Dr. Sirajo Yahaya, American University of Nigeria
Prof. Mohammad Patwary, Birmingham City University, UK
Dr. Doğu Çağdaş ATİLLA, Altınbaş University, Istanbul, Turkey
Dr. Salihu Adamu Girei, American University of Nigeria
Prof. Dimosthenis Trimis, Karlsruhe Institute of Technology, Germany
Prof. Kostas Voudouris, University of Athens, Greece
6Prof. Adeyemi Olagunju, Federal University Lafia, Nigeria
Dr. Munzali Ahmed Abana, American University of Nigeria
Prof. Danjuma Jibasen, Moddibbo Adama Fed. Uni. Nigeria
Dr. Jennifer H Mike, American University of Nigeria
Prof. Yusuf Daberi Mamman, Moddibbo Adama Fed. Uni. Nigeria
Dr. Lucky Osagie Imade, American University of Nigeria
Prof. Suleyman BASTÜRK, Altınbaş University, Istanbul, Turkey
Dr. Solomon Donsanda, American University of Nigeria
Dr. Olutayo Folashade Martins, American University of Nigeria
Dr. Isah Nusa Danjuma, Nigerian Defence Academy Kaduna, Nigeria
Dr. Salu George Thandekkattu, American University of Nigeria
Dr. Abubakar Ahmed, American University of Nigeria
Dr. Abbey Chukwuemeka Patrick, American University of Nigeria
Dr. Mustapha Babagana, University of Maiduguri Borno-Nigeria
Dr. Mathew Ayobami, American University of Nigeria, Yola
Dr. Ikechukwu Williams Eke, American University of Nigeria
Dr. Huthaifa Obeidat, Jerash University, Jordan
Dr. Mahmoud Ahmad Mahmoud, American University of Nigeria
Prof. Adeyefa Emmanuel, Federal University, Oye-Ekiti, Nigeria
Dr. Muhammed Falalu Yahaya, American University of Nigeria

Steering Committee

Abubakar Sadiq Hussaini, PhD - Chairman
Dr. Adewale James - Co-chair
Prof. Raed A. Abd-Alhameed - Co-chair
Dr. Rabiu Ibrahim - Co-chair
Prof. (Mrs) Fadipe-Joseph, University of Ilorin, Nigeria
Prof. Jonathan Rodriquez, IT, Aveiro University, Portugal
Dr. Issa Elfergani, Instituto de Telecomunicações, Aveiro, Portugal
Prof. Chris Mbah, American University of Nigeria
Prof. Abdulmumin Sa'ad, American University of Nigeria
Prof. S. S. Adamu, Bayero University Kano, Nigeria

Prof. James Katende, Namibia University of Science & Technology, Windhoek
Prof. Badeniyi Tosin, Durban University of Technology, SA
Dr. Zuhairiah Zainal Abidin, Universiti Tun Hussein Onn Malaysia (UTHM))
Prof. Ozcan Asilkan, American University of Nigeria
Prof. Maryam Ishaku Gwangudi, American University of Nigeria
Prof. Remilekun Odekunle, Moddibbo Adama Fed. Uni. Nigeria
Dr. Ahmad M. Aliyu, American University of Nigeria
Prof. A.D Usman, Ahmadu Bello University Zaria, Nigeria
Prof. Joseph Sule Rishante, American University of Nigeria
Prof. Sakah Saidu Mahmud, American University of Nigeria
Prof. Sam Musa, Moddibbo Adama Fed. Uni. Nigeria

Editorial Board

Prof. Chris Mbah, American University of Nigeria
Prof. Raed A. Abd-Alhameed, University of Bradford, UK
Prof. Jonathan Rodriquez, IT, Aveiro University, Portugal
Dr. Issa Elfergani, Instituto de Telecomunicações, Aveiro, Portugal
Prof. Abdulmumin Sa'ad, American University of Nigeria
Prof. (Mrs) Fadipe-Joseph, University of Ilorin, Nigeria
Dr. Abubakar Sadiq Hussaini, American University of Nigeria
Dr. Adewale James, American University of Nigeria
Dr. Rabiu Ibrahim, American University of Nigeria
Prof. A.D Usman, Ahmadu Bello University Zaria, Nigeria
Prof. Leo U. Ukpong, American University of Nigeria
Prof. Badeniyi Tosin, Durban University of Technology, SA
Prof. S. S. Adamu, Bayero University Kano, Nigeria
Prof. Maryam Ishaku Gwangudi, American University of Nigeria
Dr. Zuhairiah Zainal Abidin, Universiti Tun Hussein Onn Malaysia (UTHM))
Prof. Remilekun Odekunle, Moddibbo Adama Fed. Uni. Nigeria
Prof. Ozcan Asilkan, American University of Nigeria
Prof. Joseph Sule Rishante, American University of Nigeria
Prof. Sakah Saidu Mahmud, American University of Nigeria
Prof. Sam Musa, Moddibbo Adama Fed. Uni. Nigeria
Dr. Ahmad M. Aliyu, American University of Nigeria
Prof. James Katende, Namibia University of Science & Technology, Windhoek
Prof. Yakunbu Bila, Tafawa Balewa federal University Bauchi
Prof. Adeyemi Olagunju, Federal University Lafia, Nigeria
Prof. Danjuma Jibasen, Moddibbo Adama Fed. Uni. Nigeria
Prof. Yusuf Daberi Mamman, Moddibbo Adama Fed. Uni. Nigeria
Dr. Abdulfatai Atte Momoh, Moddibbo Adama Fed. Uni. Nigeria
Prof. Adeyefa Emmanuel, Federal University, Oye-Ekiti, Nigeria
Dr. Mathew Ayobam, American University of Nigeria, Yola
Dr. Reed Brian, American University of Nigeria, Yola

Secretariat (LOC members)

Abubakar Sadiq Hussaini, PhD - Chairman
Adewale James, PhD - Co-chair
Rabiu Ibrahim, PhD- Co-chair
Mr. Benson Ali, University Librarian
Mr. Byron Bullock, Dean, Student Affairs
Ms. Nnenna Mosugu, Head of Finance
Ms. Faizatu Ahmed Abubakar, Head of Human Resources
Dr. Ahmad M. Aliyu, Head of Sponsorship CMTE
Mr. Usoh Usoh, Head of Event and Venue
Mr. Dan Okereke, Head of Communications and Publicity
Mr. Mustapha Atiku Abubakar, Head of Logistics
Mr. Francis Chaming, Head of IT
Ms. Ndifreke Clinton, Head of Facilities
Ms. Emilienne Akpan, Head of Writing Center
Ms. Ogechi Danokereke, Head of Welfare CMTE
Dr. Lionel Rawlins, Head of Security
Mr. Daniel Ishaku, University Webmaster

-Contacts-

Conference Chair
Abubakar Sadiq Hussaini, PhD
School of Engineering,
American University of Nigeria
ash.hussaini@aun.edu.ng
+2349092014592

Conference Co-chair
Rabiu Ibrahim, PhD
School of Information Technology and Computing
American University of Nigeria
rabiu.ibrahim@aun.edu.ng

Conference Co-chair
Prof. Raed A. Abd-Alhameed
University of Bradford, UK
R.A.A.Abd@bradford.ac.uk
+44 (0) 1274 23 4033

Editor-in-Chief
Adewale James, PhD
School of Arts & Sciences
American University of Nigeria
adewale.james@aun.edu.ng
+2348077092831

CONTENTS

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp.1-9, November 13-16, 2023

Machine 5G Channel Estimation

Wisdom Anuhu[1], A. S. Hussaini[1, 2, 3], Abubakar Salisu[3,4], I.T .E. Elfergani[2], Charles Azubuike[1], R.A. Abd-Alhameed[3], Jonathan Rodriguez[2]

[1]School of Engineering, American University of Nigeria, Yola
{wisdom.anuhu, ash.hussaini, charles.azubuike}@aun.edu.ng
[2] Instituto de Telecomunicações – Aveiro, Portugal
{ash, i.t.e.elfergani, jonathan}@av.it.pt
[3]University of Bradford, Bradford, BD7 1DP, UK
{a.s.hussaini7, r.a.a.abd, a.salisu}@bradford.ac.uk
[4]Department of Electrical and Electronics Engineering, MAU Yola, Nigeria

Abstract

As 5G continues to gain more momentum around the world, there are still challenges that need to be addressed in order to capitalize fully on the benefits of the proposed architectures and technologies, that include small cells, advanced OFDM, beamforming, massive MIMO, and millimeter wave. A particular, challenge is 5G channel estimation due to the large and high frequency range involved. In this paper, conventional channel estimation methods such as least square, Minimum Mean Square Error, blind and semi-blind are investigated. Moreover, the application of machine and deep learning in channel estimation has been discussed. We then use the IBM Watson machine learning service for channel estimation using the DeepMIMO dataset which yielded promising results.

Keywords: Lease Square Estimation (LSE), Minimum Mean Square Error (MMSE), Machine Learning (ML), Multiple Input Multiple Output (MIMO), Frequency Division Multiplexing (FDM), Channel State Information (CSI), and Deep Neural Network (DNN).

1 Introduction

The fifth generation of mobile communication (5G) was created to accommodate the exponential increase in data and the need for reliable communications for emerging technologies. The application of IoT in industries, smart cities, connected heath care etc., has contributed to this exponential growth of data (Big data) and due to the nature of the devices used, where high data speed communication with minimal latency is required. The 5G is expected to increase data rate to about 10Gbit/s second or more, reduce the latency by 10-fold, and lower the power consumption. As a result, the millimeter wave band has been considered as the suitable spectrum to deliver on these required results. The mmWave spectrum ranges between 30GHz and 300GHz, with wavelengths between 1mm and 10mm.

In spite of the massive bandwidth, there has been some challenges and concerns when developing communication systems that operate at these high frequencies. Some of the problems include: free-space path loss and attenuation due to atmospheric absorption. Most of the frequencies used in the mmWave band often suffer from free-space path loss (due to short wavelength), but only a few frequencies are affected by atmospheric absorption (mainly 60GHz and 120GHz). In addition to the challenges facing the mmWave band is penetration loss; this is often caused by static and dynamic blockage from objects such as glass, human body, walls, doors etc.

In order to solve these challenges, many technologies and techniques have been employed into the design of mmWave communication equipments so as to maximize the benefits of the 5G. They include massive MIMO, beamforming, Orthogonal Frequency Division Multiplexing (OFDM), and channel estimation. Massive- Multiple Input, Multiple Output (MIMO) is the use of large number of antennas

(array) ranging between 16 and 256 antennas at the Base station and user device to increase the capacity of cellular networks. Moreover, MIMO systems are designed to provide multi-path transmission of data which ensures reliable communication by reducing interference in the system. Massive MIMO has been studied for sub-6 GHz systems and has been considered suitable for use in the mmWave band of higher frequencies.

Furthermore, artificial intelligence (AI) has revolutionized many industries- its application in transportation, health care, and manufacturing has yielded remarkable results. One area of AI that has become very popular and flexible to use is Machine Learning (ML). ML divided into two categories- supervised and unsupervised learning. In supervised learning, labeled data are used in training a model to be able to find correlation within the data-set. While In unsupervised learning, unlabeled data is used to train a model or algorithm in order to find meaning within the dataset. Unsupervised learning is sometimes used interchangeably with deep learning.

To better understand the role ML will play in channel estimation, we have established a solid background on some relevant 5G techniques, the challenges faced in conventional channel estimation methods, and the motivation for using ML.

2 Background

Beamforming is another technique employed in 5G architecture to optimize signals received over an array of antennas (in others words, massive MIMO). Beamforming ensures that before signals are transmitted, the amplitude and phase are adjusted towards the direction of interest thereby avoiding areas of interference. Over the years, researchers have recommended various ways of improving beamforming algorithms to accommodate the dynamic changes experienced in radio frequency (RF) transmission. Statistical beamforming is one of the recent techniques introduced to improve beamforming; [15] proposed a novel statistical beamforming technique that will serve a number of users experiencing a peculiar spatial channel correlation in MIMO systems. Their proposal was based on a study of a common phenomenon in 5G where two groups of users, one experiencing a low spatial channel correlation while the other having a higher spatial channel correlation. They addressed this issue by designing the post-beamforming vector to maximize signal to leakage and noise ratio.

In addition to the beamforming technique, OFDM is also considered as an invaluable technique which will better serve the 5G technology and beyond. Orthogonal frequency division multiplexing is a digital-carrier modulation technique that was created to improve the Frequency Division Multiplexing (FDM). This massive improvement was brought about by the introducing “orthogonality” among subcarriers- it is achieved by dividing the pilots into “closely spaced” channels. Each channel or subcarrier is then modulated by one form of digital modulation or the other. For example, the quadrature phase-shift keying (QPSK) can be applied to the channels to produce similar results as though it was applied to a single-carrier channel. In OFDM, large data streams ready to be transmitted are split into parallel data streams which are then supplied to the orthogonal carriers (that is, the subcarriers) at a lower symbol rate [2]. At this lower rate, any of the modulation schemes (e.g. BPSK, QPSK, and QAM) can be applied to the channels to produce the desired results. Although the data rate for each channel is less than the single carrier modulation, its overall data rate, however, is greater. As such, there modulation scheme have since been introduced into WiFi, LTE, and the Ultra Wide Band (UWB) systems.

Having considered the above techniques and technologies used to solve some of the challenges mmWave systems, Channel Estimation in 5G has proven to be challenging. This is because estimating a channel at high frequency is complex and carries many overheads compared to estimating a channel at a low frequency. The channel state information (CSI) which are required to estimate a channel and further assist in beam selection has proven to be challenging in 5G considering not only because of the high frequency, but also due to the amount of antennas involved in the architecture.

Channel estimation is often performed at the receiver end and then relayed to the transmitter. Therefore, the channel state information must be available at the receiver before it can be fed back to the transmitter in order to select the best channel to transmit [9]. Channel state information is ascertained instantaneously or statistically. In instantaneous channel state information, all the link characteristics or properties currently are known to the receiver by deducing the impulse response of the transmitted sequence. Statistical channel state information provides link properties like: channel gain, spatial correlation, fading distribution. CSI are rendered based on how fast or slow channel conditions change.

Least Square (LS) and Minimum Mean Square Error (MMSE) are the two commonly used pilot-based estimation algorithms in a channel. LS estimation requires no CSI to estimate a channel, while MMSE requires some statistical information to estimate the channel, which makes LS to perform faster than MMSE. The major problem with LS, however, is that it does not estimate the channel accurately while MMSE in fact provides more accurate result [8]. MMSE is slow because it takes into account many statistical parameters creating a very large overhead making its performance not only slow, but consumes a considerate amount of resources. For this reason, researchers have started looking into Machine Learning as a suitable application for channel estimation.

The application of machine learning (ML) in many industries have yielded outstanding results over the years. There is no doubt that its use in the telecommunications industry will assist in solving some of its underlying challenges particularly in 5G and beyond [14]. The motivation for ML is using models based on statistical inference obtained from a dataset to make a prediction, where the application of ML to the CSI dataset can provide superior results than the conventional channel estimation algorithms.

Motivated by this, in this paper we shall;

1. Review the performance of conventional channel estimation methods in massive MIMO systems.
2. Present the recent applications of Machine learning/deep learning in channel estimation.
3. Recommend a machine-learning based channel estimation method for application in MIMO-OFDM systems using IBM Watson.

2.1 Conventional Channel Estimation Techniques

There are three major conventional channel estimation techniques, which are: Pilot/train symbol based channel estimation, blind channel estimation, and the semi-blind channel estimation.

In pilot-based channel estimation, pilot symbol are trained to predict the channel impulse response (CIR). The pilot symbol is usually the row of bits that has been previously known to the receiver. This however, changes periodically due to different factors including user mobility and the environment. Therefore, to provide an accurate CSI, the receiver updates these changes to reflect the new pilot signal received. When a receiver receives the pilot symbols, the channel is usually estimated using either the Least Square Error (LSE) or Minimum Mean Square Error (MMSE) [13]. However, the challenge in

estimating using pilot symbol is that it creates large overheads that makes performance in MIMO-OFDM system very slow.

Many researchers on the other hand have been trying to come up with solutions that can reduce the overheads in pilot symbol based estimation so as to make it viable for use in massive MIMO system. For example, MM Rana and MK Hosain in [12] proposed the use of a normalized least mean square (NLMS) and recursive least squares (RLS) to achieve an "adaptive estimator" that is capable of updating the channel parameters/characteristics automatically so that storing prior knowledge of the channel by the receiver will no longer be necessary. The only thing their proposed algorithm requires is the received signal. Although, their results showed that the NLMS/RLS based algorithm is faster than the LSE and MMSE, the question of accuracy comes into play when it is deployed on massive MIMO systems.

Additionally, [17] proposed a novel channel estimation method that complements LSE with time domain interpolation. They introduced what is called a pilot-receiver iterative relationship with joint inter carrier interference (ICI) cancellation method that reduces pilot decoding complexity and that enables the LSE computation to yield a more accurate result. Like the proposal made by MM Rana[12], this is also likely to fail in massive MIMO systems but not due to accuracy, rather power consumption. The iterative nature of this algorithm will consume a significant amount of power by the receiver to cancel out the noise in the channel.

In blind channel estimation, statistical properties received from user terminals and the base station are used to deduce the channel coefficients. Since blind channel estimation method does not use pilot signals, the overhead is very low. However, it requires large amount of symbols to infer the statistical properties of the channel. This poses a significant challenge to MIMO-OFDM systems because of the amount of memory required for channel estimation [5]. There are two common method used in channel estimation; subspace-based and recursive-based method.

In subspace-based method, three parameters are extracted from the signal properties to estimate the channel. These parameters are: symbol rate, alphabet structure, and correlation. Usually, when a signal is received, only one of its block is subjected to the subspace-based technique to obtain the CSI. Recursive channel estimation method on the other hand estimate a channel by sampling every instance of data received while applying the recursive technique. As a result of its recursive nature, it will require significant memory to perform efficiently which can pose a serious problem when we are dealing with massive MIMO that can contain hundreds of antennas. As a result, subspace-based channel estimation is preferred to recursive based channel estimation. Importantly, subspace-based channel estimation has what is called an independent component analysis (ICA) that is the base technique used in blind channel estimation.

The ICA is considered a likely option for massive MIMO due to its mode of operation. That is, the channel coefficient are obtained by transforming the vector matrix of the received signal. This is done by calculating the singular value decomposition (SVD) of the covariance matrix, given by $C = E\{YY^T\}$ and $C=UDU^T$ [16]. Where $U \epsilon C^{MxM}$ represents the orthogonal matrix and $D = \{ \lambda 1, \lambda 2,\ldots \lambda M \}$, U and D are matrices which is used to divide a signal subspace and noise subspace. U matrix is given as $[U_s\ U_N]$ and $D = \begin{matrix} Ds & 0 \\ 0 & Dn \end{matrix}$ [16]

Afterwards the complexity of the received symbols is decreased by projecting the symbols into the subspace domain. The projection is done by what is known as "whitening" (Y_W), which is represented by $Y_w = D_s^{-1/2} U_s^T Y$, where $Y_w \epsilon C^{NxN}$. This will then result in the creation of an orthogonal matrix (W

$\epsilon\ C^{NxN}$) that will shrink the vector matrix using its mutual information in order to maximize negentropy [16].

Semi-blind channel estimators combine the use of training symbols and data symbols in order to accurately estimate a channel; i.e. semi-blind algorithms make use of the second-order stationary statistics/process, partial response signaling schemes, and other properties to produce a better spectral efficiency [4]. This concept helps in reducing the channel ambiguity often associated with OFD-MIMO matrix. One of the reasons why semi-blind methods of channel estimation came into play is to solve the pilot contamination that is usually associated with massive MIMO systems that use adaptive or blind channel estimation. Although, semi-blind uses pilot signals, its contamination percentage is greatly minimized.

The mostly widely used semi-blind channel estimation method uses SVD and it has been considered efficient in terms of bit error rate and other computational complexities. UTs left in the subspace of the singular vector covariance matrix are multiplied by the channel vectors $\{h_{1...}h_n\}$ to obtain the normalized channel matrix and the ambiguity matrix. In this context, after the pilot signals are received, the semi-blind channel estimation is estimated by:

$$H_{svd} = U_s U_s^T H_{LS}, \quad (1)$$

where $U_s\ \epsilon\ C^{MxN}$ is the signal subspace of the orthogonal matrix U, $H_{LS}\ \epsilon\ C^{MxN}$ is a matrix of the estimated channel coefficients with least square, and $H_{svd}\ \epsilon\ C^{MxN}$ is the matrix of the estimated complex channel coefficient (Ture, Garrett, & Tamal, 2017)

The above semi-blind channel estimation method is regarded as the conventional method. However, a proposal was made by [6] to optimize semi-blind channel estimation using time domain. Their results show a significant reduction of residual error when the receive diversity is used on the time domain. However, their proposal is limited to time invariant channels, and also MIMO systems with available data.

2.2 Machine Learning in Channel Estimation

The application of machine learning in the telecommunication field is progressive; in particular one area where its application increasingly gaining attention is channel estimation. The application of machine learning in channel estimation has yielded positive results, better than conventional channel estimation methods such as the LSE and MMSE. In the research carried out by [1], the researchers used deep learning to create a neural network model for 5G channel estimation of MIMO-OFDM system. They used a 2 x 2 MIMO channel model (that is, a two-antenna transceiver) to generate all the data needed to create the deep neural network model (DNN) – which has 5 layers comprising of an input layer, 3 hidden layers, and an output layer. As an input for the DNN, the channel information is attained by applying the LS estimation technique. This is done so as to minimize the mean square error (MSE).

The input realization is process is:

$$M_{nt} = \{Re\{ [h^n_{LS}(t)]_0 \}, I_m\{[h^n_{LS}(t)]_0\}, \ldots, \{Re\{ [h^n_{LS}(t)]_3 \}, I_m\{ [h^n_{LS}(t)]_3\} \}, \quad (2)$$

where n denotes the n-th realization, Re {.} is the real number, and lm {.} represents the complex number.

The output of the neural network is given as; O_{nt} = {Re{ $[h^n_{LS}(t)]_0$ }, I_m{$[h^n_{LS}(t)]_0$}, …, {Re{ $[h^n_{LS}(t)]_3$ }, I_m{ $[h^n_{LS}(t)]_3$} }. Where h^n is the output of the neural network at the n-th realization.

In order to train the DNN model, the researchers used a data set containing 250800 realizations. Of those data set, 70% percent was used for the training, 15% for the validation, and the remaining 15% of the data for testing. To evaluate the performance of the DNN-aided estimation, the results are compared to conventional channel estimation methods such as LS and LMMSE by taking using bit error rate (BER) and the mean square error (MSE) against signal to noise ratio (SNR). After carrying out the evaluation, their proposed DNN model yielded the best MSE performance at low and "mediate" SNR in contrast to LSE and LMMSE. But when the SNR increases by 13dB, the model produces the worst MSE in comparison to the two conventional channel estimators.

In a similar application of deep learning to aid in channel estimation, researchers in [11] proposed a general pipeline known as ChannelNet using deep image restoration technique to estimate a channel. The concept of image recovery from a noisy image was applied to a channel, since both can be reconstructed to represent a vector component. Therefore, their approach is to model the time-frequency grid of the response channel into a 2D image of known pilot positions. The channel grid containing the pilots is considered as the noisy image or the low-resolution (LR) image, while the estimated channel is known as the high-resolution (HR) image. Afterwards, a two phased process is used to estimate the "channel grid". The first phase involves the use of the super resolution (SR) algorithm to enhance the low resolution image of the channel. The second phase is to remove the noise effect of the image by using an image restoration technique or algorithm. The researchers used two convolutional Neural Network (CNN) algorithms (SRCNN & DnCNN) for the super resolution and image restoration networks.
The overview of their proposed pipeline can be elaborated as follows:

1. The estimated channel with noise represented as h^{LS}_p is vectorized as the low-resolution input image of the CNN.
2. The noise effect is then removed by denoising the IR network from the super resolution network; i.e., the SRCNN first uses interpolation to find the approximate value of the higher resolution image and further improves the image (channel) in a three layer CNN.

Their proposed deep learning model contained a data set of about 48000, among which, 32000 was used for training, 4000 for testing, and the remaining 4000 for validation. This was obtained from one link comprising transmitter -receiver antenna (basically a Single-input, Single output) pair. The results of the ChannelNet shows that at SNR of 12dB and below, its performance is superior to that of the LSE and MMSE. But at higher SNR, its performance or accuracy begins to drop steadily. This behavior has also been experience by [1], but with a slightly higher SNR.

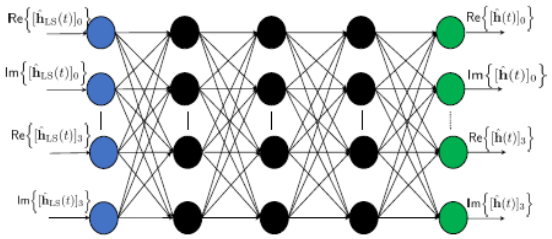


Figure 1: Their proposed DNN structure [1]

Furthermore, machine learning was used by [7] to obtain channel state information by utilizing the temporal channel correlation. Their project was inspired by the recent application of non-linear based machine learning in wireless communication such as the DNN discussed above. They based their

theory on the fact that channel state information (CSI) is a time series problem, as such similar techniques used for image recognition can be harnessed and applied for channel estimation. To obtain the CSI, they used a machine learning based timed division duplex (TDD) scheme instead of the conventional pilot-based channel estimators like LS and MMSE. More so, two other machine learning models are used to improve the CSI prediction, namely autoregressive convolutional neural network (AR-CNN) and autoregressive network with exogenous inputs (CNN-RNN). CNN is used to identify the aging pattern of the channel and then AR-CNN or CNN-RNN is used to accurately predict the CSI. A key advantage of this scheme is that channel estimation overheads is massively reduced.

In their analysis, they used a base station with about 128 antennas, and an undisclosed number of users. From the simulated result, their ML-based TDD scheme was able to reduce the channel estimation overhead by about 77% and achieving an MSE below -10dB.

In another research, [10] used deep learning to obtain all the required MIMO channel matrix by processing the incoming signal at a single pass regardless of the number of antennae used in the system. The idea is to estimate each sub-channel in the massive MIMO channel orthogonally. Their proposed deep layer perceptron architecture is able to retrieve a three-dimensional CSI matrix – where each dimension corresponds to the number of transmitting antennas, receiving antennas, and sub-carriers. Their DNN model has three hidden layers to achieve the required result, having an input as a time-domain preamble sequence. The model is trained by using a regression algorithm so as to predict each massive MIMO sub-channel in the frequency domain. Their result shows that by training the model on CSI values obtained at high SNR, the model produces the best results compared to the conventional channel estimators at low SNR. Since their DNN model was designed for general use on massive MIMO systems, their proposal suggests that the solution can be used for frequencies above 6 GHz band (mmWave) and even at the THz bands. In other words, their deep learning model can be used for channel estimation in 5G massive MIMO and beyond.

3 Machine Learning-based Channel Estimation Method for MIMO-OFDM using IBM Watson AI

The IBM community have been perfecting its AI services for more than 3 decades now. They have created some advanced tools on their IBM cloud platform that can be applied to various field of studies to achieve AI functionalities. Their machine learning services have yielded outstanding results for several projects. Inspired by this, their deep learning service was applied to channel estimation. The following procedures was addressed:

1. A dataset containing ray tracing scenarios for about a million users was acquired. The dataset can be obtained from [3]
2. The dataset is then imported to IBM ML environment
3. The model is trained using the dataset
4. The result is then analyzed.

The result shows that the IBM model was able to reduce channel estimation overhead to about 80% while achieving an MSE below -10dB. Additionally, the result shows that the model outperforms the LSE and MMSE for low and high SNR. Therefore, the IBM machine learning model could be suitable for channel estimation in 5G applications.

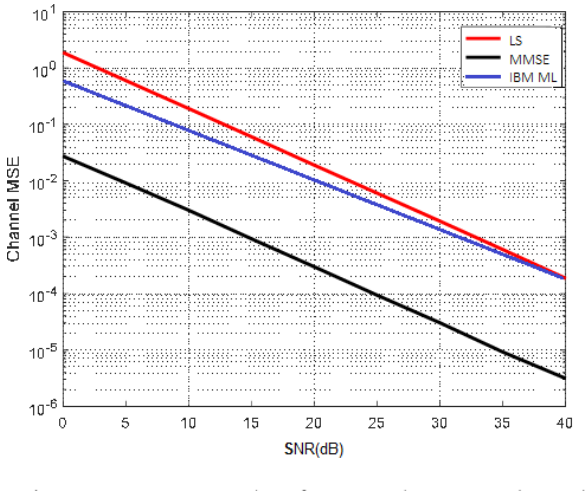


Figure 2: LS, MMSE & Proposed IBM ML performance

4 Conclusion

Channel estimation is one of the most crucial aspects of wireless communications that cannot be overlooked. Conventional channel estimation methods are sufficient for 3G and LTE communication systems, however, these methods might not perform effectively on 5G systems due to the high frequency of operation. In this paper, we have described some machine and deep learning models that could be effective for channel estimation in 5G. But there are still challenges that need to be addressed before it can be deployed on a large scale 5G network. The IBM machine learning has shown promising results, however, however, further research has to be carried out to determine its true potency.

Acknowledgement

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement H2020-MSCA-RISE-2018-EXPLOR-872897.

References

[1] An, L. H., Trinh, V. C., Tien, H. N., Wan, C., & Van, D. N. (2021). Deep Learning-Aided 5G Channel Estimation. IEEE, 1-7.
[2] Dishant, K., Sohni, S., Rashwinder, S., & Sumeet, G. (2018). OFDM Modulation Technique & its applications: A Review. International Conference on Innovations in Computing (pp. 101-105). CSL Press.
[3] DeepMIMO Dataset. [Online]. Available: http://www.DeepMIMO.net
[4] Ercan, S. Ü. (2016). Compare of Pilot Based and Semi-blind Channel Estimation Techniques in Multiple Input Multiple Output Communication Systems. ResearchGate, 1-4.
[5] Govil, R. (2018). Different Types of Channel Estimation Techniques Used in MIMO-OFDM for Effective Communication Systems. International Journal of Engineering Research & Technology (IJERT), 1-5.
[6] J, K., & Lim, J. (2009). Subspace-based iterative Semiblind channel estimation for MIMOOFDM considering residual error. IEEE Trans. Vehicular Technology Vol.58, 4660-4665.
[7] Jide, Y., Hien, Q. N., & Michail, M. (2019). Machine Learning-Based Channel Estimation in Massive MIMO with Channel Aging. IEEE, 1-6.
[8] Kais, H., Mohammad, M., Marie, Z., & Iyad, D. (2020). Channel Estimation Techniques for Millimeter-Wave Communication Systems: Achievements and Challenges. IEEE Open Journal of the Communications Society, 1-27.
[9] Ko, Y.-C., & Kim, M.-J. (2016). Channel estimation and analog beam selection for uplink multiuser hybrid beamforming system. EURASIP Journal onWireless Communications and Netwoking, 1-14.

[10] Mauro, B., Kunal, S., Carlos, B., Debashri, R., & Kaushik, R. C. (2021). Deep Learning at the Edge for Channel Estimation in Beyond-5G Massive MIMO. IEEE, 1-8.
[11] Mehran, S., Vahid, P., Ali, M., & Hamid, S. (2018). Deep Learning-Based Channel Estimation. ResearchGate, 1-5.
[12] MM, R., & MK, H. (2010). Adaptive Channel Estimation Techniques for MIMO-OFDM Systems. International Journal of Advanced, 1-4.
[13] Muhamad, A., & Indra, W. G. (2011). Channel Estimation Using Least Square Estimation (LSE) Orthogonal Frequency Division Multiplexing (OFDM) System. Applied Electromagnetic Technology (AEMT), (pp. 1-9). Lombok.
[14] Nakao, A. (2020). AI/ML integration for autonomous networking- a future direction for next-generation telecommunications.
[15] Taehyoung, K., & Sangjoon, P. (2020). Statistical Beamforming for Massive MIMO Systems with Distinct Spatial Correlations. Sensors, 1-20.
[16] Ture, P., Garrett, V., & Tamal, B. (2017). Blind channel estimation for massive MIMO. ResearchGate, 1-11.
[17] W, H., R, L., B, V., & Y, L. (2010). A New Iterative Channel Estimation for High Mobility MIMO-OFDM Systems. IEEE Trans. Vehicular Technology Conference, (pp. 1-5).

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp.10-22, November 13-16, 2023

Wastewater Challenges, Treatments and Benefits: Literature Analysis

Ezra Daniel Dzarma[1], Emmanuel Torsen[2], Danfulani Bitrus Usman[3] and Enyomeji Ademu Idama[4]
{daniel.dzarma@imsp-uac.org[1], torsen@mau.edu.ng[2], bitrus@mau.edu.ng[3], enyomeji@mau.edu.ng[4]}

University d'Abomey-Calavi, Institut de Mathématiques et de Sciences Physiques, Department of Computer Science and Information Technology, Benin Republic[1]
Department of Statistics, Modibbo Adama University, Yola, Nigeria[2]
Department of Operations Research, Modibbo Adama University, Yola, Nigeria[3]
Chemical Engineering Department, Modibbo Adama University, Yola, Nigeria[4]

Abstracts
This research focuses towards analysing the problems associated with wastewater and treatment process as well as its application in our daily living. The research implore both the generalized and bibliometric literature review method. The findings of the literature review reveals that wastewater has both health and environmental hazards such as water polution, health risks, eutrophication, environmental damage, climate change and infrastructure challenges. Meanwhile, the bibliometric literature review showed that optimization, removal and wastewater are the most frequently used terms based on the bibliometrics data extracted from web of sciennce between the period of 2012 and 2023, Zhang and Wang who had h-index citation of 15 and 14 respectively are the most global authors while China-USA had highest global international collaboration frequency. The researchers reconmmended that more wastewater treatment facilities should be deployed in Nigerian industries by the stakeholders.

Keywords: Wastewater, treatment, bibliometrix, collaboration and Disinfection

1 INTRODUCTION

Wastewater presents various environmental and public health problems. Some of the key issues associated with wastewater are water pollution, health risks, eutrophication, environmental damage, climate change, resource depletion, and infrastructure challenges.

Water Pollution: Wastewater contains a wide range of pollutants, including organic matter, nutrients (nitrogen and phosphorus), heavy metals, pathogens, and emerging contaminants (e.g., pharmaceuticals and personal care products). When released into water bodies without proper treatment, it can lead to water pollution, affecting aquatic life and ecosystem health UNEP (2016).
Health Risks: Untreated or poorly treated wastewater can contain disease-causing pathogens. The discharge of such wastewater can contaminate drinking water sources and lead to the spread of waterborne diseases (WHO 2006).

Eutrophication: Excess nutrients, mainly nitrogen, and phosphorus, from wastewater can lead to eutrophication in water bodies. This can result in harmful algal blooms, oxygen depletion, and the death of aquatic life (Smith *et al.,* 1999).
Environmental Damage: The discharge of wastewater into natural water bodies can harm aquatic ecosystems, including fish and other wildlife. It can disrupt the balance of aquatic ecosystems and lead to long-term environmental damage.

Climate Change: Wastewater treatment is energy-intensive, and the release of untreated methane gas from wastewater can contribute to greenhouse gas emissions, exacerbating climate change (WWAP, U. 2019).
Resource Depletion: Wastewater often contains valuable resources, such as water, energy, and nutrients. Failing to recover and reuse these resources represents a missed opportunity and can lead to resource depletion.

Infrastructure Challenges: Many wastewater treatment systems are outdated and inadequate, especially in developing countries. The lack of proper infrastructure for wastewater treatment poses a significant challenge in managing wastewater (Smith *et al.*, 1999).

Wastewater treatment plays a crucial role in safeguarding public health and protecting the environment. It is an interdisciplinary field that combines engineering, biology, chemistry, environmental science and Operations Research to address the challenges associated with water pollution and the disposal of wastewater. The effectiveness of wastewater treatment processes is continually improved through research and technological advancements to meet the evolving needs of society and the environment.

Water and wastewater process optimization refers to the systematic improvement of processes and technologies involved in the treatment and distribution of clean water and the collection and treatment of wastewater. The primary goals of optimization in this context are to ensure the delivery of safe, clean water to consumers and to manage and treat wastewater effectively while minimizing costs and environmental impact. Wastewater treatment is the process of removing contaminants and pollutants from domestic, industrial, and agricultural wastewater before it is released into the environment or returned to the water cycle. This essential process helps protect the environment and human health by ensuring that harmful substances are not discharged into rivers, lakes, or oceans.

Wastewater treatment typically involves several stages, including Preliminary Treatment: This stage involves the removal of large objects such as sticks, leaves, and plastics that could clog or damage equipment in the subsequent treatment stages. It may also include the removal of grit and sand (Metcalf *et al 2003*).

Primary Treatment: In this stage, solid particles and organic matter are settled and removed from the wastewater. This is often achieved through sedimentation in large tanks. Primary treatment reduces the biochemical oxygen demand (BOD) of the wastewater but does not completely eliminate dissolved and suspended contaminants (Vesilind *et al., 2003).*

Secondary Treatment: Secondary treatment is a biological process that uses microorganisms to break down the organic matter in the wastewater. Common methods include activated sludge processes, trickling filters, and rotating biological contactors. Secondary treatment further reduces BOD and suspended solids (Henze *et al.*, 2008).

Tertiary Treatment: This stage aims to further improve the water quality by removing additional contaminants, such as nutrients (nitrogen and phosphorus), pathogens, and trace organic compounds. Common methods include chemical precipitation, filtration, and advanced oxidation processes (Tchobanoglous *et al.*, 2008).

Disinfection: Disinfection is the final step to kill or inactivate any remaining disease-causing pathogens in the treated wastewater. Common disinfection methods include chlorination, ultraviolet (UV) irradiation, and ozonation.

The choice of treatment methods and the extent of treatment depend on the characteristics of the wastewater and the environmental regulations in place. The treated water can then be discharged into bodies of water, used for irrigation, or even treated further for potable water supply in some cases ((EPA 2020).

2 Wastewater Treatment and its Benefits

Clean water is a basic necessity for humans. While the human population grows, the demand for water grows as well. Since water is a finite resource, used water must be treated to continuously serve end-uses. It is on this basis that wastewater treatment comes in. These papers collectively provide information on the definition and characteristics of wastewater. Welch and Naczk (1992) defines wastewater as water negatively affected by humans and highlights its complex mixture of inorganic and organic materials. High amounts of inorganic and organic matter discharged via process effluent can seriously impair water sources or result in toxic levels in soil (Welch and Naczk, 1992). Sane, Nagarkar and Shinde (2020) emphasized the need for wastewater reuse in various sectors due to water scarcity issues, particularly in developing economies. They opined that Wastewater is a by-product of domestic, industrial, commercial, or agricultural activities. Muralikrishna and Manickam (2017) discusses different wastewater treatment technologies, focusing on domestic wastewater and the various treatment methods available. Domestic wastewater generated from domestic sources are well documented and designed (Muralikrishna and Manickam, 2017).

Wastewater is a contaminated form of water resulting from human activities, including domestic, industrial, commercial, and agricultural uses. They also emphasize the importance of wastewater management and treatment to mitigate environmental impacts and ensure the availability of clean water resources.

Therefore, Wastewater treatment is highly beneficial in manufacturing companies and other industrial businesses. Besides preserving water and avoiding water pollution, wastewater treatment boost productivity avoids equipment damage and promotes efficient operations.
Yu-shan & Wanmeng (2010) submitted that, effluent of wastewater plant after appropriate treatment could be used to circulating, cooling, agricultural irrigation, scenery, greening, underground recharging water and so on, which had broad application prospects. Wastewater reclamation and reuse not only provided direct economic benefits for industry, but also decreased industry and agriculture loss, body healthiness loss, and had remarkable social and environmental benefits.
Culp (2016) observed that wastewater treatment prevents pollution of water sources and increases the available water supply, which is crucial for future water use expansion.
Wastewater provides an effective source of nutrients that vegetation roots can absorb and allow the plant to assimilate (Mexal, et al, 2005).

Land application of wastewater is recommended as a method of recycling nutrients and organic matter while conserving freshwater resources (Mexal, et al, 2005).
It helps create a supplemental irrigation source, reduces fertilizer costs, and allows for effective remediation of wastes (Mexal, et al, 2005). Additionally, wastewater use in agriculture has been implemented worldwide and can contribute to food production in water-scarce regions (Rebora, 2011).
The benefits of treating wastewater are summarized below, note that the lists are not exhaustive:

i. Averts waterborne pollution
ii. Safeguard public health and safety
iii. Profitable to the environment
iv. Clean and safe (usable) water
v. Energy production
vi. Benefits the economy and economic activities such as employment
vii. It serve as a way of recycling nutrients while conservating fresh water resources
viii. Waste reduction
ix. Food production in water-scarce areas
x. It increases the availability of water supply

3 Wastewater Treatment Process

Wastewater treatment is the process of removing contaminants and pollutants from wastewater before it is released into the environment or returned for reuse. The specific methods and technologies used can vary depending on the source of the wastewater, its intended use, and the local regulatory requirements. Here's a general overview of the wastewater treatment process (Metcalf *et al* 2018) :

3.1 Preliminary Treatment:

Screening: Large debris, such as sticks, leaves, and plastic, are removed using screens or grates.
Grit Removal: Sand, gravel, and other heavy materials are settled out.
Primary Treatment: In primary treatment, sedimentation tanks, gravity separates the remaining suspended solids and organic matter from the water. Primary treatment reduces the biological oxygen demand (BOD) and suspended solids in the wastewater.

3.2 Secondary Treatment:

Biological treatment is used to further remove dissolved and suspended organic matter. Common methods include activated sludge, trickling filters, or rotating biological contactors. Microorganisms (e.g., bacteria) break down organic matter in the wastewater, reducing BOD and producing sludge. Secondary treatment typically follows primary treatment and is designed to remove up to 90% of the pollutants.

3.3 Tertiary Treatment (if needed):

Tertiary treatment is used to remove specific contaminants like nutrients (nitrogen and phosphorus) and fine suspended solids. Methods can include chemical precipitation, filtration, and advanced biological processes.

3.4 Disinfection:

To eliminate harmful pathogens and bacteria, wastewater is disinfected with chlorine, ultraviolet (UV) light, or ozone. This step ensures that the treated water is safe for discharge or reuse. Sludge Treatment and Disposal:the solids removed during primary and secondary treatment, known as sludge, are further processed. Options for sludge treatment include digestion, dewatering, and disposal in landfills or beneficial reuse (e.g., fertilizer) (Vesilind, *et al* 2016 & WEF 2014).

4 Bibliometrics

A bibliometrics literature review is a research methodology that involves systematically analyzing and evaluating the existing literature related to a specific field or topic using bibliometric techniques and tools. Bibliometrics is a quantitative method for studying patterns and trends in scholarly publications, such as academic papers, journal articles, books, and conference proceedings. It provides insights into how research is conducted, disseminated, and cited within a particular domain. A bibliometrics literature review aims to provide a comprehensive overview of the existing research in a specific field while also examining the various aspects of scholarly communication, collaboration, and impact (Waltman & van Eck, 2012).

The bibliometric data for this study were obtained from reputable articles database known as Web of science (WOS). Bibliometric data were analyzed using an R interface software known as bibliometrix. The wsummaryb of the main information regarding the articles extracted are as shown in table 1. The time span of the articles considered was between 2012 and october 2023, there were 256 journal

sources within the time frame considetred, 2,298 related articles to the area of study published by 6,189 authors with 20.05% annual rate of growth while the total authors' keyword was 5,292.

.

Table 1: Main Information

Description	**Results**
MAIN INFORMATION ABOUT DATA	
Timespan	2012:2023
Sources (Journals, Books, etc)	256
Documents	2298
Annual Growth Rate %	20.05
Document Average Age	3.59
Average citations per doc	17.94
References	78790
DOCUMENT CONTENTS	
Keywords Plus (ID)	3982
Author's Keywords (DE)	5292
AUTHORS	
Authors	6189
Authors of single-authored docs	21
AUTHORS COLLABORATION	
Single-authored docs	30
Co-Authors per Doc	4.61
International co-authorships %	28.89
DOCUMENT TYPES	
Article	2026
article; early access	72
article; proceedings paper	39
review	153
review; early access	8

5 Word Cloud Related to Wastewater Treatment

A bibliometrics word cloud is a graphical representation of the most frequently occurring words or phrases in a collection of bibliometric data, such as academic publications, research articles, or scientific journals. Bibliometrics is the quantitative analysis of scholarly publications to measure and analyze the impact, productivity, and characteristics of scientific research. Word clouds are a visual tool used to highlight and visualize the most significant terms or keywords within a dataset, providing a quick and intuitive way to understand the key themes, topics, and trends present in a body of academic literature (Boyack *et al.*, 2005; Van & Waltman, 2010 and Leydesdorff, & Rafols 2009)

The word cloud for the wastewater treatment is as presented in figure 1, which shows that optimization having the largest font as the most frequently used words followed by removal and other words follows subsequently.

5.1 A Treemap

A treemap is a data visualization technique used to display hierarchical data in a nested, rectangular layout. It provides a way to represent data with a hierarchical structure while also showing the distribution of values within each level of the hierarchy. Treemaps are especially useful when dealing with large datasets and want to visualize the relationships between various categories and subcategories (Johnson & Shneiderman 1991)

Figure 3 presents the tree map for wastewater treatment process optimization. The top five components that have higher percentages are: optimization 11%, removal 10%, waste-water 9%, waste-water treatment 5%, and degradation 3%

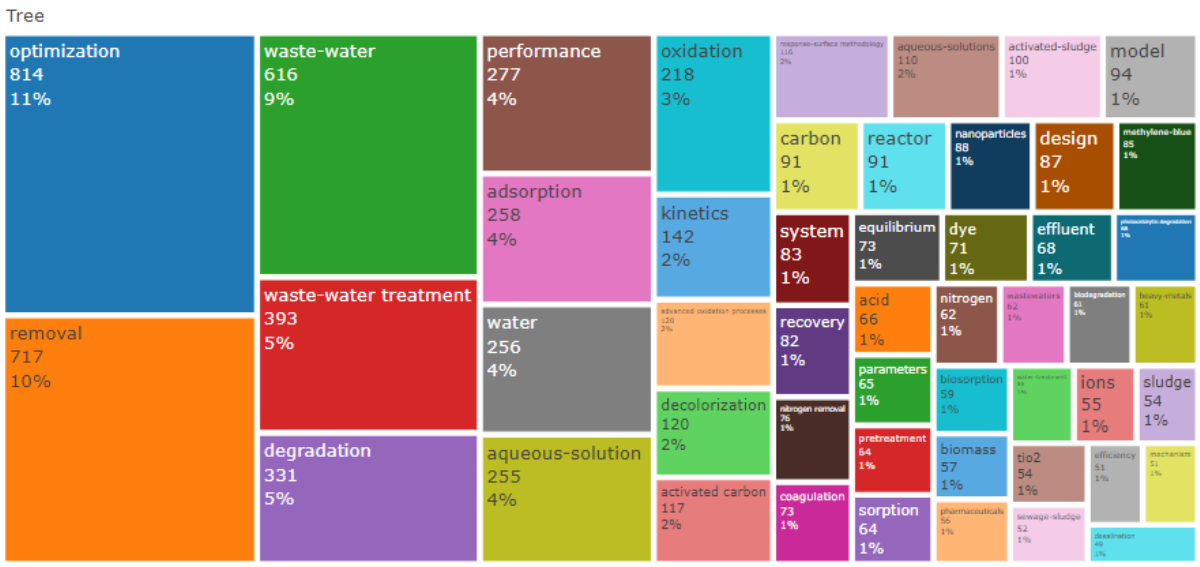


Fig 2: Treenmap

5.2 Thematic Map

A bibliometrics thematic map is a visualization tool used to explore and analyze the landscape of scientific research in a specific field or discipline. It is a graphical representation that helps researchers

and decision-makers to understand the structure, trends, and connections within a particular area of scholarly literature. This map typically uses bibliometric data, such as citation networks, co-authorship relationships, and keyword co-occurrence, to create a visual representation of the knowledge domain (Klavans & Boyack 2017). Figure 3 presents the thematic map for waste-water treatment optimization as follows: Niche theme oxidizing bacteria, partial nitrification, and dissolved-oxygen, while basic theme were optimization, Wastewater, and waste-water treatment.

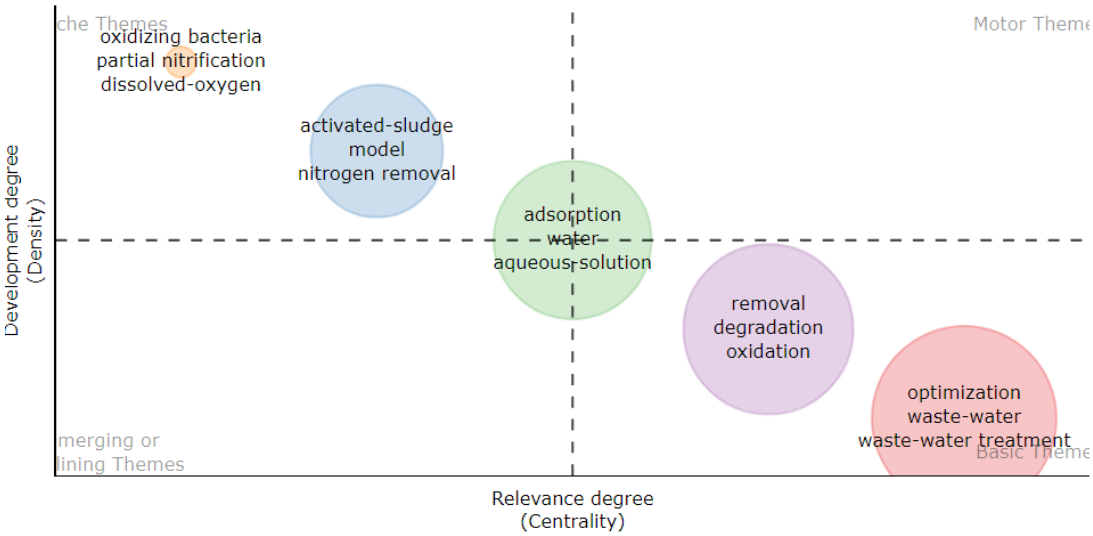


Figure 3: Thematic Map

5.4 Country Collaboration

International collaboration in academic journals refers to the practice of researchers from different countries working together to produce scholarly articles or papers. This collaboration is crucial for advancing scientific knowledge and promoting diversity of thought and perspectives in academia. Here's an explanation of international collaboration in academic journals, and its benefits (Wagner & Leydesdorff, 2015 and Abramo, *et al.*, 2013):

Diversity of Perspectives: International collaboration brings together researchers with diverse backgrounds, experiences, and perspectives. This diversity can lead to more comprehensive and well-rounded research, as different cultural, social, and academic viewpoints are integrated.
Access to Varied Resources: Collaboration often allows researchers to access resources that may not be available in their home countries. This can include specialized equipment, unique data sets, or expertise in a particular field.

Increased Credibility: Articles resulting from international collaboration tend to be viewed as more credible and authoritative. This is because they are often subject to a rigorous peer-review process, and the diversity of perspectives can enhance the quality of the research.
Enhanced Impact and Visibility: International collaboration can lead to research findings that have a broader impact, as they reach a wider audience. This can contribute to the visibility and recognition of the researchers involved.

Networking Opportunities: Collaborating internationally provides researchers with the opportunity to build a global network of colleagues, which can be valuable for future projects, career advancement, and knowledge exchange.

Access to Funding: Some research projects may require significant funding. International collaborations can access funding sources from multiple countries or organizations, increasing the likelihood of securing necessary financial support.
Addressing Global Challenges: Many of the world's most pressing challenges, such as climate change, pandemics, and poverty, are global in nature.

Figure 4 presents the pictorial international collaboration of authors across the continent of the world, while table two presents the frequency of world collaboration in the area of study. The result in table two shows that China-USA had highest frequency of collaboration of 43, follows by China-Australia with a frequency of 25, China- Canada with the 18 frequency of collaboration, Malaysia-Saudi Arabia which had frequency of collaboration of 17 is number four while other countries as presented in table 2.

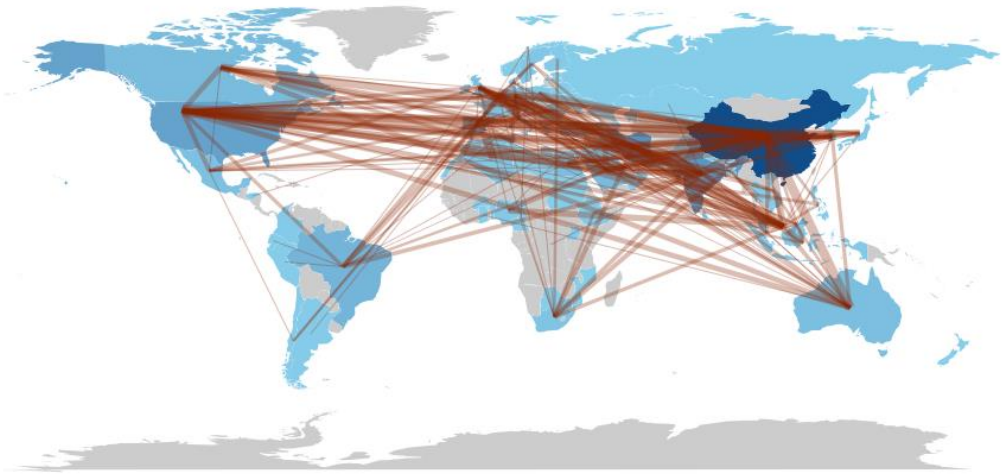


Figure 4: International Collaboration

Table 2: World collaboration

From	To	Frequency
CHINA	USA	43
CHINA	AUSTRALIA	25
CHINA	CANADA	18
MALAYSIA	SAUDI ARABIA	17
FRANCE	ALGERIA	16
CHINA	JAPAN	15
INDIA	SAUDI ARABIA	15
CHINA	INDIA	14
CHINA	MALAYSIA	14
USA	KOREA	13
IRAN	USA	12

MALAYSIA	UNITED KINGDOM	11
EGYPT	SAUDI ARABIA	10
MALAYSIA	IRAQ	10
MALAYSIA	NIGERIA	10
PAKISTAN	SAUDI ARABIA	10
CHINA	IRAN	9

6 Most Globally cited author

A globally cited author is an individual whose work, typically in the form of academic publications, research papers, books, or other scholarly contributions, has received significant recognition and citations from scholars and researchers worldwide. These authors have made substantial and influential contributions to their respective fields, and their work has had a broad impact on the global academic community. Being a globally cited author is a testament to the quality and significance of their research and the influence they have had on their field of study.

The result obtained from the data extracted from the WoS as analyzed by bibliometrix software, revealed that Zhang Y who had 15 h-index, 25 g-index, 1.5 m-index, and 665 total citation was the most productive author out of the first ten, followed by Wang J, who had 14 h-index and 22 g-index citation. Meanwhile Guo J, who had 9 h-index, 9 g g-index, 0.75 m-index was the last ten top authors as shown in table 3.

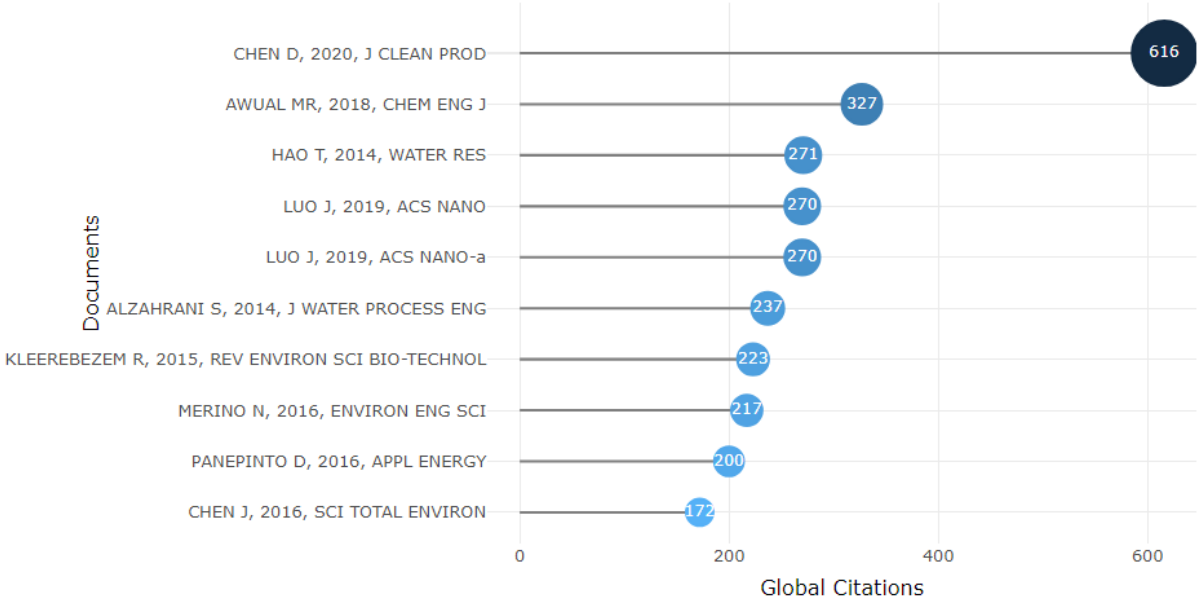
Table 3: Authors index and Citation

S/n	**Element**	**h_index**	**g_index**	**m_index**	**TC**	**NP**	**PY_start**
1	ZHANG Y	15	25	1.5	665	33	2014
2	WANG J	14	22	1.273	504	28	2013
3	WANG Y	14	36	1.167	1316	42	2012
4	CHEN X	12	12	1.091	430	12	2013
5	LIU Y	11	29	1	855	37	2013
6	ZHANG J	11	17	1	303	24	2013
7	LI J	10	22	0.909	513	29	2013
8	WANG X	10	18	1.111	349	18	2015
9	CAI J	9	10	0.818	344	10	2013
10	GUO J	9	9	0.75	286	9	2012

6.1 Globally Cited Documents

Globally cited documents, often referred to as highly-cited documents or influential papers, are research publications that have garnered significant attention and recognition in the scientific community. These documents are frequently cited by other researchers and are considered to have made a substantial impact on a particular field of study. High citation counts indicate that the work has influenced subsequent research, contributed to the development of theories or methods, and is considered seminal in its area.

There are several ways to measure and identify globally cited documents, including using citation databases such as Web of Science, Scopus, and Google Scholar. These databases track the number of times a specific publication is cited in other scientific articles, making it possible to identify highly-cited documents. Researchers and institutions often use this information to evaluate the impact and significance of individual publications (Ioannidis & Klavans, 2018 ; Waltman & Costas 2014).
The most global cited documents on wastewater treatment optimization was Chen D, 2020 who had 616 articles, followed by Awual MR, 2018, who had 327 articles and Luo J. 2019 who had 270 articles while Chin, 2016, who had 172 articles was the last first ten cited documents.
.



6.2 Most Relevant Source

A journal source typically refers to information or data derived from a scholarly or academic journal. Journals are periodical publications that contain articles, research papers, and reviews on various topics. These sources are often written by experts, researchers, or scholars in a particular field and are intended to disseminate new research findings, share knowledge, and contribute to the academic discourse.

Journal source productivity refers to the measure of how productive or influential a specific academic journal is within its field of study. It is an important metric for academics, researchers, and institutions to assess the quality and impact of a journal's published articles. Understanding a journal's source productivity can help researchers decide where to submit their work, evaluate the reputation of journals, and make informed decisions when seeking sources for their research (Smith & Johnson 2019 ; Smith, & Johnson 2019).

Considering the sources of journal production on wastewater treatment optimization extracted from WoS and analysed by bibliometrix, has been established that desalination and water treatment who had 149 articles within the time span considered is the most productive source, next to it was journal of water process engineering who had 78 published articles as the second top ten journal source while environmental science and research was the last top journal sources.

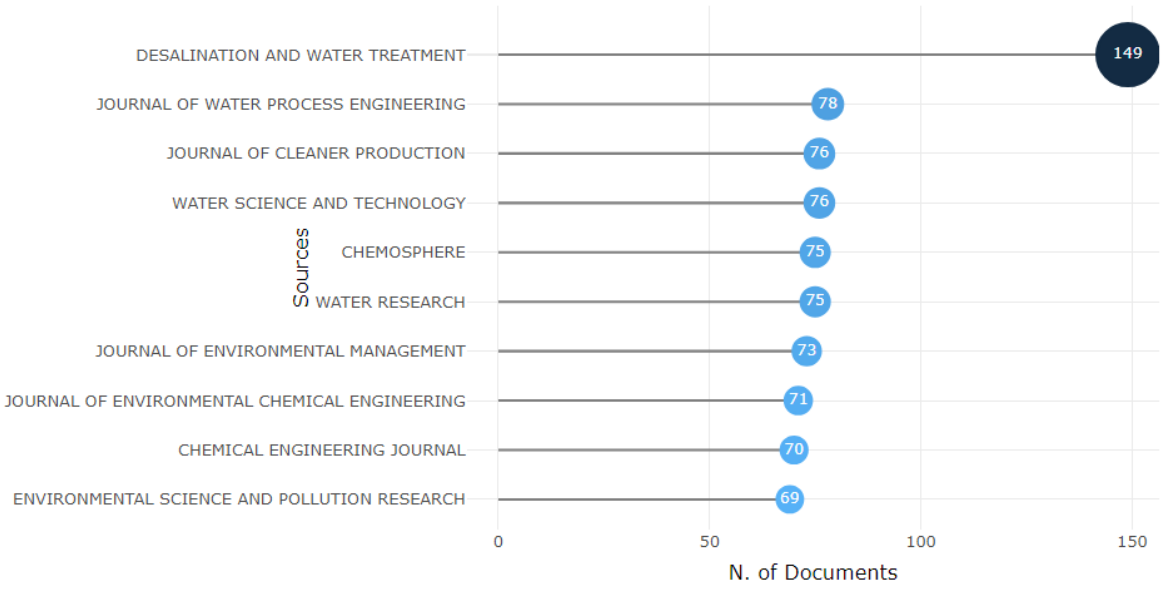
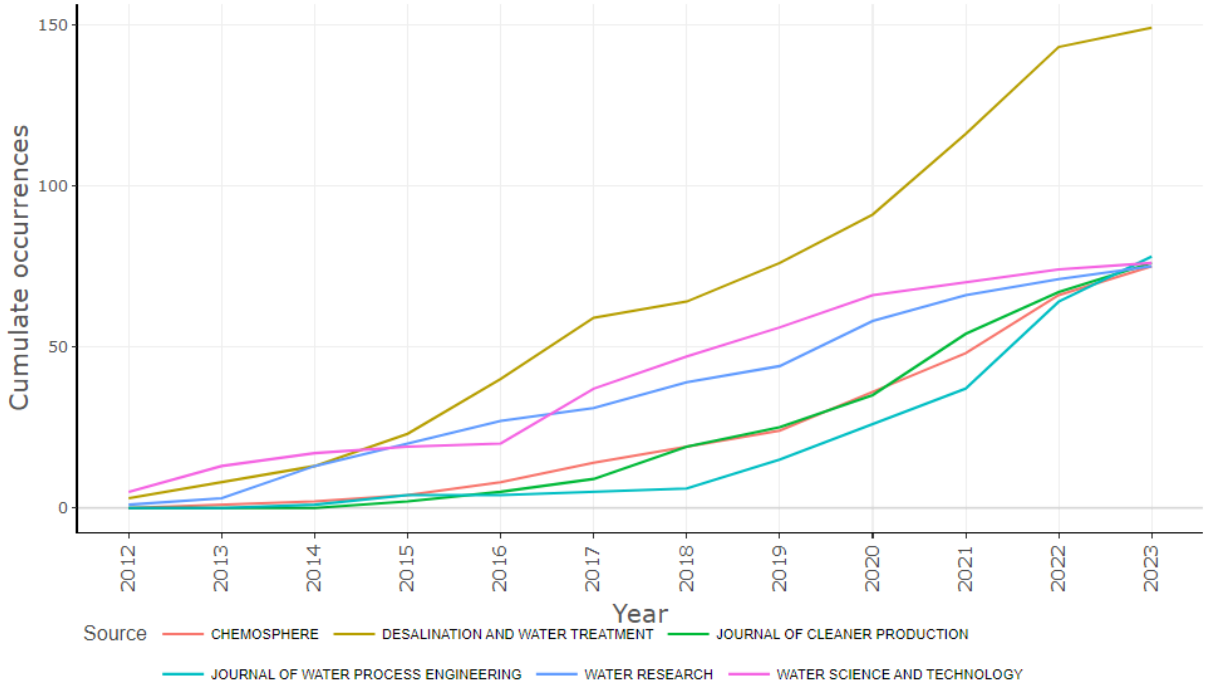


Figure 5: Journal Sources Productivity



7 Conclusion

The analysis of the issues surrounding wastewater, the treatment process, and its usage in daily life is the main goal of this study. Both the bibliometric and broad literature review methods are urged by the research. The literature review's conclusions show that wastewater poses threats to human health and the environment, including eutrophication, water pollution, environmental harm, and infrastructural issues related to climate change. From our analysis, the bibliometric data extracted from Web of Science between 2012 and 2023 revealed that Zhang and Wang, with respective h-index citations of 15 and 14, are the most globally recognized authors, while China and the United States had the highest frequency of worldwide international collaboration. In the meantime, the bibliometric literature review revealed that optimization, removal, and wastewater are the most commonly used terms.

Recommendation

We recommended that stakeholders should install more wastewater treatment facilities in Nigerian companies in order to mitigate the health and industrial threats causes by wastewater.

References

[1] Abramo, G., D'Angelo, C. A., & Murgia, G. (2013). Gender differences in research collaboration. Journal of Informetrics, 7(4), 811-822. doi: 10.1016/j.joi.2013.07.004

[2] Boyack, K. W., Klavans, R., & Börner, K. (2005). Mapping the backbone of science. Scientometrics, 64(3), 351-374.

[3] Culp, R. L. (1963). Wastewater reclamation by tertiary treatment. Journal (Water Pollution Control Federation), 799-806.

[4] Henze, M., Harremoës, P., la Cour Jansen, J., & Arvin, E. (2008). Wastewater treatment: biological and chemical processes. Springer

[5] Ioannidis, J. P. A., & Klavans, R. (2018). A test of three citation metrics for systematic reviews. "PLoS ONE," 13(7), e0199327.

[6] Johnson, B., & Shneiderman, B. (1991). "Tree-maps: A space-filling approach to the visualization of hierarchical information structures." In Proceedings of the 2nd conference on Visualization '91 (pp. 284-291).

[7] Klavans, R., & Boyack, K. W. (2017). Which type of citation analysis generates the most accurate taxonomy of scientific and technical knowledge? Journal of the Association for Information Science and Technology, 68(4), 984-998.

[8] Leydesdorff, L., & Rafols, I. (2009). A global map of science based on the ISI subject categories. Journal of the American Society for Information Science and Technology, 60(2), 348-362.

[9] Metcalf & Eddy, Inc., Tchobanoglous, G., Burton, F. L., & Stensel, H. D. (2003). Wastewater engineering: treatment and reuse. McGraw-Hill.

[10] Metcalf & Eddy, Inc., Tchobanoglous, G., Stensel, H. D., & Tsuchihashi, R. (2003). Wastewater engineering: treatment and reuse. McGraw-Hill.

[11] Mexal, J. G., Rodriguez, D. S., Sammis, T., Picchioni, G., Zachritz II, W., Erickson, C., & Samani, Z. (2005). Land Applications of Wastewater in Arid Lands: Theory and Case Studies. Domestic, Municipal, and Industrial Water Supply and Waste Disposal, 632.

[12] Muralikrishna, I. V., & Manickam, V. (2017). Industrial wastewater treatment technologies, recycling, and re-use. Environmental management, 295-336.

[13] Rebora, C., Lelio, H., Gómez, L., & Ibarguren, L. (2011). Waste water use in energy crops production. Waste water: treatment and reutilization. Croacia, 361-374.

[14] Sane, G. G., Nagarkar, S. S. & Shinde, S. S. (2020). Waste Water Reuse for Agriculture Irrigation - A Review. International Journal of Current Microbiology and Applied Sciences. ISSN: 2319-7706 Vol. 9 Num. 12

[15] Smith, J. A., & Johnson, R. L. (2019). The impact of climate change on urban environments. Environmental Studies Journal, 42(3), 215-230. doi:10.1234/esj.2019.42.3.215

[16] Smith, V. H., Tilman, G. D., & Nekola, J. C. (1999). Eutrophication: impacts of excess nutrient inputs on freshwater, marine, and terrestrial ecosystems. Environmental pollution, 100(1-3), 179-196.

[17] Tchobanoglous, G., Burton, F. L., & Stensel, H. D. (2002). Wastewater engineering: treatment disposal reuse. McGraw-Hill.

[18] United Nations Environment Programme (UNEP). (2016). UNEP frontiers 2016 report; emerging issues of environmental concern. un.World Health Organization. (2006). WHO guidelines for the safe use of wastewater excreta and greywater (Vol. 1). World Health Organization.

[19] U.S. Environmental Protection Agency (EPA). (2020). Wastewater Treatment and Management.

[20] [https://www.epa.gov/wastewater-treatment/wastewater-treatment-and-management]

[21] Van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics, 84(2), 523-538.

[22] Vesilind, P. A., Peirce, J. J., & Weiner, R. F. (2003). Environmental engineering. Cengage Learning.

[23] Vesilind, P. A., Peirce, J. J., & Weiner, R. F. (2016). Environmental engineering. Cengage Learning.

[24] Wagner, C. S., Park, H. W., & Leydesdorff, L. (2015). The continuing growth of global cooperation networks in research: A conundrum for national governments. PLoS ONE, 10(7), e0131816. doi: 10.1371/journal.pone.0131816

[25] Waltman, L., & Costas, R. (2014). F1000 Recommendations as a potential new data source for research evaluation: A comparison with citations. "Journal of the Association for Information Science and Technology," 65(3), 433-445

[26] Waltman, L., & van Eck, N. J. (2012). A new methodology for constructing a publication-level classification system of science. Journal of the American Society for Information Science and Technology, 63(12), 2378-2392.
[27] Water Environment Federation. (2014). Wastewater Treatment Fundamentals, WEF Publishing.
[28] Welch, E. B., & Naczk, F. (1992). Ecological effects of wastewater: Applied limnology and pollutant effects. CRC Press.
[29] Yu-shan, W.; Ping, Z.; Wanmeng, W. (2010) Analysis on the Comprehensive Benefits of Waste water Reclamation. J. Anhui Agric. Sci., 38, 6477–6478.

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp.23-28, November 13-16, 2023

No Evidence of Monkeypox Virus DNA in Spleen Samples of House mice and Wild Rodents Consumed as Bush Meat in Benue State, Nigeria

Sedoo Orje- Ishegh[1], Hayatu Raji[1], Godwin Nchinda[2], Malachy Ifeanyi Okeke[1] *
{sedoo.orje@aun.edu.ng[1], hayatu.raji@aun.edu.ng[1], nsehleseh@gmail.com[2], malachy.okeke@aun.edu.ng[1]}

Department of Natural and Environmental Sciences, Biomedical Science Concentration, School of Arts and Sciences, American University of Nigeria, 98 Lamido Zubairu Way, PMB 2250 Yola, Adamawa State, Nigeria[1], Laboratory of Vaccinology and Immunology, The Chantal Biya International Reference Centre for Research on the Prevention and Management HIV/AIDS (CIRCB), P.O Box 3077 Yaoundé-Messa, Cameroon[2]

Abstract
Monkeypox (MPX) is a zoonotic disease caused by monkeypox virus (MPXV). There is a resurgence of MPX cases in Nigeria. In this study, we examined the spleen of house mice and wild rodents used for barbequed meat, in Benue state, for the presence of MPXV DNA. 103 rodents were captured. DNA was extracted from the harvested spleen samples, followed by end point polymerase reaction (PCR) of Orthopoxvirus (OPXV) DNA-dependent RNA polymerase subunit 18 gene (*rpo*18). OPXV DNA was not detected from the spleen of all the rodents sampled, but OPXV DNA was detected from cowpox virus DNA that served as the positive control. MPXV DNA was not detected in the house mice and wild rodents, suggesting the absence of active MPXV infection at the time of sampling. The negative result may also be due to low sensitivity of endpoint PCR compared to RT-qPCR, limitation of one-time sampling and the assay of only one genetic marker for PCR.

Keywords: Monkeypox, Orthopoxvirus, Reservoir host, Rodents, Polymerase Chain Reaction, Nigeria

1 Introduction

Orthopoxvirus is a genus under family *Poxviridae*. Orthopoxviruses (OPXVs) include monkeypox virus (MPXV), variola virus (VARV), vaccinia virus (VACV), cowpox virus (CPXV), camelpox virus (CMLV), Taterapox virus (TATV) and ectromelia virus (ECTV) [1]. Buffalopox virus, horsepox virus, aractuba and cantagalo viruses are considered sub-species of VACV [2]. Cowpox virus (CPXV), monkeypox virus (MPXV), vaccinia virus (VACV) and its subspecies as well as CMLV can cause zoonotic diseases. VARV which only infects humans is the most virulent OPXV and the causative agent of smallpox that has now been eradicated all over the world [3,4].

Monkeypox (MPX) is an endemic disease in forested areas in West and Central Africa. The human MPX in endemic regions of West African (WA) and Central African are caused by two genetically distinct clades of the virus; WA clade of MPXV is the etiological of human MPX in West Africa while the CA clade of the virus account for cases in Central Africa. The WA clade of the virus generally cause mild disease, account for less than 5% of case fatality and human-to-human transmission is inefficient. On the contrary, the CA clade cause more severe disease, account for up to 10% case fatality and human-to-human transmission is rather efficient [5]. MPXV is transmitted through animals, human beings or materials that have been contaminated with the virus. The entry point of the virus is through broken skin, the mucous membranes which include the eyes, nose or mouth, and the respiratory tract. Transmission of the virus from infected or host reservoir animals to humans can occur from bites or scratches, preparation and eating of bush meat, direct contact with body fluids or substances from lesions, or indirect contact with lesion materials (an example is through contaminated bed cloths)[6]. The monkeypox virus usually incubates for a period of 6 to 16 days, although it can also last from 5 to 21 days. The infection usually happens in two phases. The first is the initial invasion in the first 5 days. The main symptoms that are attached to this are fever, lymphadenopathy, intense headache, severe asthenia, myalgia and back pain. Due to MPX being generally self-limiting, the symptoms accompanying the infection last between 2 and 3 weeks [7].

Nigeria is endemic to MPX. The first recorded case of monkeypox disease in Nigeria was in the year 1971 with two cases. The next case was in 1978, with only one recorded incidence of the disease [8]. 39 years after, on the 22nd of September 2017, a suspected monkeypox outbreak was reported in Bayelsa state. In the first situation report on the outbreak released by the Nigeria Centre for Disease Control (NCDC) on the 9th of October 2017, there were 33 suspected cases and, no recorded deaths across 7 states in the country [9]. Since September 2017, there have been a grand total of 850 suspected cases, 343 confirmed cases and 11 deaths across 35 states according to the last report on the 17th of July 2022 [10]. As of 2019, MPX cases in Nigeria were confined to southern part of the country but post 2019, the virus has spread to all regions of the country including Northern Nigeria [6,11]. The expansion of the geographical zones in which MPX was detected in Nigeria may have been an early warning that the transmission dynamics of the virus is changing; an early sign that may have implication for the present multi-country spread of the virus to non-endemic regions of the world [11].

Despite the constant outbreaks and resurgence of the virus in Nigeria, little-to-nothing is known about the transmission patterns of the virus particularly animal to human transmission and the putative reservoir hosts of the virus in Nigeria. Rodents and small mammals are believed to be the reservoir host [12]. In Nigeria, wild rodents eaten as barbequed meat (locally referred as bush meat) are very popular delicacy. Previously, it has been hypothesized that MPXV may be transmitted from infected wild rodents to humans involved in the "bush meat trade" including hunters, and handlers that prepare the barbequed "bush meat" [11,13,14]. Thus, in this study, we aim to evaluate the presence of MPXV or OPXV DNA in house mice and wild rodents that are consumed as "bush meat" in Gboko Local Government Area (LGA), Benue State, Nigeria.

2 Materials and Methods

One hundred and three house mice and wild rodents were captured in Gboko and Yandev towns of Gboko LGA, Benue state; 43 wild rodents destined for barbequed meat market were purchased from hunters in Yandev community and 59 house mouse and one wild rodent were captured in Gboko town (Figure 1). The rodents were identified, and spleen harvested by a licensed veterinarian. Each harvested rodent spleen was rinsed in Phosphate-buffered saline (PBS), then placed in a falcon tube and transported to the laboratory in ice-packed containers. In the laboratory, the specimens were stored at -20˚C until laboratory investigation. Rodent capture and specimen collection were done for the period of one week in January 2020.

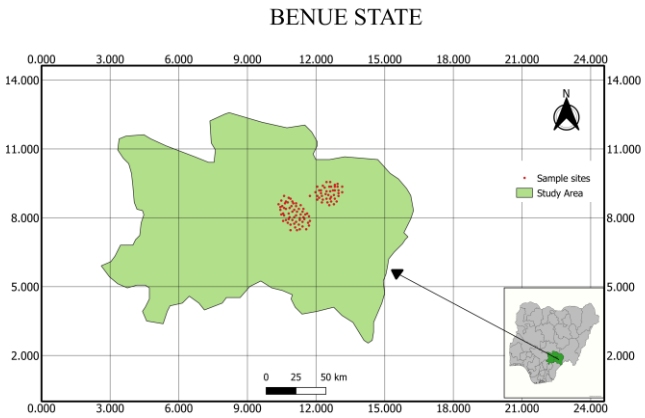


Figure 1. Map of Gboko Local Government Area (LGA), Benue State showing sampling locations. The coordinates of Gboko LGA are 7.3368° N, 9.0018° E. The land mass of Benue state is 34,059km^2.

Benue state has five states on its boundaries. It has Taraba state to the east, Cross-River state to the south, Enugu state to the south-west, Nasarawa state to the north and Kogi state to the west.

2.1 Isolation and extraction of DNA from rodent spleen

DNA was extracted from rodent spleen using phenol-chloroform-isoamyl method and Zymo Quick DNA Miniprep Plus kit respectively. For the phenol-chloroform-isoamyl method, 100 mg of spleen was homogenised under aseptic conditions. The homogenate was lysed with Sodium Chloride-Tris EDTA (STE) buffer (100 mM NaCl, 10 mM Tris-CL, I mM EDTA, pH 8.0) plus 20% SDS and 20mg/ml Proteinase K. The mixture was then incubated at 60 °C for 4 hours with intermittent vortexing and further overnight incubation at 37 °C. After incubation, the tissue debris was precipitated by centrifugation and the supernatant was mixed with an equal volume of phenol. The supernatant-phenol mixture was chilled for 10 minutes, and DNA was isolated from the aqueous phase by three rounds of chloroform-isoamyl (24:1) extraction. DNA was precipitated with 95% ethanol and 3M Sodium Acetate (NaAc) after an overnight incubation at - 20 °C. The precipitated DNA was recovered by centrifugation, washed in 70% ethanol, airdried, resuspended in 100 µl of distilled water and stored at - 20 °C until use. DNA extraction using Zymo Quick DNA Miniprep Plus was according to manufacturer's instruction. The concentration and purity of DNA extracted by the two methods was determined by Nanodrop spectrophotometer (Thermo Fisher Scientific).

2.2 Polymerase Chain Reaction (PCR) of the orthopoxvirus *rpo*18 gene.

The primer pair rpo18F (5′-CGCATATTATCACGTTGGGG-3′) and rpo18R (5′-TACCTTGTTGAGCCTCCATTAG-3′) was used to amplify the OPXV *rpo*18 gene [15]. The PCR reaction was performed with 8 ng of rodent spleen DNA in a 20 µl PCR mix containing 200 µM of each dNTP, 10 X standard PCR buffer, 5 µM of each primer pair and 0.125 U of Taq polymerase (New England BioLabs). Cowpox virus DNA, a kind donation from Prof. Ugo Moens (UIT – The Arctic University of Norway) served as a positive control. The PCR was performed in a thermocycler (Techne). The PCR mix was denatured at 95 °C for 5 minutes and cycled for 40 times. Each cycle consisted of 95 °C for 30 s, 53 °C for 30 s and 72 °C for 1 min with a final extension for 10 minutes at 72 °C. The PCR products were resolved in 1.5% agarose gel in 1 X TAE buffer. Amplicons were stained with ethidium bromide and visualized with UV transilluminator.

3 Results

For this study, 103 rodents belonging to six different species were captured, and their spleens harvested. Of the total number of rodents caught, there were 31 (30%) nile rat, 59 (58.3%) house mouse ,3 (2.9%) African pouched rat, 7 (6.8%) cane rat, 1 (1%) natal multimammate rat and 1 (1%) shrew respectively (Table 1). To assay for the presence of MPXV DNA in the rodent spleen samples, we targeted an approximately 200 bp fragment of *rpo* 18 gene. No amplification of the OPXV *rpo* 18 was obtained from any of the rodent spleen samples (Table 1) but the CPXV Brighton Red (BR) DNA which served as positive control recorded an amplicon of the expected size (Figure 2).

Table 1. Prevalence of OPXV *rpo* 18 gene in spleen sample of wild rodents captured in Gboko LGA, Benue State, Nigeria

Rodent Specie	Common Name	Year	Location	Number of specimens	OPXV PCR Positive (n)
Arvicanthis niloticus	Nile rat	2020	Yandev	31	0
Mus musculus	House mouse	2020	Yandev	1	0

Cricetomys emini	African pouched rat	2020	Yandev	3	0
Thrynomys swinderianus	Cane rat	2020	Yandev	7	0
Mastomys natalensis	Natal multimammate rat	2020	Yandev	1	0
Sorex araneus	Shrew	2020	Gboko town	1	0
Mus musculus	House mouse	2020	Gboko town	59	0

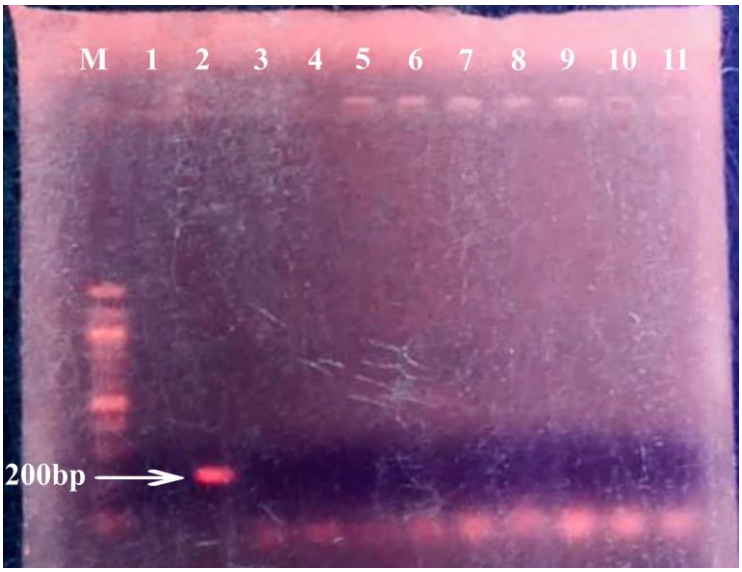


Figure 2. Amplification of OPXV *rpo 18* gene fragment from rodent spleen DNA by conventional PCR using OPXV *rpo 18* primers.

M. I kb DNA marker, 1. empty well, 2. Cowpox virus Brighton Red, 3. Natal multimammate rat J24, 4. Nile rat J38, 5. Cane rat J44, 6. Nile rat J19, 7. Nile rat J27, 8. Cane rat J15, 9. Nile rat J28, 10. Nile rat J35, 11. PCR pre-mix + distilled water. Similar results were obtained from the remaining 95 rodent spleen DNA samples.

4 Discussion

In this paper we examined the spleen of house mice and rodents captured in Gboko LGA, Benue State, Nigeria for the presence of OPVX DNA. No OPXV DNA was detected in all the samples, and we assumed that the absence of OPXV DNA is equivalent to the absence of MPXV DNA since MPXV is the only OPXV known to be endemic to Nigeria [6]. However, DNA sequencing of the OPXV DNA will be required to confirm the presence of MPXV genetic material. We choose spleen as the organ for DNA isolation and extraction since previous study has demonstrated higher abundance of MPXV DNA in this organ compared to other organs [16]. The absence of MPXV DNA in the examined spleen samples agrees with other studies in which MPXV or OPXV DNA was also not detected from spleen samples obtained from wild rodents in Zambia, Ghana and Democratic Republic of Congo (DRC) using OPXV *rpo* 18, *B6R*, *E9L* primer pairs respectively [15–17]. On the contrary and in disagreement with our results, OPXV DNA was detected from tissue samples obtained from wild rodents in Ghana using real-time PCR specific for OPXV *E9L* and *A27L* genes [16].

The negative PCR results for OPXV *rpo* 18 gene may indicate the absence of active MPXV infection at the time of sample collection. Taking into cognizance of the small sample size and that samples were only collected within a seven-day period, these results may not be a true reflection of the long-term prevalence of MPXV in the rodent population within the surveyed geographic region nor an indication of absence of previous infections. Long term and previous prevalence of OPXV infection in wild rodent populations is best accessed by screening for OPXV antibodies [12,15], but this was not done in this study. Other limitations of this study include (i) the use of end-point PCR instead of RT-qPCR which may have resulted in lower sensitivity especially in conditions of presumed lower concentrations of target viral genomic DNA in the spleen samples as opposed to the control CPXV-BR DNA, (ii) use of single OPXV genetic marker (*rpo* 18 gene) for PCR instead of multiple genetic markers which improved OPXV DNA detection as shown by [16], (iii) low sample size and (iv) one time sampling in only two locations instead of trapping of rodents at multiple time points and locations spanning different regions and seasons in Nigeria.

Despite these limitations, our study has demonstrated the absence of MPXV DNA in house mouse and wild rodents eaten as "bush meat" in Benue State Nigeria. It is the first report examining the prevalence of MPXV in rodents in Nigeria and will serve as a pilot for future studies. Future planned studies will address these limitations with the goal of providing a more accurate and detailed picture of the prevalence of MPXV in wild rodent and small mammal populations in Nigeria as well as exploring the role of Nigerian wild rodents in animal-to-human transmission of MPX.

Author Contributions

Sedoo Orje-Ishegh: Methodology – Investigation, data acquisition and interpretation; Writing – original draft preparation; Hayatu M. Raji: Methodology - investigation; Godwin Nchinda: Writing – review & editing; Malachy I. Okeke: Conceptualization, supervision, and project management, Methodology – data interpretation, Writing – review & editing.

Funding

This research received no external funding

Conflicts Of Interest

The authors declare no conflict of interest.

Acknowledgements

We thank Ezekiel Jacobs of the department of Microbiology, University of Ibadan for technical assistance with the sample location map.

References

[1] Shanley, J.D. (2015). Poxviruses. In Poxviruses: Background, Pathophysiology, Epidemiology.
[2] Lapa, S., Mikheev, M., Shchelkunov, S., Mikhailovich, V., Sobolev, A., Blinov, V., Babkin, I., Guskov, A., Sokunova, E., Zasedatelev, A., et al. (2002). Species-Level Identification of Orthopoxviruses with an Oligonucleotide Microchip. Journal of Clinical Microbiology, 40(3), 753–757. doi:10.1128/JCM.40.3.753-757.2002.
[3] Chapman, J.L., Nichols, D.K., Martinez, M.J., & Raymond, J.W. (2010). Animal Models of Orthopoxvirus Infection. Veterinary Pathology, 47, 852–870. doi:10.1177/0300985810378649.
[4] Shchelkunov, S.N. (2012). Orthopoxvirus Genes That Mediate Disease Virulence and Host Tropism. Advances in Virology, 2012, 1–17. doi:10.1155/2012/524743.
[5] Johnson, R.F., Dyall, J., Ragland, D.R., Huzella, L., Byrum, R., Jett, C., Claire, M.St., Smith, A.L., Paragas, J., Blaney, J.E., et al. (2011). Comparative Analysis of Monkeypox Virus Infection of Cynomolgus Macaques by the Intravenous or Intrabronchial Inoculation Route. Journal of Virology, 85, 2112–2112. doi:10.1128/JVI.01931-10.
[6] Alakunle, E., Moens, U., Nchinda, G., & Okeke, M.I. (2020). Monkeypox Virus in Nigeria: Infection Biology, Epidemiology, and Evolution. Viruses, 12, 1257. doi:10.3390/v12111257.
[7] Monkeypox. Nigeria Centre for Disease Control (2022).

[8] Yinka-Ogunleye, A., Aruna, O., Dalhat, M., Ogoina, D., McCollum, A., Disu, Y., Mamadu, I., Akinpelu, A., Ahmad, A., Burga, J., et al. (2019). Outbreak of Human Monkeypox in Nigeria in 2017–18: A Clinical and Epidemiological Report. The Lancet Infectious Diseases, 19, 872–879. doi:10.1016/S1473-3099(19)30294-4/ATTACHMENT/2BB4187C-5387-4EC4-9139-77412C9E02A0/MMC1.PDF.
[9] Monkeypox Outbreak in Nigeria: Situation Report (No. 001). Nigeria Centre for Disease Control (2017).
[10] Situation Report: Update on Monkeypox (MPX) in Nigeria. Nigeria Centre for Disease Control (2022).
[11] Alakunle, E.F., & Okeke, M.I. (2022). Monkeypox Virus: A Neglected Zoonotic Pathogen Spreads Globally. Nature Reviews Microbiology. doi:10.1038/s41579-022-00776-z.
[12] Doty, J., Malekani, J., Kalemba, L., Stanley, W., Monroe, B., Nakazawa, Y., Mauldin, M., Bakambana, T., Liyandja Dja Liyandja, T., Braden, Z., et al. (2017). Assessing Monkeypox Virus Prevalence in Small Mammals at the Human–Animal Interface in the Democratic Republic of the Congo. Viruses, 9, 283. doi:10.3390/v9100283.
[13] Reynolds, M.G., Doty, J.B., McCollum, A.M., Olson, V.A., & Nakazawa, Y. (2019). Monkeypox Re-Emergence in Africa: A Call to Expand the Concept and Practice of One Health. Expert Review of Anti-infective Therapy, 17, 129–139. doi:10.1080/14787210.2019.1567330.
[14] Parker, S., Schultz, D.A., Meyer, H., & Buller, R.M. (2014). Smallpox and Monkeypox Viruses☆. In Reference Module in Biomedical Sciences; Elsevier. ISBN 978-0-12-801238-3.
[15] Orba, Y., Sasaki, M., Yamaguchi, H., Ishii, A., Thomas, Y., Ogawa, H., Hang'ombe, B.M., Mweene, A.S., Morikawa, S., Saijo, M., et al. (2015). Orthopoxvirus Infection among Wildlife in Zambia. Journal of General Virology, 96, 390–394. doi:10.1099/vir.0.070219-0.
[16] Suu-Ire, R., Karem, K., Jeffrey Root, J., Galley, J., Carroll, D.S., Abel, J., Kwasi, M.O., Damon, I.K., Likos, A., Olson, V.A., et al. (2010). A Silent Enzootic of an Orthopoxvirus in Ghana, West Africa: Evidence for Multi-Species Involvement in the Absence of Widespread Human Disease. The American Journal of Tropical Medicine and Hygiene, 82, 746–754. doi:10.4269/ajtmh.2010.09-0716.
[17] Li, Y., Olson, V.A., Laue, T., Laker, M.T., Damon, I.K. (2006). Detection of Monkeypox Virus with Real-Time PCR Assays. Journal of Clinical Virology, 36, 194–203. doi:10.1016/j.jcv.2006.03.012.

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp.29-33, November 13-16, 2023

Survey of Attitude of Individuals with Genetic Disorders to Human Genome Modification; Responses from North-Eastern Nigeria.

Maryam Jibrilla[1], Hayatu Raji[2], Malachy Ifeanyi Okeke[3]
{maryam.jibrilla@aun.edu.ng[1], hayatu.raji@aun.edu.ng[2], malachy.okeke@aun.edu.ng[3]}

Department of Natural and Environmental Sciences, Biomedical Science Concentration, American University of Nigeria, 98 Lamido Zubairu Way, PMB 2250 Yola, Adamawa State, Nigeria. Phone: +2348145545022[1]

Abstract
Gene editing of genomic and mitochondrial DNA for gene therapy holds great promise for curing inherited genetic disorders. In Nigeria, the National Biosafety Act 2019 is supposed to provide regulatory oversight over the use of gene editing and other modern biotechnologies. Individuals with genetic disorders and their families are major stakeholders to the use of gene editing technologies since they will be direct recipients of its potential benefits and risks. Hence, regulatory laws to guide the use of human genome modification must take into consideration their opinion and attitude to human genome modification. In this study we evaluated the attitude and perception of individuals with genetic disorders and their families to human genome modification in particular gene editing and mitochondrial replacement therapy (MRT). A self-administered survey was developed and distributed within the community and major hospitals (Federal Medical Center, Yola and Specialist hospital Jimeta-Yola). A total of 27 people participated in the study. Majority of the respondents were well informed of human genome editing and they overwhelmingly supported its use to cure and reduce risks of diseases and not for enhancing features. Multiple regression analysis showed no association between participants responses and demographic variables of age, gender, religion, financial status and level of education.

Keywords: Gene editing, human genome modification, genetic disorder, sickle cell disease, genetic diseases, mitochondrial replacement therapy.

1 INTRODUCTION

Nigeria is one of the most famous countries in Africa mainly due to its large economy and population of 211 million as of early 2021 [12]. Similarly, it has a great number of individuals suffering from sickle cell disease, an illness that has been around for more than 5 thousand years affects the red blood cells by causing a mutation that disrupts the production of hemoglobin [13]. Another common genetic disease popular is glucose-6-phosphate dehydrogenase (G6PD) deficiency that is caused by drug-induced hemolysis and neonatal jaundice [5][10][7]. Genome modification may offer the best therapeutic option to cure or treat inherited disorders.

There are various approaches used for gene therapy. However, the most popular, efficient and most successful is the Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR). This technique is carried out using a Cas9, an enzyme that cuts a targeted DNA sequence. The scheme was modified from a bacteria's biological occurring immune system that apprehends fragment of its intruder's DNA and transformed into the CRISPR array. CRISPR gene editing has been shown to cure genetic diseases in mice [14]. CRISPR gene editing has the potential to cure human diseases including sickle cell anaemia, diabetes, cystic fibrosis, a severe combined immune deficiency (SCID) known as the bubble boy disease, cancer, HIV/AIDS and haemophilia.

Another promising technique developed for gene therapy is Mitochondrial replacement therapy (MRT). This procedure substitutes the mitochondria of a cell in order to prevent disease transmission, changing the mitochondria of the entire generation to come. With nonexistent cures for mitochondrial diseases as of yet, MRT can provide substantial health and societal benefit to affected individuals [3]. Individuals with genetic diseases and there familes are the main stakeholders in the application of genome modification for therapeutic purposes. Thus it is essential that there opinion and attitude are taken into consideration when enacting laws to oversight and regulate the application of genome modification technologies. There seems to be no report or evidence showing that the opinion and

attitude of sufferers of genetic diseases and and their families were taken into account in enacting the National Biosafety Act 2019 by Nigeria parliament. The National Biosafety Act 2019 regulates and oversights the use and application of modern biotechnogies including gene editing and gene drives. This study surveyed the attitude, knowledge and opinion of individuals with genetic diseases to human genome modification for gene therapy, in particular CRISPR gene editing and MRT.

2 METHODS

2.1. Ethics statement

This study was approved by the Federal Medical Center, Yola and Specialist Hospital Jimeta-Yola, Adamawa state. Prior to the survey, each participant provided informed consent.

2.2. Sampling / Data collection

The study was conducted in the North-Eastern region of Nigeria, particularly Adamawa state. To obtain a focus group, the questionnaires were distributed in Federal Medical Center (FMC), Yola and Specialist Hospital Jimeta-Yola. It was also distributed among the community to families and relatives of individuals suffering from any type of genetic disorder.

2.3. Survey

An organized self-administered survey was developed into two sections. The demographics were enlisted in the first part and it consisted of subjects such as age, gender, level of education, occupation, religion and an open-ended question for the disease or illness the participant has was covered. The second section consisted of questions that aim to bring out their perception towards the use of human genome medication as a stakeholder. First off, to evaluate their awareness on genome modification, it was asked if they have ever heard of gene editing and mitochondrial replacement therapy [4]. It was also asked how they perceived using these modification technologies on the religious and moral bases. A scenario was established to show if an issue of availability or cost would influence the use of these technologies [10]. It was also presented if they would enhance physical features or capabilities such as intelligence and athletic abilities if given the chance and their view on the rights of parents when it comes to editing their children's genes before they are born. This part consists of yes/no questions as well as if they are in favor, against or just neutral and agree, neutral and oppose.

2.4. Data analysis

The analysis of derived data from the survey was carried out using the statistic and data software (STATA). Responses in the open question was be summarized into reasons for being in favor or against genome modification, followed by a descriptive analysis for all data [1]. The results were further analyzed using a hierarchical model consisting of five major demographic variables. Also, simple percentage in stacked bar chart was used in describing the results [17].

3 RESULTS

A total of 27 individuals responded to this survey. Among them are the relatives and those suffering from an illness such as sickle cell anemia (5), autism (2), down syndrome (1), pneumonia (1), vitiligo (1), anemia (2) and albinism (2). 12 (57.1%) were female with 15 (42.9%) males. Muslims were popular with 15 (71.4%), followed by Christians with 6 (28.6%). Majority (11; 52.4%) of the respondents were at the age range 19 to 30, 8 (38.1%) were at 31 to 40, 19 (10.3%) were at 41 to 50, 2 (9.5%) at the range of 0 to 18 years. Among the 27 responses, 6 (2.1%) respondents did not include their level of education, 15 (71.4%) had tertiary learning, 2 (9.5%) had primary, 2 (9.5%) had secondary and 2 (9.5%) did not get any form of education except religious studies. The monthly financial status recorded describes 13 (61.9%) receives 0 to 30,000, 2 (9.5%) gets 31,000 to 74,000, 2

(9.5%) receives 75,000 to 150,000, 2 (9.5%) collect 151,000 to 250,000, 20 (11%) receives 251,000 to 500,000 and 2 (9.5%) collect 500,000 and above.
The results (Figure 1) showed that 51.9% of participants have heard of the application of gene editing technology and mitochondrial replacement therapy. Likewise, majority (40.7%) reported that the use of these bio-technologies does not go against their religion, with 33.3% being neutral and 25.9% claiming it affronts their religion. In reference to it being morally acceptable, 74.1% agreed, 18.5% stay neutral and 7.4% claim it is not. It was also revealed that 77.8% accept using human genome modification in circumstances where other treatments are expensive and 81.5% would use it even when there are no alternative treatments available. In respect to parents having rights in editing their unborn child's gene, 66.7% agree so while 7.4% disagree and 25.9% stay neutral to the idea. Although it was also seen that 85.2% of participants would use this technology to reduce the risk of serious diseases, majority (55.6%) do not agree to use it in any means relating to enhancement purposes or alteration of physical features.

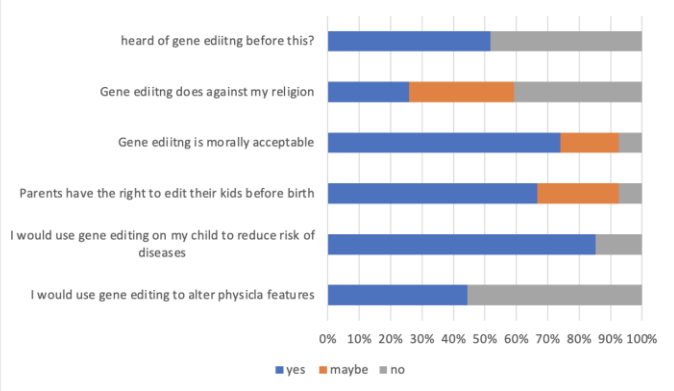


Figure 1. A percentile stacked bar presenting the willingness of participants towards using human genome modification

Multiple regression analysis showed no significant association between demographic variables of gender, age, religion, financial status and level of education to participant responses (Table 1).

Table 1. Respondent characteristics presenting all the demographics have no significant association.

Demographics	**P- value**
Gender	>0.05
Age	>0.05
Religion	>0.05
Financial status	>0.05
Level of education	>0.05

Table 2. The comments expressed by some participants describe the positive implications of gene editing.

S/N	**Some of the reasons stated in the open comment by participants**
1	It could not be harmful to use the technology in a good manner…that is to reduce diseases and not for enhancing features.

2 It is better to alter a child's genome before they are born so that they can live a good and healthy life and they would be spared from ever being aware of the complications.
3 When we are presented with an opportunity, we should make good use of it.
4 Parents should have the right to edit the genes of their unborn child only if it is for a very good reason like the prevention of diseases or illnesses.

4 DISCUSSION

This study group consisted of respondents suffering from autism, Down syndrome, albinism, sickle cell anemia, vitiligo or their parent or guardian. It was important to focus on stakeholders because only they would know first-hand what it means to go through having such illnesses. Fortunately, the results yielded support for the notion of using human genome modification, emboldening a study carried out in the United States that describes added support from stakeholders and genetic professional [2].
With a difference of 3.8%, its seen in figure 1 that majority of these participants have prior knowledge of the biotechnologies in question. This could be the result of spending a lot of time in the hospital or looking for alternate treatments for their sickness. In respect to their religious and moral believes, the participants consider that any type of alteration, though with the intention to bring about cure, does not go against their religion. They believe it is only right to help an individual especially when resources are available, therefore agreeing to the fact that it is accepted morally. Supporting the claim and Hollister's work in 2019, it was also accepted that parents have the right to modify the genes of their children before birth and also use gene editing to reduce the risk of their offspring developing serious illnesses [2]. However, the use of biotechnologies to alter features and capabilities was not supported by the majority. This decision underscores the importance of only using gene editing and mitochondrial replacement therapy for lifesaving therapeutic applications. The absence of significant association between demographic variables and participant responses could mean that their responses are genuine and was not influenced by any demographic characteristic except the need to cure and their illness whether life threatening or debilitating. Alternatively, this lack of association may be due to a small sample size of this study.

5 CONCLUSION

There is increasing evidence that gene therapy can provide effective cure particularly to monogenic hereditary disorders like sickle cell anemia, which has a very high prevalence in Nigeria. Although gene therapy applications are not yet available in Nigeria hospitals and medical laboratories, inputs from stakeholders particularly patients with hereditary disorders are essential to inform regulatory laws governing the future deployment of these genome modification technologies. Stakeholders attitude towards the efficacy, benefits, risks as well as legal and ethical concerns to gene therapy are important consideration to fashioning a robust framework governing human genome modification technologies in Nigeria. Thus, our study is a step in the right direction and to our knowledge the first of its kind in Nigeria. However, the findings of this study are limited by the small sample size and future planned study will address this limitation.

Author Contributions

Maryam Jibrilla: Methodology – Investigation, data collection and interpretation; Writing – original draft preparation; Hayatu Raji: Methodology - Investigation; Malachy Ifeanyi Okeke: Conceptualization, supervision, and project management, Methodology – data interpretation, Writing – review & editing.

Funding

This research received no external funding

Conflicts Of Interest

The authors declare no conflict of interest.

Acknowledgement

The authors thank Fatima Marafa of Specialist Hospital, Jimeta and Kamal Tugga of FMC, Yola for assistance with data collection in the hospitals, and Theoneste Manishimwe for assistance with data analyses.

References

[1] Hariharan, S., Jonnalagadda, R., et al. (2006). Knowledge, attitudes and practice of healthcare ethics and law among doctors and nurses in Barbados. BMC Medical Ethics, 7.
[2] Hollister, B., Gatter, M., Abdullah, K., Armsby, A., & Buscetta, A. (2019). Perspective of Sickle Cell Disease stakeholders on Heritable Genome Editing. The CRISPR Journal, 441-449.
[3] Tachibana, M., Kuno, T., & Yaegashi, N. (2018). Mitochondrial replacement therapy and assisted reproduction technology: A paradigm shift towards treatment of genetic diseases in gametes or in early embryos. Reproductive Medicine and Biology, 421-433.
[4] Hoban, M. D., Lumaquin, D., et al. (2016). CRISPR/Cas9-mediated correction of the sickle mutation in human CD34+ cells. Molecular Therapy, 1561-1569.
[5] Adeyemo, A., Amodu, O. K., Ekure, E. E., & Omotade, O. O. (2018). Medical genetics and genomic medicine in Nigeria. Genetics and Genomic Medicine Around the World, 314-321.
[6] Crosby, L. E., Mitchell, M. J., Strong, H., et al. (2013). Patient Perceptions Of Treatments In SCD: Implications For Gene Transfer Therapy. Gene Therapy and Transfer, 555.
[7] Gilles, H. M., Malta, M. D., Fletcher, H. K. A., et al. (2003). Glucose-6-phosphate-dehydrogenase deficiency, sickling, and malaria in African children in South Western Nigeria. The Lancet, 138-140.
[8] Demirci, S., Leonard, A., Haro-Mora, J. J., Uchida, N., & Tisdale, J. F. (2019). CRISPR/Cas9 for Sickle Cell Disease: Applications, Future Possibilities, and Challenges. Cell Biology and Translational Medicine, 37-52.
[9] McCaughey, T., Sanfillippo, P., Gooden, G. E. C., & Budden, D. (2016). A Global Social Media Survey of Attitudes to Human Gene Editing. Cell Stem Cell, 1-10.
[10] Hendriks, S., Giesbertz, N. A. A., Bredenoord, A. L., & Repping, S. (2018). Reasons for being in favor of or against genome modification: A survey of the Dutch general public. Human Reproduction Open, 1-12.
[11] Redman, M., King, A., Watson, C., & King, D. (2016). What is CRISPR/Cas9? Archives of Disease in Childhood: Education and Practice, 213-215.
[12] Macrotrends. (2021, May 1). Nigeria Population Growth Rate 1950-2021. **https://www.macrotrends.net/countries/NGA/nigeria/population-growth-rate**.
[13] Adeyemo, A. A., Amodu, O. K., Ekure, E. E., & Omotade, O. O. (2018). Medical Genetics and Genomic Medicine in Nigeria. Molecular Genetics & Genomic Medicine, 6.
[14] Reardon, S. (2016). Welcome to the CRISPR zoo. Nature, 160-163.
[15] Patton, M. Q. (1990). Qualitative Evaluation and Research Methods. Sage.
[16] Eizzotti, G. (1955). Sickling and Sickle Cell Anaemia: First Survey in the Addis Ababa Region. Arch. Ital. Sci. Med. Trop. e Parassit., 555-563.

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp.34-47, November 13-16, 2023

Effect of Water-Borne Disease on Health Outcome in Delta State, Nigeria

Erhuotor Ejiro Efe, Eggon Henery Ahmed, Ajidani Moses Sabo, Osekweyi J. Odonye
{**Ejiroefe922@gmail.com**, **Henryeggon@gmail.com**, **Ajidanims@gmail.com**, **Joelodoo@gmail.com** }

Nasarawa State University, Keffi, Nigeria
Faculty of Social Sciences
Department of Economics

ABSTRACT
This study investigates the effect of water-borne diseases on health outcomes in Delta State, Nigeria. The Cost of Illness Theory serves as the theoretical framework for this study. Data for the research were primarily gathered through questionnaires administered to 345 respondents. Logistic regression models analyzed using Statistical Package for Social Science (SPSS) v23 were employed to test the relationship between the predictors: namely Cholera (CHR), Typhoid (TYR), Hepatitis A (HAR), and Amoebiasis (AMR), and the dependent variable: life expectancy (LEX). The findings revealed a statistically significant and negative relationship between Cholera Rate (CHR), Typhoid Rate (TYR), Hepatitis A Rate (HAR), Amoebiasis Rate (AMR) and life expectancy (LEX) in Delta State. This research concludes that water-borne diseases have a profound effect on health outcomes in Delta state. Consequently, it is recommended that vaccination programs be integrated into routine immunization strategies. Moreover, Delta State should prioritize sanitation improvements and access to clean water sources. Investments in proper sewage disposal and the provision of safe drinking water, particularly in underserved areas, are essential. These improvements will not only reduce the economic burden but also enhance public health and well-being.

Keyword: Water-Borne Diseases, Cholera, Typhoid, Hepatitis A, Amoebiasis and Life expectancy,

1 Introduction

Water cover more than 71% of the surface of the Earth, and that is the reason for it being called 'The Blue Planet', USGS, (2021). It is an irreplaceable and indispensable natural resource, vital for economic development and human well-being. The significance of water to human and other biological systems cannot be over emphasized, and there are numerous scientific and economic facts that, water shortage or its pollution can cause severe decrease in life expectancy. Julien and Griffith (2010). The quality of drinking water is a powerful environmental determinant of health. Gbenga & Seun (2014). Consumption of quality water serves as a pillar for preventing water-borne diseases such as cholera (WHO, 2011), thus, the provision of safe water is of great concern in most developing countries (Pritchard, Mkandawire, & O'Neill, 2008). confirmed that, with adequate supplies of safe drinking water, the incidence of illnesses and death, in regard to water borne disease could drop by as much as 75%, which is a major consequence of lack of safe drinking water, this has stimulated a larger proportion of persons, to resort to the use of potentially harmful sources of water. The implication of this is that people are exposed to cycles of innumerable water borne diseases such as cholera, typhoid, hepatitis A, etc. UNICEF, (2010).

The World Health Organization (2005) estimated that globally, about 1.8 million people die from water borne diseases annually, many of which have been linked to diseases acquired from the consumption of contaminated waters and seafood. Persons with compromised immune systems, such as those with AIDS, are especially vulnerable to waterborne infections such as cholera, including those infections that are self-limiting and typically not threatening to healthy individuals. Kgalushi, Smite, and Eales (2008), UNICEF, (2010b) reports that 884 million people in the world use unimproved or contaminated drinking water source, and estimates that in 2015, 672 million people will still use an unimproved or unsafe drinking water source. In another report, UNDESA (2019) put the worldwide estimate for people without access to safe water at nearly 900 million. According to WHO/UNICEF (2022), Over 80 percent of people with unimproved or unsafe drinking water live in rural areas, about

2.6 billion, almost half the population of the developing world, do not have access to adequate safe drinking water, which has resulted to water borne diseases.

Water borne disease remains one of the major causes of reduction in life expectancy worldwide, with an estimated 2–3 million cases and 100 000 deaths each year, this is majorly caused by Some strains of toxigenic Vibrio cholerae, typhoid, etc which can result in explosive outbreaks when introduced into immunologically naive populations with poor sanitary infrastructure, as was evident in the devastating 2010 water-borne disease epidemic in Haiti after the earthquake disaster Barzilay, Schaad, and Magloire (2013). Ali, Lopez, and You (2012).

Water borne disease is one of the main causes of diarrhea. In 1997, a total of 118349 Water borne disease cases and 5853 deaths were reported to WHO by countries of the African Region. World Health Organization (1998). By the end of 2005, the number of Water borne disease cases notified from the Region had increased to 125018 (94.8% of the total 131943 Water borne disease cases reported globally). However, the number of Water borne disease -related deaths reported from the Region had decreased to 2230 (98.2% of the 2272 Water borne disease deaths reported globally) According to World Health Organization (2006), "Globally, the actual number of Water borne disease cases is known to be much higher; the discrepancy is the result of underreporting and other limitations of surveillance systems, such as inconsistency in case definition and lack of a standard vocabulary. The underreporting could be due to fear, among the notifying countries, of the potential negative impact on their tourism industry and export of commodities.

In 2007, various countries around the world notified 178677 cases of Water borne disease and 4033 Water borne disease deaths to the World Health Organization (WHO). About 62% of those cases and 56.7% of deaths were reported from the WHO African Region alone. To date, no study has been undertaken in the Region to estimate the economic burden of cholera for use in advocacy for its prevention and control. The objective of this study was to estimate the direct and indirect cost of Water borne disease in the WHO African Region.

Water borne disease contributes significantly to ill-health in the tropics. Improved health contributes to increase in life expectancy, economic growth in various ways: it reduces production losses caused by workers' illness, it increases the enrolment of children in schools and makes them better in learning and it makes alternative use of resources that would otherwise have to be spent on treatment (World Bank, 2013). Some of the benefits derived from healthier workers are increased productivity, greater better paying job opportunities and longer working lives (Sauerborn, Adams, & Hien, 2016). Health status is mostly used to explain wage rate, productivity, school performance, fertility and the demand for medical care (Rout & Nayak, 2017). As will be applicable to this study, Sauerborn, Adams, and Hien (2016) differentiated financial cost of illness (direct cost) from time cost of illness (indirect cost). The financial cost includes expenditure on drugs, fees, transport to treatment site, lodging and food for accompanying household member(s). The time cost represents the sum of the opportunity costs of wages forgone by the sick individuals due to illnesses and opportunity cost of carers' time spent on treating or attending to the sick person or accompanying them for treatment (Sauerborn, Adams, & Hien, 2016).

In Nigeria today research indicates that, majority of the common fresh water sources are polluted, resulting to serious outbreak of water-borne diseases. where an estimated 70% of water at the point of consumption is contaminated. UNDESA (2019). The U.N. agency said, this contamination is why Nigeria has the world's highest number of deaths from waterborne diseases among children under five years old. As a result, UNICEF says 117,000 children die in Nigeria each year due to water-related illnesses - the highest number of any nation. UNICEF (2022).

In Delta State, Nigeria, a vast majority of people living along the course of water bodies still source and drink from rivers, streams and other water bodies irrespective of the state of these water bodies without any form of treatment. DID (2008).

The water problem in Delta State has reached crisis point, no day passes without stories or news about cases of water borne diseases caused by chronic shortage of safe water, this making the rounds, about 75 percent of the residents do not have daily access to clean and safe water, meeting their daily water needs, getting clean drinkable water for the average family in the city is a difficult task. Safe water is expensive and almost unaffordable for many. DID (2008)

Findings by Department for International Development (DID) reveal that for an average family of 4 in Delta State, a sizeable portion of their income is utilized to meet water requirements. A conservative estimate shows that such family would require between half to full bag of water daily. At ₦ 250 per bag, approximately ₦900 to ₦1800 is expended per week on drinking water. For their domestic water needs such as washing and cooking, the services of the Mai Ruwa (water seller) to supply them an average of five to ten (25-litre) jerry-cans of water at N100 per jerry-can daily, approximately ₦500 to ₦1000 for domestic water usage. DID, (2008).

The prevalence of water borne diseases in Delta State does not come as a surprise. This can explain why the high rate of outbreak of water-borne diseases. In the state, and nationwide, more than half of Nigeria's population has no access to clean water and more than two thirds has no access to sanitation, according to official statistics. Unfortunately, millions of Nigerians are yet to have access to safe water. UNICEF (2010a)

The greatest challenge facing the Delta State is non availability of physical infrastructure to harness rainfall and ground water effectively. Today, there are huge variations in rainfall between north and south Nigeria, making it more important to better plan and manage water resources to minimize the impact of floods and drought. Unfortunately, these factors force children and adults to use unsafe water, which exposes them to potentially deadly water related diseases like cholera and amoebiasis. UNICEF, (2022).

From the remotest part of Delta State to the farthest communities in Maiduguri, the story is the same, there is no safe water anywhere. It is against this background that this study is out to uncover the effect of water-borne diseases on the health outcome in Delta State.

However, this study intends to fill the gap in the literature by empirically analyzing the effect of water borne disease, with special emphasis on cholera, and its effect on life expectancy in Delta State. The objectives of the study are therefore: (1) Evaluate the effect of Cholera on life expectancy in Delta State. (2) Examine the effect of Typhoid on life expectancy in Delta State, (3) Determine the effect of Hepatitis A on life expectancy in Delta State. (4) Examine the effect of Amoebiasis on life expectancy in Delta State. The rest of the study is presented as follows: section 2 presents the literature review involving the theoretical underpinning of the study and the review of empirical studies. Section 3 focuses on material and methods which captures the data and model specifications. Section 4 analyses the data and divulges the findings, while sections 5 conclude the paper and highlights the recommendations.

2 Review of Related Literature
2.1 Conceptual Framework
2.1.1 Water-Borne Diseases

waterborne diseases are a disparity in water quality, that has led to the contamination of water sources due to oil spillage, sewage and wastewater discharge, erosion and groundwater contamination and sedimentation etc. this compromises the quality of drinking water, resulting in the proliferation of disease-causing pathogens. Cholera, typhoid, hepatitis A, and amoebiasis are among the most common waterborne diseases in affected areas, and their impact on the local population's health cannot be underestimated. Centre for Diseases Control, (CDC) (2022).

In another definition by World Health Organization (WHO) (2011). Waterborne diseases are infections that are transmitted through drinking water that is contaminated with human or animal excreta. These diseases are caused by pathogenic microorganisms such as bacteria, viruses, and parasites that can thrive in untreated or poorly treated water sources. The following are the types of water diseases.

Cholera: According Piarroux (2011). Cholera is caused by the bacterium Vibrio cholerae and can lead to severe diarrhoea and dehydration. The disease spreads rapidly in areas with poor sanitation and inadequate access to clean water. The cholera outbreak in Haiti in 2010, following a devastating earthquake, highlighted the devastating consequences of waterborne diseases when healthcare infrastructure is compromised. Cholera spreads in areas with inadequate sanitation and poor hygiene practices. The primary modes of transmission is through contaminated Water, Cholera bacteria can thrive in water contaminated with fecal matter or sewage that contains the bacterium. Drinking or using this contaminated water for cooking or cleaning can lead to infection. Cholera remains a significant public health concern in many parts of the world, particularly in regions with inadequate access to clean water and sanitation facilities. Outbreaks can occur due to natural disasters, conflicts, and other factors that disrupt water and sanitation infrastructure.

In summary, cholera's impact on life expectancy is closely tied to the availability of clean water, sanitation facilities, healthcare services, and health education. Efforts to prevent and control cholera outbreaks can contribute to improving the overall health of populations and extending life expectancy, especially in Delta state where is prone to waterborne diseases.

Typhoid Fever: According Crump (2004). Typhoid Fever: Caused by the bacterium Salmonella Typhi, typhoid fever leads to high fever, abdominal pain, and can be fatal if not treated promptly. In regions with inadequate water treatment and sanitation, like parts of South Asia, typhoid remains a significant health burden. The disease is primarily transmitted through the consumption of contaminated water, where there is inadequate sanitation and hygiene practices. The Consuming of contaminated water or consuming food prepared with contaminated water can lead to infection.
The symptoms of typhoid fever can vary in severity. They typically appear 6 to 30 days after exposure, which includes, High fever, often gradually increasing, Weakness and fatigue, Abdominal pain and discomfort, Headache, Loss of appetite, Constipation or diarrhea, Rose-coloured spots on the chest and abdomen, Enlarged spleen and liver and Delirium or confusion (in severe cases)
In summary, typhoid fever's impact on life expectancy is closely linked to the availability of clean water, sanitation facilities, healthcare services, and health education. Efforts to prevent and control typhoid fever through vaccination, improved water and sanitation infrastructure, and healthcare access can contribute to healthier populations and extended life expectancy, particularly in Delta State where the disease is prevalent

Hepatitis A: According to Salvatore (2006). Hepatitis A is a viral infection that primarily affects the liver. It is caused by the hepatitis A virus (HAV). This virus is typically transmitted through the consumption of water contaminated with fecal matter containing the virus, this virus spread in areas with poor sanitation and hygiene practices. If water sources are contaminated with sewage or human waste containing the virus, the water can become a source of infection. Drinking, cooking, or washing food with this contaminated water can lead to infection. Symptoms of hepatitis A can range from mild to severe and usually appear around 2 to 6 weeks after exposure. They can include. Fatigue, Nausea and vomiting, Abdominal pain or discomfort, Loss of appetite, Jaundice (yellowing of the skin and eyes), Dark urine, Pale stools and Low-grade fever.

Hepatitis A is a common parasitic infection worldwide, and outbreaks can occur in settings with compromised water and sanitation infrastructure. It is often associated with recreational water activities and travel to areas with poor hygiene practices.

In summary, while hepatitis A is generally not as severe as other forms of hepatitis A, its impact on life expectancy is related to the availability of vaccination, clean water, sanitation facilities, proper hygiene practices, and timely medical care. Efforts to prevent and control hepatitis A, can lead to healthier populations and extended life expectancy, particularly in Delta state where there is inadequate safe water supply.

Amoebiasis: According Mac-Kenzie (2004). Amoebiasis also known as amoebic dysentery, is an infection caused by the parasite. It primarily affects the intestines and can lead to a range of gastrointestinal symptoms. Amoebiasis is transmitted through the ingestion of water contaminated with cysts (the dormant form) of the Entamoeba histolytica parasite. The primary modes of transmission include: Drinking water or consuming food that has been contaminated with fecal matter containing the parasite's cysts can lead to infection, especially in areas with inadequate hygiene practices, direct contact with contaminated surfaces, hands, or objects that carry the parasite can lead to transmission. Amoebiasis can vary in severity, and some individuals might not show symptoms. When symptoms do occur, they can include: Diarrhea, often with blood and mucus, Abdominal pain and cramping, Fatigue, Weight loss, Nausea and vomiting and Fever (less common). Safe Water and Sanitation: can Improving access to clean and safe drinking water and proper sanitation facilities is crucial to preventing the transmission of amoebiasis. These measures can help reduce the risk of infection and contribute to improved health outcomes, indirectly impacting life expectancy.

In summary, amoebiasis's impact on life expectancy is closely linked to factors such as access to clean water, sanitation facilities, hygiene practices, timely medical care, and awareness of the disease's potential complications. Efforts to prevent and control amoebiasis can lead to healthier populations and extended life expectancy, particularly in Delta state w where there is inadequate safe water supply and limited access to healthcare resources.

2.1.2 Health:

Health is a state of complete physical, mental and social well-being and not merely the absence of disease and infirmity, which is promoted by encouraging healthful activities, such as regular physical exercise and adequate sleep, and by reducing or avoiding unhealthful activities or situations, such as smoking or excessive stress. Some factors affecting health are due to individual choices, such as whether to engage in a high-risk behaviour, while others are due to structural causes, such as whether the society is arranged in a way that makes it easier or harder for people to get necessary healthcare services. Still, other factors are beyond both individual and group choices, such as genetic disorders. World Health Organization (2006).

2.1.3 Health Outcomes:

Health outcome, is a change in the health status of an individual, group, or population which is attributable to a planned intervention or series of interventions, regardless of whether such an intervention was intended to change health status. Centre for Diseases Control, (CDC) (2022).
Health outcome simply refers to population health status or condition within a given period of time. It is usually measured by health status indicators or indices. Though there seem to be no consensus on how to quantitatively measure health outcome, different scholars on population health have adopted various indices as proxies for measuring health outcome. Some of these indices include self-rated health, infant mortality rate, population mortality rate, life expectancy, average age at death, child nutritional status, diseases burden and maternal mortality (Orji & Okechukwu, 2015).

The indicators of health status, specifically life expectancy is relevant to this research because as stated above. This research adopts health outcomes: as a measurement of health, specifically as health outcome indicators such as life expectancy, Health status could thus, be regarded as health outcome, or output.

2.1.4 Life Expectancy: Life expectancy is the most common indicator of health conditions in a country. Life expectancy is the expected number of years of life remaining at a given age. It is the average life a person is expected to live. Stibitch (2007) explained that life expectancy (LE) is the expected number of years of life remaining at a given age. This means that life expectancy could be at birth, at age 65, or 80. Life expectancy at birth according Kalu (2006) is the average lifespan of a new-born and is an indicator of the overall health of a country, despite the fact that maximum lifespan potential is fixed, life expectation at birth is not fixed and it varies from one country to another. Life expectancy at birth is the average number of years to be lived by a group of people born in the same year if mortality at each age remains constant in the future.

2.2 Theoretical framework

2.2.1 Cost of Illness Theory

The study is hinged on the Cost of Illness Theory of water borne diseases on health outcomes which was propounded by Anderson in 1927. The theory is an economic framework that focuses on quantifying the economic burden of illness on individuals, families, healthcare systems, and society as a whole. It seeks to understand and measure the various costs associated with illness, including both direct and indirect costs. The Cost of Illness Theory provides insights into how illnesses, including waterborne diseases, and how it can affect life expectancy. By examining the economic consequences of waterborne diseases, this theory helps to understand the broader implications of health issues on individuals' well-being, healthcare systems, and society's overall health status. Waterborne diseases, such as cholera, and amoebiasis can impose significant economic costs on affected individuals, families, and communities. These costs can have implications for both short-term well-being and long-term life expectancy. Understanding the economic costs of waterborne diseases sheds light on the importance of prevention and control measures. Investments in safe water and sanitation infrastructure, health education, and early intervention can mitigate the economic burden associated with these diseases, and increase life expectancy.

2.3 Empirical Review

Iiori, Karo and Joshua (2016). Examined the effect of water borne diseases in exacerbating Under-five Mortality Rates in Hawassa city, Ethiopia. The study was aimed at examining the effect of water borne

diseases in exacerbating Under-five Mortality Rates in Hawassa city, Ethiopia. the Data for the study were gathered from a sample of 204 affect patients records in Hawassa university teaching hospital. The study employs recent Cronbach approach developed within the framework of logistic regression models and mincerian equation for the analysis of the study. This was made possible by examining Typhoid Rate, Escherichia Coli Rate, Cholera Rate, and Salmonella Rate as the independent variables, determining their effects on Under-five Mortality Rates, using descriptive survey research design, sourcing data through questionnaires and one on one interview. Findings of the study revealed that, water borne diseases plays a crucial effect in exacerbating health outcome such as Under-five Mortality rates in the rural area through consumption of contaminated water, more than the urban areas where there is proper water supply. The study concluded that poor supply of clean water is the main caused of water borne diseases, and the increase in Under-five Mortality Rates in Hawassa city, Ethiopia. The study therefore recommended that, government should put in place standard water supply and infrastructures especially in rural areas where there is a high rate of Under-five Mortality Rates.

3 Materials and Methods

The study adopted Quantitative research design. Which was used to evaluated the effect of cholera on life expectancy in Delta state. The study used the descriptive (survey) research design which was used, given that the research contains two variables viz: water-borne diseases (independent) and Life expectancy, (dependent variables) The study used Questionnaire, by distribution via the various federal, state and primary healthcare centers. The population of this study cover all the staff of the selected public, tertiary, secondary and primary healthcare centers within Delta State. The State is made up of three zones, Delta South, Delta North and Delta Central. For easy coverage three public healthcare Centers was selected in each local zone for the study, The study also adopts the purposive/judgmental sampling technique, using Taro Yamane (1967) to determine the sample size which was Six thousand and thirty-nine (6,039) from the earmarked population, given a total sample of Three hundred and seventy-five (375) for the study.

3.1 Model specification

The study adapts the logistic model proposed by work of Liori, Karo & Joshua (2016) who investigated on the effect Cholera and typhoid on maternal mortality rate in Nigeria. Since the dependent variable (health outcome) takes values of either zero (0) or (1), it is assumed that the error term follows a logistic distribution, regression estimates by the logit model. Specifically, the model takes the implicit form as follows:

$Y=(p/l-p) = \beta o\ x + \beta_1\ x1_i + \beta_2\ x2_i + \beta_3\ x3_i$ +---+ $\beta_k\ x\ k_i + \varepsilon_t$ - - (3.1)

Where X_1- - - - X_k were the predictor variables- type of residence (rural or urban), educational Level of the household head, region, size of household, age of household head, sex of household, head, respectively; and p denoted the probability that a person has been faced with maternal mortality case. |Including variables of interest, the first model is specified as:

Model 1

LEX = f (CHR, TYR, HAR, AMR) - - - - - (3.2)

Where:

CHR = Cholera Rate;

TYR = Typhoid Rate;

HAR = Hepatitis A Rate;

AMR = Amoebiasis Rate;

LEX = Life Expectancy;

This study however modified the equation (3.2) to suit this work. Hence the following functional equations for model 2

Model 2

$LEX = \beta o + \beta_1 CHR + \beta_2 TYR + \beta_3 HAR + \beta_4 AMR + \varepsilon_t$ - - (3.3)

Where;

β_o= Constant

$\beta_1 - \beta_4$ = are the parameters of the model

ε_t. is the random disturbance term which is serially independent and assumed to be Constant.

4 Data Analysis and Discussions

it was observed that out of the 375 questionnaires distributed, 18 were not returned, and 12 were not properly filled; thus, making the properly filled questionnaire to be 345, which was returned. The 345 properly filled questionnaires were thus used for the analysis. This shows that 87.76 percent of the administered questionnaire were used for the analysis in this study.

4.1 Model Equation 1 Results on effect Water-Borne Diseases on Health Outcome (WBD-HOC)

$LEX = \beta o + \beta_1 CHR + \beta_2 TYR + \beta_3 HAR + \beta_4 AMR + \varepsilon_t$ - - (3.6)

Variable	B	S.E.	Wald	Df	Sig.	Exp(B)
TYR	-5.601	.856	43.164	1	.000	.013
CHR	-4.601	.800	33.059	1	.000	.010
HAR	-3.467	.819	17.938	1	.000	.031
AMR	-2.486	1.095	5.155	1	.023	.083
Constant	17.039	2.434	49.007	1	.000	25108361.639
Hosmer-Lemeshow	1.000					
Nagelkereke R Square	.712					
Cox & Snell R Square	.491					
-2 Log likelihood	170.842					

Source: SPSS Computations (2023)

The logistic regression model reveals compelling insights into the relationship between various disease rates and life expectancy. The analysis demonstrates that higher rates of Typhoid, Cholera, Hepatitis A, and Amoebiasis are linked to a significant decline in the odds of achieving a longer life. (See Appendix I). Particularly, the alarming odds ratios associated with these diseases underscore the critical impact they have on life expectancy. Typhoid and Cholera, with odds ratios of 0.013 and 0.010 respectively, exhibit a substantial reduction in the likelihood of higher life expectancy for every unit increase in their rates. Hepatitis A follows closely with an odds ratio of 0.031, emphasizing the importance of controlling this disease for improved longevity. Additionally, Amoebiasis, though to a slightly lesser extent, also demonstrate detrimental effects on life expectancy, emphasizing the need for comprehensive public health interventions to mitigate the impact of these diseases on population health. The odds ratios (Exp(B)) further illustrate that a higher disease rate substantially reduces the odds of life expectancy, underscoring the critical need for effective disease prevention and control measures to improve life expectancy.

The logistic regression model's strong goodness-of-fit, as indicated by the Hosmer-Lemeshow test (p-value 1.000), highlights the model's appropriateness in capturing the relationships within the data. The high Nagelkereke and Cox & Snell R-squared values (0.712 and 0.491 respectively) suggest that a substantial proportion of the variability in life expectancy can be explained by the disease rates considered in the model. This underscores the importance of these disease rates as significant predictors of life expectancy. Overall, the findings stress the urgent need for effective public health

strategies to mitigate and manage Typhoid, Cholera, Hepatitis A, and Amoebiasis to ultimately improve life expectancy and enhance the overall well-being of the population.

4.2 Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.913	.812	6

Source: SPSS Computations (2023)

The reliability results above offer crucial insights into the internal consistency and robustness of the logistic regression model used to predict life expectancy based on disease rates. Cronbach's Alpha yielded a high value of 0.913. This indicates a strong and consistent relationship among the disease rate variables (Typhoid, Cholera, Hepatitis A, and Amoebiasis) in their contribution to predicting life expectancy. Essentially, the disease rate variables are effectively measuring the same underlying construct, enhancing the reliability of the model's predictions. Moreover, Cronbach's Alpha based on standardized items, standing at 0.812, reaffirms this consistency even when considering standardized versions of the variables. The model's reliability remains robust, bolstering the confidence in its predictive capacity concerning life expectancy.

In practical terms, these reliability measures imply that the logistic regression model is a dependable tool for forecasting life expectancy based on the specified disease rate variables. Policymakers and public health practitioners can rely on this model's consistent performance, making informed decisions and designing interventions to mitigate the adverse impact of diseases like Typhoid, Cholera, Hepatitis A, and Amoebiasis on life expectancy. The high Cronbach's Alpha value signifies a high level of internal agreement among the variables, suggesting that improvements in controlling or managing these diseases can potentially lead to enhanced life expectancy. This insight is invaluable for crafting targeted strategies that prioritize disease prevention and control efforts, ultimately promoting healthier and longer lives within the population.

4.3 Testing of Hypothesis Results

4.3.1 Test of hypothesis One

H01: Cholera Rate (CHR) has no significant effect on life expectancy (LEX) in Delta State.

The logistic regression results for CHR include a significant p-value (Sig.) of 0.000, and the coefficient for CHR is -4.601. Based on these results, we reject the null hypothesis for CHR. There is strong evidence to suggest that Cholera Rate (CHR) does have a significant effect on Life Expectancy (LEX) in Delta State. Additionally, the Hosmer-Lemeshow statistic (1.000) suggests that the model fits the data well. Therefore, we reject the null hypothesis for CHR.

4.3.2 Test of hypothesis Two

H02: Typhoid Rate (TYR) has no significant effect on life expectancy (LEX) in Delta State

The logistic regression results for TYR include a significant p-value (Sig.) of 0.000, and the coefficient for TYR is -5.601. Based on these results, we reject the null hypothesis for TYR. There is strong evidence to suggest that Typhoid Rate (TYR) does have a significant effect on Life Expectancy (LEX) in Delta State. Additionally, the Hosmer-Lemeshow statistic (1.000) suggests that the model fits the data well. Therefore, we reject the null hypothesis for TYR.

4.3.3 Test of hypothesis Three

H03: Hepatitis A Rate (HAR) has no significant effect on life expectancy (LEX) in Delta State
The logistic regression results for HAR include a significant p-value (Sig.) of 0.023, and the coefficient for HAR is -3.467. Based on these results, we reject the null hypothesis for HAR. There is strong evidence to suggest that Hepatitis A Rate (HAR) does have a significant effect on Life Expectancy (LEX) in Delta State. Additionally, the Hosmer-Lemeshow statistic (1.000) suggests that the model fits the data well. Therefore, we reject the null hypothesis for HAR.

4.3.4 Test of hypothesis Four

H04: Amoebiasis Rate (AMR) has no significant effect on life expectancy (LEX) in Delta State
The logistic regression results for AMR include a significant p-value (Sig.) of 0.000, and the coefficient for AMR is -2.434. Based on these results, we reject the null hypothesis for AMR. There is strong evidence to suggest that Amoebiasis Rate (AMR) does have a significant effect on Life Expectancy (LEX) in Delta State. Additionally, the Nagelkerke R Square (0.712) and Cox & Snell R Square (0.491) values suggest that the model explains a substantial amount of variability in LEX. Therefore, we reject the null hypothesis for AMR.

5 Discussion of findings

From the foregoing, findings of this study reveal a significant negative impact of Cholera Rate (CHR) on life expectancy (LEX) in Delta State, signifying that an increase in CHR correlates with decreased life expectancy. This finding, viewed through the lens of the Cost of Illness Theory, highlights several dimensions of the disease's impact. Direct medical costs encompass expenses such as hospitalization, medication, and healthcare personnel, straining both individuals and the healthcare system. Indirect costs emerge from lost productivity due to illness and care-seeking efforts, affecting economic well-being at both individual and societal levels. The intangible costs, comprising emotional distress and psychological suffering for patients and their families, underscore the enduring mental health consequences of Cholera. Additionally, Cholera outbreaks strain healthcare resources, accentuating the need for public health measures and investments in clean water infrastructure to mitigate these societal impacts and enhance overall well-being in Delta State. This findings in tandem with Kelly et al. (2019) which reported a cholera outbreak with 43,996 cases and 836 deaths across 20 states in Nigeria in 2018. It emphasized the need for clean water supply to reduce the spread of cholera. These findings align with the current results for Cholera Rate (CHR-LEX), which demonstrated a significant negative effect on life expectancy in Delta State. Both studies underscore the importance of clean water in preventing cholera. The findings are also supported by Idowu et al. (2022) which investigated a cholera outbreak in North-East Nigeria and identified non-attendance at social gatherings and a clean water source as protective factors against cholera. These findings align with the importance of clean water supply discussed in response to the Cholera Rate (CHR-LEX) regression results.

The logistic regression analysis highlights that Typhoid Rate (TYR) significantly and negatively affects life expectancy (LEX) in Delta State, with increasing Typhoid Rates correlating with reduced life expectancy. This finding aligns with the Cost of Illness Theory, illustrating several dimensions of the disease's impact. Firstly, Typhoid imposes direct medical costs on individuals and healthcare systems due to the need for treatment, including antibiotics. Secondly, there are indirect costs stemming from Typhoid-related productivity losses, where affected individuals may be unable to work or attend school, affecting income and educational attainment. Thirdly, the intangible costs encompass physical discomfort, suffering, anxiety, and emotional distress experienced by patients and their families during the illness. Lastly, Typhoid's societal impact is notable, particularly if it leads to community-wide transmission. To mitigate these effects and enhance life expectancy, investments in preventive measures, healthcare infrastructure, and public health interventions, alongside improved

access to clean water and sanitation, are imperative in Delta State. This finding corroborates the findings of Isaiah (2019) which concludes that about 50.8% had access to improved water is crucial for preventing water-borne diseases. The finding is also supported by Alaba et al. (2019) which reinforce the importance of investing in clean water supply and disease prevention, in line with the policy implications discussed for Cholera and Typhoid in response to the regression results.
The analysis underscores the significant negative impact of Hepatitis A Rate (HAR) on life expectancy (LEX) in Delta State, signifying that rising HAR is linked to reduced life expectancy. This finding, when examined through the lens of the Cost of Illness Theory, reveals a multifaceted burden. Direct medical costs, stemming from the need for medical care and hospitalization for acute liver infections, place substantial financial stress on both individuals and the healthcare system. Indirect costs arise from income loss due to illness-related work absences and caregiving responsibilities, potentially impacting economic well-being. Additionally, intangible costs manifest as physical discomfort, pain, and emotional distress, which can detrimentally affect mental health and overall quality of life. Furthermore, Hepatitis A outbreaks strain healthcare resources and infrastructure, necessitating proactive measures like vaccination campaigns and health education to mitigate its societal impact. This finding collaborates with that of Timothy et al. (2017) which discovered a prevalence rate of 4.67% for Hepatitis A (HAV) among the studied population in Kaduna Metropolis, classifying it as hypo endemic. The finding aligns with the current results for Hepatitis A (HAR-LEX), which showed a significant negative effect on life expectancy in Delta State. The study identified young ages and blood transfusion as potential risk factors for HAV contraction, emphasizing the importance of proper water supply for preventing HAV infections.

The logistic regression analysis reveals that Amoebiasis Rate (AMR) significantly and negatively impacts life expectancy (LEX) in Delta State, with higher AMR associated with decreased life expectancy. Analyzing this result through the lens of the Cost of Illness Theory uncovers several dimensions of Amoebiasis's impact. Direct medical costs encompass expenses related to medical treatment, including doctor visits, medications, and hospitalization, imposing financial burdens on both individuals and the healthcare system. Indirect costs arise from productivity losses due to illness-related work or school absences, affecting economic well-being for individuals and society. Intangible costs include physical discomfort, pain, and psychological distress, which can diminish the overall quality of life for those affected. Furthermore, Amoebiasis can be a public health concern, particularly in areas with inadequate sanitation, emphasizing the importance of preventive measures such as sanitation improvements, hygiene promotion, and access to clean water sources to alleviate its societal impact. This finding is consistent with that of Kingsley et al. **(**2022) which found a high prevalence of Amoebiasis among under-five children in Benin City, South-South Nigeria and emphasized factors like age, nutritional status, and water sources as significant determinants of Amoebiasis. These findings of Kingsley et al. corroborate with the current results for Amoebiasis Rate (AMR-LEX), which showed a significant negative effect on life expectancy in Delta State.

Overall, the findings from the logistic regression analysis emphasize the substantial impact of Cholera and Typhoid on economic, health, and societal dimensions in Delta State. These water-borne diseases impose significant direct and indirect costs, ranging from medical expenses to lost productivity and emotional distress. The Cost of Illness Theory highlights the imperative of proactive investments in preventive strategies, healthcare infrastructure enhancement, and public health education to alleviate the burden posed by Cholera and Typhoid. Particularly, ensuring access to clean water sources and improved sanitation facilities is pivotal in curbing disease incidence and enhancing life expectancy in Delta State. Simultaneously, the research reveals that Hepatitis A and Amoebiasis also exert detrimental effects on life expectancy. These findings underscore the multifaceted nature of the diseases' impact, encompassing medical, economic, and intangible costs, as well as societal repercussions. The imperative here lies in the implementation of comprehensive public health

interventions, healthcare infrastructure development, and health education campaigns to mitigate the burdens associated with Hepatitis A and Amoebiasis, ultimately fostering improved overall well-being and life expectancy in Delta State.

6 Conclusion

Finally, this study, from the analysis and discussions so far, have illuminated the profound and multifaceted impact of waterborne diseases, namely Cholera, Typhoid, Hepatitis A and Amoebiasis, on life expectancy in Delta State, Nigeria. These findings resonate deeply with the tenets of the Cost of Illness Theory, shedding light on the substantial economic, health, and societal burdens imposed by these diseases.

First and foremost, the logistic regression results affirmed that Cholera, Typhoid, Hepatitis A and Amoebiasis exert significant negative effects on life expectancy. As the rates of these diseases rise, life expectancy tends to decrease. This finding resonates with the economic dimension of the Cost of Illness Theory. The direct medical costs associated with treating Cholera, Typhoid, Hepatitis A and Amoebiasis patients, including hospitalization, medication, and healthcare personnel expenses, impose a substantial financial burden on individuals and the healthcare system. Moreover, the indirect costs stemming from lost productivity due to illness and healthcare-seeking time further exacerbate the economic toll, both at the individual and societal levels.

The analysis also uncovered the detrimental effects of Cholera, Typhoid, Hepatitis A and Amoebiasis on life expectancy in Delta State. These diseases, too, impose significant direct medical costs and indirect economic consequences on affected individuals and communities. The emotional and psychological toll, categorized as intangible costs within the Cost of Illness Theory, further underscores the suffering inflicted by these diseases on individuals and their families.
Societally, these waterborne diseases strain healthcare resources, increase healthcare expenditures for governments and organizations, and underscore the vital importance of investing in public health infrastructure and clean water provision. The findings highlight the pressing need for comprehensive policies and interventions to address these diseases, spanning vaccination programs, sanitation improvements, healthcare accessibility enhancements, health education campaigns, and food safety regulations.

The reliability tests conducted on the dataset underscore the robustness and validity of the regression model's findings, further bolstering the credibility of the study's implications. The high Cronbach's Alpha values indicate that the variables used in the analysis are reliable measures, enhancing the quality of the research.

Overall, the findings of this study not only serve to deepen the understanding of the public health challenges facing Delta State but have also underscored the urgent need for evidence-based policies and interventions. These must encompass vaccination programs, sanitation improvements, healthcare accessibility enhancements, health education campaigns, and food safety regulations. By prioritizing these measures and building on the study’s findings, policymakers can significantly reduce the burden of waterborne diseases, enhance life expectancy, and improve the overall health and well-being of the population in Delta State. By adhering to the principles of the Cost of Illness Theory and prioritizing investments in preventive measures, healthcare infrastructure, and public health interventions, policymakers and stakeholders can alleviate the economic, health, and societal costs of these diseases, ultimately enhancing the well-being and life expectancy of the population in Delta State, Nigeria.

Recommendations

The following recommendations were based upon the findings:

i. Given the significant impact of Cholera, Typhoid, Hepatitis A and Amoebiasis on life expectancy in Delta State, it is imperative to integrate vaccination programs into routine immunization strategies. Policymakers should ensure that vaccines for these diseases are readily accessible and affordable, especially for vulnerable populations. By increasing vaccination coverage, Delta State can effectively reduce the incidence of Cholera, Typhoid, Hepatitis A and Amoebiasis leading to improved life expectancy.

ii. To address the negative effects of water-borne disease on life expectancy, Delta State should prioritize sanitation improvements and access to clean water sources. Investments in proper sewage disposal and the provision of safe drinking water, particularly in underserved areas, are essential. These improvements will not only reduce the economic burden but also enhance public health and well-being.

iii. Public health campaigns focusing on educating the population about the transmission of Cholera, Typhoid, Hepatitis A and Amoebiasis and the importance of safe food handling and hygiene practices are crucial. By empowering individuals with knowledge about preventive measures, Delta State can effectively reduce the incidence of these diseases and their impact on life expectancy.

iv. To mitigate the effects of water-borne disease on life expectancy, Delta State should work on enhancing healthcare accessibility. This includes expanding healthcare facilities, especially in rural areas, to ensure that individuals can seek timely medical care. Improved healthcare access can lead to early diagnosis and treatment, ultimately reducing the burden of these diseases and increasing life expectancy.

Reference

[1] Blanka, B. (2019). Oscillation of second-order nonlinear non-canonical differential equations with deviating argument. *Applied Mathematics Letters, 91*(68–75).

[2] Kusano, T., & Naito, Y. (1997). Oscillation and nonoscillation criteria for second order quasilinear differential equations. *Acta Math. Hungar, 76*(81–99).

[3] Agarwal, R.P., Grace, S.R., & O'Regan, D. (2003). *Oscillation Theory for Second Order Dynamic Equations*. Taylor & Francis.

[4] Bainov, D.D., & Mishev, D.P. (1991). *Oscillation Theory for Neutral Differential Equations with Delay*. Adam Hilger.

[5] Agarwal, R.P., Bohner, M., Li, T., & Zhang, C. (2013). A new approach in the study of oscillatory behavior of even-order neutral delay differential equations. *Appl. Math. Comput, 225*(787–794).

[6] Triana, C.A., & Fajardo, F. (2013). Experimental study of simple harmonic motion of a spring-mass system as a function of spring diameter. *Revista Brasileira de Ensino de Física, 35*(4), 4305.

[7] Saker, S. (2010). *Oscillation Theory of Delay Differential and Difference Equations: Second and Third Orders*. LAP Lambert Academic Publishing.

[8] Triana, C.A., & Fajardo, F. (2013). Experimental study of simple harmonic motion of a spring-mass system as a function of spring diameter. *Revista Brasileira de Ensino de Física, 35*(4), 4305.

[9] French, A.P. (1964). *Vibrations and Waves*. Norton.

[10] Donald, J. Z., Skwame, Y., Sabo, J., & Ayinde, A. M. (2021). The use of linear multistep method on implicit one-step second derivative block method for direct solution of higher order initial value problems. *Abacus (Mathematics Science Series), 48*(2), 224-237.

[11] Fatunla, S.O. (1980). Numerical integrators for stiff and highly oscillatory differential equations. *Math Comput., 34*, 373-390.

[12] Skwame, Y., Bakari, A. I., & Sunday, J. (2017). Computational method for the determination of forced motions in mass-spring systems. *Asian Research Journal of Mathematics*, *3*(1), 1-12.
[13] Sabo, J., Kyagya, T. Y., & Vashawa, W. J. (2021). Numerical simulation of one step block method for treatment of second order forced motions in mass spring systems. *Asian Journal of Research and Reviews in Physics*, *5*(2), 1-11.
[14] Omole, E. A., & Ogunware, B. G. (2018). 3-point single hybrid block method (3PSHBM) for direct solution of general second order initial value problem of ordinary differential equations. *Journal of Scientific Research & Reports, 20*(3), 1-11.
[15] Olanegan, O. O., Ogunware, B. G., & Alakofa, C. O. (2018). Implicit hybrid points approach for solving general second order ordinary differential equations with initial values. *Journal of Advances in Mathematics and Computer Science, 27*(3), 1-14.
[16] Kwari, L. J., Sunday, J., Ndam, J. N., Shokri, A., & Wang, Y. (2023). On the simulations of second-order oscillatory problems with applications to physical systems. *Axioms, 12, 9,* 10. **https://doi.org/10.3390/axioms12030282**.
[17] Arevalo, C., Soderlind, G., Hadjimichael, Y., & Fekete, I. (2021). Local error estimation and step size control in adaptative linear multistep methods. *Numer. Algorithms, 86*, 537-563.
[18] Sabo, J. (2021). Single step block hybrid methods for direct solution of higher order initial value problems. *M.Sc. Thesis, Adamawa State University, Mubi-Nigeria*. (Unpublished), 5-11.
[19] Areo, E. A., & Rufai, M. A. (2016). An efficient one-eight step hybrid block method for solving second order initial value problems of ODEs. *International Journal of Differential Equation and Application, 15*(2), 117-139.
[20] Skwame, Y., Donald, J. Z., Kyagya, T. Y., Sabo, J., & Bambur, A. A. (2020). The numerical applications of implicit second derivative on second order initial value problems of ordinary differential equations. *Dutse Journal of Pure and Applied Sciences, 6*(4), 1-14.
[21] Lydia, J. K., Joshua S. Ndam J. N., & James, A. A. (2021). On the numerical approximations and simulations of damped and undamped duffing oscillators. *Science Forum (Journal of Pure and Applied Science), 21*, 503-515.
[22] Olabode, B. T., & Momoh, A. L. (2016). Continuous hybrid multistep methods with Legendre basic function for treatment of second order stiff ODEs. *American Journal of Computational and Applied Mathematics, 6*(2), 38-49.
[23] Jator, S. N., & Li. (2009). A self-starting linear multistep method for the direct solution of a general second order initial value problem. *International Journal of Computer Math, 86*(5), 817-836.

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp.48-61, November 13-16, 2023

An Analysis of Service Quality Dimensions on Good University Experience in a Private University

Usoh E. Usoh
{usoh.usoh@aun.edu.ng}

School of Business & Entrepreneurship
American University of Nigeria

Abstract
Any new institution, particularly any new university, is a new invention. As such, it must decide how to structure its services to boost good university experience for its students. The current study examines the essential service quality dimensions perceived by students and its contribution to good university experience for students in a Nigerian private university. The study explores the quantitative research design. Data was collected using a structured questionnaire, and the sample size was 288. Exploratory Factor Analysis (EFA) was adopted for discovering and analyzing the essential service quality dimensions that are major players in the model. The structural equation model (SEM) was used to investigate the influence of service quality on good university experience. The study findings revealed a four-factor solution, one significant result that only partially supports the three-dimensional structure proposed in the HESQUAL model. It also revealed that of the four factors, only three were known to influence good university experience for the students.

Keyword: Quality of service, good university experience, student satisfaction, HESQUAL model, sustainable development goal (SDG).

1 Background of Study

Any new institution, particularly any new university, is a new invention. As such, it must decide what it should be and how it will brand and structure its services to inspire a good university experience for the students. However, each University also has its flavor, style, and mission. In this, no two institutions are alike, and this is because the institutions are involved in providing quality services in different ways, coming from different histories and traditions. The uniqueness of these universities is driving a growing competition among higher educational institutions, including private universities, and the increased competitive intensity can be attributed to factors such as the high premium attention universities are placing toward meeting the expectations and needs of their students. The issue of competition is causing many institutions, especially private universities, to rethink and redefine their existence to distinguish themselves in the quality of service delivered to students to gain a competitive advantage in the marketplace (47).

To Clemes et al. (9), analyzing service quality dimensions is an important strategy towards guaranteeing good university experience for the students. By "good", the researcher aligns with the definition provided by the Oxford Advanced Learner's Dictionary, "something pleasant; that you enjoy or want". In addition, service quality is essential when discussing "the art" of creating a strong university brand and sustaining an advantage in a highly competitive market (9). This is the primary reason higher educational institutions worldwide are paying attention to providing high quality of service that translates into having a good university experience.

Therefore, to promote good university experience, universities, including private universities, must examine the quality of service in their institutions. The analysis helps universities understand how their students think about the service quality in the institution. This has created the need to investigate service quality's role in influencing a good university experience for students. Therefore, the current study aims to collect in-depth information about the quality of service offered by a private university in Nigeria. Therefore, the study examines the essential service quality dimensions as perceived by students that provide an overall good university experience in a private university such as the American

University of Nigeria (AUN). The study seeks to achieve the following objectives: a. Explore the essential service quality dimensions contributing to a good university experience. b. Investigate the influence of service quality dimensions on good university experience.

2 Conceptual Framework

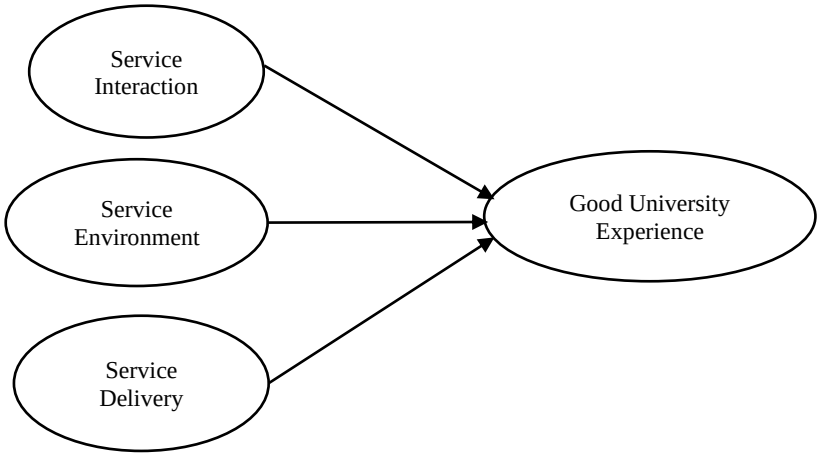


Figure 1: Conceptual Framework

3 Literature Review

3.1 Service Quality as a Framework

In literature, service quality is considered a multidimensional framework and viewed from different perspectives. The term was first defined by Parasuraman et al. (38) as "the gap between the expectation of the customers on the service and the real delivery of the service." In Rust and Oliver's (42) view, service quality is a comparison to excellence in service encounters. According to Ghotbabadi et al. (18), service quality is the best tool for analyzing information on customer satisfaction and experience regarding an organization's services. The definition has continued to evolve given that the unit of measurement for service quality is not uniform—it differs from industry to industry, especially considering the differences in the various industries.

In service quality literature, four basic service quality models have been conceptualized. The first is the Nordic model by Gronroos (21), who identifies two service quality dimensions: Functional quality (the how?) reflects how the service is delivered, and technical quality (the what?) reflects the outcome of the service. Another important model is the SERVQUAL model proposed by Parasuraman et al. (38). The model was based on gap analysis, which initially identified ten dimensions of service quality: reliability, responsiveness, competence, access, courtesy, communication, credibility, security, understanding/knowing the customer, and tangibles. The dimensions in the model were reduced to five: tangibles, reliability, responsiveness, assurance, and empathy (39). Major criticisms of the SERVQUAL model include that the model focuses on the "service-delivery" process and, hence, does not take into cognizance the "service-encounter" outcomes (6,18). Also, it has poor reliability and validity (11). In 1994, Rust and Oliver asserted that measuring service quality entails three distinct features: designing the service product, designing the service environment, and delivering the service.

In identifying these distinct features, the authors proposed a three-dimensional model: the service product (technical quality), service delivery (functional quality), and service environment. The next model was the hierarchical structure model by Dabholkar et al. (14). The Hierarchical Service Quality Model (HESQUAL) is a higher-order factor structure defined using two levels (dimensions and sub-dimension levels) of attributes (14). These levels, as presented in figure 1, are described using three core dimensions: customer-employee interaction (functional quality), physical environment (service environment), and service outcome (technical quality) (14, 6). According to scholars, these dimensions can be adapted to fit the context of the research studies, including the quality of service offered in higher educational institutions (12, 23). Furthermore, the hierarchical model, according to Brady and Cronin (6), is an adaptation of Rust and Oliver's (42) three-dimension model that corrects the inconsistency in the SERVQUAL model. That is, its inability to define "what" needs to be tangible, reliable, responsive, assured, and empathetic.

3.2 Service Quality in Higher Education

Previous studies on service quality in higher educational institutions looked at the concept, definitions, perceptions, and contexts in which service quality is applied in higher education (44, 28, 37). The Hierarchical Service Quality Model (HESQUAL) has also been explored in studies related to higher educational institutions. In this model, the quality-of-service interaction refers to the faculty-student and staff-student relationships. It represents an essential construct in measuring the perceptions of service quality in higher education. The sub-dimensions in service quality interaction include personal interaction, expertise, attitudes and behavior, course content, course delivery, quality of programs, quality of teaching, accessibility, and administrative staff (44, 8, 4). Service quality in higher education is about faculty-student interaction and the physical and institutional environment (48, 25). This includes library facilities, lab facilities, classroom and facilities, university landscape, buildings, cleanliness of the campus, ambience, campus and social life. The service delivery outcome deals with the resulting outcome of the service provided, or in simple terms, what is/has the student benefited from the educational experiences? To scholars like Oldfield and Baron (37) and Hennig-Thurau et al. (24), the extent of the benefit must be that students gain knowledge and the requisite skills and competencies for career preparation in the global labor market. The sub-dimensions include general education, personal and social education, vocational education, information technology, global education, general international knowledge, intellectual development, intercultural sensitivity, world-mindedness, cultural cosmopolitanism, tolerance, understanding, and open-mindedness, higher social values, quality of life.

Other studies have utilized models such as the HESQUAL model, mostly connected to the relationship between the quality of service in the institution's core service areas or programs. For example, in a study by Clemes et al. (9), the findings, among others, provide an empirical understanding of those critical dimensions of service quality in higher education that ensure students' overall satisfaction and experience. Also, Teeroovengadum et al. (46) measured service quality attributes by adapting the following core dimensions: administrative quality, physical environment quality, core educational quality, support facilities quality, and transformative quality. Schijns's (43) study measures service quality in the context of online university programs vis-à-vis students' level of satisfaction and students' willingness to recommend the online program. Other studies have also examined the quality of service as a determinant of student satisfaction and experience in these contexts: academic services and programs, university facilities, student life, university environment, technology environment, support services, athletics, institution image and reputation, perceived value, international program, social life and environment. In a search of relevant databases using Google Scholar, there is a relatively small body of literature in the area of service quality in Nigerian universities. For instance, Bassey et al. (3) study quality service in the context of quality assurance practices in Nigerian universities. Borishade et al. (5) examine service quality in Nigerian higher education as a determining factor of

student satisfaction and loyalty. Sulaiman et al. (45) examine the perception of students on the various services offered in a university. The existing accounts fail to provide empirical insights on the practical implication of the service quality component on good university experience in higher educational institutions, especially in Nigerian universities.

3.3 Good University Experience

To Elsharnouby (15), a "good" university experience is complex because it captures the various aspects of the student's university-wide experience. Ng and Forbes (36) assert the complexity and attribute it to the fact that a "good" university experience is an evolving concept, uncertain in nature, and is not a pre-established phenomenon. In a report published in 2008 by the Commonwealth of Australia, it was reported that a "good" student experience in a university is essential in two dimensions: Firstly, the students are more likely to complete their educational studies if they find it pleasant. Secondly, these students are also more likely to return for graduate study if they have had a pleasurable encounter in the previous experience. To Elsharnouby (15), the experience involves two levels: core and supplementary. According to the author, the core is centered around the student learning experience, while supplementary factors shape the student's overall university experience. These factors include the quality of the physical environment, library facilities, educational technology, social environment, and campus climate (9, 15).

4 Hypotheses Development

4.1 Research Hypothesis One (H1)

Studies have provided empirical evidence on the relationship between service quality and university experience. For example, in Joseph and Joseph (28), the authors examine various variables, including service quality and student satisfaction with their university experience. In particular, in their study findings, Joseph and Joseph argue on the importance of continuous performance of these variables for enhanced overall university experience for the students. Ford et al. (16) highlight that while the underlying service quality dimensions vary from institution to institution, the question about students' satisfaction with their university experience was strategically important. Ng and Forbes' (36) comprehensive review of students' university experience found that though other variables such as value, social support, and new friendships contributed to having a good university experience, the core quality service variable was a student learning experience. In another interesting study, Chong and Ahmed examine service quality in universities to include context associated with service quality as a "luxury" and "citizenship right" (10, p.48). To the authors, every encounter in the service quality experience in these contexts inspired a "persistent desire to be nurtured as a learner, service as a customer, accepted as a citizen, and respected as a dignified individual" (10, p. 48). Findings from several other studies have also reported how enhancement in service quality has boosted students' overall university experience (44, 7). In light of the preceding arguments, if a private university provides quality service to its students, then it will be said to provide a good university experience. In this regard, the conclusion can be reached that the quality of service in a private university significantly influences a good university experience for the students.

H1a: Quality of service interaction significantly influences good university experience.
H1b: Quality of service environment significantly influences good university experience.
H1c: Quality of service delivery outcome significantly influences good university experience.

5 Research Methodology

5.1 Research design

The study explores the quantitative research design.

5.2 Population of Study

The sampling population is the students' population at the American University of Nigeria (AUN), Yola-Adamawa state, located in Nigeria's North East. According to records from the Academic Registry, AUN presently has nearly 1000 undergraduate students.

5.3 Sample size and sampling procedure

To determine the sample size, the Krejcie-Morgan formula (30) was used at a 95% confidence level and 5% level of precision. According to the literature, the Krejcie-Morgan formula is commonly used for determining sample size for categorical data (1). The sample size benchmark based on the Krejcie-Morgan formula is 277.71 = 278. Convenient sampling, a non-probability sampling method, was used to administer the questionnaire. However, freshmen (first-year students) were not required to participate in the survey. This is because, as freshmen, they are adjusting to a new learning environment and may need help addressing the item questions/statements in the questionnaire. In total, 288 completed questionnaires were received.

5.4 Definition of Variables

In the study, the significant variables are latent: quality of service - service interaction, service environment, and service delivery outcome; and good university experience. Several observed variables represent each of these latent variables.

Service interaction (SI): faculty personal interaction (SI_1), faculty expertise (SI_2), staff expertise (SI_3), faculty attitudes and behavior (SI_4), staff attitudes and behavior (SI_5), course content (SI_6), faculty course delivery (SI_7), quality of programs (SI_8), quality of teaching (SI_9), faculty accessibility (SI_{10}), staff accessibility (SI_{11}).
Service environment (SE): library facilities (SE_1), lab facilities (SE_2), classroom and facilities (SE_3), university landscape (SE_4), buildings (SE_5), cleanliness of the campus (SE_6), campus ambience (SE_7), campus and social life (SE_8), and sporting facilities (SE_9)
Service delivery outcome (SD): general education (SD_1), personal and social education (SD_2), vocational education (SD_3), information technology (SD_4), global education (SD_5), requisite skills and competencies (SD_6), intellectual development (SD_7), intercultural sensitivity (SD_8), world mindedness (SD_9), cultural cosmopolitanism (SD_{10}), tolerance (SD_{11}), understanding and open-mindedness (SD_{12}), higher social values (SD_{13}), quality of life (SD_{14})
Good university experience (GE): student learning experience (GE_1), robust campus climate (GE_2), faculty-student interaction (GE_3), classroom environment (GE_4), cafeteria services and environment (GE_5), technological environment (GE_6), residence hall environment (GE_7)

5.5 Data source and collection

The primary data source was used, and data was collected using a structured questionnaire. The questionnaire was designed using a 5-point Likert scale and represents the degree of respondent's agreement or disagreement with the questions/items statements in the questionnaire.

5.6 Reliability

The reliability index estimates our research instrument's internal consistency. The reliability of the latent factors and their variables was tested. For these, the Chronbach Alpha (α) index was used. Cronbach Apha (α) index greater than or equal to 0.7 is considered reliable (17).

5.7 Methods of data analysis

The descriptive statistical tool—percentages, was used to describe the respondents' basic demographics. The Exploratory Factor Analysis (EFA) was adopted to examine the essential service quality dimensions. EFA provides a technique for discovering and analyzing the key influencing

variables that are significant players in the model (22, 49). The Keiser Mayer-Olkin (KMO) of 0.70 or greater (31) and Bartlett's statistical significance test were used to test the suitability of the data set. The Principal Component Analysis (PCA) is applied to extract the factors with eigenvalues equal to or greater than one that were extracted and retained.

Structural equation modeling (SEM) was used to determine the influence of service quality dimensions on good university experience and test for the significance of the research hypotheses. Scholars like Kocakaya and Kocakaya (29) have argued for the relevance of SEM in measuring and relating the variables and revealing the connectedness, if any, of the variables. To Hox and Bechger (26), SEM produces better statistics than other single multivariate techniques, allowing for the specification and estimation of more complicated path models with latent factors. Data was analyze using SPSS and AMOS SPSS Softwares.

6 Results and Findings

6.1 Respondents demographics

The results of the data analysis indicate that 49.0% of the respondents were males while 51.0% were females. The spread based on students' years of studies was sophomore 34.7%, junior 28.1%, senior/fourth year 27.4%, and senior/fifth year 9.7%. As noted earlier, first-year students were excluded from the study since they were new to the university environment. The 9.7% for senior/fifth year is understandable since it constitutes law and engineering. The schools are new and offer five-year degree programs. Also, these schools constitute a small fraction of the student population compared to the other three schools. These respondents were spread across the five undergraduate schools: Arts & Sciences 22.6%, Business & Entrepreneurship 21.9%, IT & Computing 21.5%, Law 24.0%, and Engineering 10.1%.

6.2 Factor Analysis

The results of the Exploratory Factor Analysis, as indicated in Table 1.0, confirm the value of KMO = 0.903. The benchmarks for the interpretation of the value of KMO, as cited in Watkins (49), have it that a KMO value in the 0.90s, as is the case in the current study analysis, is described as "marvelous" and acceptable. Bartlett's Test of Sphericity is statistically significant, meaning a patterned relationship exists. The KMO and the Bartlett test confirmed the suitability of EFA for the dataset. SPSS was configured to analyze the data using a pre-fixed number of factors, in this case, three -- service interaction, service environment, and service delivery outcome, as indicated in the study framework. The analysis resulted in a lower value of communalities (minimum value of 0.274 and maximum value of 0.543). However, Hadi et al. (22) argue that the higher the value of communality, the better the extracted factor's explanation of the variance; factor extraction with eigenvalues equal to or greater than 1 revealed an eight-factor solution. The solution produces a higher value of communalities, indicating a good fit and a better EFA solution. In the factor rotation analysis, the researcher suppresses small coefficients and requested SPSS to assign coefficient values equal to or greater than 0.4-factor loading. Yong and Pearce (50) argue that for a factor, say F5, to be regarded as a factor, it is expected to load at least three variables. Given the argument by Yong and Pearce, factors F5, F6, and F8 all load two variables each; hence, they are not regarded as factors. In this case, they are eliminated.

Table 1: Factor Analysis and Communalities

	F1	F2	F3	F4	F7	Comm.
SI_1		0.705				0.605
SI_2		0.619				0.491
SI_3		0.613				0.498
SI_4		0.521				0.549
SI_5		0.542				0.543
SI_6						0.571

SI_7		0.405				0.460
SI_8						0.527
SI_9		0.464				0.487
SI_{10}						0.747
SI_{11}						0.709
SE_1				0.464		0.497
SE_2				0.622		0.570
SE_3			0.543			0.616
SE_4			0.720			0.640
SE_5			0.664			0.690
SE_6			0.588			0.660
SE_7			0.578			0.573
SE_8			0.425			0.566
SE_9				0.706		0.621
SD_1						0.645
SD_2						0.564
SD_3					0.646	0.574
SD_4				0.476		0.582
SD_5					0.460	0.608
SD_6					0.464	0.537
SD_7	0.446					0.522
SD_8					0.589	0.604
SD_9	0.528					0.608
SD_{10}	0.614					0.599
SD_{11}	0.614					0.586
SD_{12}	0.621					0.541
SD_{13}	0.642					0.664
SD_{14}	0.650					0.582
Reliability (α)	0.813	0.758	0.807	0.687	0.709	
Percentage Variance Explained	29.726	5.915	5.013	4.382	3.301	
Total Variance Explained						58.345
KMO						0.903
Bartlett's Test of Sphericity						0.000

Table 1.0 provides information on the exploratory factor analysis. In the table, the total variance explained is 58.345. Factor one (F1) with Cronbach Alpha 0.813 has seven variables accounting for 29.726% of the total variance. Factor two (F2) with Cronbach Alpha 0.758 has seven variables that account for 5.915% of the total variance. Factor three (F3) with Cronbach Alpha 0.807 has six variables, accounting for 5.013% of the total variance. Factor four (F4) with Cronbach Alpha 0.687 has four variables, accounting for 4.382% of the total variance. Factor seven (F7) with Cronbach Alpha 0.709 has four variables, accounting for 3.301% of the total variance. The factors with an index value of Cronbach Alpha considered reliable include F1 (α=0.813), F2 (α=0.758), F3 (α=0.807), and F7 (α=0.709). Factor F4, with α = 0.687, is unreliable, hence eliminated. The final factor analysis produces a four-factor solution, as indicated in Table 2.0. The four-factor solution is perhaps one significant finding of this study that does not entirely support the three-dimensional structure proposed in the HESQUAL model.

Table 2: Four-factor EFA solution

F1 - **Psychosocial competence**	F2 - **Service interaction**	F3 – **Service environment**	F7 – **Global competence**
SD_7 - ***intellectual development***	**SI_1** - *faculty personal interaction*	**SE_3** - *classroom and facilities*	**SD_3** - *vocational education*
SD_9 - ***world mindedness***	**SI_2** - *faculty expertise*	**SE_4** - *university landscape*	**SD_5** - *global education*
SD_{10} - ***cultural cosmopolitanism***	**SI_3** - *staff expertise*	**SE_5** - *buildings*	**SD_6** - *requisite skills and competencies*

SD_{11} - ***tolerance***	**SI_4** - *faculty attitudes and behavior*	**SE_6** - *cleanliness of the campus*	**SD_8** - *intercultural sensitivity*
SD_{12} - ***understanding and open mindedness***	**SI_5** - *staff attitudes and behavior*	**SE_7** - *campus ambience*	
SD_{13} - ***higher social values***	**SI_7** - *faculty course delivery*	**SE_8** - *campus and social life*	
SD_{14} - ***quality of life***	**SI_9** - *quality of teaching*		

Naming the Factor: The final step in Exploratory Factor Analysis is interpreting and naming the factor. This is done by assigning a name and a meaning to each factor. In doing so, the domain of each factor represents or has a common characteristic that captures the themes represented among the majority of the variables in the group. In naming the reliable latent factors, the researcher adapts the naming in the HESQUAL model. The common characteristics among the variables under the factor (F1, F2, F3, and F7) are considered. For example, in Factor One (F1), the variables SD_7, SD_9, SD_{10}, SD_{11}, SD_{12}, SD_{13}, and SD_{14} share a commitment towards personal and societal growth, achieved through promoting diversity, empathy, lifelong learning, and values that enhance the well-being of individuals and communities. The common characteristic is psychosocial competence (34). According to the authors, psychosocial competence is about nurturing students to be active, productive and responsible members of society. In other words, the service delivery outcome is psychosocial competencies. Hence, the factor is named "Psychosocial competence." For Factor Two (F2), the variables are SI_1, SI_2, SI_3, SI_4, SI_5, SI_7, SI_9. The researcher maintains the common characteristic of quality-of-service interaction. Therefore, the factor is named "Service interaction." For Factor Three (F3), the variables are, SE_3, SE_4, SE_5, SE_6, SE_7, SE_8. The researcher also maintains the common characteristics of the service environment. That is, the factor is named "Service environment." In the final factor, Factor Seven (F7), the shared focus of vocational, global, requisite skills and competencies, and intercultural sensitivity education prepare individuals for success in an interconnected and diverse society through knowledge, skills, and cross-cultural engagement. The common characteristic is global competence (13). The service delivery outcome is toward educating the students for competence at the global stage. So, it is named "Global competence." The outcome of the factor analysis requires that the framework (see Figure 2), and hypotheses be adjusted as follows:

Revised Hypothesis One

H1a: The quality-of-service interaction significantly influences a good university experience.
H1b: The quality-of-service environment significantly influences a good university experience.
H1c: The quality of psychosocial competence significantly influences good university experience.
H1d: The quality of global competence significantly influences good university experience.

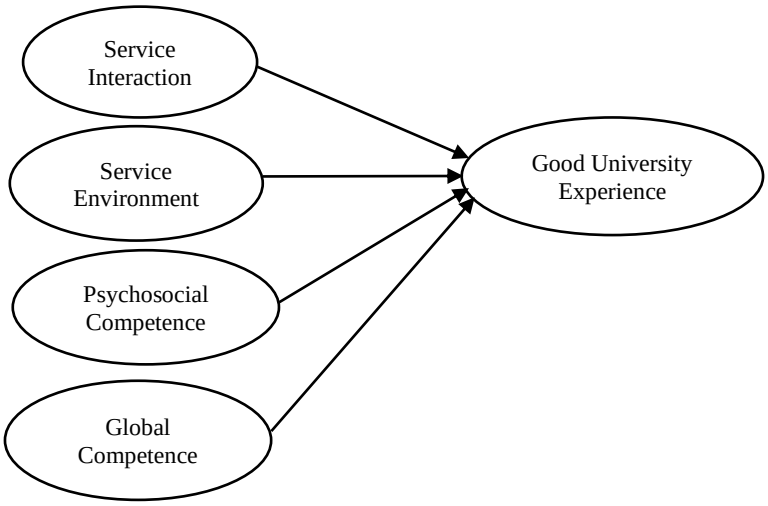


Figure 2: The revised conceptual framework to be tested.

6.3 Structural equation model

The structural equation model was analysed to determine the direct relationship between the service quality variables which are service interaction (SI), service environment (SE), psychosocial competence (PC), global competence (GC), and the dependent variable, good university experience (GUE). In the analysis, factor loadings of 0.5 and above are considered strong and acceptable. Factor loadings for variable SD_3 – vocational education, and GE_5 – cafeteria service and environment, were 0.48 and 0.38, respectively, hence eliminated. Table 3.0 shows the goodness of fit measures for this model. The indexes indicate that the model presents a good level of adequacy. For example, the chi-square statistic indicates that the difference between the observed and predicted variance-covariance matrix is statistically significant. The ratio of chi-square to its degree of freedom is 1.527, representing an acceptable ratio. The standardized RMR value of 0.051 indicates an acceptable fit (35) and measures the average absolute discrepancy between the predicted and the observed correlations. The Root Mean Square Error of Approximation (RMSEA) value closer to zero is a perfect fit model. However, RMSEA less than or equal to 0.06 indicates a close fit model (11). For this model, RMSEA is 0.043, representing a close fit model. The comparative fit index (CFI) of 0.927 and incremental fit index (IFI) of 0.928 represent a good fit. Though the goodness-of-fit index (GFI) of 0.882 falls a little below the general expectation of GFI = 0.90, scholars have described the value of GFI in the range of 0.87 as a reasonable model fit (2).

Table 3: Goodness of fit measures for SEM model

Goodness of fit measures	Value	Levels of acceptance	Model acceptability
Test of Chi-square (χ^2)	583.441	Not applicable	Not applicable
Degree of freedom (DF)	382		
CMIN/DF	1.527	Less than 5	
p-value	0.000		
GFI	0.882	≥ 0.90	Reasonable
IFI	0.928	≥ 0.90	Good
CFI	0.927	≥ 0.90	Good
RMSEA	0.043	less than/equal to 0.06	A close fit model
Standardize RMR	0.051	less than/equal to 0.05	Acceptable fit

Testing of Hypothesis One: The structural equation model was used to test the significance of the direct relationship in hypothesis one (H1a, H1b, H1c, H1d). The level of significance (α) is put at 0.05. Hypothesis H1a states that service interaction quality significantly influences a good university experience. That is SI → GUE. From Table 4.0, the unstandardized regression estimate for SI → GUE is 0.455 with a standard error of 0.117. The standardized estimate is 0.423, with a *p*-value of 0.000. Since the *p*-value (0.000) is not greater than 0.05 significance level, it is concluded that the hypothesis is significant. In other words, the quality-of-service interaction significantly influences the good university experience for the students. For hypothesis H1b, the quality of the service environment significantly influences a good university experience. That is SE → GUE. Table 4.0 shows the unstandardized regression weight of 0.227, with a standard error of 0.086. The standardized regression estimate is 0.273, and the *p*-value is 0.009. This means that the hypothesis is significant at a 0.05 level of significance. Hence, it is concluded that the quality-of-service environment significantly influences the good university experience for the students. Hypothesis H1c: The quality of psychosocial competence significantly influences good university experience. That is PC → GUE. Here, the unstandardized regression estimate is -0.176 with a standard error of 0.296. The standardized regression weight is 0.194, and the *p*-value is 0.0542. It can also be said that the *p*-value (0.0542) is

not greater than the 0.05 level of significance. Hence, the hypothesis is significant. It is therefore concluded that the quality of psychosocial competence significantly influences good university experience for the students. In hypothesis H1d, the quality of global competence significantly influences good university experience. That is GC → GUE. In the table (Table 4.0), the unstandardized regression weight is 0.479, with a standard error of 0.333. The standardized regression weight is 0.487, and the *p*-value is 0.151. The hypothesis is insignificant, with the p-value (0.151) greater than the 0.05 significance level. Hence, it is concluded that the quality of global competence does not directly influence good university experience for the students.

Table 4: Unstandardized and standardized regression weights for SEM model

	Unstandardized regression weights			**Standardized regression weights**
	Estimates	Standard error	*P*-value	Estimates
GUE ← PC	-0.176	0.296	0.542	-0.194
GUE ← SI	0.455	0.117	0.000	0.423
GUE ← SE	0.227	0.086	0.009	0.273
GUE ← GC	0.479	0.333	0.151	0.487
SD_{14} ← PC	1.000			0.641
SD_{13} ← PC	0.976	0.097	0.000	0.604
SD_{12} ← PC	1.039	0.114	0.000	0.642
SD_{11} ← PC	0.797	0.111	0.000	0.526
SD_{10} ← PC	0.917	0.113	0.000	0.566
SD_{9} ← PC	1.036	0.107	0.000	0.696
SD_{7} ← PC	0.895	0.100	0.000	0.630
SI_{9} ← SI	1.000			0.544
SI_{7} ← SI	0.959	0.132	0.000	0.528
SI_{5} ← SI	0.943	0.138	0.000	0.547
SI_{4} ← SI	1.092	0.156	0.000	0.566
SI_{3} ← SI	0.985	0.142	0.000	0.558
SI_{2} ← SI	0.972	0.136	0.000	0.582
SI_{1} ← SI	1.010	0.138	0.000	0.605
SE_{8} ← SE	1.000			0.653
SE_{7} ← SE	0.980	0.104	0.000	0.675
SE_{6} ← SE	0.992	0.106	0.000	0.667
SE_{5} ← SE	0.853	0.112	0.000	0.529
SE_{4} ← SE	1.117	0.116	0.000	0.692
SE_{3} ← SE	0.971	0.111	0.000	0.615
SD_{8} ← GC	1.000			0.593
SD_{6} ← GC	1.000			0.623
SD_{5} ← GC	1.197	0.110	0.000	0.700
GE_{1} ← GUE	1.000			0.612
GE_{2} ← GUE	1.115	0.132	0.000	0.629
GE_{3} ← GUE	1.138	0.135	0.000	0.624
GE_{4} ← GUE	1.046	0.122	0.000	0.640
GE_{6} ← GUE	1.195	0.155	0.000	0.617
GE_{7} ← GUE	1.228	0.180	0.000	0.487

7 Discussion of Findings

An important finding that stands out from the exploratory factor analysis results is that the service delivery outcome dimension was split into two dimensions. The new dimensions were named psychosocial competence and global competence. This split demonstrates the relevance of service delivery outcomes in universities and the need for these institutions to ensure students, on graduation, have these competencies. Nair and Ranjan (34) justify the splitting in their argument that social transformation combined with technological advances in the world requires that higher institutions train and prepare students with the essential competencies to face the complex life challenges facing

the world today. Psychosocial competence, otherwise known as “life skills”, imbibe in the students the ability to successfully handle day-to-day life challenges and issues (34, 33). These life skills reflect the students' intellectual development, mindfulness of their world, learning tolerance by living with people from different cultures and backgrounds, displaying high social values, and demonstrating an acceptable quality of life. These attributes sum up the kind of education that shapes the students; when this happens, the students have the right skills and competencies to redefine society. It is the core of the United Nations Sustainable Development Goal number 4 that provides inclusive and equitable quality education that promotes lifelong learning opportunities for all. On the other hand, in the words of Cushner (13), global competence is essential given that students generally feel disconnected from other parts of the world and need help understanding the challenges people in different countries are going through. Global competence is about having knowledge of the world and its happenings, having the proper set of skills and competencies to confront these happenings and being respectful and sensitive to other people's cultures. More so, scholars like Parkinson (40) have connected factors like globalization as the driving force for the institutionalization of global competence in the curriculum of universities such as AUN. The National Education Association (NEA) 2010 policy brief re-echoed promoting global competence in higher institutions to support this assertion. It noted that it was not a luxury rather a necessity. These findings provide understanding of the direction the competition in the higher education market is moving toward and having this understanding is essential for determining university positioning strategies.

The results of this study further show that the quality of service interaction at AUN significantly influences the good university experience for the students. This means that the variables, faculty personal interaction, faculty expertise, staff expertise, faculty attitudes and behaviors, faculty course delivery method, and the quality of teaching are essential factors contributing to students having a pleasant university experience. For instance, are faculty members open to honest, friendly and instructive interaction with the students? This kind of interaction provides the atmosphere for faculty-student bonding that promotes mentoring. The faculty's way of course delivery in class is important. Is it the “memorize and release” method, the dull in-class note-taking, or the active, lively class participation way of course delivery? All these depend on the faculty member's expertise and demonstrate qualitative, insightful, and impactful teaching in the knowledge it confers. The finding reflects those of other scholars who also confirmed the association between the quality of service interaction and overall university experience (41, 20, 27, 32). Grantham et al. (20) reported that faculty personal interaction with students indicates that students value their teachers who, in the students’ assessment, are easy going and fun. This suggests a less disconnected relationship between the faculty and the students, immensely benefiting the students. Also, Iroegbu and Agboola (27) revealed that high cordiality between faculty and students often results in positive academic outcomes and university experience. It is encouraging to compare the findings of this study with those found by Ginns et al. (19), who suggest that the quality of teaching is an essential factor for quality assurance, student learning, and experience.

In this study, the service environment at AUN was found to influence a good university experience for the students significantly. The variables in the service environment include classrooms and facilities, university landscape, buildings, campus cleanliness, campus ambience, and campus social life. Take, for instance, classrooms and facilities; students advocate for small classrooms with functional teaching facilities to aid student learning. The finding further suggests that having a clean and landscaped campus provides a serene campus ambience that fosters a good university experience for the students. Not only so, the young men and women in today’s universities want a robust campus social life to have a good university experience. These findings broadly align with evidence from previous work of scholars. For example, it is interesting to note that in the findings by Pereda et al. (41), the modernity of classroom facilities and campus cleanliness indicated high factor loadings.

The subsequent finding of this study shows that psychosocial competence significantly influences good university experience for students. In the psychosocial competence factor are these essential variables: intellectual development, world-mindedness, cultural cosmopolitanism, tolerance, understanding and open-mindedness, higher social values, and quality of life. That is, students know that their education at AUN equips them with the life skills to navigate societal challenges and live active and productive lifestyles to help foster a pleasant university experience. The last finding of this study worthy of reporting is that the factor of global competence has no direct connection with good university experience for the students, given that the hypothesis (H1d) was not significant.

8 Implication for Research and Practice

What are the implications of the study findings to research and practice? This section of the study addresses the question with valuable insights. To Msmi, "education is a social process" (33, p.25) that performs a social function and has social relevance. The high point of this statement is that education can be a valuable tool for solving the world's many problems today. Implications of the study finding: Firstly, it suggests a revised quantitative framework for determining service quality in higher education institutions. Secondly, it places a high responsibility on university administrators to create a robust university experience for their students. In doing these, the current study findings suggest an emphasis on the service interaction, service environment quality, preparing the students to have psychosocial and global competencies. Thirdly, the issues emerging from the study findings relate to creating a strong university brand and sustaining an advantage in the market. Scholars have advocated that universities that want to create an advantage that is competitive and sustainable must begin to emphasize, encourage and implement strong university values and attributes (9). As revealed in the current study, some of these values include robust faculty-student interaction, faculty expertise and specialization, healthy faculty/staff attitudes and behaviors, and teaching and course delivery quality. The study findings also listed small classrooms and facilities, a clean university landscape, aesthetic buildings, and fun-filled campus life. Implementing these values and attributes implies that currently enrolled students are more likely to complete their educational studies if they find the university experience pleasant. They are also likely to return for graduate study.

9 Conclusion

This study aimed to collect in-depth information on the quality of service in one of Nigeria's private universities. The study was successful as it could document and identify the various factors students value in their university experience. It also establishes a quantitative framework for investigating the essential service quality dimensions perceived by students that provide a good university experience for the students. In general, the empirical findings of the study establish that the quality of service at AUN, one way or the other, fosters a good university experience for the students. In particular, the findings show three were significant in the four direct relationships between service quality and good university experience.

10 Limitation and Suggestion for Future Research

The most important limitation lies in the fact that the scope of the study makes the findings less generalizable to all universities in Nigeria. It is also unfortunate that the study did not include graduate students. Notwithstanding these limitations, the study made valuable contributions to the existing knowledge of service quality and good university experience in higher education. A further study could examine these variables to allow broader generalizations.

References

[1] Adam, A. M. (2020). Sample size determination in survey research. *Journal of Scientific Research & Reports, 26*(5), 90-97.

[2] Buckley, T. C., Blanchard, E. B., & Hickling, E. J. (1998). A confirmatory factor analysis of posttraumatic stress symptoms. *Behavior Research and Therapy, 36*, 1091-1099.

[3] Bassey, B. A., Owan, V. J., & Agunwa, J. N. (2019). Quality assurance practices and students' performance evaluation in universities of South-South Nigeria: A structural equation modelling approach. *British Journal of Psychology Research, 7*(3), 1-13.

[4] Bigne, E., Moliner, M. A., & Sanchez, J. (2003). Perceived quality and satisfaction in multiservice organizations: The case of Spanish public services. *The Journal of Services Marketing, 17*(4/5), 420–433.

[5] Orishade, T. T., Ogunnaike, O. O., Salau, O., Motilewa, B. D., & Dirisu, J. I. (2021). Assessing the relationship among service quality, student satisfaction, and loyalty: The Nigerian higher education experience. *Heliyon, 7*, e07590.

[6] Brady, M. K., & Cronin, J. J. (2001). Some new thoughts on conceptualizing perceived service quality: A hierarchical approach. *Journal of Marketing, 65*(3), 34–49.

[7] Cardona, M. M., & Bravo, J. J. (2012). Service quality perceptions in higher education institutions: The case of a Colombian University. *Estudios Gerenciales, 28*, 23-29.

[8] Clemes, M. D., Ozanne, L. K., & Tram, L. (2001). An examination of students' perceptions of service quality in higher education. *Journal of Marketing for Higher Education, 10*(3), 1–19.

[9] Clemes, M. D., Gan, C. E. C., & Kao, T. (2008). University student satisfaction: An empirical analysis. *Journal of Marketing for Higher Education, 17*(2), 292-325.

[10] Chong, S. Y., & Ahmed, P. A. (2014). Phenomenology of university service quality experience: Uncovering the essence of meaning among business undergraduates in Malaysia. *International Journal of Educational Management, 28*(1), 36-52.

[11] Chong, S. Y., & Ahmed, P. A. (2014). Phenomenology of university service quality experience: Uncovering the essence of meaning among business undergraduates in Malaysia. International Journal of Educational Management, 28(1), 36-52.

[12] Browne, M. W., & Cudeck, R. (1993). Alternative ways of assessing model fit. In K. A. Bollen & J. S. Long (Eds.), Testing structural equation models (pp. 136-162). Newbury Park, CA: Sage.

[13] Curran, J. M., & Rosen, D. E. (2006). Student attitudes towards college courses: An examination of influences and intentions. Journal of Marketing Education, 28(2), 135–148.

[14] Cushner, K. (2014). Strategies for enhancing intercultural competence across the teacher education curriculum. In S. Sharma, J. Phillion, J. Rahatzad, & H. L. Sasser (Eds.), Internationalizing Teacher Education for Social Justice: Theory, Research, and Practice. Charlotte, NC: Information Age Publishing Inc.

[15] Dabholkar, P., Thorpe, D. I., & Rentz, J. O. (1996). A measure of service quality for retail stores: Scale development and validation. Journal of the Academy of Marketing Science, 24(1), 2-16.

[16] Elsharnouby, T. H. (2015). Student co-creation behavior in higher education: The role of satisfaction with the university experience. Journal of Marketing for Higher Education, 25(2), 238-262.

[17] Ford, J. B., Joseph, M., & Joseph, B. (1999). Importance-performance analysis as a strategic tool for service marketers: The case of service quality perceptions of business students in New Zealand and the USA. The Journal of Services Marketing, 13(2), 171.

[18] George, D., & Mallery, P. (2003). SPSS for Windows step by step: A simple guide and reference (4th ed.). Boston: Allyn & Bacon.

[19] Ghotbabadi, A. R., Baharun, R., & Feiz, S. (2012). A Review of Service Quality Models. In 2nd International Conference on Management (pp. 11-12). Conference Proceedings, held at the Holiday Villa Beach Resort & Spa, Malaysia.

[20] Ginns, P., Prosser, M., & Barrie, S. (2014). Students' perceptions of teaching quality in higher education: The perspective of currently enrolled students. Studies in Higher Education, 32(5), 603-615.

[21] Grantham, A., Robinson, E. E., & Chapman, D. (2015). "That truly meant a lot to me": A qualitative examination of meaningful faculty-student interaction. College Teaching, 63, 125-132.

[22] Grönroos, C. (1984). A service quality model and its marketing implications. European Journal of Marketing, 18(4), 36–44.

[23] Hadi, N. U., Abdullah, N., & Sentosa, I. (2016). An easy approach to exploratory factor analysis: Marketing perspective. Journal of Educational and Social Research, 6(1), 215-223.

[24] Hajdari, S. (2019). Service Quality in Higher Education Institutions: An Overview of Model Assessing it. European Journal of Business and Management Research, 4(3).

[25] Hennig-Thurau, T., Lange, M. F., & Hansen, U. (2001). Modeling and managing student loyalty: An approach based on the concept of relationship quality. Journal of Service Research, 3(4), 331-344.

[26] Hill, M. C., & Epps, K. K. (2010). The impact of physical classroom environment on student satisfaction and student evaluation of teaching in the university environment. Academy of Educational Leadership Journal, 14(4), 65-79.
[27] Hox, J. J., & Bechger, T. M. (1999). An introduction to structural equation modeling. Family Science Review, 11, 354-373.
[28] Iroegbu, E. E., & Agboola, B. M. (2019). Student engagement variables and first-year undergraduate retention rate in the University of Uyo, Akwa Ibom State, Nigeria. American Journal of Education and Learning, 4(1), 98-116.
[29] Joseph, M., & Joseph, B. (1997). Service quality in education: A student perspective. Quality Assurance in Education, 5(1), 15-21.
[30] Kocakaya, S., & Kocakaya, F. (2014). A Structural Equation Modeling on Factors of how Experienced Teachers affect the Students' Science and Mathematics Achievements. Education Research International, 1-8. Retrieved from https://doi.org/10.1155/2014/490371
[31] Krejcie, R. V., & Morgan, D. W. (1970). Determining Sample Size for Research Activities. Educational and Psychological Measurement, 30, 607-610.
[32] Lloret, S., Ferreres, A., Hernandez, A., & Tomas, I. (2017). The exploratory factor analysis of items: Guided analysis based on empirical data and software. Anales de Psicologia, 33, 417-432.
[33] Mitchell, J., & Marken, K. (2020). Profs-in-Commons: Enhancing Student–Faculty Engagement in a Library Learning Commons. In E. Sengupta, P. Blessinger, & M. D. Cox (Eds.), International Perspectives on Improving Student Engagement: Advances in Library Practices in Higher Education (Innovations in Higher Education Teaching and Learning) (pp. 167-182). Emerald Publishing Limited, Bingley.
[34] Msmi, D. (2020). Enhancing academic performance through life skills education: A conceptual study. International Journal of Life Skills Education, 6(2), 24-34.
[35] Nair, A. R., & Ranjan, S. (2020). Life skills education: Origin and development of the concept. International Journal of Life Skills Education, 6(2), 5-23.
[36] Hu, L., & Bentler, P. M. (1995). Evaluating model fit. In R. H. Hoyle (Ed.), Structural equation modeling: Concepts, issues, and applications (pp. 76-99). Thousand Oaks, CA: Sage.
[37] Ng, I. C., & Forbes, J. (2009). Education as service: The understanding of university experience through the service logic. Journal of Marketing for Higher Education, 19(1), 38–64.
[38] Oldfield, B. M., & Baron, S. (2000). Student perceptions of service quality in a UK university business and management faculty. Quality Assurance in Education, 8(2), 85.
[39] Parasuraman, A., Zeithaml, V. A., & Berry, L. L. (1985). A conceptual model of service quality and its implications for Future Research. Journal of Marketing, 49(4), 41-50.
[40] Parasuraman, A., Zeithaml, V. A., & Berry, L. L. (1988). SERVQUAL: A multiple-item scale for measuring consumer perceptions of service quality. Journal of Retailing, 64(1), 12–40.
[41] Parkinson, A. (2009). The rationale for developing global competence. Online Journal for Global Engineering Education, 4(2/2), 1-14.
[42] Pereda, M., Airey, D., & Bennett, M. M. (2007). Service quality in higher education: The experience of overseas students. Journal of Hospitality, Leisure, Sport and Tourism Education, 6(2), 55-67.
[43] Rust, R. T., & Oliver, R. L. (1994). Service quality: New directions in theory and practice. Thousand Oaks, CA: Sage.
[44] Schijns, J. M. C. (2021). Measuring Service Quality at an online University: Using PLS-SEM with archival data. Tertiary Education and Management, 27, 161-185.
[45] Soutar, G., & McNeil, M. (1996). Measuring service quality in a tertiary institution. Journal of Educational Administration, 34(1), 72.
[46] Sulaiman, Y., Bosede, F. F., & Ganiyat, A. B. (2022). An assessment of students' perception on school services in Nigerian Private Universities: Evidence from Al-Hikmah University. Journal Plus Education, 30(1), 90-112.
[47] Teeroovengadum, V., Kamalanabhan, T. J., & Seebaluck, A. K. (2016). Measuring Service Quality in Higher Education: Development of a Hierarchical Model. Quality Assurance in Education, 24(2), 244-258.
[48] Wæraas, A., & Solbakk, M. (2009). Defining the essence of a university: Lessons from higher education branding. Higher Education, 57(4), 449–462.
[49] Walter, U., Edvardsson, B., & Ostrom, A. (2010). Drivers of customers' service experiences: A study in the restaurant industry. Managing Service Quality, 20(3), 236-258.
[50] Watkins, M. W. (2018). Exploratory Factor Analysis: A Guide to Best Practice. Journal of Black Psychology, 44(3), 219-246.

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp.62-73, November 13-16, 2023

Evaluating the relationship between entrepreneurial marketing, competitive advantage, and small business enterprises performance

Theoneste Manishimwe[1], Hassan Yusuf[2], Jamiu Oluomoh[3], Yusuf Kani[4],
theoneste.manishimwe@aun.edu.ng, hassan.yusuf@aun.edu.ng, jamiu.oluomoh@aun.edu.ng

American University of Nigeria (AUN), School of Business and Entrepreneurship, Business Administration[1,4]
American University of Nigeria (AUN), School of Business and Entrepreneurship, Entrepreneurship Management[2]
American University of Nigeria (AUN), School of Arts & Sciences, Mathematics/Statistics[3]

Abstract
This study investigates the impact of entrepreneurial marketing on the competitive advantage of Small Business Enterprises (SBEs) in Nigeria. Data was collected from 257 SBEs using random sampling and analyzed using Smart-Partial Least Square software. The research explores how entrepreneurial marketing influences SBE performance and the mediating role of competitive advantage. It offers insights into how SBEs can enhance their competitive edge and performance through entrepreneurial marketing. The study also fills a research gap in entrepreneurial marketing for SBEs in developing countries, highlighting the need for a tailored marketing framework for these regions.

Keywords: Entrepreneurial marketing · Competitive advantage · SBE performance

1 Introduction

Globally, Small Business Enterprises (SBEs) in emerging markets face challenges such as a limited consumer base. The COVID-19 pandemic has significantly impacted these businesses, leading to changes in consumer behavior and decreased demand in certain industries such as public transportation, tourism, and hospitality. On the other hand, some industries like e-commerce, online food delivery, and cloud computing have experienced growth (Shaharuddin, 2020). This disruption of supply chains and global trade has led to losses and employment challenges for SBEs. In response to these challenges, governments and central banks have implemented policies to support businesses. During the pandemic, SBEs have faced challenges related to low innovation capability. However, some SBEs have managed to increase their innovative capabilities and sales volume through the use of digital channels. Government programs have also played a role in supporting their innovation efforts.

When it comes to competition, small businesses differ from large businesses in several aspects. Large businesses tend to have a larger customer base due to their size and reach. In terms of risk management and financial analysis, small businesses may have more limited options and resources compared to large corporations. This is where the lack of marketing efforts and poor awareness of SBE products among the population can be attributed to these challenges. However, firms in emerging markets can strive to gain sustainable competitive advantage by employing multiple business models and aligning resources and capabilities effectively. Chinese firms, for example, have demonstrated their ability to overcome the traditional perception of being low-cost players with limited innovative capability, emerging as strong global contenders and leaders in various industries (Ranjith, 2016). The issue of competitive advantage and performance of SBEs has been inadequately addressed by prior studies. However, there is a growing recognition of the importance of studying competitive advantage in SBEs. One study found that differentiation has a positive impact on firm performance in SBEs, although the impact is relatively lower compared to previous studies (Anwar, 2018). Another study highlighted the significance of business model innovation (BMI) in SME performance, with BMI having a significant positive impact on competitive advantage and SME performance. Entrepreneurial marketing is a concept that combines entrepreneurship and marketing, with a focus on creating customer value

through innovativeness, creativity, selling, networking, and flexibility. It has been found that entrepreneurial marketing has a direct and indirect effect on marketing performance through competitive advantage (Hidayatullah et al., 2019).

The Resource-Based View (RBV) theory suggests that a firm's competitive advantage is derived from its unique bundle of resources, capabilities, and routines that are difficult for competitors to imitate. The Dynamic Capabilities Theory (DCT) complements RBV by emphasizing the firm's ability to adapt and change its resources and capabilities in response to environmental changes (Bhattacharyya & Jha, 2015). Both theories play a crucial role in enhancing the performance and competitiveness of SBEs. RBV contributes to driving SME performance by leveraging their unique resources and capabilities. DCT helps stimulate RBV by enabling SBEs to adapt and enhance their capabilities in response to rapid environmental changes, thereby enhancing their competitive advantages. The ways in which entrepreneurial marketing (EM) facilitate the competitive advantage that enhances the performance of SBEs, particularly in large business environments, have not yet been fully established. To fill this gap in the literature, we used partial least square structural equation modeling (PLS-SEM) to explore if EM directly or indirectly contributes to SBE performance through competitive advantage.

2 Entrepreneurial Marketing (EM)

The Entrepreneurial marketing (EM), a concept introduced by Stokes in 2000 and later expanded upon by Morris et al. in 2002, is a unique approach to marketing that prioritizes innovation and the proactive identification of opportunities for acquiring and retaining profitable customers (Eggers et al., 2020). Unlike traditional marketing, which focuses on coordinating the marketing mix and building the brand, EM extends the marketer's role to include initiating change and creating new opportunities by uniquely combining marketing tools. This approach is particularly beneficial for small firms, enabling them to compete and sustain their businesses in challenging markets. In contrast to the "top-down" processes of segmentation, targeting, and positioning used in traditional marketing, EM targets markets through "bottom-up" self-selection and recommendations from customers and other influential groups (Eggers et al., 2020). This approach allows for a more organic and customer-centric marketing strategy, where customers and influencers play a significant role in shaping the market perception of the brand.

Most EM research is conducted within the context of Small and Medium Enterprises (SMEs). However, few studies have been conducted within the context of small business enterprises in Nigeria (Eggers et al., 2020). EM intertwines with other activities and behaviors in small business enterprises such as customer engagement, innovation, and entrepreneurial approaches to marketing based on four interrelated orientations: innovation orientation, entrepreneurial orientation, market orientation, and customer orientation (Eggers et al., 2020). Therefore, the concept of EM is significant in studies on small business enterprises. EM is a unique approach that allows business owners to operate successfully with limited resources. It includes activities to develop and exploit social capital, which can significantly contribute to the performance of small and medium-scale businesses.

In today's digital age, understanding how to effectively implement digital marketing strategies is crucial for small businesses, especially given the challenges associated with the use of digital marketing and social media (Eggers et al., 2020). The ability to identify and operate in a particular market niche, along with strategic positioning and entrepreneurship, is key for small firms to gain a competitive advantage and achieve business performance. Despite its importance, EM is often overlooked in marketing research literature, which tends to focus more on large-scale enterprises. This has led to calls for the development of a framework for SMEs in developing countries to address the complex and versatile marketing environment in these regions (Eggers et al., 2020). Morrish (2011) suggested that firms practicing EM can obtain a competitive advantage by uniquely positioning

product offerings that are both cheaper and different (Eggers et al., 2020). This can be achieved by combining unique elements such as branding and production methods that create new offerings very different from those of competitors. EM can be effective in creating competitive advantage in challenging markets where traditional marketing alone becomes impractical (Eggers et al., 2020). However, previous studies on EM research correlated with competitive advantage and firm performance have shown inconsistent results due to different constructs used in different studies (Eggers et al., 2020) This suggests gaps or inconsistencies in the literature regarding how EM is conceptualized and measured. Further research is needed to better understand these gaps and develop a more comprehensive understanding of the relationship between EM, competitive advantage, and firm performance.

3 Hypotheses Development

3.1 EM and Competitive Advantage

Entrepreneurial marketing, recognized as a crucial antecedent for competitive advantage, has been studied across various sectors. Small culinary businesses in Medan City, Indonesia, have acknowledged the benefits of entrepreneurial marketing and innovation in enhancing competitiveness, with policy interventions potentially accelerating this impact (Suryani & Claudya, 2020). In the same industry, dimensions of entrepreneurial marketing such as proactiveness, calculated risk-taking, innovativeness, opportunity focus, resource leveraging, customer intensity, and value creation have significantly and positively influenced competitive advantage (Makmur et al., 2018). In Batu City's tourism sector in Indonesia, entrepreneurial marketing has indirectly affected marketing performance by creating a competitive advantage (Hidayatullah et al., 2019). A study in large-sized Egyptian companies suggests a positive association between entrepreneurial marketing and the firm's marketing performance and competitive advantage (Mahrous et al., 2020). By focusing on elements like proactiveness, opportunity focus, calculated risk-taking, innovativeness, customer intensity, resource leveraging, and value creation, entrepreneurial marketing can enhance a company's competitive advantage and manage resources for optimal innovation performance (Wahyudi, 2017). These findings lead to the proposed hypothesis.Based on these findings, the proposed hypothesis is as follows:

H_1: *Entrepreneurial marketing has a significant positive effect on the competitive advantage of small business enterprises in Nigeria.*

3.2 EM and SBEs Performance

Entrepreneurial marketing (EM) has been identified as a beneficial approach for firms across various contexts, particularly advantageous for small to medium-sized enterprises (SMEs) and in turbulent environments. Recent studies have highlighted EM as a vital tool for firms and small business enterprises to perform well in competitive markets, irrespective of environmental conditions (Adel et al., 2020). However, the relationship between EM and performance can be influenced by factors such as market orientation and entrepreneurial proclivity. Matsuno et al. (2002) found that the positive influence of entrepreneurial proclivity on performance is mediated by market orientation (Matsuno et al., 2002). Conversely, a negative link was found between an entrepreneurial marketing orientation and financial performance due to sector specificity (Crick et al., 2021). This suggests that owner-managers of under-resourced small firms should exercise caution when implementing entrepreneurial marketing strategies utilizing an individualistic business model. Collaborating with competitors can equip owner-managers with new resources and capabilities and provide improved ways to operate within their industries. Given these considerations, the proposed hypothesis is:

H_2: *Entrepreneurship Marketing has a significant positive effect on small business enterprises' performance.*

3.3 Competitive Advantage and SBEs Performance

Competitive advantage can directly impact business performance (Hidayatullah et al., 2019). Achieving price advantage positively affects market performance (Andriyanto et al., 2019), and service advantage strongly influences market performance, especially when high-quality customer relationships and production capacity are present (Kaleka & Morgan, 2017). However, competitive advantage and performance are distinct concepts and should not be used interchangeably. Competitive advantage refers to a company's ability to operate more efficiently or provide higher-quality products and services than its competitors (Beatty, 1992). Despite this, organizations with competitive advantage may not always achieve superior performance (Grahovac & Miller, 2009). Performance is influenced by various factors, including the ability to capture opportunities, imitate resources, and solve problems (Jones & Rowley, 2009). Therefore, organizations with competitive advantage may still face challenges in achieving performance goals. It's crucial to understand the complex relationship between competitive advantage and performance to refine strategic management theories and improve management practices. Given these considerations, the proposed hypothesis is:

H_3: *Competitive advantage has a significant positive effect on small business enterprises' performance.*

3.4 The Role of Competitive Advantage as a Mediating Variable Between Entrepreneurial Marketing and Small Business Enterprises Performance

Competitive advantage has been recognized as a crucial intermediary between entrepreneurial marketing and the performance of small business enterprises. Research has shown that competitive advantage mediates the connection between entrepreneurship orientation and marketing performance (Zaini et al., 2014). It also partially mediates the impact of entrepreneurial orientation and knowledge management on business performance (Pratono & Pudjibudojo, 2016). Marketing capability fully mediates the relationship between firm performance and both entrepreneurial orientation and entrepreneurial management (Puspaningrum, 2020). Moreover, competitive advantage has been found to mediate the influence of entrepreneurial marketing on marketing performance (Hidayatullah et al., 2019). The resource-based theory highlights the strategic role in fostering competitive advantage that influences performance. It proposes that a firm's internal resources and capabilities should be the basis for its strategy. Understanding the relationships between resources, capabilities, competitive advantage, and profitability is key to successful strategy formulation (Makmur et al., 2018). The dynamic capability theory emphasizes the significance of entrepreneurial marketing as a strategic orientation and action that interacts with dynamic capabilities to create competitive advantage and performance (Boccardelli & Magnusson, 2006). Based on these considerations, the proposed hypothesis is:

H_4: *Competitive advantage mediates the relationship between entrepreneurial marketing and small business enterprises performance.*

4 Research Methodology

4.1 Sample

This study was conducted on Small Business Enterprises (SBEs) in Adamawa state, Nigeria, with a focus on those registered with the government. A total of 400 SBEs participated in the research, and 257 correctly filled out questionnaires were used for data analysis.

The minimum sample size for PLS-SEM analysis is determined by either ten times the largest number of indicators used to measure a construct or ten times the largest number of structural paths directed at a particular construct in the structural model. In this case, the largest number of indicators was seven,

and the largest number of paths pointing to a construct was four. Therefore, the required minimum sample size was 40 or 90, respectively. However, this study's sample size was 257, significantly exceeding the recommended minimum.

The SBEs were approached face-to-face with written consent and were limited to managers, owners, or supervisors of registered and full-time operating SBEs. A random sample was selected using a drop and pick later approach for questionnaire distribution. The eligibility criteria required that the businesses be registered under the Corporate Affairs Commission (CAC) and operate full time. Data collection occurred from July 2019 to February 2020. Of the 262 SBEs that responded to the invitation, five were excluded due to incomplete questionnaires, resulting in a final sample size of 257. The questionnaire was tested using item loadings on the 257 samples. Items with less than 0.5 loading were removed, resulting in seventeen items being removed from the EM variable and three items from the competitive advantage variable. Further reductions were made based on the Confirmatory Factor Analysis (CFA) on the full sample of 257 respondents.

4.2 EM, SBE's Performance, Mediating and Moderating Variables

Our research focuses on entrepreneurial marketing as the sole independent variable, utilizing the four dimensions of entrepreneurial marketing - entrepreneurial orientation, market orientation, customer orientation, and innovation orientation - as proposed by Jones & Rowley (2009) (Jones & Rowley, 2009). This model is particularly relevant for an in-depth analysis of entrepreneurial marketing in Small Business Enterprises (SBEs), especially in developing economies. Thus, we operationally define entrepreneurial marketing as the discovery and creation of market opportunities by SBEs in terms of the four aforementioned orientations. Responses were collected on a six-point Likert scale, with 1 indicating strong disagreement and 6 indicating strong agreement. The instrument, consisting of 42 items, was adapted from a research questionnaire on Entrepreneurial Marketing Practices by Osuagwu (2022). The dependent variable in our study is the performance of the SBEs. Performance is evaluated based on how effectively an organization achieves its goals. We assessed SBE performance from both non-financial and financial perspectives. The instrument for measuring SBE performance, as suggested by Raimi & Manishimwe (2021), includes financial measures such as profitability, growth, turnover, return on assets, and seven non-financial measures including market share, marketing effectiveness, employee commitment, competitive image/reputation, job satisfaction, competitive position, and customer satisfaction (Raimi & Manishimwe, 2021). The instrument comprises 11 items and uses a scale of 1-6 where 1 signifies strong disagreement and 6 signifies strong agreement.

In this research, competitive advantage is the mediating variable. As defined by Barney (1991), competitive advantage is the outcome of a strategy that reduces costs, exploits market opportunities, or neutralizes competitive threats (Barney, 1991). This implies that competitive advantage is not the strategy itself but the result of it, and it predicts performance rather than being performance itself. Hence, competitive advantage acts as an intervening variable in a robust model. It's measured using a single item on a Likert scale of 1-6, where 1 signifies strong disagreement and 6 signifies strong agreement.

4.2.1 Data Analysis

We use PLS-SEM to test our model structure using SmartPLS 4.0 software. PLS is important to analyze the data since it is simultaneously testing the relationships proposed in this research but using less stringent conditions than alternative methods while at the same time, providing better estimation (Suandi et al., 2022).

5 Results

5.1.1 Measurement Assessment

Table 1 presents the Composite Reliability (CR) and Average Variance Extracted (AVE) outputs from the Confirmatory Factor Analysis (CFA). It is observed that all CR values are greater than 0.6, and all AVE values are greater than 0.5, yet less than their corresponding CR. The smallest AVE value is for SBEs performance, with a value of 0.58, which is slightly greater than the minimum limit of 0.5. All AVEs fall within the range of 0.5–0.6, while all CRs are within the range of 0.8–1.0. This indicates that all AVEs are smaller than CR, leading to the conclusion that the model has met the convergent validity requirements.

Table 2 shows the values for the square root of the AVE. In accordance with these results, the square root value of AVE is always greater than the greatest correlation between the variable and other variables under study. This reflects the fulfillment of discriminant validity requirements. The maximum threshold of correlation between variables indicating no multicollinearity is 0.8 (Diongue et al., 2022). From Table 2, we see the highest correlation is 0.749, which is still under the threshold. This suggests that the model has met the discriminant validity requirements and there is no multicollinearity issue.

Table 1. Validity Test for EM, CA and SBEs performance

Latent variable	Indicator	Loadings	CR	AVE
Entrepreneurial marketing	EM1	0.689	0.957	0.958
	EM10	0.675		
	EM11	0.823		
	EM12	0.836		
	EM13	0.847		
	EM14	0.628		
	EM15	0.672		
	EM16	0.673		
	EM18	0.677		
	EM19	0.676		
	EM2	0.656		
	EM20	0.685		
	EM3	0.802		
	EM4	0.789		
	EM5	0.799		
	EM6	0.806		
	EM7	0.810		
	EM8	0.703		
	EM9	0.731		
Competitive advantage	CA4	0.796	0.838	0.721
	CA5	0.899		
SBEs performance	FP1	0.659	0.810	0.581
	FP2	0.525		
	FP3	0.539		
	NFP1	0.557		
	NFP2	0.718		
	NFP3	0.648		
	NFP4	0.647		

Table 2. Discriminant validity test (Fornell-Larcker criteria)

	Competitive Advantage	Entrepreneurship Marketing	SBEs Performance

Competitive Advantage	0.749		
Entrepreneurship Marketing	-0.224	0.739	
SBEs Performance	0.589	-0.380	0.617

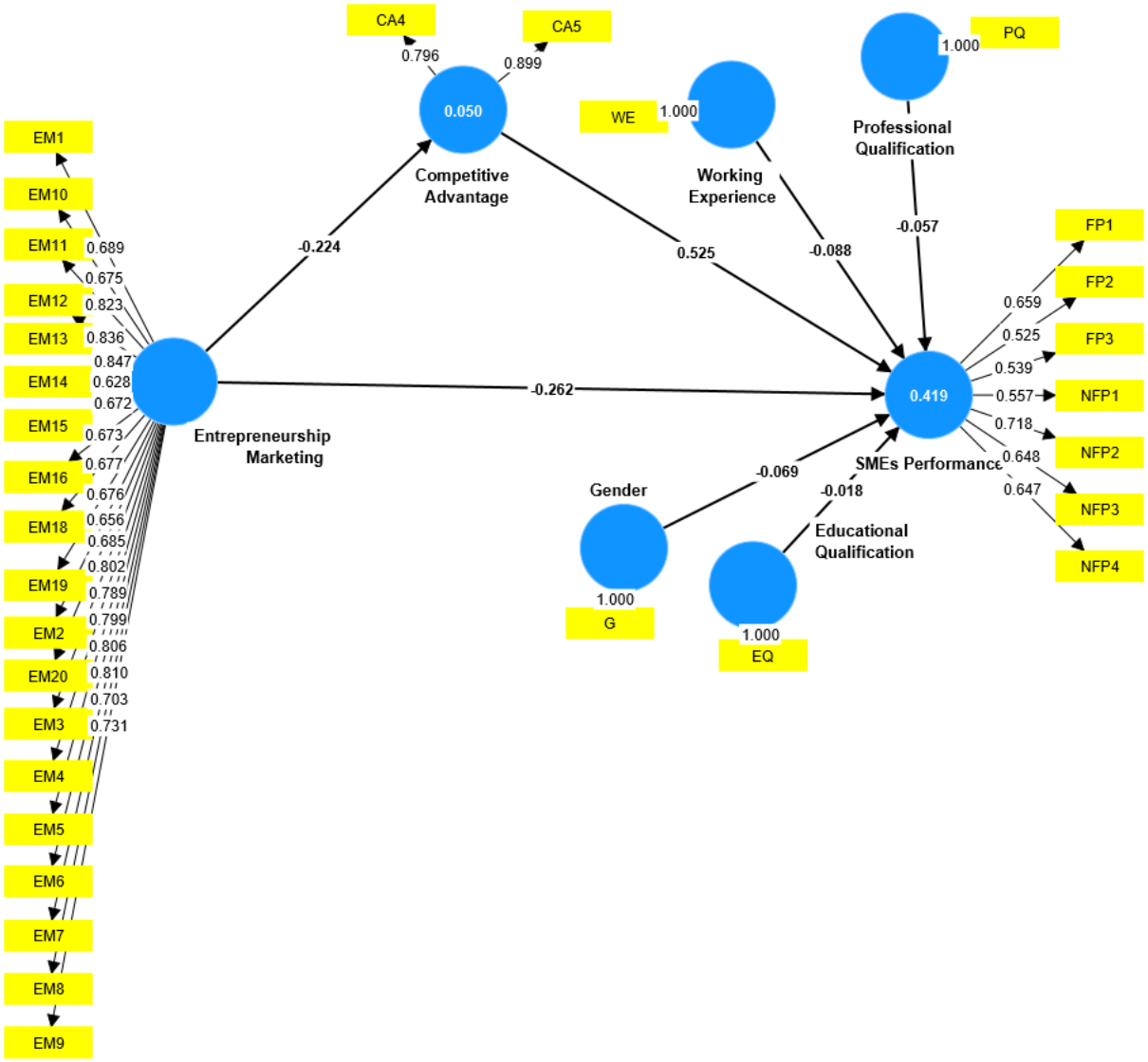


Figure 1. PLS-SEM Result

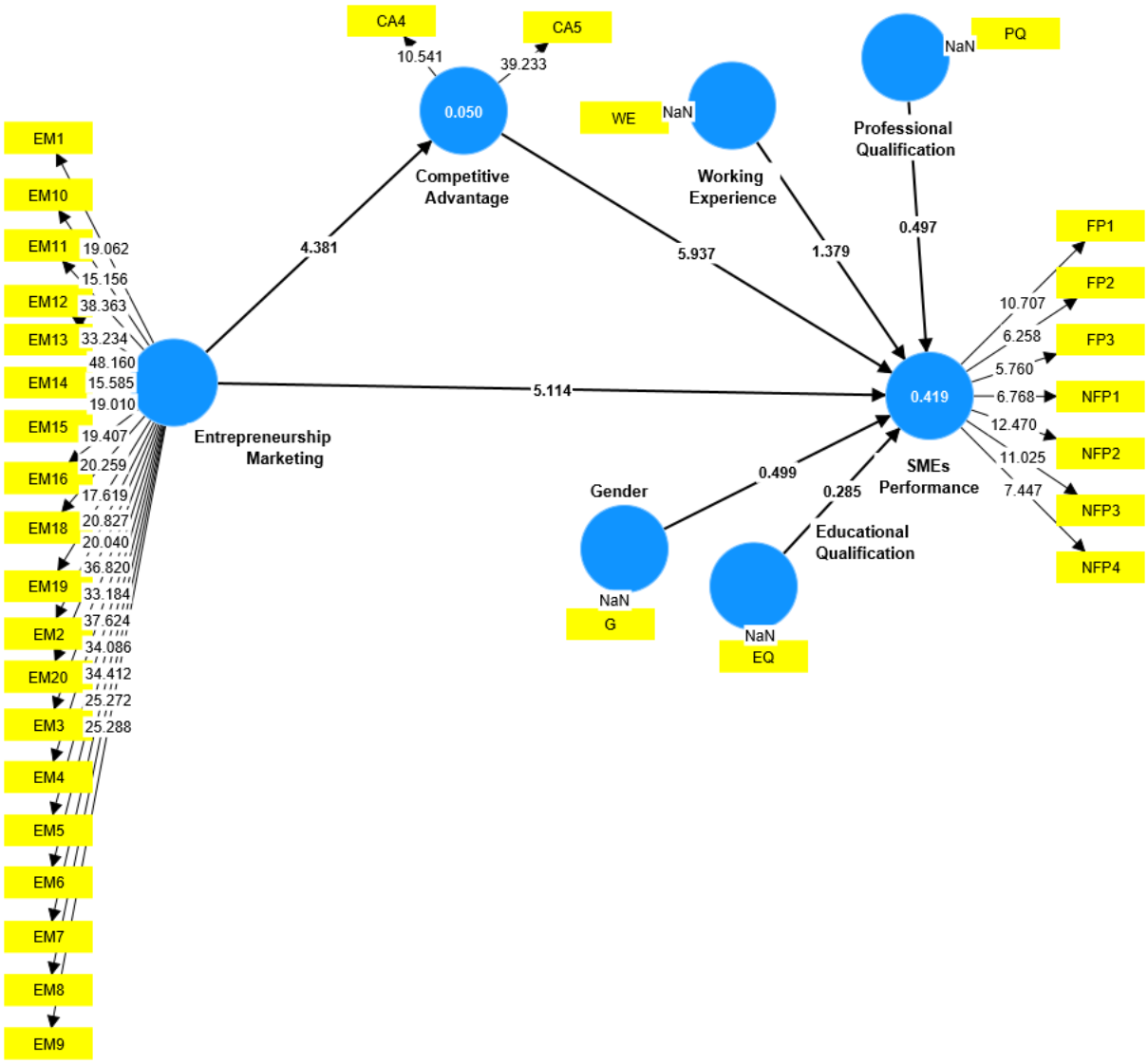


Figure 2. PLS-SEM Result with Bootstrapping

Table 3. Results of relationship analysis between variables

	Original sample (O)	Sample mean (M)	SD	T-Stat	P values	Hypothesis testing results
CA-> SBEsP	0.525	0.524	0.088	5.937	0.000	Supported
EM-> CA	-0.224	-0.230	0.051	4.381	0.000	Rejected
EM-> SBEsP	-0.262	-0.269	0.051	5.114	0.000	Rejected
EM->CA->SBEsP	0.118	0.122	0.037	3.143	0.002	Supported

CA competitive advantage, EM entrepreneurial marketing, SBEsP small and medium-sized enterprises performance

6 Results

Figures 1 and 2 display the results of the PLS (Partial Least Square) equation modeling technique using Smart PLS. The hypothesis that postulated a positive and significant relationship between entrepreneurial marketing, competitive advantage, vigilant leadership, and bank performance was tested using Smart PLS. The results are displayed in Figs. 1, 2, and Table 3. The coefficient of

determination, R2, is 0.050 for competitive advantage and 0.419 for SBEs performance. This means that entrepreneurial marketing explains 5.0 percent of the variance of competitive advantage, while entrepreneurial marketing and competitive advantage jointly explain 48.1 percent of the variance of SBEs performance.

The Smart PLS results also indicate that the determinant of competitive advantage, that is entrepreneurial marketing (EM), has a path coefficient of -0.224, while determinants of SBEs performance (SBEsP) have path coefficients as follows: 0.525 for the effect of competitive advantage (CA) and -0.262 for the effect of entrepreneurial marketing (EM) It can be concluded that competitive advantage have a direct positive effect and the strongest effect on SBEs performance.

The importance of the structural path in bootstrapping is demonstrated by Table 3 and Fig. 2. A two-tailed t-test with a significance level of 5 percent can be used to determine whether the path coefficients of the inner model are significant. As a result, the proposed hypotheses that suggest a positive and significant relationship between entrepreneurial marketing and competitive advantage, as well as between entrepreneurial marketing and bank performance, were rejected. However, the proposed hypothesis that proposes a positive and significant mediating effect of competitive advantage on entrepreneurial marketing's impact on SBEs' performance was supported.

7 Discussion and conclusions

Numerous studies have confirmed the significant influence of entrepreneurial marketing (EM) on competitive advantage, either directly or through a marketing orientation. However, in the context of Small Business Enterprises (SBEs), EM can sometimes negatively impact competitive advantage. Certain aspects of EM, such as innovation, customer intensity, value creation, and risk-taking, were found not to significantly influence competitive advantage (Crick et al., 2021). EM is rooted in the principle of innovation, a key driver of competitive advantage. Innovative SBEs actively pursue and implement new ideas, technologies, and processes to stimulate growth and competitiveness. Without innovation, businesses may find it challenging to compete with rivals and sustain their operations. Therefore, a lack of innovation can obstruct the execution of EM strategies and limit business growth and success (Crick et al., 2021). The study by Eggers et al. (2020) discusses the conceptualization of EM, which results in three dimensions: bootstrapping (cost efficiency), controlling change (innovation), and risk-taking. However, these EM dimensions may not significantly or negatively affect competitive advantage if they are not integrated into the broader strategic goals and objectives of the firm (Crick et al., 2021). Factors such as insufficient resources and capabilities, inadequate market understanding, ineffective implementation and execution, external environmental factors, and lack of organizational support and culture may contribute to a non-significant or negative effect of EM on competitive advantage. Limited resources and capabilities can hinder the effective implementation of EM dimensions, leading to a lack of impact on competitive advantage (Crick et al., 2021)

Previous studies suggest that entrepreneurial marketing can have negative effects on the competitive advantage of SBEs due to poorly defined innovation initiatives, lack of market orientation, and insufficient marketing resources. Furthermore, EM was found to have a significant and negative effect on SBEs performance. Although the authors expected EM to positively influence firm performance, this finding is important considering that relatively few previous studies reviewed the concept of entrepreneurial marketing to performance in the context of SBEs. The study conducted on 184 small tourism and hospitality firms in New Zealand found a negative relationship between entrepreneurial marketing orientation and financial performance (Crick et al., 2021). It was observed that employing an individualistic business model constrained certain decision-makers' ability to pursue growth-oriented objectives. Some EM dimensions such as risk-taking were found to have no significant effect on firm performance (Hanaysha & Al-Shaikh, 2022). Another study found a negative relationship

between long planning horizon and entrepreneurial marketing intensity (EMI) in entrepreneurial firms in Egypt (Mahrous et al., 2020). Entrepreneurial experience may not directly impact business performance (Adel et al., 2020). These results confirm that competitive advantage mediates the relationship between EM and MSME marketing performance. The researchers found that entrepreneurial practices can be negatively influenced by the institutional environment because companies are expected to operate within certain limitations, regulations, and government norms (Hanaysha & Al-Shaikh, 2022). It's important to note that the negative relationship between entrepreneurial marketing orientation and financial performance is not a universal phenomenon and is influenced by the level of coopetition. Under low levels of coopetition, this relationship remains negative. However, under high levels of competition, the relationship becomes positive, indicating that effective collaboration with competitors can mitigate the negative impact and enhance financial performance (Crick et al., 2021).

There are few studies that provide evidence that competitive advantage has a positive effect on the performance of SBEs. Research on SBEs assumes that competitive advantage affects the performance of SBEs because the independent variables they have to predict the performance of SBEs are also important to achieve competitive advantage. Competitive advantage has been found to have a positive impact on the superior performance of SBEs. Studies conducted in Pakistan, Indonesia, and the culinary sector have all shown that competitive advantage plays a significant role in enhancing the performance of SBEs. In the context of Pakistani manufacturing SBEs, it was found that innovation, along with competitive advantage, positively influences export performance (Perdana & Prasasti, 2023). Entrepreneurial orientation was found to influence company performance through competitive advantage.

SBEs that have a competitive advantage have low costs, can exploit market opportunities, and neutralize competitor threats. Entrepreneurial marketing has a direct or indirect effect on competitive advantage and performance. The mediating role of competitive advantage in the relationship between entrepreneurial marketing and performance is supported by multiple studies. Puspaningrum found that entrepreneurial orientation, which is a component of entrepreneurial marketing, improves marketing performance through sales growth and competitive advantage (Puspaningrum, 2020). Similarly, Bang et al. found that entrepreneurial marketing has a direct positive impact on competitive advantage, which in turn affects social performance and competitive advantage (Bang et al., 2022). Hendra et al. found that market orientation and innovation have a positive effect on marketing performance mediated by competitive advantage (Hendra et al., 2022). Therefore, competitive advantage plays a crucial role in mediating the relationship between entrepreneurial marketing and performance. It has been observed that entrepreneurial capabilities, including marketing capabilities, correlate positively with SME performance. Hence, it is crucial for SBEs to develop and enhance their marketing capabilities to improve their entrepreneurial marketing performance and achieve sustainable success.

Theoretically, the study findings validate both RBV and DCT propositions, demonstrating that entrepreneurial marketing influences SBE performance through competitive advantage, either directly or indirectly. This underscores the importance of leveraging internal resources and capabilities to enhance performance and highlights the need for understanding the relationships between resources, capabilities, competitive advantage, and profitability for successful strategy formulation for SBEs. This is corroborated by research on the relationship between a firm's dynamic capabilities and its competitive performance.

Practically, for marketing managers and teams, understanding this relationship is crucial. They are advised to develop a framework tailored for SBEs in developing countries like North-East Nigeria and prioritize the development and utilization of internal resources and capabilities to enhance competitive advantage and improve SBE performance. The use of Smart-Partial Least Square (Smart-PLS 4)

software for structural equation modeling analysis (SEM) is recommended as a practical tool for exploring this relationship. This understanding can enable marketing managers and teams to better meet customer needs by leveraging entrepreneurial marketing practices, leading to improved customer satisfaction and loyalty.

In term of limitations, the study acknowledges potential negative effects of entrepreneurial marketing on competitive advantage but does not provide a comprehensive analysis of these effects or explore specific strategies to address them. Future research should aim to expand the scope of the study by including a broader range of SBEs from different regions to enhance the generalizability of the findings. Future research should consider incorporating additional variables that may influence the relationship between entrepreneurial marketing, competitive advantage, and SBE performance.

Reference

[1] Adel, H. M., Mahrous, A. A., & Hammad, R. (2020). Entrepreneurial marketing strategy, institutional environment, and business performance of SMEs in Egypt. *Journal of Entrepreneurship in Emerging Economies*, *12*(5), 727–746. https://doi.org/10.1108/JEEE-11-2019-0171

[2] Andriyanto, I., Arifin, J., & Ayuningtyas, A. (2019). Antecedent Factors of Competitive Advantage and its Impact on Performance. *Proceedings of the Proceedings of the 1st International Conference on Economics, Management, Accounting and Business, ICEMAB 2018, 8-9 October 2018, Medan, North Sumatra, Indonesia*. Proceedings of the 1st International Conference on Economics, Management, Accounting and Business, ICEMAB 2018, 8-9 October 2018, Medan, North Sumatra, Indonesia, Medan, Indonesia. https://doi.org/10.4108/eai.8-10-2018.2288714

[3] Anwar, M. (2018). BUSINESS MODEL INNOVATION AND SMEs PERFORMANCE — DOES COMPETITIVE ADVANTAGE MEDIATE? *International Journal of Innovation Management*, *22*(07), 1850057. https://doi.org/10.1142/S1363919618500573

[4] Bang, W. S., Park, J. Y., & Cho, D. (2022). Exploring the Relationships among Entrepreneurial Marketing on Social Performance and Competitive Advantage: Mediating Effect of Marketing Competence of Non-profit Organizations. *Journal of Distribution and Logistics*, *9*(2), 81–95. https://doi.org/10.22321/jdl2022090205

[5] Barney, J. (1991). Firm Resources and Sustained Competitive Advantage. *Journal of Management*, *17*(1), 99–120. https://doi.org/10.1177/014920639101700108

[6] Beatty, R. W. (1992). Competitive Human Resource Advantage Through the Strategic Management of Performance. In D. M. Schweiger & K. Papenfuß (Eds.), *Human Resource Planning* (pp. 153–168). Gabler Verlag. https://doi.org/10.1007/978-3-322-83820-9_14

[7] Bhattacharyya, S. S., & Jha, S. (2015). Mapping micro small and medium enterprises from the resource-based view and dynamic capability theory perspectives and innovation classification. *International Journal of Entrepreneurship and Small Business*, *25*(3), 331. https://doi.org/10.1504/IJESB.2015.069700

[8] Boccardelli, P., & Magnusson, M. G. (2006). Dynamic capabilities in early-phase entrepreneurship. *Knowledge and Process Management*, *13*(3), 162–174. https://doi.org/10.1002/kpm.255

[9] Crick, J. M., Karami, M., & Crick, D. (2021). The impact of the interaction between an entrepreneurial marketing orientation and coopetition on business performance. *International Journal of Entrepreneurial Behavior & Research*, *27*(6), 1423–1447. https://doi.org/10.1108/IJEBR-12-2020-0871

[10] Diongue, D. M. L., Sagnane, L., Emvoutou, H., Faye, M., Gueye, I. D., & Faye, S. (2022). Evaluation of Groundwater Quality in the Deep Maastrichtian Aquifer of Senegal Using Multivariate Statistics and Water Quality Index-Based GIS. *Journal of Environmental Protection*, *13*(11), 819–841. https://doi.org/10.4236/jep.2022.1311052

[11] Eggers, F., Niemand, T., Kraus, S., & Breier, M. (2020). Developing a scale for entrepreneurial marketing: Revealing its inner frame and prediction of performance. *Journal of Business Research*, *113*, 72–82. https://doi.org/10.1016/j.jbusres.2018.11.051

[12] Grahovac, J., & Miller, D. J. (2009). Competitive advantage and performance: The impact of value creation and costliness of imitation. *Strategic Management Journal*, *30*(11), 1192–1212. https://doi.org/10.1002/smj.778

[13] Hanaysha, J. R., & Al-Shaikh, M. E. (2022). An Examination of Entrepreneurial Marketing Dimensions and Firm Performance in Small and Medium Enterprises. *Sustainability*, *14*(18), 11444. https://doi.org/10.3390/su141811444

[14] Hendra, H., Winoto Tj, H., & Tecoalu, M. (2022). The Effect of Market Orientation and service innovation on marketing performance mediated by competitive advantage. *International Journal of Economic, Business,*

Accounting, Agriculture Management and Sharia Administration (IJEBAS), *2*(3), 351–360. https://doi.org/10.54443/ijebas.v2i3.261

[15] Hidayatullah, S., Firdiansjah, A., Patalo, R. G., & Waris, A. (2019). *The Effect Of Entrepreneurial Marketing And Competitive Advantage On Marketing Performance*. *8*(10).

[16] Jones, R., & Rowley, J. (2009). Presentation of a generic "EMICO" framework for research exploration of entrepreneurial marketing in SMEs. *Journal of Research in Marketing and Entrepreneurship*, *11*(1), 5–21. https://doi.org/10.1108/14715200911014112

[17] Kaleka, A., & Morgan, N. A. (2017). Which Competitive Advantage(s)? Competitive Advantage–Market Performance Relationships in International Markets. *Journal of International Marketing*, *25*(4), 25–49. https://doi.org/10.1509/jim.16.0058

[18] Mahrous, A., Genedy, M. A., & Kalliny, M. (2020). The impact of characteristics of intra-organizational environment on entrepreneurial marketing intensity and performance in Egypt. *Journal of Entrepreneurship in Emerging Economies*, *12*(5), 621–642. https://doi.org/10.1108/JEEE-08-2019-0115

[19] Makmur, N., Chairunisa, Y., & Qamariah, I. (2018). The Effect of Entrepreneurial Marketing on Competitive Advantage: Small Culinary Souvenir Industry in Jalan Mojopahit Medan, Indonesia. *Proceedings of the 1st Economics and Business International Conference 2017 (EBIC 2017)*. 1st Economics and Business International Conference 2017 (EBIC 2017), Medan, Indonesia. https://doi.org/10.2991/ebic-17.2018.90

[20] Matsuno, K., Mentzer, J. T., & Özsomer, A. (2002). The Effects of Entrepreneurial Proclivity and Market Orientation on Business Performance. *Journal of Marketing*, *66*(3), 18–32. https://doi.org/10.1509/jmkg.66.3.18.18507

[21] Perdana, R., & Prasasti, A. (2023). Entrepreneurial orientation, company performance, and competitive advantage in Indonesian culinary SMEs. *Small Business International Review*, *7*(1), e547. https://doi.org/10.26784/sbir.v7i1.547

[22] Pratono, A. H., & Pudjibudojo, J. K. (2016). Transforming Entrepreneurial Resources to Competitive Advantage: The Role of Social Capital and Marketing capability. *Mediterranean Journal of Social Sciences*. https://doi.org/10.5901/mjss.2016.v7n2s1p265

[23] Puspaningrum, A. (2020). Market Orientation, Competitive Advantage and Marketing Performance of Small Medium Enterprises (SMEs). *Journal of Economics, Business, & Accountancy Ventura*, *23*(1), 19. https://doi.org/10.14414/jebav.v23i1.1847

[24] Raimi, L., & Manishimwe, T. (2021). Small Business Survival of Onslaughts of Boko Haram Insurgency, COVID-19 Pandemic, and Economic Crisis in Yola, North-East Nigeria: Leveraging Entrepreneurial Marketing. In S. Stephens (Ed.), *Advances in Business Strategy and Competitive Advantage* (pp. 97–118). IGI Global. https://doi.org/10.4018/978-1-7998-7657-1.ch005

[25] Ranjith, V. K. (2016). Business Models and Competitive Advantage. *Procedia Economics and Finance*, *37*, 203–207. https://doi.org/10.1016/S2212-5671(16)30114-9

[26] Shaharuddin, A. (2020). Guest Editors' Notes: COVID-19: The Pandemic's Impacts on The Economy and Realisation of Maqasid Al-Shariah and Islamic Finance. *The Journal of Muamalat and Islamic Finance Research*, 1–2. https://doi.org/10.33102/jmifr.v17i3.278

[27] Suandi, E., Herri, Yulihasri, & Syafrizal. (2022). Evaluating the relationship between entrepreneurial marketing, competitive advantage, and Islamic banks performance. *Journal of Financial Services Marketing*. https://doi.org/10.1057/s41264-022-00169-6

[28] Suryani, W., & Claudya, M. (2020). Competitive advantage: Empirical evidence from the small business of culinary. *Jurnal Inovasi Ekonomi*, *6*(01), 1–8. https://doi.org/10.22219/jiko.v0i0.13483

[29] Wahyudi, T. A. (2017). The Effect of Entrepreneurial Marketing on Managing Resources and Its Impact on Innovation Performance. *Proceedings of the International Conference on Business and Management Research (ICBMR-17)*. International Conference on Business and Management Research (ICBMR-17), West Sumatra, Indonesia. https://doi.org/10.2991/icbmr-17.2017.34

[30] Zaini, A., Hadiwidjojo, D., Rohman, F., & Maskie, G. (2014). Effect Of Competitive Advantage As A Mediator Variable Of Entrepreneurship Orientation To Marketing Performance. *IOSR Journal of Business and Management*, *16*(5), 05–10. https://doi.org/10.9790/487X-16510510

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp.74-83, November 13-16, 2023

An Assessment of Factors Influencing Women Entrepreneurs' Willingness to Accept Loans in Kano Metropolis

Abubakar Hamid Danlami[1], Rabi Bashir[2]
{ah.danlami@aun.edu.ng[1], rabibasheer88@gmail.edu.ng[2]}

Department of Economics, School of Arts and Sciences, American University of Nigeria[1],
Department of Economics, Faculty of Social Sciences, Bayero University Kano[2]

Abstract
This study was carried out to explore the extent to which women entrepreneurs willingness to credit in Kano metropolis and to explore the major problems hindering women entrepreneurs towards fundraising in Kano Metropolis. A total of three hundred and seventy-six (376) women entrepreneurs were selected as the sample of the study. The analysis of the data was done using both descriptive and inferential statistics. The result of the estimated logit modelrevealed that high interest and collateral requirements prevent women entrepreneurs to access loans from financial institutions. Hence, the study recommends that financial institutions should introduce and operate an Islamic finance system, to encourage women entrepreneurs to go for loans as the interest rate is one of the most important constraints to women entrepreneurs seeking financial credits. Additionally, collateral demand attached to a loan for women should be removed to encourage women entrepreneurs to raise capital.

Keywords: Women, Entrepreneurs, Gender, Loan, Willingness.

1 Introduction

Entrepreneurship remains the gateway to sustainable wealth creation in Nigeria. Nigeria has serious business and investment potential as aresult of an abundance of dynamic human, vibrant, and natural resources [1]. Entrepreneurship is a process of creating and innovating new businesses and development of new business methods and vision by an entrepreneur to produce incremental value and wealth and thereby contributing to economic growth [2]. Entrepreneurship is often showcased in small and medium scale enterprises (SMEs). The entrepreneurship that is part of SMEs is very relevant, giving adequate opportunities for the use of local raw materials for vertical and horizontal linkages of business [3].

Women entrepreneurship plays an important role in the economic development of a Country. These days, more women are no longer bound to traditional, gender specific roles and venturing into the business world. They have been successful in breaking their confinement within limits of their homes by entering into varied kinds of professionals and services. Women entrepreneurs have proved to be on the same level with their men counterparts in business expertise and are rising as elegant and energetic entrepreneurs [4]. In Global Entrepreneurship Monitor (GEM) 2012 Women‟s Report, an estimated 126 million women were starting or running new businesses in 67 economies around the world by year 2012. Women have similar entrepreneurial potential as men to contribute to wealth creation and employment by starting and developing their own businesses.

Women in Nigeria have been known to operate SMEs business effectively in areas such as food production and preservation, craft and cottage industries, trading, farming and services provision. The deterioration of the economic situation since the 1980s adversely affected the women economic condition globally. Hence, it exposed them to a high poverty level situation that has resulted in regarding them as the poorest of the poor [5,6]. Unfortunately, their potential has not been fully realised and utilised because of the systemic challenges that women entrepreneurs face [7].

As a result, they need both financial and other business assistance to cope with their socioeconomic tendencies facing them in the economy. Occasionally, programmes by governments and public

agencies provide skills, start-up capital and other inputs, which are meant to support women interactions within the formal sector. Despite the empowerment supports, many of these programmes have been mostly adhoc and poorly sustained. With the expansion of global capital and growing transnational trade, the informal sector in Nigeria when women's creativity is largely ignored and left to rot through non-gender sensitive economic programmes. These and many other concerns have raised new questions on how women are benefiting from global trade and which environment is needed to support women's involvement.

Access to credit by women entrepreneurs' is hampered by numerous factors including low level of education, higher interest rate by the lending institutions, socio-cultural factors that place women in a lower status in the society as compared to men in as far as running businesses is concerned.

In Kano State, it is well observed that women have less involvement in entrepreneurial activities. Women that involved in entrepreneurial activities are mostly not indigenes they are either from Igbos, Yorubas and others. Most of the women in Kano engaged in home business. Kano is majority Muslim populated state, and majority is Hausa or Hausa/Fulani. There is notion among the women in Kano especially the Muslims that collecting loan banks is against the teaching of the religion. Others have the notion that when loan are collected from the banks the interest also known as (Riba) to them is forbidden. Thus even if the women have met all the necessary requirements to collect loan from any financial institutions, some of the women are not willing to collect loan from banks. This may be as a result of religion belief and more importantly lack of trust. In the Northern part of Nigeria especially in Kano, women do not trust the financial institutions. They believe that these financial institutions have exploitative agenda and have tendencies to lead them to financial hardship if they couldn't pay back the loan in due time. Cultural belief is one major barrier to women entrepreneurs in Africa. Majority of cultural practices in Africa is that women main purpose is to either work in the farmlands, or just stay at home. Women are denied qualitative education right from birth, this has hinder their ability to explore more opportunities to get involve in entrepreneurial activities. This cultural believe that women should stay at home or work in farmland have become a major barrier for women to get involve in entrepreneurial activities to some extent get access to loans from financial institutions. Hence this study assessed the determinants of women entrepreneurs' access to credit in Kano State. The study specifically addressed how collateral requirements and interest rate affects women entrepreneurs access to credit facilities in Kano Metropolis.

2 Literature Review

In this section, we carry out the review of previous relevant studies conducted on the relationship between gender and credit accessibility in different areas. For instance, [8], identified the important women entrepreneurial motivation factors and its impact on entrepreneurial success. The study identified ambition, skills and knowledge, family support, market opportunities, independence, government subsidy, and satisfaction are the important entrepreneurial motivational factors. The study also concluded that ambition', knowledge and skill', independence 'dimensions of entrepreneurial motivation has a significant impact on entrepreneurial success.

[9] examined women empowerment and participation in economic activities as tools for self-reliance and development of the Nigerian society. This study concludes that major economic activities recorded in the country were crop farming, trading, craft, and food processing, hairdressing, and poultry production. These economic activities were funded by women through personal savings, family, philanthropists, cooperative societies, loans, and credits. Lack of government support, corruption, cultural restrictions, family burden, husband influence, and low level of education were recorded as obstacles encountered by women in economic activities. Provision of a sustainable land tenure system,

soft loans and credits, training and re-training programmes, as well as the establishment of cooperative society would increase women's participation in economic activities; accessing and willingness to utilize entrepreneurial loans and credits, and by extension and implication, contributing to societal development in Nigeria.

Furthermore, [10], examined the factors that determine women`s access to microcredit program in Lagos, the study revealed that all the variables that were used in measuring the determinants of women`s access in microcredit are significant except the variable age which is not significant. Furthermore, [11], found that Household size and marital status were more likely to increase access to credit. This finding was supported by the findings of [12] as it was pointed out by [13], who examined the factors affecting access of women enterprise funds by women groups in Kenya.

Moreover, Studies by [14,15, and 16], indicated that women entrepreneurs are gaining recognition in entrepreneurial activities. Nevertheless they are confronted with challenges like inadequacy of funds for start-up and expansion, lack of electricity/infrastructural facilities, un-conducive business environment, customers' dissatisfaction and complaints, high level of competition and lack of trust worthy personnel. In addition, they pointed out that information asymmetry, business risks and transactional cost influence access to finance.[17], examined how lending procedures hinders access to credit service by women entrepreneurs, using both qualitative and quantitative methods,he found out that all the variables have a causal relationship with access to credit by women entrepreneurs.

Lastly, [18], attempted to determine the accessibility of women enterprise fund by women enterprise owners in Tharaka South District,the study revealed that access to women enterprise fund and studied variables were closely related. This study was similar to that of [19], who showed that factors such as; income, credit and education level of the respondents have positive impactson the net profits and capital of Small Micro Enterprises

3 Methodology

3. 1 The population of the Study

There is no specific data to determine the number of female entrepreneurs in Kano State at large and how many are within the Kano Municipal. The present study is focused on Kano Metropolitan Areas namely Fagge, Dala, Gwale, Tarauni, Nassarawa, Kumbotso, Ungogo, and Kano Municipal.

3.2 Sample Size

Since the exact number of women entrepreneurs is not known, the study does not have a sample frame. Since there is an absence of a sample frame, the study used the formula developed by Cochran (1963) for the unknown population to estimate the sample size.
The sample size determination formula as cited by [20] is given as:

$$n_0 = \frac{Z^2 pq}{e^2}$$

Where:
$n_0$is the sample size, Z^2 is the abscissa of the normal curve that cuts off an area α at the tails (1 – α equals the desired confidence level, e.g., 90%), e is the desired level of precision, p is the estimated proportion of an attribute that is present in the population, and q is 1-p.
There is a 90% confidence interval, 0.5 standard deviation and margin error of 0.05 was used.
i.e $(1.645)^2$ x 0.5(1.0.5)/$(0.05)^2$

$$\frac{2.706 \text{ x } 0.25}{0.0025}$$

$\frac{0.6765}{0.0025}$ =270.6

Although,because of the problem of non-response biased a total of 400 questionnaires were distributed as in line with some previous studies [21, 22, 23, 24, 25].

3.3 Sampling Technique

The study made use of multi-stage sampling technique. The proportion of each segment is calculated and the questionnaires were divided on the basis of such proportion estimated in each segment, and cluster sample using multi-stage random sampling was used to select the respondents from each segment comprising the number of women entrepreneurs in Kano Metropolitan area, Kano State. This sampling technique is employed because it has two advantages viz:

(a) It is easier to administer than most single stage designs mainly because of the fact that sampling frame under multi-stage sampling is developed in partial units.

(b) A large number of units can be sampled for a given cost under multistage sampling because of sequential clustering, whereas this is not possible in most of the simple designs ([26,27].

The study sampled three local governments at the first stage. Based on the estimated number of markets in each of these LGA and presumably having more women entrepreneurs the following LGA in Kano Metropolitan was sampled out, they include Fagge, Kano Municipal, and Ungogo. The purposive sampling technique was used in this stage.

The second stage was the stage at which two (2) wards in which a recognized market is located in the sampled LGAs. This includes; Fagge; Sabon Gari East and Fagge A. Kano Municipal; Jakara and Sharada. Ungogo; Rijiyar Zaki and Bachirawa. This gives a total of six (6) wards were used in this study. The purposive sampling technique was used in this stage.

In the third stage, one market each was sampled from each ward sampled out from the study. These include, Fagge, Sabon Gari market from Sabon Gari East and Singer Market from Fagge A. Also, Kano Municipal; Jakara Market from Jakara and Sharada Maraket from Sharada. While, Ungogo; Rijiyar Zaki Market from Rijiyar Zaki and Bachirawa Market from Bachirawa. This gives a total of six (6) markets utilized as the sampled areas.

In the fourth stage is where the questionnaires were distributed to the respondents based on purposive random sampling. The samples of the questionnaire were shared equally across the sampled markets (i.e. 67 questionnaires distributed in each market).

3.4 Method of Data Analysis

To examine how collateral requirements and interest rate affects women entrepreneurs access to credit facilities in Kano Metropolis. The study employed the binary logit model for this. Following [28], the theoretical model can be derived as:

$$P = E\left(Y = \frac{1}{X_i}\right) = \frac{1}{1+e^{-(B_i+B_2X_i)}} \quad (1)$$

$$z = \beta_1 + \beta_2 X_i \text{ then, } P_i = \frac{1}{1+e^{-Z_i}} = \frac{e^z}{1+e^z} \quad (2)$$

If P represents the probability of occurrence (say if the respondent had collected loan or not), the probability of not occurrence can be expressed as:

$$1\text{-}P_i = \frac{1}{1+e^{z_i}} \quad (3)$$

Hence the odd ratio between the probabilities of occurrence and non-occurrence can be expressed as:

$$\frac{P_i}{1-P_i} = \frac{1+e^{z_i}}{1+e^{-z_i}} = e^{z_i} \quad (4)$$

Where:$\frac{P_i}{1-P_i}$represents the odd ratio of if the respondent had collected loan. That is the ratio of the probability that a female entrepreneur had once collected loan to the probability of otherwise. Taking the natural log of equation (4) we obtained the following expression as:

$L_i = \ln\left(\frac{P_i}{1-P_i}\right) = Z = \beta_1 + \beta_2 X_i$ (5)

Where L means the log of odd ratios, equation (5) represents what is known as the logit model which is used when the defendant variable takes a binary value; 0 or 1.

The empirical logit model estimated in this study can be expressed as:

$$\ln\left[\frac{P_i}{1-P_i}\right] = \beta_o + \beta_1 \mathrm{L\,GS_i} + \beta_2 \mathrm{OPR_i} + \beta_3 \mathrm{CLR_i} + \beta_4 \mathrm{RAF_i} + \beta_5 \mathrm{MLW_i} + \beta_6 \mathrm{LRP_i} + \beta_7 \mathrm{AFI_i} + \beta_8 \mathrm{AGE_i} + \beta_9 \mathrm{MRS_i} + \beta_{10} \mathrm{EDU_i} + \beta_{11} \mathrm{TRB_i} + \beta_{11} \mathrm{HHS_i} + \beta_{12} \mathrm{HIR_i} + \delta_i (6)$$

Where: P_i is the probability that a female entrepreneur will collect a loan and $P_i/(1-P_i)$ is the odds of a female entrepreneur will collect a loan in relation to the not collecting loan. β_s represent the various coefficients of the model .

$\left[\frac{P_i}{1-P_i}\right]$= willingness to accept (0 for not willing and 1 otherwise)

β_i = Coefficients

LS= Legal Status

OPR= Operations

CLR=Collateral required

RAF= Religions Affiliation

MLW= Maximum Loan Willing to pay

LRP= Length of repayment period

AFI=Accessibility to financial institutions

AGE=Age

MRS=Marital Status

EDU=Education

TRB=Tribe

HHS=Household Size

hir= High Interest rates

δ_i = error term

4 Results

The demographic and socio-economic characteristics of the respondents captured from the study area include; gender distribution, age, level of income, educational qualification, marital status, type of residence, household size, occupational distribution, and level of income of the respondents, were analyzed in this section using the simple descriptive statistics analysis as captured in Figure 1below:

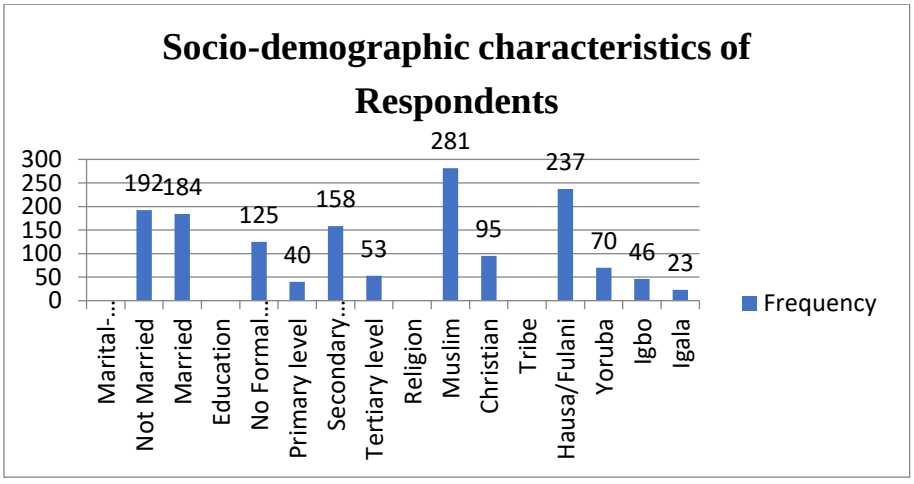


Fig. 1 Socio – demographic characteristics of respondents

Figure 1 shows the demographic distribution of the respondents. From the chart, the result shows that majority of the respondents consisting of 192 (51.06%) are not married while 184(48.94%) of the respondents are married. Also, the educational qualification of the respondents shows that 125(33.24%), while 40(10.64%) of the respondents have primary level education and 158(42.02%) of the respondents have Secondary level education as 53(14.10%) of the respondents have only Tertiary level education. Likewise, 281(74.73%) of the respondents are Muslims as 95(25.27%) of the respondents are Christians. Based on the ethnic distribution, 237(63.03%) of the respondents are Hausa/Fulani while, 70(18.62%) of the respondents are Yorubas, and 46(12.23%) of the respondents are Igbo's as 23(6.12%) are Igalas.

Going by the results, it is evident that the Hausa/Fulani women are less involved in entrepreneurial activities compared to women from other ethnic groups. Likewise, Christian ladies are more involved in entrepreneurial activities compared to Muslim ladies. This by implication shows the cultural dimension of the involvement of women entrepreneurs in Kano metropolis.

4.2 Determinants of willingness to accept loan

The model used the binary dependent variable logit model to determine willingness to accept loans by women entrepreneurs from financial institutions in Kano Metropolis. The table below presents the logit estimate of the first model.

Table 1: Factors affecting Women Entrepreneurs' willingness to accept Credit

VARIABLES	Coefficient	Odd Ratios
Legal_Status	-1.718*	0.179*
	(0.941)	(0.169)
Operation	0.707**	2.027**
	(0.301)	(0.610)
Collateral_Required	5.390***	219.2***
	(1.593)	(349.2)
High_Interest_Rates	-3.137***	0.0434***
	(1.114)	(0.0484)
Religion_Affiliation	-0.370	0.691
	(0.767)	(0.530)
Religion_Affiliation	0.0612	1.063
	(0.871)	(0.926)
Maximum_Loan_Willing	5.06e-06	1.000
	(4.75e-06)	(4.75e-06)
Repayment	0.850***	2.339***
	(0.268)	(0.628)
Accessibility_Financial_Institut	-10.59***	2.52e-05***
	(2.637)	(6.64e-05)
AGE	0.0312	1.032
	(0.0522)	(0.0539)
Marital_Status	1.457*	4.293*
	(0.759)	(3.259)
Education	-0.541***	0.582***
	(0.147)	(0.0858)
Religion	-4.293***	0.0137***
	(1.609)	(0.0220)
Hausa	1.568	4.798
	(1.047)	(5.023)
Yoruba	3.990**	54.03**
	(1.625)	(87.80)
Igbo	0.574	1.776
	(1.858)	(3.299)
Household_Size	1.705***	5.500***

	(0.488)	(2.684)
Constant	-7.762***	0.000425***
	(2.900)	(0.00123)

Source: computed by the authors using STATA 14. Note: the asterisks ***, ** and * indicate significance at 1%, 5% and 10% respectively. The figures in parenthesis () are standard errors

The Table 1 above shows the estimated logit model of estimated variables on the factors that determine the willingness to accept loans from financial institutions by women entrepreneurs in Kano Metropolis. From the results, the variable operation which measures the length of operating the business by women entrepreneur was found positive and statistically significant with the coefficient of 0.707 at 5% level of significance. The longer they operate there are more willing to accept loan from financial institutions. This is in line with the apriori expectations as those women entrepreneurs who work more may need loan to maintain the length of operations. The odd ratio shows that the odds of accepting loans is higher when they operate longer than when they operate less. This finding is in line with the work of [11]Kweyu (2017), who found that years of operation has a significant influence on women access to credit facilities.

In addition, results show the coefficient collateral requirement by financial institutions was found to be positive with a coefficient of 5.390 and statistically significant at 1%. Collateral requirement is one factor that determines the willingness to accept loan from financial institutions by women entrepreneurs. This doesn't conform to the apriori expectation as collateral requirement should discourage women from seeking financial assistance.

Also, the variable high-interest rate was found to be negative and statistically significant at 1% with the coefficient of -3.137. This result conforms to the apriori expectations as higher interest will make women entrepreneurs to be less willing to accept/collect loan from financial institutions. This implies that with high interest rate women entrepreneurs are less willing to collect loan from financial institutions. Interests prove to be a significant factor in women decision to accept loans from financial institutions or not. In addition, the coefficient of the variable length of repayment is positive and statistically significant at 1% with the coefficient of 0.850. This implies that the length of repayment of loans is a significant factor in determining women willingness to accept loan from financial institutions. The result shows with higher length of repayment the more willing women are to accept loans from financial institutions. This should be a stochastic variable as which it can take any sign. By implication if time of repayment is long enough, women entrepreneurs could go for loan and if the length of repayment is short women entrepreneurs will not go for loan. As in this case, women entrepreneurs may still go for loan perhaps the length of repayment may be long.

Also, accessibility of financial institutions has a negative coefficient value of -10.59 and found to be statistically significant at 1%. The variable accessibility of financial institutions as proved to be significant factors that determine women entrepreneurs' willingness to accept loans from financial institutions. The results show that the less accessible the financial institutions the less willing women are to accept loan from the financial institutions. The sign of the coefficient is negative which doesn't conform with the apriori expectation because accessibility to financial institutions should encourage women entrepreneurs to accept loan, the negative sign may be due to the fact that women entrepreneurs are less willing to accept loan because the financial institutions are close to them.

Also, education has a negative coefficient of -0.541 and statistically significant at 1% which implies that education to be a significant factor that determines women entrepreneurs' willingness to accept loans from financial institutions. The sign is a stochastic variable which may take any sign as educated person may be willing to accept or decline a loan offer depending on other factors she may be looking

at. The result shows that the higher the level of education the less willing the women entrepreneurs to accept loans from financial institutions. This finding is in line with the work of [11]Kweyu (2017), who posit that education level has a significant influence on women access to credit facilities.

Likewise, the coefficient of religion is -4.292 and was found to be a negative and statistically significant at 5%. The variable conforms to the apriori expectation since religion has distance itself from loans with interest. The variable has proved significant factor that determines the women entrepreneur willingness to accept loan from financial institutions. Due to religion regulations women entrepreneurs are less willing to accept loan from financial institutions. The result shows that Igbo women entrepreneurs are more likely to accept loan that other tribe among the respondents.

Also, the sign of the coefficient of household size is positive and statistical significant at 1%. This conforms to the apriori expectations as persons with higher household size may seek for a loan to maintain the house. The results show that the higher the household size of the women entrepreneur the more willing they are to collect loans from financial institutions. This finding is in line with the findings of [29]Boniface (2012) who investigated the effects of microcredit and social capital on female entrepreneurship. He found out that, household size has an influence on access to credit facilities by women entrepreneur

The findings from the results above show that women are not likely to collect loans because of high interest rate irrespective of demographic characteristics. This situation shows why all religions and ethnic background are against asking and collecting interest in business activities. Also, interest increase with time, as such most of the women will find it difficult to pay the loans given the increasing interest rate. This problem has affected women entrepreneurs from access loans from financial institutions.

5 Conclusions

This study shows that high-interest rates and collateral requirements prevent women entrepreneurs to access loans from financial institutions in Kano Metropolis. While religious affiliation is a major factor affecting women entrepreneurs' access to credit facilities.Tell your readers about the endless opportunities and the various entrepreneurialactivities that Kano metropolis women engage in. Then demonstrate how Kano – being a center of commerce and trade serves as a ground for ample opportunities vis-à-vis entrepreneurialactivities. Show how the chances are for win-win situation if the women can access credits with no interests, such as the ones provided by some Islamic-related financial institutions such as Ja'iz Bank, TAJ Bank, and other interest-free financial institutions.

Policy recommendations

Considering the relevance of entrepreneurial activities especially to women in Kano metropolis – "Center of Commerce," and considering the role of women in societal development, the following policy recommendations have been offered in order to address the problem in that sector:

This study recommends that financial institutions should prepare financial provisions or packages for women entrepreneurs who are willing to accept loans based on Islamic financing jurisprudence via Shari'ah principles. Financial institutions should make provision for training women entrepreneurs on how to raise capital to expand their businesses and also give then incentives with fewer conditions attached to it. This can be done through the media -- both the electronic and print media, and both in local languages and English to encourage the women to collect loans from these financial institutions.

Multi-National Corporations (MNCs) vis-à-vis Corporate Social Responsibilities (CSR). These companies need to pay back to their host communities. That can be done via giving out soft loans without strings attached, and devoid interests, usury, or anything prohibited by Islam.
Politicians who represent women especially and Kano metropolis women in this context, should embark on certain "Constituency Projects" of disbursing wealth as capital to run a business. Equally, philanthropists should embark on similar kind of friendship

References

[1] Ihugba, O.A., Alex O., & Njoku, A.C. (2013). Theoretical Analysis of Entrepreneurship Challenges and Prospects in Nigeria. International Letters of Social and Humanistic Sciences, 16, 21-34.
[2] Moses, L., Iyiola, O.O., Akinbode, M.O., Obigbemi, I.A., & Eke, O.P. (2015). Women Entrepreneurship in Nigeria: Policy Framework, Challenges, and Remedies.
[3] Abdullahi, M.S., Ghazali,P.L., Awang, Z., Mohd Tahir, I., Ali, M., & Salim, N.A. (2015). The Effect of Nigeria Finance, Infrastructure, and Training on the Performance of Small and Medium-Scale Enterprises (SMEs) in Nigeria. International Journal of Business and Technopreneurship, 5(3), 421-452.
[4] Pharm, A.D., & Sritharan, R. (2013). Problems Being Faced by Women Entrepreneurs in Rural Areas. The International Journal of Engineering and Science, 2(3), 52-55.
[5] Cheston, S. (2002). Empowering Women Through Microfinance. A Publication Sponsored By UNIFEM.
[6] Burkett, I. (2002). Microfinance in Australia: Current Realities and Future Possibilities. A Paper Presented to Westpac Foundation and University of Queensland.
[7] Hanson, S. (2009). Changing Places through Women's Entrepreneurship, 85(3), 245-267.
[8] Krishnamoorthy, V., & Balasubramani, R. (2014). Motivational Factors Among Women, 3(2), 12-26.
[9] Ekesionye, E.N., & Okolo, A. (2012). Women Empowerment and Participation in Economic Activities: Indispensable Tools for Self-Reliance and Development of Nigerian Society. Educational Research and Review, 7(1), 10-18.
[10] Olateji, A.D., Aminu, A.W., & Danmola, R.A. (2017). The Determinants of Women Entrepreneurs' Access to Microcredit Program: A Case Study of Cowrie's Microfinance Bank (CMB) Lagos, Nigeria. International Journal of Development and Sustainability, 6(8), 783-791.
[11] Eze, C.C., Emenyonu, C.A., Henri-Ukoha, A., Oshaji, I.O., Ibeagwa, O.B., C. Chikezie, C., & Chibundu, S.N. (2016). Women Entrepreneurs' Access to Microfinance Bank Credit in Imo State, Nigeria. Global Journal of Agricultural Research, 4(1), 9-17.
[12] Balogun, U.O., Bustaman, U.S.A., & Johari, F.B. (2016). Determinant Factors Affecting Women Social Enterprise Performances in Sokoto State, Nigeria. Asian Journal of Social Sciences and Humanities, 5(2), 47-53.
[13] Esther, M.M. (2016). Factors Affecting Access of Women Enterprise Fund by Women Groups in Nakuru West Sub-County, Kenya.
[14] Muntai, M. (2010). What Do We Know About the Patterns and Determinants of Female Entrepreneurship Across Countries? European Journal of Development Research, 22(3), 277-293.
[15] Waari, D.N., & Mwangi, W.M. (2015). Factors Influencing Access to Finance by Micro, Small, and Medium Enterprises in Meru County, Kenya. International Journal of Economics, Commerce, and Management, 111(4), 1-15.
[16] Chinonye, O., & Chima, M. (2010). Women Entrepreneurship Development in Nigeria: The Effect of Environmental Factors. Petroleum-Gas University of Ploiesti Bulletin, XII(4), 43-52.
[17] Karanja, J.G., Mwangi, A.K., & Nyakarimi, S.N. (2014). Analysis of Factors Influencing Access to Credit Services by Women Entrepreneurs in Kenya, 5(11), 34-41.
[18] Machira, H.K., Njati, I.C., Thaine, K.S., & S, G.H. (2014). Accessibility of Women Enterprise Fund and Small and Micro-Women Enterprise Owners in Tharaka South District, Kenya, 16(1), 79-103.
[19] Gichuki, C.N., Milcah, M.M., & Kinuthia, L.N. (2014). Performance of Women-Owned Enterprises Accessing Credit from Village Credit and Savings Associations in Kenya. Journal of Global Entrepreneurship Research, 4(16), 2-13.
[20] Israel, G.D. (2009). Determining Sample Size. University of Florida IFAS Extension Paper Series No.PEOD6.
[21] Danlami, A.H., & Applanaidu, S.D. (2021). Sustaining a Cleaner Environment by Curbing Down Biomass Energy Consumption. In W. Leal Filho et al. (Eds.), "African Handbook of Climate Change Adaptation," 1423-1439. Springer. **https://doi.org/10.1007/978-3-030-42091-8_211-1**.
[22] Kofarmata, Y.I., & Danlami, A.H. (2021). A Micro-Level Analysis of the Intensity of Agricultural Finance Supply in Nigeria: Empirical Evidence. SN Business & Economics, 1(12), 1-17. Springer Journal. Available at: **https://doi.org/10.1007/s43546-020-00011-y**.

[23] Danlami, A.H. (2019). Assessment of Factors Influencing Firewood Consumption in Bauchi State, Nigeria. Journal of Sustainability Science and Management, 14(1), 99-109.
[24] Danlami, A.H., Applanaidu, S.D., & Islam, R. (2018). Axiom of the Relative Income Hypothesis and Household Energy Choice and Consumption in Developing Areas: Empirical Evidence Using Verme Model. Kasetsart Journal of Social Sciences, 39, 422-431.
[25] Danlami, A.H. (2017a). Determinants of Household Electricity Consumption in Bauchi State, Nigeria. Hyperion Economic Journal, 5(1), 16-28.
[26] Danlami, A.H. An Analysis of Household Energy Choice and Consumption in Bauchi State, Nigeria [Thesis]. School of Economics, Finance, and Banking: Universiti Utara Malaysia; 2017b.
[27] Kothari, C.R. (2004). Research Methodology, Methods, and Techniques (2nd ed). New Delhi: New Age International (P) Limited.
[28] Danlami, A.H., Applanaidu, S.D., & Islam, R. (2017). From Biomass Cooking Fuel to Modern Alternatives for Bauchi State Households: A Preliminary Analysis. Biofuels, 8(3), 323-331.
[29] Boniface, N.E. (2012). Implication of Access to Microcredit for Female Entrepreneurship in Cameroon. Research Report No. 39/12.

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp.84-93, November 13-16, 2023

Achieving Superior Organizational Performance in Nano, Micro Small and Medium-scale Enterprises through Innovativeness in a Crises-oriented Environment: A Conceptual Paper

Juliana Ajuma Omale[1]
{Juliana.omale@aun.edu.ng}

School of Business and Entrepreneurship, American University of Nigeria, 98 Lamido Zubairu Way, Yola Township bypass, PMB 2250, Yola, Adamawa State, Nigeria.

Abstract
Nano, Micro, Small, and Medium Enterprises (NMSMEs) have a pivotal global role in promoting economic development. However, their performance is significantly influenced by inadequate innovations, and challenges in managing external factors. The study was entrenched in contingency theory, which forms the theoretical underpinning for the study's conceptual model. This conceptual model portrays the interplay between innovativeness and superior organizational performance, with the crises-oriented environment serving as a moderating variable. Extensive literature review, indicated that different forms of innovativeness are positively related to firm performance in varying degrees and the crises-oriented environment positively moderates the link between innovativeness and superior firm performance. However, when the crises environment involves weaponized conflict, fierceness and risk of harm to people, it may positively moderate the link between innovativeness and superior firm performance. Conceptually, propositions were formulated and directions for future studies were suggested.

Keywords: Innovativeness, NMSMEs, Crises-oriented Environment, Superior Organizational Performance.

1 Introduction

One common interest among businesses across the globe is progressive performance both in financial and non-financial forms. This is because business continuity is hinged on superior organizational performance. [1] In this ever-changing business landscape laced with different forms of crises, scholars have raised questions as to how relentless commitment to innovation can impact superior organizational performance.

The field of Innovation has garnered growing attention from scholars over the years.[2-8] Past research has consistently shown that innovative firms outperform their conventional counterparts, underscoring the importance of embracing innovativeness.[9,10] Innovativeness reflects an organization's inclination to be involved in, and back novel notions, uniqueness, investigation and innovative procedures that may birth new offers or technical methods.[11] Innovation refers to the capability of an organization to successfully sell its creations as defined by Hitt et al 2001 in Haroon Hafeez et al.[12] Lumpkin and Dess [11] classified innovativeness into two categories: Technological innovativeness; it involves produce and procedural design, R&D, engineering, and focus on tech skills and gathering of industry data and product-market innovativeness which emphasizes product design, advertisement, market research, and promotion. Globally, Nano, Micro, Small, and Medium Enterprises (NMSMEs) play a pivotal role in driving economic prosperity.[13-15] They are the primary contributors to wealth creation, employment generation, poverty reduction, private sector growth, and fostering partnerships.[14] Recognizing the significant impact of NMSMEs on economic development, policymakers and researchers, particularly in the fields of entrepreneurship and strategic management, have increasingly focused their attention on these enterprises.[13,15] The success of every business depend on its interaction with the environment in which it operates. As mentioned in Ontorael et al. [16] Wheelen and Hunger defined the external environment as external forces including entities like the government, climate, host community, trade unions,

debtors and creditors which have direct impact on the organization. The political, economic, social, technological, legal and environmental climes impact businesses in multiple ways. [17-22] Lots of businesses have been bedevilled by negative performance and failure due to their inability to innovatively navigate the crises-oriented environment. [18-20] This raises inquiries as to whether NMSMEs truly benefit from available literature on innovativeness, firm performance and the environment. To this end, this study seeks to review current literature on innovativeness, superior organizational performance and the crises-oriented environment.

2 Literature Review

This subsection concentrates on establishing conceptual definitions and providing an empirical review regarding innovativeness, crisis-oriented environment, and superior organizational performance.

2.1 Innovativeness

Joseph Aloi Schumpeter, an economist, was an early researcher on innovation and entrepreneurship in economic growth, as referenced by Śledzik.[23] In his theory of economic development, Schumpeter posited that ground-breaking changes serve as the foundation for economic development, propelling the economy forward. In 1934 and 1939, Schumpeter divided development into various categories, including the introduction of new products or the addition of new features to existing ones, changes in production technology, new market entry, the acquisition of new raw material sources, and the transformation of industry structures. He went further to view innovation as the core driver of economic change, giving rise to creative destruction, where old products or processes are replaced by new ones, as described by Śledzik.[23] Innovation is often considered the driving force behind economic growth.

[12] Similarly, innovativeness reflects an organization's commitment to embracing and supporting novel ideas, originality, exploration, and innovative processes that can lead to the emergence of new offerings or technological methods.[12] To Gary Hamel[8], its simply capitalism and open market in a different form. He explains that new entrants come into existing markets with new innovations and if the existing market players are not innovative, they become irrelevant and lose out. Griffin [24] considered innovativeness as just one facet within a set of traits that evolved to address changes in the environment. Meanwhile, Miller and Friesen [15] introduced two innovation models that are contingent on the type of company and its objectives: the conservative and entrepreneurial models. The conservative model pertains to innovation undertaken as a means of safeguarding and retaliating against competitors to reclaim market share, whereas the entrepreneurial model involves ongoing and assertive internal innovation efforts aimed at gaining a competitive advantage over rival firms. In this research, innovativeness is conceptualized as the creative response to environmental stimuli, where imaginative ideas are transformed into practical solutions for identified challenges, leading to economic benefits through either novel approaches or the expansion of existing knowledge.

Scholars have reported from their findings, how essential innovativeness is and how it has impacted firm performance. Among them are [25,26,5,27,4,6,3,10,] However, other scholars found adverse impact of innovativeness on the performance of firms.[28,29] This study operationalized innovativeness as thus; readiness to change beliefs and discover new options, value and incentives for new trials, cost attached to research and development, number of professionals and scientists employed in the organization, percentage of total sales dedicated to initiating and implementing product-market innovation, new product or service count, how often service or product lines change and the extent of emphasis on technological development as well as seek to form a repute from attempting novel approaches and know-hows, these measures have been used over and over by scholars including Miller

and Friesen [15], Karagozoglu and brown, Hage, Miller, Covin & Slevin, Zahra and Covin and Salehand Wang, according to Lumpkin & Dess.[11]

2.2 Superior firm performance

Emphasizing the importance of grasping the concept of performance is essential, as the fundamental goal of every business is to achieve profitability.[30] Firm performance represents the outcome or accomplishment influenced by the company's utilization of its owned resources.[31] It is the satisfaction of stake-holders.[32] Organizational performance encompasses the results of the activities that transpire during the course of an organization's daily operations.[33] Lumpkin and Dess [11] stated the opinion of Cameron about performance construct as being multidimensional stressing the need to understand it. They stressed that Entrepreneurial activities may be favourable for one aspect of performance and unfavourable to another; e.g. committing huge resources to research and development (R&D) plus innovation of products may gear towards increased market share and profit eventually, but may also erode short-term profitability, therefore depending on a single performance measure may lead to deceptive statistic and wrong theory building. In other words, studies designed to test different variables in relation to performance, should use multiple performance indices such as financial indices; growth in sales and profit, and non-financial indices; customer satisfaction, market share, reputation, public image, employee satisfaction and goodwill.

A performance measurement system is a group of indices utilised by organizations to be productive and reach their goals, it is divided into monetary and non-monetary performance measures. The non-financial performance measures system (NFPMS) was developed because of the inadequacy of the financial performance indices to effectively measure performance. Consistent with Arokodare et al.[1] this study will conceptualize superior performance measures as monetary (sales growth and profit) and non-monetary (market share, competitive advantage, customer satisfaction and creativity).

2.3 Crises-oriented Environment

In Ontorael et al.[16] scholars defined a corporate environment as a network of resources surrounding an organization to provide support during competitive challenges. He expressed the viewpoint, drawing from Crijns and Ooghi that two environments play a pivotal role at every stage of a firm's development. These environments encompass the internal, which pertains to the entrepreneur's characteristics, and the external, which includes aspects like industry conditions, market dynamics, competitors, and the economic climate. As per Wheelen and Hunger 2001, as cited in Ontorael et al.[16], the external environment refers to forces outside the firm that directly impact the company, such as government regulations, trade unions, shareholders, creditors, interest groups, and the communities in which the company operates. According to Organization of Economic Cooperation Development (OECD),[21] a conflict-affected area is one that is characterized by weaponized conflict, extensive fierceness or other risks that could harm people. It may present itself as a conflict of international or non-international nature involving more than one state.

It may involve a war of freedom, insurgency, or civil war. Insurgency creates a bad image for a country, increases poverty, impacts business performance negatively and reduces the inflow of foreign direct investment. [34] Despite these, the goal of sustainability drives the business owner to secure the ongoing existence of the organization they oversee in a nation or region grappling with a series of ongoing crises [35] Entrepreneurs should strive to comprehend how to navigate a range of crises, brought about by political, economic, social, technological, legal, and environmental factors.[17-20]

3 Empirical Evidence

To establish the connection between innovativeness and superior firm performance, with a crises-oriented environment as a moderating variable, a comprehensive review and synthesis of various scholarly studies were conducted. These efforts resulted in two distinct categories of propositions: (i) the relationship between innovativeness and superior firm performance and (ii) the role of a crises-oriented environment as a moderator in the relationship between innovativeness and superior firm performance.

i. Innovativeness and superior firm performance

The impact of innovativeness on firm performance has been researched by many scholars and different findings have been postulated. Recently, a new study found that innovativeness has a significant effect on sales growth and recommended that firms should focus on developing curiosity and innovativeness to impact sales growth and overall firm performance positively.[3] In another study, innovativeness was seen to have a positive impact on sales growth.[4] Mahmutaj and Krasniqi,[5] conducted research on how diverse types of innovativeness impact sales growth, their findings reveal that innovation that had to do with marketing increased sales but new to-firm products did not increase sales, this is similar to findings from other studies like Chandler and Hanks 1994, Subramanian and Nilakanta 1996, referenced by Mahmutaj and Krasniqi.

[5] Odunayo and Adeniran's [6] investigation found innovativeness to have a significant impact on sales growth, they recommended that managers should emphasize more on innovating new products. Furthermore, Ali [7] found that innovativeness impacted sales growth and overall firm performance positively. A recent article establishes that product innovativeness in larger organizations has a positive relationship with firm performance, however, this was aided by access to a network of interconnected resources Noone et al.[36] In a recent study, it was found that Product innovation can substantially boost the financial performance of a competitor-oriented firm, while a technology-oriented firm can enhance its growth and market performance through the same means.

[37] Kiiru et al. [38] further affirmed that innovativeness impacted performance in a positive way in Kenya, however, market innovation influenced performance more compared to product and process innovation. Consistent with Bach et al. [39] there is a consensus that generally, innovativeness impacts superior organizational performance positively. However, different forms of innovativeness such as product, market and process innovations have varying impact on the strength of the association. It is worthy of note that in the short run, product innovation may not impact positively on performance. Based on the auspicious empirical results regarding the relationship between innovativeness and firm performance, this study puts forth the following proposition:

Proposition 1: *Different forms of innovativeness are positively related to firm performance in varying degrees.*

ii. Crises-Oriented Environment as a moderator between innovativeness and firm performance

Numerous studies have employed various variables as moderators in the connection between innovativeness and firm performance. Among which a few explored the role of the crises-oriented environment, as a moderator. Firms aiming for superior performance in such challenging conditions must prioritize learning and adopting innovativeness. Insurgency creates a bad image for a country, increases poverty, impacts business performance negatively and reduces the inflow of foreign direct investment. [40] Hence there is a need for business owner to secure the ongoing existence of their organization through innovative thinking. [35] In their study, Sakar and Clegg [41] found that small

businesses became more innovative with product and processes in the face of daring crises. The crises situation became more of an entrepreneurial opportunity rather than a problem. Raimi [42] also found that innovation orientation impacts performance more positively in a crisis's situation. In line with this, Wang et al. [43] opined that when firms managed conflict with competition in focus, the impact of outbound open innovation on performance was more, that is to say that in the face of crises they became more innovative and it resulted in better performance. In his systematic literature review, Samra [44] recognized three patterns of organizational innovation behaviour in crisis situation: a cyclical behaviour where most companies cut costs and are reluctant to innovate, a neutral behaviour focused on maintaining the status quo, and a counter-cyclical behaviour where companies ramp up their innovation efforts. These innovative behaviours are influenced by various factors that hinder innovation. Moreover, his research indicates that innovation has a positive impact on firms' performance during crises, with this impact depending on the degree of environmental turbulence.

Similarly, temporary business model innovativeness in the time of covid-19 crises impacted firm performance positively [45] Similarly, Clauß et al. [46] also advanced from their research that value proposition and value creation dimensions of business model innovation led to a positive performance while value capture dimension did not impact performance positively. In the same direction, Lee and Trimi [47] did a study on convergence innovation (CI) in covid-19 crises situation and concluded that CI is more productive when compared to other forms of innovativeness because it involves a fusion of a whole lot of external ideas, technologies, unique lifestyle etc. for a common purpose. consistent with results from other studies on innovativeness, Amankwah-Amoah [48] came up with the concept of CoviNovation which connotes innovation that stemmed from crisis and they identified different forms of innovations in the aviation industry which led to continuity in business despite the covid crisis. Away from the general norm, Adam and Alarifi [49] found in their research that rather than impacting performance positively, innovativeness in a turbulent environment led to a positive impact on the survival of businesses.

In another twist, Cefis and Marcili [50] considered the time lapse and type of innovativeness to study the impact of innovativeness on business survival, they found that new businesses with technologically innovative characteristics within 2 years of their operation enjoyed a extended adaptive survival, while non-technological innovativeness was detrimental to the survival of other new businesses. Based on the definition advanced by [16,21,34,17-20], the conflict-oriented environment will be operationalized as weaponized conflict, concerns of kidnapp risks, unstable government policies, and fluctuations in pricing, multiple tax impositions and any risk of harm to life. The review indicates that a significant portion of research has explored crisis-oriented environments in various contexts. However, there is a notable lack of research that includes armed conflict, among other factors, as a moderating element in the relationship between innovativeness and performance, particularly in the Nigerian context. The study therefore, proposes that:

Proposition 2: *Crises-oriented environment encompassing armed conflict, fierceness and risk of harm to people may positively moderate the link between innovativeness and superior firm performance.*

4 Development of Theoretical Framework and Conceptual Model

This sub-section concentrated on the establishment of the theoretical framework and the interconnection between the foundational theory and the study's conceptual model. The study is grounded on Contingency theory as its foundational framework. This choice was made because the theory's principles and philosophy align closely with the dynamics of the relationship between innovativeness, a crises-oriented environment, and superior organizational performance. The rationale

for employing contingency theory in this study is rooted in its theoretical elucidation of the study's objectives and how it relates to the conceptual model.

4.1 Contingency Theory

Lawrence & Lorsch [51] are the proponents of the contingency theory which believes that the strength of the link between two factors depends on the extent of a third factor.[52] Contingency theory was introduced in the 1960s to help in solving some of the problems of the bureaucratic theory and to facilitate the best practice view to management. It dominated academic conversations on organization design over the 1960s and 1970s.[52] Despite enjoying substantial endorsement from scholars, the contingency theory is not without some criticisms. Abba et al. [53] mentioned Galunic and Eisenhardt's assertion that contingency theory is not dynamic as it is said to have failed to deal with inevitable organizational changes. Donaldson, a critic of the contingency theory also argued that it may not be practical for organizations to align themselves perfectly with their consistently changing environment. This is because as the organization adjusts its structure to match the contingencies, the contingencies themselves evolve, rendering the organizational structural changes ineffective in achieving alignment. He Further argued that, organizational managers might not possess the knowledge of the theory's ideal states of fit, making it challenging to steer their organizations in that direction.[53] In their study, Rauch et al. [10] while addressing the issue of moderator variables, stated that moderator variables surfaced based on the premise of contingency theory proposed by Lawrence & Lorsch [51].

The contingency theory believes that the strength of relationship between two variables depends on the extent of a third variable. A whole lot of researchers have responded to the emergence of the contingency theory and have added moderator variables to their studies. In their study which was based on the contingency theory, Andrews and Johansen [54] concluded that there is a strong association between each element of the environment and organization's performance. Rosenbusch et al. [55] also carried out a study based on contingency theory, they pointed out that the environment is usually focused on as a precursor of Entrepreneurial Orientation (EO), but they acknowledged that it could be a precursor or a moderating factor. Most EO studies in which innovativeness is a dimension have adopted the contingency framework.[55] Earlier EO literature has suggested that future EO research should be based on the contingency framework.[10,11,56-58]

Based on the foundational theory of this study, an interaction conceptual model was developed to explore the relationship between innovativeness and various dimensions of superior organizational performance, with the moderating influence of a crises-oriented environment. The conceptual model in this study illustrates the connection between the dependent variable (Y) and the independent variable (X), with the moderating variable (Z). The dependent variable is defined as superior firm performance, encompassing factors such as sales growth, profit, market share, competitive advantage, customer satisfaction, and organizational creativity. The independent variable (X) represents innovativeness, operationalized through indicators like a willingness to change beliefs and explore new possibilities, the value and incentives for experimentation, research and development costs, the number of professionals and scientists employed, the percentage of total sales allocated to product-market innovation initiatives, the sum total of new products or services introduced, the frequency of changes in product or service lines, and the emphasis on technological advancement. Meanwhile, the moderating variable (Z) signifies the crisis-oriented environment, operationalized by elements like armed conflict, concerns of kidnap risks, unstable government policies, and fluctuations in pricing and multiple tax impositions. This conceptual model is depicted in Figure 1.

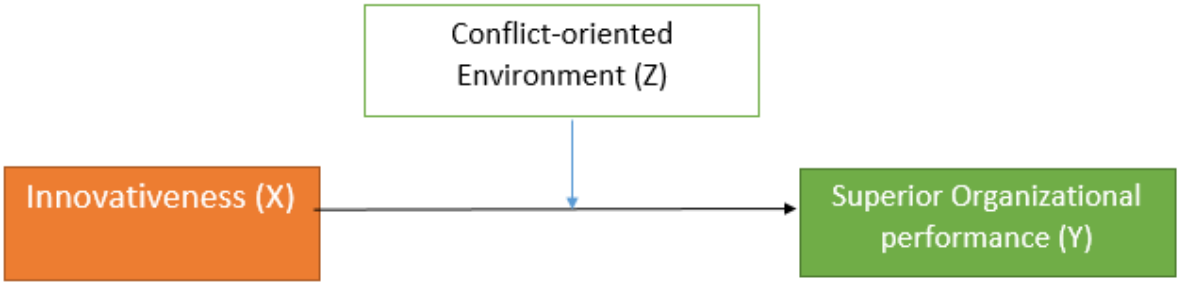


Fig. 1. Conceptual framework.

Source: Literature review, 2023

5 Conclusion and future research

This paper presents a comprehensive examination of the concepts of innovativeness and crises-oriented environments from diverse scholarly perspectives. It serves as a reference to the existing body of knowledge regarding the conceptual connections between these variables in the field of entrepreneurship. The study offers precise conceptual definitions and elucidates the intricate interactions among innovativeness, crises-oriented environments, and superior firm performance. Furthermore, it presents a conceptual model that researchers can utilize to gauge the moderating impact of a crises-oriented environment on the relationship between innovativeness and superior firm performance.

Given the heightened level of environmental volatility and the rapid onset of interruptions in today's business landscape, there is an imperative need for in-depth empirical investigations to enhance the development of the concept of a crises-oriented environment, characterized by factors such as weaponized conflict, extensive fierceness or other risks that could harm people and businesses. Review have shown that 71.76% of the articles analysed by Smara [44] primarily operationalized crises in terms of global financial crises and the recent COVID-19 crisis, but it is noteworthy that armed-conflicts are increasingly prevalent in various regions. Therefore, there is a pressing need for additional studies to examine how the crises-oriented environment, as defined by OECD [21], influences the relationship between innovativeness and firm performance.

Moreover, the literature review highlights that the type of innovation pursued by an organization plays a pivotal role in determining the duration it takes for observable effects on performance. It is advisable for scholars to consider the time elapsed between innovation implementation and the current performance status as a moderating factor in the relationship between innovativeness and organizational performance.

Lastly, as recently reported by the Small and Medium Enterprises Development Agency of Nigeria (SMEDAN),[14] businesses are categorized into four groups based on their size and assets. A significant finding is that 96.9% of all enterprises in Nigeria fall within the nano and micro categories. Notably, only 5% of the literature reviewed by the researcher focused on micro enterprises. Consistent with the International Labour Organization (ILO) [59] report from 2019, it is evident that these smaller enterprises contribute substantially to economic growth by generating employment opportunities, yet they remain relatively neglected in entrepreneurship

studies. Therefore, future research endeavours should prioritize a more comprehensive examination of nano and micro enterprises to support their growth and development. Specifically, more empirical studies are required to investigate and validate the significance and impact of innovativeness in the performance of nano and micro enterprises; and as a corollary, to examine whether the presence of a crises-ridden environment will hinder the relationship or enhance it.

References

[1] Arokodare, M. A., Kuforiji, A. A., Makinde, G. O., & Asikhia, O. U. (2020). Strategic entrepreneurship and superior firm performance: The moderating role of entrepreneurial mindset. J Crit Rev, 7(19), 1975-1987. **Link**

[2] Groza, M. D., Zmich, L. J., & Rajabi, R. (2021). Organizational innovativeness and firm performance: Does sales management matter? Industrial Marketing Management, 97, 10–20. **Link**

[3] Peljko, Ž., & Antončič, J. A. (2022). Entrepreneurial curiosity, innovativeness of the entrepreneur, and company growth. Behavioral Sciences, 12(11), 424. **Link**

[4] Miočević, D., Talaja, A., & Alfirević, N. (2021). Disentangling performance outcomes of a firm's innovativeness: A resource-advantage perspective. Journal for East European Management Studies, 26(3), 392–414. **Link**

[5] Mahmutaj, L. R., & Krasniqi, B. A. (2020). Innovation Types and Sales Growth in Small Firms: Evidence from Kosovo. South East European Journal of Economics and Business, 15(1), 27–43. **Link**

[6] Odunayo, O. A., & Adeniran, A. B. (2021). The Link between Product Innovation and Sales Growth: Case Study of Shoes and Garment Enterprises in Ibadan, Nigeria. SSRG International Journal of Industrial Engineering, 8(1), 36–42. **Link**

[7] Ali, H. S. (2021). The role of firm innovativeness in the time of Covid-19 crisis: Evidence from Chinese manufacturing firms. Asian Journal of Technology Innovation, 30(3), 689–714. **Link**

[8] London Business School. (2014, January 10). Gary Hamel: What I mean when I talk about innovation. London Business School. **Link**

[9] Anderson, B. S., Kreiser, P. M., Kuratko, D. F., Hornsby, J. S., & Eshima, Y. (2014). Reconceptualizing entrepreneurial orientation. Strategic Management Journal, 36(10), 1579–1596. **Link**

[10] Rauch, A., Wiklund, J., Lumpkin, G. T., & Fresé, M. (2009). Entrepreneurial Orientation and Business Performance: An Assessment of past Research and Suggestions for the Future. Entrepreneurship Theory and Practice, 33(3), 761–787. **Link**

[11] Lumpkin, G. T., & Dess, G. G. (1996). Clarifying the entrepreneurial orientation construct and linking it to performance. Academy of Management Review, 21(1), 135. **Link**

[12] Hafeez, M. H., Shariff, M. N. M., & Lazim, H. B. M. (2012). Relationship between Entrepreneurial Orientation, Firm Resources, SME Branding and Firm's Performance: Is Innovation the Missing Link? American Journal of Industrial and Business Management, 2(4), 153–159. **Link**

[13] Pratono, A. H., & Mahmood, R. (2015). Entrepreneurial orientation and firm performance: How can micro, small and medium-sized enterprises survive environmental turbulence? Pacific Science Review, 1(2), 85–91. **Link**

[14] Small and Medium scale Enterprises Development Agency of Nigeria [SMEDAN], National Bureau of Statistics [NBS]. (2021). MSME SURVEY REPORT. **Link**

[15] Miller, D., & Friesen, P. H. (1983). Strategy-making and environment: The third link. Strategic Management Journal, 4(3), 221–235. **Link**

[16] Ontorael, R., Suhadak, & Mawardi, M. K. (2017). ANALYSIS OF THE INFLUENCE OF EXTERNAL AND INTERNAL ENVIRONMENTAL FACTORS ON BUSINESS PERFORMANCE: A STUDY ON MICRO SMALL AND MEDIUM ENTERPRISES (MSMES) OF FOOD AND BEVERAGE. Russian Journal of Agricultural and Socio-Economic Sciences, 66(6), 47–56. **Link**

[17] Nomor, Iorember. (2017). Political Stability and Economic Growth in Nigeria. IOSR Journal of Economics and Finance (IOSR-JEF), 8(2), 45–53. **Link**

[18] Mustapha, A. A., Fatsuma, U. B., & Abdullahi, A. (2018). The Negative Impacts of Boko Haram Insurgency on Northern Nigeria. Journal of Humanities and Social Science, 23(7), 72-80. **Link**

[19] Awojobi, O. N. (2014). The Socio-Economic implications of Boko Haram insurgency in the North-East of Nigeria. International Journal of Innovation and Scientific Research, 11(1), 144–150. **Link**

[20] Benny Ong Ming Zhe, Abdul Hamid, N. (2021). The Impact of Digital Technology, Digital Capability and Digital Innovation on Small Business Performance. Research in Management of Technology and Business, 2(1), 499–509. **Link**

[21] OECD. (2016). Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas. Available from: **https://www.oecd-ilibrary.org/governance/oecd-due-diligence-guidance-for-responsible-supply-chains-of-minerals-from-conflict-affected-and-high-risk-areas_9789264252479-en**

[22] United Nations. (2022). US$1.1 billion needed to reach 5.5 million people in north-east Nigeria with humanitarian assistance in 2022. Available from: **https://nigeria.un.org/en/171628-us11-billion-needed-reach-55-million-people-north-east-nigeria-humanitarian-assistance-2022**
[23] Śledzik, K. (2015). Schumpeter's Theory of Economic Development: An Evolutionary Perspective. Available from: **https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2671179**
[24] Griffin, A. S. (2016). Innovativeness as an emergent property: a new alignment of comparative and experimental research on animal innovation. Philosophical Transactions of the Royal Society B, 371(1690), 20150544. **Link**
[25] Ambad, S. N. A., & Wahab, K. A. (2013). Entrepreneurial Orientation among Large Firms in Malaysia: Contingent Effects of Hostile Environments. Int J Bus Soc Sci, 4(16). **Link**
[26] Basso, O., Fayolle, A., & Bouchard, V. (2009). Entrepreneurial Orientation: the making of a concept. The International Journal of Entrepreneurship and Innovation, 10(4), 313–321. **Link**
[27] Martens, C. D. P., Lacerda, F. M., Belfort, A. C., & De Freitas, H. M. R. (2016). Research on entrepreneurial orientation: current status and future agenda. International Journal of Entrepreneurial Behaviour & Research, 22(4), 556–583. **Link**
[28] Alarape, A. A. (2013). Entrepreneurial orientation and the growth performance of small and medium enterprises in Southwestern Nigeria. Journal of Small Business and Entrepreneurship, 26(6), 553–577. **Link**
[29] Yimer, A. A., Haimanote, W. M., Brajaballav, K., & Jaladi, R. (2019). The effect of entrepreneurial orientation on perceived business success of small-scale manufacturing in Ethiopia. Int J Mech Eng Technol, 10(1), 482-492. **Link**
[30] Olanipekun, W. D., Abioro, M. A., Akanni, L. F., Arulogun, O. O., & Rabiu, R. O. (2015). Impact of strategic management on competitive advantage and organisational performance - Evidence from Nigerian Bottling Company. J Policy Dev Stud, 9(2), 185-198. **Link**
[31] Syafarudin, A. (2016). Strategy of leadership and innovation in improving company performance against competitive advantage: A case study of PT. Pegadaian (Ltd) Indonesia. Int J Econ Commerce Manag, 4(6), 471-482. **Link**
[32] Santos, J. B., & Brito, L. A. L. (2012). Toward a subjective measurement model for firm performance. Bar Brazilian Administration Review, 9(spe), 95–117. **Link**
[33] Musyoka, S. M. (2016). Factors that influence organizational performance in the hospitality industry: A case study of Sankara Nairobi (Doctoral Thesis). United States International University-Africa. Available from: **https://erepo.usiu.ac.ke/bitstream/handle/11732/3192/SHARON%20MULE%20MUSYOKA%20MBA%202016.pdf?sequence=1&isAllowed=y**.
[34] Francis, A. A. (2019). The impacts of political violence and terrorism on Socio-Economic processes, good governance and on Nigeria's foreign policy. International Journal of Peace and Conflict Studies, 6(1), 1–18. **Link**
[35] Kaadan, W., & Harkiolakis, N. (2022). Business survival in conflict zones: the case of bureau Veritas in Iraq. International Journal of Teaching and Case Studies, 13(4), 359. **Link**
[36] Noone, B. M., Lin, M., & Sharma, A. (2022). Firm performance during a crisis: effects of adhocracy culture, incremental product innovation, and firm size. Journal of Hospitality & Tourism Research. **Link**
[37] Acar, A. Z., & Özşahin, M. (2018). THE RELATIONSHIP AMONG STRATEGIC ORIENTATIONS, ORGANIZATIONAL INNOVATIVENESS, AND BUSINESS PERFORMANCE. International Journal of Innovation Management, 22(01), 1850009. **Link**
[38] Kiiru, D. K., Mukulu, E., & Ngatia, P. (2023). Innovativeness and Performance: Evidence from Kenyan SMEs. European Journal of Business and Management Research, 8(2), 113–119. **Link**
[39] Bach, T. M., Dalazen, L. L., Da Silva, W. V., Ferraresi, A. A., & Da Veiga, C. P. (2019). Relationship between Innovation and Performance in Private Companies: Systematic Literature review. SAGE Open, 9(2), 2158244019855847. **Link**
[40] Francis, A. A. (2019). The impacts of political violence and terrorism on Socio-Economic processes, good governance and on Nigeria's foreign policy. International Journal of Peace and Conflict Studies, 6(1), 1–18. **Link**
[41] Sarkar, S., & Clegg, S. (2021). Resilience in a time of contagion: Lessons from small businesses during the COVID-19 pandemic. Journal of Change Management, 21(2), 242–267. **https://doi.org/10.1080/14697017.2021.1917495**
[42] Raimi, L., & Manishimwe, T. (2021). Small business survival of onslaughts of Boko Haram insurgency, COVID-19 pandemic, and economic crisis in Yola, North-East Nigeria. In Advances in business strategy and competitive advantage (pp. 97–118). **https://doi.org/10.4018/978-1-7998-7657-1.ch005**Wang, T., Wu, J., Gu, J., & Hu, L. (2020). Impact of open innovation on organizational performance in different conflict management styles: Based on resource dependence theory. International Journal of Conflict Management, 32(2), 199–222. **https://doi.org/10.1108/ijcma-09-2019-0165**

[43] Wang, T., Wu, J., Gu, J., & Hu, L. (2020). Impact of open innovation on organizational performance in different conflict management styles: based on resource dependence theory. *International Journal of Conflict Management*, 32(2), 199–222. **https://doi.org/10.1108/ijcma-09-2019-0165**
[44] Smara, R. (2022). Innovation in times of crisis: A systematic literature review. Vestnik Sankt-Peterburgskogo Universiteta, 21(3), 472-494. **https://doi.org/10.21638/11701/spbu08.2022.306**
[45] Clauß, T., Breier, M., Kraus, S., Durst, S., & Mahto, R. V. (2021). Temporary business model innovation – SMEs' innovation response to the Covid-19 crisis. R & D Management, 52(2), 294–312. **https://doi.org/10.1111/radm.12498**
[46] Clauß, T., Abebe, M., Tangpong, C., & Hock, M. (2021). Strategic Agility, business model Innovation, and Firm Performance: An Empirical investigation. IEEE Transactions on Engineering Management, 68(3), 767–784. **https://doi.org/10.1109/tem.2019.2910381**
[47] Lee, S. M., & Trimi, S. (2021). Convergence innovation in the digital age and in the COVID-19 pandemic crisis. Journal of Business Research, 123, 14–22. **https://doi.org/10.1016/j.jbusres.2020.09.041**
[48] Amankwah-Amoah, J. (2021). COVID-19 pandemic and innovation activities in the global airline industry: A review. Environment International, 156, 106719. **https://doi.org/10.1016/j.envint.2021.106719**
[49] Adam, N. A., & Alarifi, G. (2021). Innovation practices for survival of small and medium enterprises (SMEs) in the COVID-19 times: The role of external support. Journal of Innovation and Entrepreneurship, 10(1). **https://doi.org/10.1186/s13731-021-00156-6**
[50] Cefis, E., & Marsili, O. (2019). Good times, bad times: Innovation and survival over the business cycle. Industrial and Corporate Change, 28(3), 565–587. **https://doi.org/10.1093/icc/dty072**
[51] Lawrence, P. R., & Lorsch, J. W. (1967). Organization and environment: Managing Differentiation and Integration. Boston: Division of Research, Graduate School of Business Administration, Harvard University.
[52] Virpi, T. (2022). Contingency theory and the information processing view. In Edward Elgar Publishing eBooks, (pp. 248–266). **https://doi.org/10.4337/9781839104503.00020**
[53] Abba, M., Yahaya, L., & Suleiman, N. (2018). Explored and Critique of Contingency Theory for Management Accounting Research. **https://www.semanticscholar.org/paper/Explored-and-Critique-of-Contingency-Theory-for-Abba-Yahaya/57d4dfb70f5bf103857d7d89489efb15763764b1**
[54] Andrews, R., & Johansen, M. (2012). Organizational environments and performance: A linear or nonlinear relationship? Public Organization Review, 12(2), 175–189. **https://doi.org/10.1007/s11115-012-0173-z**
[55] Rosenbusch, N., Rauch, A., & Bausch, A. (2011). The mediating role of entrepreneurial orientation in the task Environment–Performance relationship. Journal of Management, 39(3), 633–659. **https://doi.org/10.1177/0149206311425612**
[56] Covin, J. G., & Slevin, D. P. (1991). A conceptual model of entrepreneurship as firm behavior. Entrepreneurship Theory and Practice, 16(1), 7–26. **https://doi.org/10.1177/104225879101600102**
[57] Lumpkin, G. T., & Dess, G. G. (2001). Linking two dimensions of entrepreneurial orientation to firm performance. Journal of Business Venturing, 16(5), 429–451. **https://doi.org/10.1016/s0883-9026(00)00048-3**
[58] Wales, W. J. (2015). Entrepreneurial orientation: A review and synthesis of promising research directions. International Small Business Journal, 34(1), 3–15. **https://doi.org/10.1177/0266242615613840**
[59] Publications Production Unit (PRODOC) of the ILO. (2019). SMALL MATTERS: Global evidence on the contribution to employment by the self-employed, micro-enterprises, and SMEs. International Labour Office. **https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---publ/documents/publication/wcms_723282.pdf**

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp.94-103, November 13-16, 2023

Non-Financial Disclosure and Stock Prices: A Literature Review

Mary John
{mary.john@aun.edu.ng}

American University of Nigeria, School of Business and Entrepreneurship

Abstract
Corporate managers are currently encountering increasing pressure from stakeholders to enhance the disclosure of nonfinancial information regarding their companies. This arises due to the insufficiency of traditional financial data provided by companies, which lacks additional information crucial for making investment decisions. A growing body of literature has emerged, aiming to investigate the relationship between nonfinancial disclosure and stock prices through the utilization of various methodologies and models. This manuscript critically assesses existing literature that seeks to elucidate the significance of nonfinancial disclosure in eliciting reactions in stock prices. Specifically, the study focuses on three key nonfinancial disclosure variables: environmental, social, and governance factors. Based on the analysis, the paper concluded that the findings from previous studies are inconclusive and varied, thereby indicating the necessity for further research employing different analytical techniques.

Keywords: Nonfinancial disclosures, stock prices, literature review

1 Introduction

The corporate reporting landscape has experienced considerable transformations during the past three decades. These transformations have occurred because of mounting pressure from investors and other stakeholders for companies to provide more comprehensive information that is pertinent to decision-making (Cortesei and Vena, 2019). As an illustration, numerous companies are issuing separate reports on corporate social responsibility and the environment in order to update stakeholders on their efforts to support the local community and safeguard the environment (Ramiah et al., 2013). There exists a contentious debate regarding the impact of accounting disclosures on stock prices. This is because certain scholars argue that the market rewards companies with outstanding traditional accounting performance metrics, such as earnings per share and book value per share, rather than other additional voluntary disclosures (Thilini et al., 2020). Other facets of disclosure, such as information concerning a company's carbon emissions, have been found to influence investors' decision-making (Griffin et al., 2017).

In a voluntary reporting environment, companies are presented with the option to provide additional information that goes beyond the conventional financial reports. Nevertheless, it is reasonable to argue that these companies can only offer supplementary disclosure if they derive some form of advantage (Bowerman & Sharma, 2016). Scholars have previously highlighted the advantages associated with providing nonfinancial disclosure, which include the reduction of information asymmetries between the company and its investors (Lee, Walker, & Zheng, 2017). The reduction of information asymmetries is beneficial for the firm as it mitigates the risks of adverse selection and inflated market valuation of the company's stocks (Healy & Palepu, 2001). Given that investors require more information for their decision-making processes, the integration of both financial and nonfinancial information should result in a more accurate valuation of stocks.

The investigation into how nonfinancial disclosure interacts with financial performance and firm value has been undertaken. Initial research suggests that certain nonfinancial disclosures, such as environmental commitments and social responsibility information beyond the minimum legal requirements, impede corporate performance (Clark &Viehs, 2014). This is due to the additional costs associated with such disclosures, which inevitably diminish firm value. Kim and Lyon (2015) note that, "the entirety of the environmental regulatory framework is constructed on the premise that firms must be compelled to make environmental improvements, as they would otherwise deem them costly

or unprofitable and thus not pursue them independently." However, recent literature on nonfinancial information literature posits that environmental, social, governance, and intellectual capital disclosures have the potential to enhance firm value (Fatemi, Glaum & Keiser, 2017; Fatemi, Fooladi, &Tehranian, 2015).

Among the various forms of nonfinancial disclosures, it appears that stakeholders, including investors, creditors, customers, and society as a whole, are particularly interested in information pertaining to the environment, governance, and the disclosure of social and intellectual capital. One notable example is the increasing demand from stakeholders for companies to demonstrate their responsibility towards the environment by disclosing how they are addressing their business's impact on the local community. Initially, companies would typically provide a separate nonfinancial report within their annual reports, alongside the more traditional financial information. However, this approach has recently evolved to incorporate the reporting requirements outlined in the integrated reporting framework (Stent & Dowler, 2015). It is worth noting that unlike financial reporting, the practice of nonfinancial disclosure is typically voluntary in most countries. It is worth mentioning, though, that South Africa has made it mandatory for all companies listed on the Johannesburg Stock Exchange to provide integrated reports, while nonfinancial disclosure remains largely a voluntary endeavor in other jurisdictions.

The resource-based perspective posits that the decrease in information asymmetry resulting from the provision of nonfinancial information has the potential to benefit the firm through the creation of essential intangible assets (Branco, 2006). Internal intangible assets can be categorized as the implementation of effective routines and procedures, the development of new resources and skills, and the enhancement of employee motivation, morale, loyalty, and commitment. On the other hand, external intangible assets consist of improving relationships with stakeholders and enhancing corporate image and reputation (Branco & Rodrigues, 2006). In the light of these considerations, the significance of the resource-based perspective on nonfinancial disclosure lies in its ability to attract fundamental resources that facilitate the establishment and sustainability of competitive advantage. Jensen (2002) argued that the "enlightened (long-term) value maximization necessitates that firms take into account the interests of all their important constituent groups." This means that both financial and nonfinancial information must be provided by companies to meet the information needs of all stakeholders.

In this paper, we review the extant literature that investigated the association between nonfinancial disclosure variables and stock prices with the aim of gaining a deeper understanding of the relationship and make recommendations for future research. The paper contributes to the field of corporate reporting by providing a comprehensive review of the empirical literature on the relationship between nonfinancial disclosures (environmental, social, governance) and stock prices. It highlights the controversies and inconsistencies in existing research, identifies critical gaps in understanding the context-specific impact of disclosures, emphasizes the growing importance of integrated reporting, and introduces the resource-based view to elucidate the benefits of nonfinancial disclosures in attracting intangible resources. Overall, the paper serves as a valuable resource for researchers and practitioners, enriching our understanding of the intricate connection between nonfinancial disclosures and stock valuation.

In the next section, the concepts of the nonfinancial disclosure variables and stock prices are briefly discussed. The review of empirical studies is presented in section 3. Section 4 concludes the paper.

2 Conceptual Discussions

2.1 Stock Price Reaction

The phenomenon known as Stock Price Reaction pertains to alterations in the prices of shares as a consequence of internal and/or external occurrences affecting the firm (Shakil, 2020). The prices of stocks play a pivotal role in determining the market capitalization and the comprehensive worth of the stock market. To express this mathematically, market capitalization in the context of a firm refers to the product of the market price per share and the number of outstanding shares (Abdelkarim&Almumani, 2018). Market capitalization stands as the universally recognized gauge of the overall affluence generated by a firm, which in turn signifies the complete value of a firm's stock. The economic theory pertaining to the production and distribution of goods and services posits that the accumulation of capital signifies economic advancement and progress (Abraham & Ofosu, 2018).

The expansion of the stock market is gauged by its market capitalization and is a factor that investors take into consideration when making investment decisions. Numerous factors contribute to stock price fluctuations, including earnings per share, book value per share, and dividend per share. Furthermore, in addition to these accounting variables, recent scholars contend that non-financial metrics, such as environmental and social disclosures, also have an impact on stock prices due to their perceived influence on a company's long-term viability. Recent literature suggests that companies that exhibit superior corporate disclosure, encompassing intellectual capital as well as environmental, social, and governance disclosure, are rewarded by the market (Pae & Choi, 2011; Woudstra et al., 2017).

2.2 Environmental Disclosure

The interconnections between the constituents of environmental disclosure and the aspects of natural capital are intricately intertwined. Natural capital pertains to the constituents of the natural world that are directly or indirectly linked to the well-being of humans (The Economics of Ecosystems and Diversity [TEEB], 2010). In addition to traditional natural resources such as water, timber, energy, and mineral reserves, the disclosure of natural capital also encompasses the manner in which businesses manage endangered species, biodiversity, and ecosystems. Natural capital can be comprehended as "the repository of natural ecosystems that generates a continuous flow of valuable goods and services, which function as inputs or indirect advantages to businesses and establish the foundation of our economy. If we excessively exhaust our reserves of natural capital, nature might be unable to replenish them" (Balmforth, 2014).

2.3 Social Disclosure

It has long been acknowledged that the operations of a company can have an impact on society from a variety of perspectives. This holds true regardless of the industry in which the business operates. Social capital encompasses "the tangible and intangible resources that are embedded within, accessible through, and derived from the network of relationships possessed by an individual or social unit" (Nahapiet and Ghoshal, 1997). The objective of social disclosure is to provide information regarding the social impact of a business on all of its stakeholders. "Social capital determines the return on investments in other forms of capital, namely, the opportunities to convert financial and human capital into profits through a network of relationships and exchanges with acquaintances and customers" (Pulino et al., 2022). According to the United Nations Global Compact (UNGC) (2022), social sustainability refers to a company's efforts to identify and manage its impact on people.

2.4 Governance Disclosure

The primary purpose of a proficient corporate governance framework is to impart strategic guidance to an organization, ensure comprehensive adherence to corporate regulations, and safeguard the interests of stakeholders. The board of directors delineates the organization's approach towards

corporate social responsibility, tax planning, remuneration, and anti-corruption measures, among other matters. According to Clark et al. (2014), "effective corporate governance strategies foster transparency, thereby resulting in a reduction of equity costs, risks, and information asymmetries". Due to its perceived impact on the wealth of shareholders, the market reacts to the corporate governance mechanisms employed by firms. Furthermore, empirical studies have demonstrated that companies with inadequate corporate governance structures exhibit subpar operational performance and diminished valuation (Clark et al., 2014). Three key factors commonly utilized to gauge the level of governance disclosure are corporate strategy, management, and shareholders.

3 Review of Empirical Studies

3.1 Environmental Disclosure and Stock Prices

Early studies in this area have sought to assess the role of voluntary disclosures in corporate outcomes. For example, (Dedman et al., 2008) examined the impact of voluntary disclosure on market reactions (measured as abnormal stock returns) in a sample of listed UK pharmaceutical firms and found a significant variation of market reactions across firms depending on their sizes. Similarly, Déjean and Martinez (2014) investigated the relationship between corporate disclosure and cost of equity of companies listed in the SBF 120 stock market index. The study found no convincing evidence that environmental disclosure suggests that corporate disclosure leads to reduced cost of equity. While Dedman et al. (2008) did not disaggregate and test the individual effects of voluntary disclosure components such as environmental, governance and social disclosures, Déjean and Martinez (2014) did not directly study stock price reactions. However, the findings of these studies seem to suggest that the stock market pays a premium for firms that have superior disclosure.

Later studies, such as the research conducted by Clarkson et al. (2013), have examined the extent to which environmental disclosure contributes to the value relevance of companies in the United States operating within the top five industries with the highest levels of pollution. The findings demonstrated a positive association between voluntary environmental disclosure and incremental value relevance. Such outcomes are in line with the signaling theory, which posits that firms that disclose a greater amount of information tend to experience higher share prices. In addition, Plumlee et al. (2015) investigated the relationship between firm value and voluntary disclosure. Environmental disclosure was measured using the index of the Global Reporting Initiatives (GRI). The results from panel data analysis suggested that voluntary disclosure positively impacts value through both cost of equity and cash flow components. Both Clarkson et al (2013) and Plumlee et al (2015) covered a sample of top polluting companies in the US.

Recent research endeavors have aimed to elucidate the impact of divulging environmental information on the valuation of corporations. In his investigation spanning from 2010 to 2015, Hassan (2018) examined the ramifications of voluntary environmental disclosures on the worth of a subset of companies from the Standard and Poors Global 1200. The outcomes of employing structural equation modeling alongside. The findings from this study bear resemblance to those of Shakil (2020), whose inquiry delved into the moderating influence of organizational visibility on the association between firm value and environmental disclosures.

In addition, using a sample companies listed on Indonesian Stock Market, Deswanto and Siregar (2018) investigated the interaction among firm value, financial performance, environmental disclosures, and environmental performance. The study found an insignificant positive effect of financial performance on environmental disclosures, and that the prior year's environmental performance positively impacted current environmental disclosures. The findings further revealed that market value is not significantly associated with environmental disclosures and that environmental

disclosures do es not significantly moderate the relationship between financial performance, firm value, and environmental performance.

Aboud et al. (2018) examined the influence of ESG disclosures on company value, as measured by Tobin's q, for the top 30 most valuable companies in Egypt. The results indicated that companies listed in the ESG index exhibited higher valuations. Notably, this investigation delved into the combined effect of ESG, but did not offer insights into the individual roles played by each component of environmental, social, and governance disclosures. Additionally, Gerged et al. (2020) scrutinized the impact of environmental disclosure on firm value, measured by Tobin's q, among companies in the Gulf Cooperation Council. The results of the fixed effect regression analysis revealed a positive and significant relationship between corporate environmental disclosure and firm value.

There is also evidence indicating a negative correlation between the disclosure of environmental information and the reactions of stock prices. Alessi et al. (2020) have presented evidence that supports the existence of a significant negative Greenium, which refers to the risk premium associated with the level of environmental transparency and greenness displayed by firms in Europe, as observed through individual stock returns. The study found compelling evidence supporting the presence of a pricing factor that is linked to climate risk, and it has demonstrated that the Greenium, is both negative and highly statistically significant.

In a study conducted by Fan et al. (2020), the determinants of environmental disclosure among Chinese firms operating in industries with high pollution levels were examined the results demonstrated that firms that engage in greater levels of environmental disclosure also experience improved firm valuation. Additionally, Aryani (2021) conducted an analysis to investigate the impact of carbon disclosure on firm value, while also examining the moderating effect of foreign ownership. The findings indicated that the presence of carbon disclosure had a notable detrimental impact on the overall worth of the company.

3.2 Social Disclosure and Stock Prices

Empirical literature on the effects of social disclosure is gaining prominence. These studies include Gao et al. (2015) who conducted a study to examine the determinants of nonfinancial disclosure quality. The results revealed that the performance of corporate social responsibility brings about economic benefits, such as increased valuations in seasoned offerings, enhanced stock liquidity, and reduced yields to maturity in bond issuances. Also, De Klerk, de Villiers and van Staden (2015) assessed the association between corporate social performance and stock prices in a sample of largest companies in the UK. The study found that superior corporate social responsibility disclosures were positively related to higher stock prices.

Usman and Amran (2015) examined the effect of corporate social responsibility practices on financial performance of firms listed on the Nigerian Stock Exchange. The results indicated that the disclosures of human resource, products and customers and community involvement positively enhance corporate financial performance. It should be noted that Usman and Amran (2015) focused on accounting and not market-based measures of corporate performance. In addition, the study did not examine the aggregate extent of the social responsibility disclosures.

Furthermore, Bowerman and Sharma (2016) tested whether corporate social responsibility disclosure leads to incremental (additional) value relevant information to shareholders among listed large companies in Japan and the US. The findings indicated that the shareholders in the UK take into consideration the disclosure of corporate social responsibility in the overall information they require for their investment decision making. In contrast, Japanese shareholders did consider that corporate

social responsibility disclosure as having additional value relevance above the traditional financial information. Also, Miralles-quir et al. (2018) analyzed whether there is a significant influence of social responsibility activities by firms on the São Paulo Stock Exchange and found that the market reacts positively to social and governance disclosure practices.

Veltri and Silvestri (2020) conducted a systematic review of the interaction of financial and nonfinancial information provided in integrated reports on share prices. The findings showed that shareholders value nonfinancial information disclosure and that disclosure is positively related to increasing firms' market value. The results also revealed that integrated reporting adoption and its quality possess favorable financial impacts. The study supports the value relevance of the new reporting regime known as integrated reporting. Furthermore, Cordazzo et al (2020) examined the value relevance of the Non-Financial Disclosure Directive introduced by the European Union. The results indicated that investors value accounting information more than non-financial information in their investment decisions. Specifically, the study established a significant positive association between accounting information and share price, while the effect of nonfinancial information was insignificant. The results of this study further augment the controversy regarding the role of nonfinancial information in stock price reaction.

Moreover, the study by Govindan et al. (2021) encompassed an examination at the firm-level across different countries, focusing specifically on the logistic sector. The objective was to identify the factors that determine and influence the value relevance of corporate social responsibility (CSR) performance among firms in this industry. The findings indicated a lack of significant positive impact on both CSR performance and share prices of companies operating in the logistic sector. Notably, the dataset comprised of companies originating from both developed and developing nations.

3.3 Governance Disclosure and Stock Prices

Conflicting findings are prevalent in empirical research concerning the connection between governance disclosure and corporate outcomes. In their study, Coram et al. (2011) investigated the potential influence of increased disclosure of non-financial performance indicators on the decision-making processes of financial analysts and the prioritization of information when assessing stock prices. The study involved the participation of eight financial analysts employed by six stockbroking firms in Sydney and utilized verbal protocol analysis as a research methodology. The findings revealed a notable emphasis on non-financial performance indicators, although this emphasis was not consistently applied.

Uyar&Kılıc (2012) undertook a study with the objective of examining the influence of voluntary disclosure on stock prices. The principal outcome yielded from their empirical inquiry demonstrated that voluntary disclosure possessed a value-relevant impact, signifying that it exerted an influence on the overall value of the firms. This observation implies that market participants attach significance to voluntary disclosure, and those companies that furnish a greater amount of voluntary information tend to be appraised more favorably by investors. Furthermore, Li et al. (2017) conducted a study with the aim of investigating the relationship between environmental, social, and governance (ESG) disclosure and firm value. For this purpose, they utilized data obtained from firms listed in the FTSE 350. The outcomes of their analysis indicated a positive correlation between the extent of environmental, social, and governance disclosure and firm value. This discovery implies that greater levels of transparency, accountability, and enhanced trust from stakeholders contribute to the augmentation of firm value.
Yoon, Lee, and Byun (2018) investigated the relationship between ESG performance and firm value using data from companies listed on the Korean Stock Exchange. Their findings indicated that corporate social responsibility practices positively influenced a firm's market performance, although the effect on share prices varied depending on firm characteristics and environmental sensitivity. In

the same vein, Miralles-Quiros et al. (2018) examined the effect of ESG disclosures on stock prices for 51 commercial banks from 20 stock exchanges. The results indicated that investors valued the three pillars of environmental, social, and governance differently. The researchers also discovered that the significance of ESG performance in relation to value was notably higher for banks situated in countries with a legal system based on common law, particularly in the aftermath of the global financial crisis.

Furthermore, Widiatmoko et al. (2020) examined the influence of corporate governance on the disclosure of intellectual capital and the market capitalization of companies listed in Indonesia. Their analysis using path models revealed a positive impact of corporate governance practices on the disclosure of intellectual capital, which subsequently resulted in a positive effect on market capitalization. Cordazzo et al. (2020) conducted a study on the relevance of ESG disclosure following the implementation of the EU Directive on non-financial reporting during the fiscal years of 2016 and 2017. Their findings indicated that financial figures were linked to share prices, while non-financial, environmental, and social information did not demonstrate any relevance in terms of value, both before and after the application of the Legislative Decree. This suggests that non-financial, environmental, and social information did not offer additional value-relevant information to investors in the context of the mandatory non-financial disclosure required by the new regulation.

Xu et al. (2020) investigated the influence of government involvement and corporate social responsibility on the value of firms. Their analysis was based on data from all publicly listed A-share firms during the period of 2008 to 2015. The findings of their study unveiled that the disclosure of corporate social responsibility contributed an additional value to firms, particularly for privately-owned enterprises (POE). Furthermore, Shakil (2020) undertook a study to examine the impact of performance in the areas of environment, society, and governance on the volatility of stocks. The study also explored the moderating role of firm size in this relationship. The results indicated that performance in the areas of environment, society, and governance had an unfavorable effect on stock volatility, with firm size playing a significant role in moderating this association. Moreover, Pulino and colleagues (2022) evaluated the influence of performance in the areas of environment, society, and governance on financial performance. The study found a positive effect of disclosing information related to ESG on financial performance.

4 Literature Gaps

The literature review suggests several gaps and inconsistencies in the empirical research on the effects of social disclosure. These gaps include mixed findings on economic benefits, varied impact on stock prices among other gaps. For example, while some studies (e.g., Gao et al., 2015) find that corporate social responsibility (CSR) leads to economic benefits, such as increased valuations and enhanced stock liquidity, other studies (e.g., Govindan et al., 2021) show a lack of significant positive impact on both CSR performance and share prices, creating a gap in understanding the consistency and universality of these benefits.

In addition, studies (e.g., De Klerk, de Villiers, and van Staden, 2015) indicate a positive association between superior CSR disclosures and higher stock prices, while others (e.g., Cordazzo et al., 2020) suggest that non-financial information, including CSR, may have an insignificant effect on share prices. This inconsistency raises questions about the factors influencing the impact of CSR on stock prices. Some studies (e.g., Usman and Amran, 2015) focus on accounting-based measures of corporate performance, while others (e.g., Bowerman and Sharma, 2016) explore the views of shareholders and the role of CSR disclosure in investment decisions. This diversity in measurement approaches highlights a gap in the literature concerning the use of market-based measures and the aggregate extent of CSR disclosures.

Variations in findings between different countries and industries, as seen in studies like Govindan et al. (2021), imply that the impact of CSR on financial performance may be context dependent. This geographic and sectoral variability points to a need for more comprehensive and contextual research. The varying results on the value relevance of non-financial information, as demonstrated in studies such as Cordazzo et al. (2020), raise questions about the extent to which non-financial information, including CSR disclosure, plays a role in stock price reactions and investor decision-making. Lastly, while Veltri and Silvestri (2020) support the value relevance of integrated reporting and non-financial information, their findings may not be universally applicable. This suggests the need for further research to explore the impact of integrated reporting in different contexts.

The literature gaps seem to revolve around the varying results and inconsistent implications of environmental, social and governance disclosure on corporate outcomes. While some studies suggest a clear positive relationship between disclosure and firm performance, others find that the impact is nuanced, influenced by factors such as firm characteristics, regulatory environments, and the specific aspect of ESG disclosure under consideration. This inconsistency highlights the need for further research to better understand and reconcile these conflicting findings and provide more comprehensive insights into the impact of environmental, social and governance disclosure on corporate outcomes.

5 Conclusion

The resource-based view suggests that nonfinancial disclosure can attract intangible resources, both internal and external, benefiting firms. These resources can lead to competitive advantage and long-term value maximization.to meet the interests of all stakeholder groups, firms should provide both financial and nonfinancial information. This aligns with the concept of enlightened long-term value maximization, which considers the interests of all important constituents. This paper reviews the literature on the relationship between nonfinancial disclosure variables (environmental, social, and governance) and stock prices. It delves into the growing importance of such disclosures in the corporate reporting landscape. The review identifies several gaps in the literature. These include inconsistencies in findings regarding the impact of nonfinancial disclosure, the influence of contextual factors, and the varying importance of different types of disclosures (environmental, social, governance, and intellectual capital). Addressing these gaps requires further empirical research to provide a more comprehensive and nuanced understanding of the relationship between nonfinancial disclosure and corporate outcomes.

The paper highlights the evolving landscape of corporate reporting, the varying impacts of nonfinancial disclosures on corporate outcomes, and the need for context-specific research to reconcile these differences. It emphasizes the importance of providing both financial and nonfinancial information to meet the diverse information needs of stakeholders, investors, and the broader society. More research is essential to gain a deeper understanding of how different types of nonfinancial disclosures influence stock prices and corporate performance in various contexts.

The paper makes several noteworthy contributions to the field of corporate reporting, stock valuation, and the impact of nonfinancial disclosures.One of its key contributions is the extensive and systematic review of the empirical literature on the relationship between nonfinancial disclosures (environmental, social, governance) and stock prices. This review provides a valuable synthesis of existing research, which can serve as a valuable resource for scholars and practitioners seeking insights into this complex area. Secondly, the paper underscores the controversies and inconsistencies present in the literature regarding the effects of nonfinancial disclosures on stock prices and firm performance. By acknowledging these varying findings, it prompts researchers to explore and understand the underlying factors contributing to these differences.

Thirdly, through its analysis, the paper pinpoints several research gaps, such as the context-specific impact of nonfinancial disclosures and the varying importance of different types of disclosures. These gaps provide a roadmap for future research, offering opportunities to delve deeper into specific areas and contexts.The paper highlights the growing significance of integrated reporting, emphasizing its value relevance and potential to meet the evolving information needs of stakeholders. This is particularly relevant in a business landscape where the integration of financial and nonfinancial information is gaining prominence. Fourth, the incorporation of the resource-based view in understanding the benefits of nonfinancial disclosures, and their role in attracting intangible resources, provides a valuable theoretical framework. It underscores the potential for long-term value maximization through the provision of comprehensive information.

The paper's limitation resides in the selection of the examined papers, thus allowing for the presence of subjectivity. For future investigations, it is advisable to strive for reviewing a larger number of studies that are currently emerging in this specific field of research. Additionally, the paper did not utilize data due to its lack of empirical nature, which consequently fosters subjectivity in the analysis. Nonetheless, despite these identified constraints, the paper presents valuable insights pertaining to the existing studies on the association between non-financial disclosures and stock prices.

References

[1] Abdelkarim, M., &Almumani, Y. (2018). An empirical study on effect of profitability ratios & market value ratios on market capitalization of commercial banks in Jordan. International Journal of Business and Social Science, 9 (4), 39–45.

[2] Aboud, A., Diab, A., Aboud, A., & Diab, A. (2018). The impact of social , environmental and corporate governance disclosures on firm value Evidence from Egypt. Journal of Accounting in Emerging Economies, 8(4), 442-458.

[3] Abraham, O., & Ofosu, A. (2018). Effects of intellectual capital disclosure on market capitalization of listed companies in Ghana. Journal of Accounting, 6(2), 18-27.

[4] Alessi, L., Ossola, E., & Panzica, R. (2020). The Greenium matters : greenhouse gas emissions , environmental disclosures , and stock prices. JRC Working Papers in Economics and Finance,

[5] Balmforth, Z. (2014). Business and investors: providers and users of natural capital disclosure. KPMG, London.

[6] Bowerman, S., & Sharma, U. (2016). The effect of corporate social responsibility disclosures on share prices in Japan and the UK. Corporate Ownership and Control, 13(2), 202–216.

[7] Branco, M., & Rodrigues, L. (2006). Corporate social responsibility and resource-based perspectives. Journal of Business Ethics, 69, 111–132.

[8] Cortesei, A. & Vena, L. (2019). Disclosure quality under Integrated Reporting: A value relevance approach. Journal of Cleaner Production, 220: 745-755.

[9] Clark, G. L., Feiner, A., & Viehs, M. (2014). From the Stockholder to the Stakeholder: How Sustainability Can Drive Financial Outperformance. Available at SSRN 2508281.

[10] Coram, P. J., Mock, T. J., & Monroe, G. S. (2011). Financial analysts ' evaluation of enhanced disclosure of non- fi nancial performance indicators. The British Accounting Review, 43(2), 87–101.

[11] Cordazzo, M., Bini, L., & Marzo, G. (2020). Does the EU Directive on non-financial information influence the value relevance of ESG disclosure ? Italian evidence. June, 1– 14.

[12] Dedman, E., Lin, S. W., & Prakash, A. J. (2008). Voluntary disclosure and its impact on share prices : Evidence from the UK biotechnology sector. Journal of Accounting and Public Policy, 27, 195–216.

[13] Déjean, F., & Martinez, I. (2014). Environmental Disclosure and the Cost of Equity : The French Case. Accounting in Europe, 6(1), 57-80.

[14] De Klerk, M., De Villiers, C., Van Staden, C. (2015). The influence of corporate social responsibility disclosure on share prices: evidence from the United Kingdom. Pacific Accounting Review, 27(2), 208-228.

[15] Deswanto, R.B., & Siregar, S.V. (2018). The associations between environmental disclosures with financial performance, environmental performance, and firm value. Social Responsibility Journal, 14(1), 180-193.

[16] Fan, L., Yang, K., & Liu, L. (2020). New media environment, environmental information disclosure and firm valuation: evidence from high-polluting enterprises in China. Journal of Cleaner Production, 123253.

[17] Fatemi, A. M., Fooladi, I. J., & Tehranian, H. (2015). Valuation effects of corporate social responsibility. Journal of Banking and Finance, 59, 182–192.

[18] Fatemi, A., Glaum, M., & Kaiser, S. (2017). ESG performance and firm value: The moderating role of disclosure. Global Finance Journal, 38,45-64.
[19] Gao, F., Dong, Y., Ni, C., & Fu, R. (2015). Determinants and Economic Consequences of Non-financial Disclosure Quality. April, 37–41.
[20] Gerged, A. M., Beddewela, E., & Cowton, C. J. (2020). Is corporate environmental disclosure associated with firm value ? A multicountry study of Gulf Cooperation Council firms. April, 1–19.
[21] Govindan, K., Kilic, M., Uyar, A., & Karaman, A. S. (2021). International Journal of Production Economics Drivers and value-relevance of CSR performance in the logistics sector : A cross-country firm-level investigation. International Journal of Production Economics, 231(June 2020), 107835.
[22] Griffin, P.A., Lont, D.H., & Sun, E.Y. (2017). The relevance to investors of greenhouse gas emission disclosures. Contemporary Accounting Research. 34 (2), 1265-1297.
[23] Hassan, O. A. G. (2018). The impact of voluntary environmental disclosure on firm value : Does
[24] organizational visibility play a mediation role ? Business Strategy and the EnvirJuly, 1–14.
[25] Healy, P.M. & Palepu, K.G. (2001). Information asymmetry, corporate disclosure, and the capital markets: A review of the empirical disclosure literature. Journal of Accounting and Economics, 31, 405-440.
[26] Jensen, M. C. (2002). Value maximization, stakeholder theory and the corporate objective function. Business Ethics Quarterly, 12(2), 235–257.
[27] Kim, E.-H., & Lyon, T. P. (2015). Greenwash vs. brown wash: Exaggeration and undue modesty in corporate sustainability disclosure. Organization Science, 26, 705–723.
[28] Lee, E., Walker, M., Zheng, C. (2017). Do Chinese state subsidies affect voluntary corporate social responsibility disclosure? Journal of Accounting and Public Policy, 36(3), 179- 200.
[29] Li, Y., Gong, M., Zhang, X., & Koh, L. (2017). AC. The British Accounting Review. https://doi.org/10.1016/j.bar.2017.09.007
[30] Miralles-quir, M., Miralles-quir, L., Miguel, L., & Gon, V. (2018). The Value Relevance of Environmental , Social , and Governance Performance : The Brazilian Case. https://doi.org/10.3390/su10030574
[31] Nahapiet, J. and Ghoshal, S. (1997). Social capital, intellectual capital and the creation of value in firms. Academy of Management Proceedings, 1997, 1, 35-39, doi: 10.5465/ambpp. 1997.4980592.
[32] Pae, J., & Choi, T. H. (2011). Corporate Governance, Commitment to Business Ethics, and Firm Valuation: Evidence from the Korean Stock Market. Journal of Business Ethics, 100(2), 323–348.
[33] Plumlee, M., Brown, D., Hayes, R. M., & Marshall, R. S. (2015). Voluntary environmental disclosure quality and firm value : Further evidence. Journal Of Accounting And Public Policy. https://doi.org/10.1016/j.jaccpubpol.2015.04.004
[34] Pulino, S. C., Ciaburri, M., Magnanelli, B. S., & Nasta, L. (2022). Does ESG Disclosure Influence Firm Performance ? 1–18.
[35] Ramiah, V., Martin, B., Moosa, I. (2013). How does the stock market react to the announcement of green policies? Journal of Banking and Finance, 37(5), 1747-1758.
[36] Shakil, M. H. (2020). Environmental , social and governance performance and stock price volatility : A moderating role of firm size. Journal of Public Studies: an International Journal, 22(3), 1–11.
[37] Stent, W., Dowler, T. (2015). Early assessments of the gap between integrated reporting and current corporate reporting. Meditari Accountancy Research, 23(1), 92-117.
[38] TEEB (2010), The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations.
[39] Thilini, et al. (2020). Does Integrated Reporting Enhance the Value Relevance of Information? Evidence from Sri Lanka. Sustainability, 12(19), 8183
[40] Usman, A.B., & Amran, N.A.B. (2015). Corporate social responsibility practice and corporate financial performance: evidence from Nigeria companies. Social Responsibility Journal, 11(4), 749-763.
[41] Uyar, A., & Kılıc, M. (2012). Value relevance of voluntary disclosure : evidence from Turkish firms. 13(3), 363–376. https://doi.org/10.1108/14691931211248918
[42] Veltri, S., & Silvestri, A. (2020). The value relevance of corporate financial and nonfinancial information provided by the integrated report : A systematic review. May, 1–17. https://doi.org/10.1002/bse.2556
[43] Widiatmoko, J., Goreti, M., Indarti, K., Pamungkas, I. D., Widiatmoko, J., Goreti, M., Indarti, K., & Pamungkas, I. D. (2020). Corporate governance on intellectual capital disclosure and market capitalization. Cogent Business & Management, 7(1). https://doi.org/10.1080/23311975.2020.1750332
[44] Woudstra, U., Berghout, E., Tan, C.-W., van Eekeren, P., & Dedene, G. (2017). Resource Complementarity and IT Economies of Scale: Mechanisms and Empirical Evidence. Information Systems Management, 34(2), 185–199. https://doi.org/10.1080/10580530.2017.1288527
[45] Xu, S., Chen, X., Li, A., & Xia, X. (2020). Journal of. Emerging Markets Review, 100717. https://doi.org/10.1016/j.ememar.2020.100717
[46] Yoon, B., Lee, J.W., & Byun, R. (2018). Does ESG Performance Enhance Firm Value? Evidence from Korea.Sustainability 2018, 10(10), 3635; https://doi.org/10.3390/su10103635

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp.104-115, November 13-16, 2023

Private Sectors and Sustainable Development Goals in Africa: The Role of Corporate Governance

Abubakar Ahmed[1], Aliyu Magaji Mafindi[2], Sani Mahmud Madobi[3]
{abubakar.ahmed2024@aun.edu.ng[1], mafindi18@gmail.com[2], namadobi1@gmail.com[3]}

Department of Accounting, School of Business and Entrepreneurship, American University of Nigeria Yola[1], Adamawa State-Nigeria, Petroleum Training Institute Warri, Delta State-Nigeria[2], Department of Business Administration, Ahmadu Bello University, Zaria, Kaduna State-Nigeria[3]

Abstract
This article examines the correlation between corporate governance and sustainable development goals (SDGs) in the African context. Employing panel data from 42 African nations spanning from 2017 to 2020, the study uses the Ordinary Least Square (OLS) regression technique to test the research hypotheses. The findings demonstrate a notable positive linkage between corporate governance and SDGs. Consequently, policymakers can draw upon the conclusions of this investigation to devise practical and actionable measures pertaining to corporate governance to facilitate the attainment of SDGs. Specifically, corporate governance mechanisms can be relied upon to accomplish sustainable development agenda in developing nations. The contribution of this paper lies in its ability to showcase that corporate governance significantly contributes to the realization of both national and global objectives, such as the SDGs..

Keywords: Sustainable development goals (SDGs), corporate governance, institutional theory, Africa

1 Introduction

Since its inception, the United Nations (UN) Sustainable Development Goals (SDGs) agenda is rapidly gaining momentum beyond the 193 member states to encompass Non-Governmental Organizations (NGOs), public policy bodies, and private sector organizations (Bebbington and Unerman, 2017). The recognition of the private sector's role in achieving these goals is increasingly being acknowledged by policymakers. Recent scholarly work suggests that all 17 goals are connected to companies, albeit to varying degrees and in an uneven manner (Frey and Sabbatino, 2018; Rashed and Shah, 2020). Consequently, to achieve the desired outcomes within the designated timeframe, both the public and private sectors must actively engage and collaborate to address challenges and foster opportunities. Corporate governance plays a critical role in enabling the private sector's participation in the pursuit of overarching objectives (Agyemang et al., 2019). Therefore, understanding the role of corporate governance will inform policymakers on how to create social and economic value related to the SD.

Institutional theory could elucidate the connection between corporate governance and sustainable development. According to the theory, firms, in their pursuit of legitimacy, conform to rules, norms, and expectations in response to social and regulatory pressures. The theory refers to self-regulatory institutions to strengthen a firm's commitment to sustainability, thus bolstering its corporate legitimacy (Haque and Ntim, 2017). Legitimacy serves as a strategic asset for organizational success, enhancing a firm's relationship with the government and other stakeholders (Li et al., 2017). The literature posits three forms of institutional isomorphism that explicate the impact of pressure on firms, namely coercive, cognitive, and normative (DiMaggio and Powell, 1983). Coercive isomorphism pertains to the direct and indirect influence of institutional forces on organizational structures and processes that facilitate the attainment and maintenance of firm legitimacy. These forces encompass government regulations, laws and policies, as well as the broader cultural expectations that shape corporate conduct.

Cognitive isomorphism entails the process of augmenting legitimacy through the adherence to the optimal methods employed by the dominant entities within the industry. In simpler terms, organizations strive to imitate the exemplary practices embraced by prominent companies within the

same sector. Lastly, normative isomorphism elucidates a scenario in which a firm's frameworks and processes are influenced by the network of managers, specialized personnel, and employee unions. Overall, the institutional theory posits that the national institutional milieu molds the formal regulations, policies, and constraints of companies. Consequently, as Sustainable Development (SD) encompasses extensive national objectives, we anticipate that the structures of corporate governance have an impact on the degree to which these objectives are accomplished by African nations. As constituents of the national institutional frameworks, corporate governance mechanisms, such as the robustness of accounting and auditing standards, regulations addressing conflict of interest, and shareholder governance, could potentially influence SD.

The discussion encompassing the function of the private sector in accomplishing Sustainable Development (SD) at the institutional level has been fervent (Betti, Consolandi, and Eccles, 2018). In acknowledgement of the private sector's role, the European Commission implemented measures in 2018 with the goal of stimulating private sector involvement in pursuing the Sustainable Development Goals (SDGs). These measures encompass a strategy to connect finance with sustainability by redirecting capital flows towards sustainable investments, managing financial risk associated with climate change, social matters, and environmental deterioration, as well as fostering long-term financial and economic activities (Betti et al., 2018, p2). Furthermore, the scope of corporate governance has broadened in recent years, extending beyond the provision of responsible management of firms to encompassing environmental, social, and governance obligations. This advancement necessitates that firms operate in accordance with social and environmental standards to uphold a positive relationship with their stakeholders (Arayssi, Jizi, and Tabaza, 2019). The significance of the institutional framework and corporate governance is of greater importance for African nations, particularly those characterized by feeble institutional frameworks. In such a setting, there is an elevated risk of investors' wealth being seized and managers engaging in unprofitable investments. Nevertheless, the implementation of corporate governance mechanisms, such as investor protection and the rigorous enforcement of accounting and reporting standards, can alleviate conflicts of interest (Gompers, Ishii, and Metrick, 2003). Within this context, we investigate the impact of corporate governance on Sustainable Development Goals (SDGs).

This study is motivated by a range of factors. Firstly, the United Nations Sustainable Development Goals (SDGs) present fresh opportunities for research in various interconnected domains, encompassing the natural sciences, humanities, and other social sciences. Notably, Bebbington and Unerman (2017) have advocated for greater interdisciplinary research in sustainable development, acknowledging the crucial role played by corporate entities in achieving transformative global progress. In response to this call, this article seeks to examine the potential impact of corporate governance structure on the attainment of the SDGs in Africa. Furthermore, African nations lag their European, North American, and Asian counterparts in terms of the pace of SDG achievement, owing to unique institutional and cultural factors. This is primarily due to the African continent's high prevalence of corruption, weak institutional frameworks, and political instability, among other elements (Agyemang et al., 2019). Though Agyemang and colleagues (2019) investigated the influence of corporate governance at the country level on foreign direct investment, their analysis did not encompass sustainable development (SD). Consequently, there exists a scarcity of empirical research concerning the contribution of national factors and institutional structures within the private sector towards the attainment of Sustainable Development Goals (SDGs). Considering this, the present study stands as one of the initial empirical inquiries aiming to scrutinize the potential influence of corporate governance on sustainable development in Africa.

The analysis encompasses 42 African nations for which complete data on all variables is accessible from 2017 to 2020. The outcomes reveal a positive correlation between corporate governance and

sustainable development (SD). The robustness of these findings is confirmed through the utilization of alternative estimation techniques, such as fixed-effect, random-effect, and GMM. Ultimately, the results highlight the necessity for African policymakers to formulate practical and implementable policies that enhance corporate stewardship by reinforcing accounting and auditing standards, regulating conflicts of interest, and improving shareholder governance. Thus, this paper makes significant contributions in multiple aspects. Primarily, it expands the existing literature by being among the earlier studies that furnish evidence supporting the reliance on corporate governance to achieve the Sustainable Development Goals (SDGs). These findings enrich the ongoing discourse on the role of the private sector in contributing to sustainable development, especially in Africa where many nations suffer from deficient regulatory and institutional frameworks. In recent times, African nations have made notable progress in terms of their economic advancement, with countries like Nigeria, Rwanda, and Morocco being counted among the fastest-growing economies across the globe. Nevertheless, as regulators and policymakers have shifted their focus from economic growth and development to sustainable development (SD), it becomes crucial to examine the factors that influence SD. These findings indicate that establishing effective governance in the private sector could significantly contribute to the accomplishment of the Sustainable Development Goals (SDGs). Furthermore, this research holds policy implications for African countries as well as their development partners in terms of enhancing the continent's contribution to the global economy through the reinforcement of regulations governing the private sector.

The next section discusses the conceptual issues and develops the study hypotheses. The research methodology is discussed in section three. The result and findings are discussed in section four, while section five is dedicated to conclusions and implications of the findings.

2 Literature Review and Hypothesis Development

2.1 Sustainable Development Goals

SD refers to an economy's ability to maintain living standards above mere economic growth (Hope, 2020). The goal of SD is the long-term stability of the economy and environment. In the context of this work, SD and SDGs are used interchangeably to imply the ability of the present generation to meet its societal goals without compromising the future generation's ability to meet its economic needs. The UN 2030 agenda, which was developed by the United Nations General Assembly (UNGA) in 2015, aims to provide a plan of action that ensures the world's sustainability in the future. The SDGs comprise seventeen (17) core areas linked to actions to reduce poverty and inequality, the impact of climate change, and improve education and health, among other things. As noted earlier, the focus of policymakers has shifted from mere public sector actions to incorporating private sector support in achieving the SDGs (Frey and Sabbatino, 2018). Also, the adoption of the United Nations 2030 agenda by all member nations has further increased stakeholder pressure to scrutinize the extent to which companies are complying with regulations and their commitment to sustainability (Martínez-ferrero and García-meca, 2020).

2.2 Corporate Governance

Corporate governance refers to the internal and external mechanisms developed to support a company's effort to achieve its objectives. These mechanisms involve an attempt to create and manage the relationship with all stakeholders: the board of directors, investors, the state and its legislative framework, and the public sector in general (Benvenuto et al., 2021). Traditionally, corporate governance studies have focused on the firm-level analysis of variables on organizational outcomes. However, we can gain valuable insights by analyzing country-level governance indicators on broader national objectives. Evidence of such analysis exists in the literature. For example, Hillier and Pindado (2010) showed that research and development are affected by corporate governance variables,

including common law legal environment, strong law enforcement, minority shareholder protection, bank-based financial statement, a strong market for corporate control, and effective board control. Also, Lameira et al. (2013) showed that economic development is positively associated with a country's corporate governance indicators. Klapper and Love (2004) provide evidence that when macro changes occur, corporate governance at a national level affects financial markets. These pieces of evidence suggest that country-level corporate governance can be investigated in relation to global objectives such as the SDGs.

2.3 Hypotheses Development

Studying the effect of corporate governance on SD has recently attracted the attention of academics, regulators, and policymakers. The empirical studies can be broadly classified into two: those that sought to determine firm-level governance variables on SDGs through sustainability disclosure (Consuelo et al., 2018; Consuelo and Martínez, 2019; Martínez-ferrero and García-meca, 2020) and those that related corporate governance with corruption aspect of SDGs (Carrillo et al., 2019; Jaggi and Macchioni, 2020). In the first instance, Martinez-Ferrero and Garcia-Meca (2020) assessed the contribution of internal corporate governance to SDGs using data from 11 industries in 21 European countries. They found that firms with greater corporate governance strength contributed to the realization of SDGs by disclosing more informative sustainability reports. Also, Pucheta-Martinez and Chiva-Ortells (2018) examined the effect of directors representing controlling shareholders, i.e., institutional shareholders, on SD in the context of CSR reporting. Their results demonstrated the relevance of directors in influencing strategic decisions.

Furthermore, Agyemang et al. (2019) found that corporate governance mechanisms, including board effectiveness, strength in auditing and accounting standards, conflict of interest regulation, and shareholder activism, lead to the inflow of foreign direct investment in Africa. Similarly, Al Maqtari et al. (2020) showed that country-level corporate governance positively influences SD through its effect on entrepreneurial conditions. Other studies found that country-level corporate governance indicators increase per capita wealth (Abdolmohammadi and Tucker, 2002), mitigate tax evasions (Benkraiem et al., 2021), and improve sustainability (Guidara et al., 2021).

It is noteworthy that previous studies have generally studied corporate governance effect on SD based on firm-level, and specific governance variables such as female directors, board independence, and CEO duality. Extant literature seems to suggest that good corporate governance contributes to the realization of SDGs through increased sustainability disclosure, including corruption disclosure and CSR reports. In line with the findings of these studies, we predict that corporate governance positively affects SD in Africa.

H1: Corporate governance has a positive influence on the level of SD in Africa.

3 Data and Model Specification

We used a quantitative approach to achieve the research objectives. We collected panel data from forty-two (42) out of fifty-four (54) African countries for a period of four (4) years (2017 to 2020). Twelve countries were excluded from the sample because they did not have the complete data for all the variables. The data were obtained from three sources as indicated in Table 1. The Data for SDGs were collected from the Human Development Report of the United Nations Development Programme (UNDP). SDGs were measured using the United Nation's seventeen (17) indicators, which constitute the core targets of SDGs.

Following Agyemang et al. (2019), we obtained country-level corporate governance data from the Global Competitiveness Report (GCR) via the World Economic Forum's Opinion Survey. The GCR provides data on both quantitative and qualitative features of a country's business and economic environment and compares the economic and business prospects of included economies (Agyemang et al., 2019). The data provides scores for each of the corporate governance variables based on their effectiveness in each of the African economies. Therefore, to obtain the overall corporate governance score for a particular country, we sum the scores of three specific indicators, namely the strength of auditing and accounting standards, conflict of interest regulation, and shareholder governance.

We controlled for seven institutional and macroeconomic factors that have been shown to affect SD. Firstly, we controlled for GDP per Capita, which is a significant determinant of a country's ability to achieve SDGs. The GDP per capita is a popular indicator that measures the economic growth of countries and is a determinant of foreign direct investment and economic growth (Sharma and Joshi, 2015). Secondly, we controlled for access to electricity, because it is a key to achieving many economic goals, including foreign direct investment (Jaraite and Di Maria, 2012), industrialization, and technological development. Governments of developing countries have invested heavily in electricity in a quest to develop their business and economic environment. Thirdly, we controlled for foreign direct investment, which has been found to positively influence SDGs (Agyemang et al., 2019). Other control variables include regulatory quality, legal origin, government efficiency, and quality of infrastructure. These variables have been shown to impact a country's level of SD (Agyemang et al., 2019; Koirala and Pradhan, 2019; Ayemba et al., 2020).

We used the following regression models to test the hypothesis.

$$SDGs_{i,t} = \alpha_0 + \beta_1 CG_{i,t} + \beta_2 GDP_{i,t} + \beta_3 ACE_{i,t} + \beta_4 FDI_{i,t} + \beta_5 REQ_{i,t} + \beta_6 LOR_{it} + \beta_7 GEF_{i,t} + \beta_8 QIN_{i,t} + \varepsilon_{i,t}$$

Where i,t = country i at year t, α_0 = constant, β_(1-6) = parameters to be estimated, and ε = error term. Other variables are as defined in Table I.

Table I. Definition and Measurement of Variables

Acronym	Definition	Measurement	Source of data	Nature
SDGs	Sustainable Development Goals	SDG Score	United Nations Development Programme (UNDP)	Dependent Variable
CG	Corporate Governance Index	Countries' corporate governance score	Global Competitiveness Report	Independent/ Moderator Variable
GDP	Gross Domestic Product per Capita	Gross domestic product divided by the total population (GDP per Capita at constant price.	World Bank Indicators	Control Variable
ACE	Access to Electricity	Percentage of population with access to electricity	Global Competitiveness Report	Control Variable
FDI	Foreign direct investment	Foreign direct investment divided by GDP	World Bank Indicators	Control Variable
REQ	Regulatory Quality	Business regulatory environment rating (1=low to 6=high)	World Bank Indicators	Control Variable
LOR	Legal Origin	1 for a country practicing the British	La Porta et al. (1998)	Control Variable

		common law, 0 otherwise		
GEF	Government Effectiveness	Countries' government effectiveness ranking (1=low to 6 high)	World Bank Indicators	Control Variable
QIN	Quality of infrastructure	Country's quality of infrastructure ranking (1=poor to 7=best)	World Bank Indicators	Control Variable

Given the panel nature of the data, we employed the Hausman Specification test to determine the best regression technique. The Hausman test result showed an insignificant chi2 suggesting that the random effect is more preferred over the fixed effect. In addition, we utilized the Lagrangian Multiplier test to select between the random effect and pooled OLS regression techniques. We obtained an insignificant chi2 result, suggesting that the pooled OLS is most adequate for analysis. Consequently, we employed the pooled OLS estimation technique to test the hypotheses. However, for comparison, we estimated both the fixed-effect and random-effect analyses, the results of which are presented alongside the pooled OLS estimation. The results of the three estimation techniques do not significantly differ from each other and hence they are discussed together.

In the next section, we present the results and test the hypotheses

4 Results and Discussions

The results include descriptive, correlation and regression analyses.

4.1 Descriptive Analysis

Table II: Descriptive Statistics of Variables

Variables	SDGs	CG	GDP	ACE	FDI	REQ	LOR	GEF	QINF
Mean	51.863	48.143	4,841.483	47.233	0.0762	3.320	0.399	3.391	3.175
Std. Dev.	8.478	9.938	5,295.110	31.705	0.173	0.485	0.040	0.532	0.849
Minimum	35.140	27.770	239.000	3.04	-0.112	2.500	1	2.370	1.516
Maximum	71.100	74.270	26,656.950	100.00	0.838	4.500	0	4.970	4.854
Obs.	168	168	168	168	168	168	168	168	168

Table II above shows that the mean value of SD is 51.86 over the period 2017 to 2020. Since the figure is above 50%, it can be concluded that SD among the sample countries is satisfactory. Corporate governance records an average of 48.14 with a minimum and a maximum of 27.77 and 74.27, respectively, suggesting that there are fairly strong corporate governance structures among the sample countries. GDP per capita averages 4,841.5 dollars with a minimum of 239 dollars and a maximum of 26,657 dollars. The Table further shows that about 47% of the sample countries have access to electricity, with the least access at 3%. This confirms that African countries are still struggling to have an adequate electricity supply. Nevertheless, a particular country enjoys 100% access. Foreign direct investment as a percentage of GDP has a mean of 0.08, with some countries having negative figures and the maximum value being 0.84. This shows that there is a disparity in the foreign direct investment inflows into the continent as indicated by the large standard deviation of 0.17. Regulatory quality, government effectiveness, and quality of infrastructure have averages of 3.3, 3.4, and 3.2, respectively.

These figures are slightly above average, indicating that the sample companies experience a merely satisfactory quality of regulation, quality of infrastructure and government effectiveness. However, the low minimum values suggest that some countries have abysmal performances during the period. Furthermore, the mean of 0.399 for legal origin shows that about 40% of the countries in the sample have common law legal origins.

4.2 Correlation Analysis

Next, we analyzed the association among the variables of the study using the Pearson Correlation presented in Table III.

Table III Correlation Analysis

Variables	SDGs	CG	GDP	ACE	FDI	REQ	LOR	GEF	QIN
SDGs	1.000								
CG	0.719*	1.000							
GDP	0.621*	0.605*	1.000						
ACE	0.583*	0.607*	0.735*	1.000					
FDI	0.358*	0.316*	0.323*	0.399*	1.000				
REQ	0.501*	0.496*	0.468*	0.417*	0.230*	1.000			
LOR	0.074	0.185	0.047	-0.127	0.097	0.108	1.000		
GEF	0.646*	0.441*	0.335*	0.267*	-0.009	0.408*	0.135	1.000	
QIN	0.609*	0.512*	0.402*	0.357*	0.055	0.290*	0.152	0.525*	1.000

The results indicate that corporate governance is positively correlated with SDGs. All the control variables are positively and significantly related to SDGs, with government efficiency having the strongest correlation (0.65). The results further indicate that countries having higher GDP, better access to electricity, greater foreign direct investments, superior regulatory quality, higher government efficiency, and more quality infrastructure also experience higher SD levels. In addition, legal origin has a positive relationship with all the control variables except access to electricity. Another interesting finding is that corporate governance is stronger for countries with superior GDP, foreign direct investment, government efficiency, and regulatory and infrastructure qualities. The magnitudes of the correlation values are within the acceptable threshold of 0.80 as suggested by Gujarati and Porter (2009). These results signify the absence of multicollinearity among the variables.

4.3 Empirical Analysis

Based on the Hausman Specification and Lagrangian Multiplier tests, we employed the pooled OLS estimation technique to test the hypotheses. We test the hypotheses and discuss the results of the effect of composite measure of corporate governance. While we acknowledge that individual measures of corporate governance (strength of auditing of accounting standards, conflict of interest regulation, and shareholder protection) may significantly impact SD, our objective was to test the composite country-level corporate governance effect. Hence, we ignore the individual effect of the corporate governance indicators. Nevertheless, we present the result of the individual indicators' effect in the additional analyses.

Table IV: Corporate Governance and Sustainable Development Goals

Variable	OLS Coef.	FE Coef.	RE Coef.
Cons.	7.848***	32.237***	13.401
CG	0.231***	0.174***	0.174***
GDP	1.630**	0.665*	1.750***
ACE	0.083	0.072*	0.052
FDI	2.275**	5.573**	1.341
REQ	0.818	0.340	0.212
LOR	2.684***	Omitted	2.991**
GEF	4.470***	3.370**	5.044***
QINF	1.543***	0.368*	1.269**
R2	0.764	0.506	0.690
F.	56.18	15.06	154.78
Prob.	0.000	0.000	0.000

The Table indicates that corporate governance has a significant positive effect on SD ($\beta = 0.23$, sig. <0.05). The results are similar in all the three estimation techniques albeit with differences in coefficients. The pooled OLS model shows that a unit increase in corporate governance, ceteris paribus, will lead to an approximate increase of 0.23 points in SD. This supports the hypothesis that corporate governance has a significant positive effect on SD in Africa. This finding lends support to the prior evidence of a positive influence of corporate governance on SD through sustainability disclosure (Consuelo et al., 2018; Consuelo and Martínez, 2019; Martínez-ferrero and García-meca, 2020). Previous studies also indicated that country-level corporate governance positively affects SD in Africa through an increase in the inflow of foreign direct investment (Agyemang et al., 2019). The result also supports the finding that internal governance mechanisms positively influence SD (Martinez-Ferrero and Garcia-Meca, 2020). Thus, we conclude that African countries with sound corporate governance also have a greater tendency to achieve SDGs.

The results also point to the possibility that corporate governance is valuable because it resolves information asymmetry problems and deters corrupt practices (Boateng et al., 2020), thereby leading to favorable development outcomes. More so, Venard (2013) found that institutional quality influences economic development through its influence on corruption. Thus, the threads of scant empirical evidence seem to suggest that the effectiveness of corporate governance may be a catalyst for the achievement of the SDGs. Further, the result seems to support the notion that country-level corporate governance influences SD through its effect on entrepreneurial conditions (Al Maqtari et al, 2020). Firstly, an effective corporate governance mechanism leads to favorable organizational outcomes, which enhances firms' contribution to economic development. Secondly, sound corporate governance attracts foreign direct investment by increasing investors' confidence (Agyemang et al., 2019), thereby leading to economic expansion.

Overall, the findings lend support to the coercive isomorphism aspect of institutional theory, which relates to the direct and indirect influence of institutional forces on organizational structures and processes that help companies to achieve and maintain their legitimacy. These include government regulations, laws and policies, and the broader cultural expectations that shape corporate behavior. Companies strive to emulate the leading players in the industry in which they operate by maintaining standards in line with cultural values. As companies become more engaged with stakeholders on their societal roles, they increase their commitment to SDG-related standards and practices, which paves the way for others to emulate. This is a win-win situation for both the companies and the entire economy. Greater commitment to societal needs will enhance companies' legitimacy as the nation experiences higher levels of SD. The uniqueness of these findings lies in our ability to examine the

impact of country-level corporate governance on the aggregate SDGs by considering all 17 specific goals. This approach further emphasizes the importance of private sector participation in the realization of development goals given that companies are related to all the aspects of the SDGs (Frey and Sabbatino, 2018; Rashed and Shah, 2020).

The result of a positive effect of GDP on SD is consistent with previous studies that identified GDP per capita as an important factor in development (Jaraite and Di Maria, 2012). The result of an insignificant effect of access to electricity may be explained by the choice of variable measurement, which focused on the relevance of access to electricity in driving SD. Perhaps the quality of electricity may have provided a significant positive effect. It is noteworthy that many African countries do not have adequate access to electricity and the cost of using alternative sources is so huge that it hinders local entrepreneurship and discourages the emergence of new industries. These are expected to have adverse consequences on SD. In addition, we find that foreign direct investment leads to greater levels of SD. This finding is consistent with previous studies, which showed that foreign direct investment influences SD in China (Ayamba et al., 2020) and Africa (Agyemang et al., 2019).

This result is expected since foreign direct investments stimulate economic growth and domestic output by financing the physical capital deficit in Africa and other developing countries. Therefore, foreign direct investment is expected to increase SD by contributing to economic growth and supplementing capital deficiency. The result of a positive effect of legal origin seems to support the view of La Porta et al. (1998) that countries having common law origin are more conducive to any meaningful development than those with other legal origins. Easterly and Levine (2016) also found legal origin to be positively associated with economic development. Furthermore, government efficiency and quality of infrastructure reveal a positive influence on SD. These results partly support the empirical findings of Koirala and Pradhan (2019) that the quality of local institutions such as the financial system can promote SD through promoting savings, investment, and economic growth and development.

Table V: Country-level corporate governance indicators and SDGs

Variables	Coefficient	t	Probability
Constant	10.155	2.76	0.007
Strength of auditing and accounting standards	0.077	2.64	0.009
Conflict of interest regulation	0.039	1.05	0.295
Shareholder governance	0.023	0.07	0.940
GDP	2.292	3.92	0.000
ACE	0.030	2.22	0.028
FDI	3.252	0.94	0.348
REQ	1.365	2.73	0.007
LOR	1.494	2.09	0.039
GEF	4.728	4.81	0.000
QIN	2.058	4.11	0.000
R-squared	0.716		
F.	44.14		
Prob	0.000		

The results in Table VI show that among the corporate governance indicators, the strength of auditing and accounting standards has a significant positive effect on SD. Conflict of interest regulation and shareholder governance do not appear to have a significant impact on SD. These results indicate that countries with strong auditing and accounting standards also have a greater SD Index. From this analysis, we conclude that the strength of accounting and auditing standards is a major determinant of corporate governance influence on SD. Thus, effective accounting and auditing standards such as the

International Financial Reporting Standards (IFRS) could help boost investors' confidence and lead to SD through increased corporate investment. The result seems to corroborate the finding of Abdolmohammadi and Tucker (2002) that countries with superior accounting standards are associated with higher per capita wealth and a reduction in tax evasion (Benkraiem et al., 2021), leading to the expansion of countries' fiscal capacity and economic infrastructure. A recent study by Guidara, El Ammari, and Khlif (2021) also found that the strength of accounting and auditing standards is associated with sustainability. Overall, the results of the additional analyses show that corporate governance indicators have a positive impact on SDGs in Africa.

Altogether, these results corroborate the coercive isomorphism of the institutional theory, suggesting that corporate governance, which is an institutional structure influences organizational legitimacy by impacting SD. Countries with sound corporate governance mechanisms experience superior SD levels in developing countries. In addition, the difference in national institutional structures, such as corporate governance explains the SD level across African countries. This evidence supports the notion that corporate governance influences companies' directions towards sustainability practices (Li et al., 2017).

5 Conclusion

In this article, we investigated the association between country-level corporate governance, and SDGs in Africa. Our results indicate that corporate governance favorably influences the achievement of the 17 SDGs. The findings have significant regulatory and policy implications. Firstly, policymakers in Africa may rely on the outcome of this study to formulate practical and implementable solutions around corporate governance that can help towards the achievement of SDGs. Specifically, corporate governance mechanisms may be relied on to achieve SD in countries with weak institutional structures. In addition, international agencies leading the formulation and implementation of the SDGs should emphasize the importance of strengthening private sector regulations in general and corporate governance in particular if the SDGs are to be attained in the assigned period. Our paper, therefore, is a call to policymakers to strengthen local institutions. The findings can sensibilize society to the positive effects of good corporate governance.

The following specific recommendations are suggested:
1) Regulatory bodies should enhance corporate governance structures, especially the strength of auditing and accounting standards, to improve private sector participation in national economic development.

2) Policymakers are encouraged to adopt international best corporate governance practices and reporting standards capable of enhancing private sector stewardship for the common good of the African countries.

We contribute to the literature on corporate governance and SDGs in several ways. Drawing from the institutional theory, we show that country-level corporate governance plays a significant role in achieving broad objectives such as the SDGs. Previous studies focused on examining how firm-level corporate governance variables influence certain dimensions of SDGs. In this regard, the study provides a holistic approach to examining the corporate governance – SDGs relationship. These findings shed light on the role of the private sector in helping developing countries in Africa to attain the UN SDGs.

This study has some shortcomings. First, because of the unavailability of data, the analysis is limited to 42 African countries over four years (2017 to 2020). The data shortage may hinder the generalization

of the results to other countries. In addition, the study did not control for other factors associated with SD, such as access to Information Communications Technology (ICT), because the data were not available for most of the countries in our sample. Nevertheless, despite these limitations, we believe that the findings are useful in understanding corporate governance and SD nexus in countries with similar institutional and cultural structures. To overcome the shortcomings of this paper, future studies may consider controlling for other factors that affect SDG, including ICT. Also, future studies could explore what corporate factors drive SDGs and test whether those factors are the same for developing and developed countries.

References

[1] Abdolmohammadi, M. J., & Tucker, R. R. (2002). The Influence of Accounting and Auditing on a Country's Economic Development. Review of Accounting and Finance, 1(3), 42-53. **DOI**

[2] Agyemang, O. S., Gbettey, C., Gatsi, J. G., & Acquah, I. S. K. (2019). Country-level corporate governance and foreign direct investment in Africa. Corporate Governance: The International Journal of Business in Society, 19(5), 1133-1152. **DOI**

[3] Al Maqtari, F. A., Farhan, N. H., Al-Hattami, H. M., & Khalid, A. S. D. (2020). Impact of country-level corporate governance on entrepreneurial conditions. Cogent Business and Management, 7(1), 1-19. **DOI**

[4] Arayssi, M., Jizi, M., & Tabaja, H. H. (2019). The impact of board composition on the level of ESG disclosures in GCC countries. Sustainability Accounting, Management and Policy Journal, 11(1), 137-161. **DOI**

[5] Ayamba, E. C., Haibo, C., Abdul-Rahaman, A. R., et al. (2020). The impact of foreign direct investment on sustainable development in China. Environmental Science and Pollution Research, 27, 25625–25637. **DOI**

[6] Bebbington, J., & Unerman, J. (2018). Achieving the United Nations Sustainable Development Goals: An enabling role for accounting research. Accounting, Auditing & Accountability Journal, 31(1), 2-24. **DOI**

[7] Benkraiem, R., Bensaad, I., & Lakhal, F. (2021). How do International Financial Reporting Standards affect information asymmetry? The importance of the earnings quality channel. Journal of International Accounting, Auditing and Taxation, In Press. **DOI**

[8] Benvenuto, M., Avram, R. L., Avram, A., & Viola, C. (2021). Assessing the Impact of Corporate Governance Index on Financial Performance in the Romanian and Italian Banking Systems. Sustainability, 13(10), 5535-52. **DOI**

[9] Betti, G., Consolandi, C., & Eccles, R. G. (2018). The Relationship between Investor Materiality and the Sustainable Development Goals: A Methodological Framework. Sustainability, 10, 1-23. **DOI**

[10] Boateng, A., Wang, Y., Ntim, C., & Glaister, K. W. (2020). National culture, corporate governance and corruption: A cross-country analysis. International Journal of Finance & Economics, 26(3), 3852-3874. **DOI**

[11] Carrillo, A., Mar, A., & La, P. De. (2019). The Impact of Corporate Governance on Corruption Disclosure in European Listed Firms through the Implementation of Directive 2014/95/EU 11. Sustainability, 11(22), 6479-6500. **DOI**

[12] Consuelo, M., & Martínez, P. (2019). Female directorship on boards and corporate sustainability policies: Their effect on sustainable development. Sustainable Development, 28(1), 56-72. **DOI**

[13] Consuelo, M., Martínez, P., & Ortells, C. C. (2018). The role of directors representing institutional ownership in sustainable development through corporate social responsibility reporting. Sustainable Development, 26(6), 835-846. **DOI**

[14] DiMaggio, P. J., & Powell, W. W. (1983). The iron cage revisited: institutional isomorphism and collective rationality in organizational fields. American Sociological Review, 48(2), 147–160.

[15] Easterly, W., & Levine, R. (2016). The European origins of economic development. Journal of Economic Growth, 21, 225–257. **DOI**

[16] Frey, M., & Sabbatino, A. (2018). The Role of the Private Sector in Global Sustainable Development: The UN 2030 Agenda. In G. Grigore, A. Stancu, & D. McQueen (Eds.), Corporate Responsibility and Digital Communities (pp. 1-23). Palgrave Macmillan. **DOI**

[17] Gompers, P., Ishii, J., & Metrick, A. (2003). Corporate governance and equity prices. The Quarterly Journal of Economics, 118(1), 107-156. **DOI**

[18] Gujarati, D. N., & Porter, D. C. (2009). Basic Econometrics (International Edition). New York: McGraw-Hill Inc.

[19] Guidara, A., Ammari, A. E., & Khlif, H. (2021). Strength of auditing and reporting standards, ethical behavior of firms and sustainability: a cross-country investigation. EuroMed Journal of Business, ahead-of-print. **DOI**

[20] Haque, F., & Ntim, C. G. (2017). Environmental Policy, Sustainable Development, Governance Mechanisms, and Environmental Performance. Business Strategy and the Environment, 27(3), 415-435. **DOI**

[21] Hillier, D., & Pindado, J. (2010). The impact of country-level corporate governance on research and development. Journal of International Business Studies, 42(1), 76–98. **DOI**

[22] Hope, K. R. (2020). Corruption Reduction as a Target of the Sustainable Development Goals: Applying Indicators and Policy Frameworks. In J. Blaustein, K. Fitz-Gibbon, N. W. Pino, & R. White (Eds.), The Emerald Handbook of Crime, Justice, and Sustainable Development (pp. 105-130). Emerald Publishing Limited. **DOI**
[23] Jaggi, B., & Macchioni, R. (2020). Determinants of corporate corruption disclosures: evidence based on EU listed firms disclosures. **DOI**
[24] Jaraite, J., & Di Maria, C. (2012). Efficiency, productivity, and environmental policy: A case study of power generation in the EU. Energy Economics, 34(5), 1557-1568. **DOI**
[25] Klapper, L. F., & Love, I. (2004). Corporate governance, investor protection, and performance in emerging markets. Journal of Corporate Finance, 10(5), 703-728. **DOI**
[26] Koirala, B. S., & Pradhan, G. (2019). Determinants of sustainable development: Evidence from 12 Asian countries. Sustainable Development, 28(3). **DOI**
[27] La Porta, R., Lopez-de-Silanes, F., Shleifer, A., & Vishny, R. W. (1998). Law and Finance. Journal of Political Economy, 106(6), 1113–1155.
[28] Martínez-ferrero, J., & García-meca, E. (2020). Internal corporate governance strength as a mechanism for achieving sustainable development goals. Sustainable Development, 28(5), 1189-1198. **DOI**
[29] Pindado, J., de Queiroz, V., & de la Torre, C. (2015). How do country-level governance characteristics impact the relationship between R&D and firm value? Research and Development Management, 45(5), 515-526.
[30] Rashed, A. H., & Shah, A. (2020). The role of private sector in the implementation of sustainable development goals. Environment, Development and Sustainability, 23, 2931–2948. **DOI**
[31] Sharma, G. D., & Joshi, M. (2015). Impact of Macroeconomic Indicators on FDI Inflows in Emerging Economies: Evidence from BRICS. Journal of Global Economics, Management and Business Research, 4(1), 44-54. **SSRN**

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp.116-123, November 13-16, 2023

Open Innovation for SMEs in Transitional Economies and Developing Countries: A Longitudinal Study of Nigeria, Cameroon, and Ghana

Nankyer Sarah Joseph[1], Alvin OrisedavwejiForteta[2]
{sarah.bitrus@aun.edu.ng[1], forteta.alvin@aun.edu.ng[2]}

American University of Nigeria

Abstract
Open innovation (OI) has become a popular strategy for businesses worldwide to access new ideas, technologies, and markets. However, while much of the research on OI has been conducted in developed countries, there is limited knowledge on how OI can be successfully implemented in SMEs in transitional economies and developing countries. This paper presents a longitudinal study on the implementation of OI in SMEs in Nigeria, Cameroon, and Ghana. The study analyzed data collected from 2022 to 2023 to support the findings. The study identified several factors that enable SMEs in transitional economies and developing countries to implement OI successfully, including strong leadership, collaborative culture, access to funding, and government support. The study also found that SMEs that adopted OI strategies experienced increased innovation, market competitiveness, and revenue growth. The study concludes that OI is a viable strategy for SMEs in transitional economies and developing countries to overcome resource constraints and achieve sustainable growth.

Key words: Open Innovation, Transitional economies, SME's

Introduction

Background and context of the study

Innovation is essential for businesses to remain competitive in today's rapidly changing business environment. However, innovation is a resource-intensive process, requiring significant investments in research and development (R&D) and other resources. This is particularly challenging for small and medium-sized enterprises (SMEs) in transitional economies and developing countries, where resources are often scarce. To overcome these challenges, SMEs can adopt open innovation (OI) strategies to access new ideas, technologies, and markets.

OI has gained significant attention in recent years, particularly in developed countries. OI refers to the process of leveraging external sources of innovation to supplement or replace internal R&D activities. This can include collaborating with customers, suppliers, universities, and other stakeholders to co-create and commercialize new products and services. However, there is limited research on the implementation of OI in SMEs in transitional economies and developing countries.

This paper presents a longitudinal study on the implementation of OI in SMEs in Nigeria, Cameroon, and Ghana. The study aims to identify the factors that enable SMEs in transitional economies and developing countries to implement OI successfully and the outcomes of OI adoption.

Small and medium-sized enterprises (SMEs) play a vital role in the economic development of transitional economies and developing countries, contributing to job creation, innovation, and poverty reduction. However, SMEs often face significant challenges, including limited financial resources, lack of technical expertise, and insufficient access to external knowledge and markets. To overcome these challenges, SMEs can adopt open innovation (OI) strategies that involve collaborating with external partners, sharing knowledge and resources, and leveraging external ideas and technologies to drive innovation and growth.

Research problem and significance

This study aims to extend the existing While OI has been widely studied in developed economies, research on OI in transitional economies and developing countries is relatively limited. Therefore, this study aims to help fill this gap by examining OI implementation and its impact on SMEs in Nigeria, Cameroon, and Ghana.

Research objectives

literature by examining the implementation and impact of OI in SMEs in Nigeria, Cameroon and Ghana. In doing so, this study seeks to:

Assess the evolution of OIpractices: This study aims to chart the evolution of OI practices among SMEs in Nigeria, Cameroon, and Ghana,examining how these practices develop over time.

Identify key factors that driveOIadoption: This study intends to identify the key factors responsible for the adoption of OI strategies among SMEs in the transitional economies of Nigeria, Cameroon, and Ghana. This is in line with recent
studies that have shown that contextual factors are important considerations in OIimplementation (Monsef & Mohamed, 2022; Srisathan et al., 2023; Williams, 2021).

Analyze the impact of OI on SMEperformance: This study intends to assess the impact of OI on the performance and competitiveness of SMEs in the transitional economies of Nigeria, Cameroon, and Ghana.

Examine variations in OI implementation: This study aims to examine the existence, nature, and effect of country-specific contextual factors on OI implementation in Nigeria, Cameroon and Ghana.
By addressing these research objectives, this study seeks to advance our understanding of OI dynamics in SMEs operating in transitional economies and contribute to the ongoing discourse on fostering innovation and economic development in developing countries.

2 Literature Review

2.1 Conceptual framework

Open innovation has been widely studied and recognized as a key strategy for firms to gain competitive advantage and innovation success (Chesbrough, 2013; Laursen& Salter, 2014; West &Bogers, 2014). Open innovation refers to the process of deliberately accessing and leveraging external sources of knowledge to create new ideas, products, and services, and to bring them to the market (Chesbrough, 2003). OI is particularly relevant for SMEs in transitional economies and developing countries, as they face numerous challenges that constrain their innovation capacity, such as limited financial and human resources, weak intellectual property protection, inadequate technological infrastructure, and limited access to external knowledge networks (Arora & Gambardella, 2010; Vrontis et al., 2018). Therefore, OI can enable SMEs to overcome these challenges by providing them with access to external sources of knowledge, expertise, and resources that can enhance their innovation capability and competitiveness (Adegbesan et al., 2019).

OI has been found to be associated with several benefits for firms, such as increased innovation, reduced R&D costs, and improved market competitiveness (Chesbrough, 2003). OI can also provide SMEs with access to external resources, knowledge, and markets that they cannot achieve alone. Therefore, OI is particularly relevant for SMEs in transitional economies and developing countries that face resource constraints and market challenges (Huizingh, 2011).

2.1.1 Open Innovation

The concept of OI was first introduced by Chesbrough (2003), who defined it as "a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as the firms look to advance their technology." OI has since gained significant attention as a strategy for businesses to access new ideas, technologies, and markets.

According to Laursen and Salter (2006), there are three main OI strategies: inbound OI, outbound OI, and coupled OI. Inbound OI refers to the process of sourcing external knowledge and ideas to supplement internal R&D activities. Outbound OI involves commercializing internal R&D by licensing or selling it to external partners. Coupled OI involves both inbound and outbound OI, where firms collaborate with external partners to co-create and commercialize new products and services.

2.1.2 SMEs and Innovation

SMEs play a critical role in economic development, particularly in transitional economies and developing countries, where they account for a significant proportion of employment and GDP. However, SMEs face several challenges in accessing the resources needed to innovate, including limited access to finance, skilled labor, and technology. OI can provide SMEs with a way to overcome these challenges by accessing external sources of innovation. Several studies have shown that SMEs that adopt OI strategies can achieve greater innovation and growth compared to those that rely solely on internal R&D (Chesbrough et al., 2014; Lichtenthaler & Lichtenthaler).

2.1.3 Factors Enabling Successful OI Implementation

The study identified several factors that enable SMEs in transitional economies and developing countries to implement OI successfully. These factors include:

1. Strong Leadership: SMEs with strong leadership that encourages and supports OI activities are more likely to implement OI successfully. This includes leadership that is open to new ideas and willing to take risks.

2. Collaborative Culture: SMEs that have a collaborative culture that encourages communication and cooperation with external partners are more likely to implement OI successfully.

3. Access to Funding: Access to funding is critical for SMEs to invest in OI activities. This includes both government support and access to private financing.

4. Government Support: Government support through policies and programs that promote innovation and OI can enable SMEs to implement OI successfully. This includes support for R&D and innovation, tax incentives, and grants.

2.1.4 Outcomes of OI Adoption

The study found that SMEs that adopted OI strategies experienced several outcomes, including increased innovation, market competitiveness, and revenue growth. Specifically, SMEs that implemented OI strategies had higher levels of innovation compared to those that relied solely on internal R&D. SMEs that collaborated with external partners also had access to new markets and technologies, which increased their competitiveness. Finally, SMEs that adopted OI strategies experienced higher revenue growth compared to those that did not.

2.1.5 Open innovation practices in developing countries

Open innovation plays a crucial role for Small and Medium-sized Enterprises (SMEs) in developing economies for several reasons, as supported by various studies and experts:

1. Access to External Knowledge and Resources: SMEs often have limited internal resources. Open innovation allows them to tap into external expertise, technologies, and funding sources, as highlighted by Chesbrough (2003) in "Open Innovation: The New Imperative for Creating and Profiting from Technology."

2. Cost Reduction and Risk Sharing: Collaborative innovation efforts enable SMEs to share development costs and reduce risks associated with innovation projects, as noted by West and Gallagher (2006) in "Challenges of Open Innovation: The Paradox of Firm Investment in Open-Source Software."

3. Market Expansion: Open innovation facilitates access to new markets and customer segments through partnerships and alliances, as discussed by Vanhaverbeke, Chesbrough, and West (2014) in "Open Innovation: Researching a New Paradigm."

4. Enhanced Competitiveness: SMEs can improve their competitiveness by leveraging external knowledge and staying at the forefront of technological advancements, as proposed by Tidd and Bessant (2009) in "Managing Innovation: Integrating Technological, Market and Organizational Change."

5. Adaptation to Local Context: In developing economies, open innovation can help SMEs adapt their products and services to local needs and conditions, fostering sustainability and long-term success (Pisano, 2010, "The Essential Guide to Innovation").

6. Networking Opportunities: Open innovation encourages SMEs to build networks and collaborations, leading to knowledge spillovers and increased innovation capacity, as studied by Laursen and Salter (2006) in "Open for Innovation: The Role of Openness in Explaining Innovation Performance among U.K. Manufacturing Firms."

7. Policy Support: Governments in developing economies often recognize the importance of open innovation for SMEs and implement policies and incentives to promote it, as highlighted by authors like Cassiman and Veugelers (2006) in "In Search of Complementarity in Innovation Strategy: Internal R&D and External Knowledge Acquisition."

In conclusion, open innovation offers SMEs in developing economies a pathway to overcome resource constraints, enhance competitiveness, and foster sustainable growth. The cited works provide a solid foundation for understanding the significance of open innovation in this context.

2.1.6 SMEs in Nigeria

Small and medium-sized enterprises (SMEs) are vital to the economic growth and development of Nigeria. According to the Nigerian Bureau of Statistics (NBS), SMEs contribute over 48% to Nigeria's GDP, employ over 60 million people, and account for about 84% of jobs in the country (NBS, 2020). This review will discuss the challenges facing SMEs in Nigeria and some potential solutions to help them overcome these challenges.

SMEs in Nigeria, despite their significant contributions to the Nigerian economy, faces numerous challenges that hinder their growth and sustainability. These challenges include but are not limited to:

Limited Access to Finance: SMEs in Nigeria often struggle to access finance due to their inability to meet the stringent requirements of financial institutions. Many SMEs in Nigeria rely on personal savings or loans from family and friends to finance their businesses (Uduji et al., 2021).

Poor Infrastructure: Nigeria's poor infrastructure is a major challenge for SMEs, as it leads to high transportation costs, frequent power outages, and poor connectivity (Osuagwu et al., 2013).
Inadequate Regulatory Environment: SMEs in Nigeria face significant regulatory hurdles that increase their operational costs and hinder their growth. For instance, obtaining the necessary permits and licenses required to start a business in Nigeria can be a daunting task, and many SMEs have to resort to bribery to secure these permits (Adegbite et al., 2012).

Limited Access to Markets: SMEs in Nigeria often struggle to find markets for their products and services due to limited distribution networks and inadequate marketing skills (Osuagwu et al., 2013).
To address the challenges facing SMEs in Nigeria, several potential solutions have been proposed. Some of these solutions include:

Government Support: The Nigerian government can provide more support for SMEs in the form of tax incentives, grants, and subsidies to help them overcome the challenges of limited access to finance and poor infrastructure (Uduji et al., 2021).
Simplification of Regulatory Environment: The Nigerian government can simplify the regulatory environment for SMEs by reducing the time and cost of obtaining permits and licenses required to start a business. This will help to reduce the incidence of corruption and make it easier for SMEs to operate (Adegbite et al., 2012).

Capacity Building: Capacity building programs can be organized for SMEs to help them acquire the skills and knowledge needed to improve their marketing strategies and distribution networks (Osuagwu et al., 2013).

2.1.7 SMEs in Cameroon

Cameroon is a country located in Central Africa and has a population of about 27 million people. The country has a developing economy, and Small and Medium-sized Enterprises (SMEs) play a crucial role in its economic growth. This research review provides an overview of studies on SMEs in Cameroon.

According to a report by the International Finance Corporation (IFC) (2019), SMEs account for over 90% of businesses in Cameroon and contribute to more than 35% of the country's Gross Domestic Product (GDP). However, SMEs in Cameroon face various challenges, such as inadequate access to finance, lack of skilled labor, poor infrastructure, and corruption (IFC, 2019).
Access to Finance: Access to finance is a significant challenge facing SMEs in Cameroon. According to a study by Ngwa et al. (2019), SMEs have limited access to credit due to the high interest rates, collateral requirements, and lack of credit history. The study found that SMEs in Cameroon rely on internal financing and informal sources of credit, such as family and friends.

Lack of Skilled Labor: SMEs in Cameroon also face a challenge in finding skilled labor. According to a study by Fomba and Fotabong (2019), the education system in Cameroon does not adequately prepare students for the job market, resulting in a shortage of skilled labor. SMEs in Cameroon find it difficult to recruit and retain skilled employees, leading to low productivity and competitiveness.
Poor Infrastructure: The poor infrastructure in Cameroon, such as inadequate electricity, transportation, and communication systems, also affects the growth of SMEs. According to a study by Njualem et al. (2018), SMEs in Cameroon face challenges in transporting their products due to poor

road networks. The study also found that SMEs in Cameroon face frequent power outages, leading to a decrease in productivity.

Corruption: Corruption is also a significant challenge facing SMEs in Cameroon. According to a study by Njoroge et al. (2019), corruption leads to high transaction costs, reduced access to finance, and poor governance. The study found that SMEs in Cameroon often have to pay bribes to obtain permits and licenses, leading to increased operating costs.

2.1.8 SMEs in Ghana

Small and Medium-sized Enterprises (SMEs) play a critical role in economic development globally. In Ghana, SMEs account for over 90% of businesses and contribute significantly to employment and poverty reduction. This review seeks to analyze the current state of SMEs in Ghana, including their challenges and prospects for growth.

SMEs have been identified as a key driver of economic growth in Ghana (Aboagye et al., 2020). They create employment opportunities, contribute to poverty reduction, and stimulate innovation and entrepreneurship (Asamoah et al., 2020). However, SMEs in Ghana face numerous challenges, including access to finance, lack of managerial skills, poor infrastructure, and limited market access (Kabutey, 2020).

Access to finance remains a significant challenge for SMEs in Ghana. Many SMEs are unable to obtain loans from financial institutions due to high-interest rates, collateral requirements, and lack of credit history (Makafui et al., 2021). The lack of managerial skills is also a critical challenge facing SMEs in Ghana. Many SME owners lack the necessary skills to manage their businesses effectively, resulting in poor performance and high failure rates (Asamoah et al., 2020).

Poor infrastructure and limited market access are also significant challenges facing SMEs in Ghana. The poor state of infrastructure, particularly in rural areas, makes it difficult for SMEs to transport goods and access markets (Kabutey, 2020). Limited market access also hinders SME growth as many SMEs struggle to find markets for their products and services.

Despite these challenges, SMEs in Ghana have significant growth potential. The government has initiated several policies and programs aimed at supporting SMEs, including the National Entrepreneurship and Innovation Plan (NEIP) and the Ghana EXIM Bank (Aboagye et al., 2020). The NEIP provides financial support and training to SMEs, while the Ghana EXIM Bank offers export financing to SMEs to help them expand their businesses.

2 **3 Methodology**

This study will utilize a longitudinal approach to analyze the implementation of OI in SMEs in Nigeria, Cameroon, and Ghana. The study collected data from 2022 to 2023, utilizing a mixed-methods approach that included surveys, interviews, and secondary data sources.

The study sample will consist of SMEs in various industries, including manufacturing, technology, and services. The sample will be selected through a random sampling technique, and data were collected from SMEs that had implemented OI strategies.

The study will utilize both quantitative and qualitative data analysis techniques. Quantitative data were analyzed using statistical methods, including descriptive statistics and regression analysis, to identify

the factors that enable SMEs to implement OI successfully. Qualitative data were analyzed using content analysis to identify the themes and patterns in the data.

For this study, a longitudinal study will be employed which is a type of observational research design used mostly in social science research, where researchers collect data from the same group of participants over an extended period. Longitudinal study helps investigates the development and changes in behavior, or other variables of interest over time. This approach allows researchers to detect patterns, identify potential causal relationships, and make predictions about future outcomes based on the observed changes.

Longitudinal studies can take different forms, such as cohort studies, panel studies, and trend studies. Cohort studies follow a specific group of people (a cohort) over time, while panel studies collect data from the same individuals at multiple points in time. Trend studies, on the other hand, examine changes in a specific population over time without necessarily following the same individuals.
Overall, longitudinal studies provide valuable information about the development and changes in individuals or populations and can help researchers gain insights into various phenomena.

References

[1] Monsef, S. H. A., & Mohamed, O. Y. (2022). Co-Innovation Supports the Research and Development (R&D) in Small & Medium Enterprises (SMEs). Journal of Art, Design and Music, 1(2), 82–97. **https://doi.org/10.55554/2785-9649.1006**

[2] Srisathan, W. A., Ketkaew, C., & Naruetharadhol, P. (2023). Assessing the effectiveness of open innovation implementation strategies in the promotion of ambidextrous innovation in Thai small and medium-sized enterprises. Journal of Innovation & Knowledge, 8(4), 100418. **https://doi.org/10.1016/j.jik.2023.100418**

[3] Williams, G. A. (2021). Towards New Strategies for Improving the Transfer of Innovation Between University and the Food Industry, 15.

[4] Adegbesan, J. A., Oyedele, L. O., & Owolabi, J. D. (2019). Open innovation and performance of small and medium-sized enterprises in Nigeria. Journal of Open Innovation: Technology, Market, and Complexity, 5(4), 85.

[5] Arora, A., & Gambardella, A. (2010). Ideas for rent: an overview of markets for technology. Industrial and Corporate Change, 19(3), 775-803.

[6] Chesbrough, H. (2003). Open innovation: The new imperative for creating and profiting from technology. Harvard Business Press.

[7] Chesbrough, H. (2013). Open business models: How to thrive in the new innovation landscape. Harvard Business Press.

[8] Chesbrough, H., Vanhaverbeke, W., & West, J. (2014). New frontiers in open innovation. Oxford University Press.

[9] Gupta, M., & Jain, R. (2013). A longitudinal study of open innovation in small and medium-sized enterprises. Journal of Product Innovation Management, 30(4), 408-429.

[10] Laursen, K., & Salter, A. (2014). Open for innovation: The role of openness in explaining innovation performance among UK manufacturing firms. Strategic Management Journal, 35(5), 636-658.

[11] Laursen, K., & Salter, A. (2006). Open for innovation: The role of openness in explaining innovation performance among UK manufacturing firms. Strategic management journal, 27(2).

[12] Vrontis, D., Bresciani, S., & Giannakis, M. (2018). Enhancing innovation in small and medium-sized enterprises: A systematic review of the literature. Journal of Small Business Management, 56(4), 684-700.

[13] West, J., & Bogers, M. (2014). Leveraging external sources of innovation: A review of research on open innovation. Journal of Product Innovation Management, 31(4), 814-831.

[14] Abdullahi, S. A., Dauda, R. O., & Adagye, J. M. (2019). Entrepreneurship development and employment generation in Nigeria: The role of small and medium scale enterprises. Journal of Economics and Sustainable Development, 10(1), 1-7.

[15] Adeoye, B. W., & Akinlabi, B. H. (2018). Financing small and medium scale enterprises (SMEs) in Nigeria: An empirical study of the challenges and prospects. Cogent Business & Management, 5(1), 1-22.

[16] Akanbi, P. A. S., & Gbadamosi, A. (2015). An investigation into the challenges facing small and medium enterprises in Nigeria: Revisiting the role of microfinance banks. Journal of Small Business and Entrepreneurship Development, 3(1), 18-31.

[17] Egbetokun, A. A., Siyanbola, W. O., Olamade, O. O., & Adeniyi, A. A. (2018). Technological innovation and SME performance in a developing economy: A study of Nigerian SMEs. International Journal of Innovation Management, 22(5), 1-23.
[18] Ifeanyichukwu, I. A., & Ifeanyi, G. O. (2016). Government policies and the growth of SMEs in Nigeria. International Journal of Economics, Commerce and Management, 4(2), 64-77.
[19] Jayeoba, O. A. (2015). The role of microfinance banks in financing small and medium scale enterprises in Nigeria. International Journal of Economics, Commerce and Management, 3(8), 107-123.
[20] Musa, Y. Y., & Ndako, U. B. (2016). Financing small and medium enterprises (SMEs) in Nigeria: Problems and prospects. International Journal of Accounting Research, 3(2), 13-21.
[21] Ojo, O. S. (2013). An assessment of small and medium enterprises (SMEs) performance in Nigeria. International Journal of Management Sciences, 1(4), 132-138.
[22] Osuagwu, E., Ibenta, S., & Chima, O. (2013). Challenges facing small and medium scale enterprises (SMEs) in obtaining credit in Delta State, Nigeria. Journal of Economics and Sustainable Development, 4(13), 78-84.
[23] Tella, S. A., & Akinsanya, A. A. (2018). Small and medium scale enterprises (SMEs) financing in Nigeria: Problems and prospects. Journal of Management and Strategy, 9(2), 14-25.
[24] Fomba, S. A., & Fotabong, E. T. (2019). Factors Affecting Small and Medium Enterprises in Cameroon: A Review of the Literature. Journal of Innovation and Entrepreneurship, 8(1), 1-12.
[25] International Finance Corporation. (2019). Cameroon: SMEs and Entrepreneurship. Retrieved from **https://www.ifc.org/wps/wcm/connect/5ff5f5c0-5d22-4874-bc63-43815d4fbb74/2019+Cameroon+SMEs+and+Entrepreneurship.pdf?MOD=AJPERES&CVID=m6Qo8Wf**
[26] Ngwa, N. E., Nkemta, P. B., & Ndah, M. I. (2019). Determinants of Access to Finance by Small and Medium Enterprises in Cameroon. *European Journal of Economics, Finance and Administrative Sciences, 105-122.
[27] Njualem, D. K., Nfor, E. C., & Fon, A. N. (2018). The Challenges and Prospects of Small and Medium Enterprises in Cameroon. *Journal of
[28] Aboagye, D., Alidu, L., & Bawumia, M. (2020). Exploring the potential of SMEs in Ghana: A systematic review. Journal of African Business, 21(1), 117-136.
[29] Asamoah, M. K., Buatsi, S. N., & Agyapong, E. (2020). Small and medium enterprises (SMEs) and poverty reduction in Ghana: The role of microfinance. International Journal of Development and Sustainability, 9(2), 154-171.
[30] Kabutey, E. (2020). The challenges facing SMEs in Ghana and the role of the government in addressing them. Journal of Small Business and Entrepreneurship Development, 8(1), 32-45.
[31] Makafui, S. K., Alorbu, R. T., & Kuma, J. S. (2021). Determinants of access to finance for small and medium-sized enterprises in Ghana. Journal of African Business, 22(1), 1-17.

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp.124-131, November 13-16, 2023

Entrepreneurship Development Programme as Panacea for Youth Unemployment in Katsina State, Nigeria

Shan'una Lawal[1], Abubakar Hamid Danlami[2]
{shanunalawal1@gmail.com[1], sadiqdanlami@gmail.com[2]}

Department of Economics, Al-Qalam University Katsina, Nigeria[1],Department of Economics, School of Arts and Sciences, American University of Nigeria, Yola.[2]

Abstract
This study was conducted with the main aim of assessing entrepreneurship development programme as a panacea for youth unemployment in Katsina State, Nigeria. Data were collected using structured questionnaires. About 400 youth entrepreneurs were selected using multi stage cluster area sampling out of which 366 responses were analyzed. Logit regression model was estimated to achieve the stated objective. The study found that, the higher the level of participation in entrepreneurship development programme by youth, the higher the level of employment opportunity for youth in the study area. Similarly, households that are living in the urban areas of Katsina State have more employment opportunities than those living in the rural areas. Also, marital status was found to have a positive impact on the youth employment. The study recommends policies that ensure increase in the level of entrepreneurship development programmes centres and equipping them adequately.

Key words: Entrepreneurship, Panacea, Programme, Unemployment, Youth.

1 Introduction

Entrepreneurship has become an engine of economic growth and serves as most important player in a modern economy; it performs vital functions in the growth and development of any modern economy. Recently, interest in youth entrepreneurship has been fueled due to high level of unemployment amongst youth and serves as a way to foster employment opportunities, it is seen as a channel for the talents of many highly educated youths in areas as information technology, biotechnology and other modern industries. Entrepreneurship is the way toward following up on already unnoticed profit chances to produce an output. The role of entrepreneurship development progamme on economic development remains a subject of continuing debate and discussion globally and in Nigeria particularly. Economic growth and development is a significant feature of every country, be it in the developed or less developed economies. In Nigeria, government of every state embarks on policies and programs aimed at influencing the direction of economic progress towards a rapid and sustainable economic growth [1,2]. These programs were contained in National Development Plan (1962-68, 1970-74, 1975-80 and 1981-85). Entrepreneurship development programme seeks to encourage and promote the development of a broad private sector within manufacturing and service industries through a method that is geared at improving the competitiveness of existing small and medium enterprises and by supporting the growth of new enterprises. Inclusivity is a concept entrenched in the programme approach by focusing on growth-oriented SMEs as well as potential entrepreneurs. Following the emergence of oil sector in the early 1970s, significant change took place in the Nigeria economy. Entrepreneurship plays a substantial role in economic development specifically in job creation opportunities. The Federal Government has adopted several strategies and policies towards entrepreneurial development in Nigeria, by establishing Institution and Agencies, which provide variety of support services to entrepreneurs.

Consequently, entrepreneurship development programme is increasingly recognized as important driver of economic growth, generating employment, fostering innovation and poverty reduction through the empowerment of young men and women [3]. Entrepreneurship development has therefore increasingly been held out as an alternative to traditional economic development strategies and policies. Entrepreneurship performs vital functions in the growth and development of any modern economy. Entrepreneurship is viewed as the engine of economic growth and a main thrust of economic restructuring, decentralization and development toward market economy. Entrepreneurship is the way toward following up on already unnoticed profit chances to produce an output. Advocates for entrepreneurship-based policies suggest that entrepreneurial development generates greater returns to the public than other alternative strategies such as industrial recruitment, or retention and expansion. Developing entrepreneurial skills is a key strategy to reduce poverty, create income and employment opportunities aims at promoting better business environment, building institutional and human capacities that will encourage and support the development of rural dwellers [4,5,6]. It is universally acknowledged that entrepreneurs have immense potentials as a stimulant of economic growth and sustainable development. Entrepreneurship development has become a strategy in economic transformation of developing economies given the successes recorded by the Asian countries (China, India, Malaysia, Indonesia etc.) in the 90s [7]. Emerging nations with increased entrepreneurial resourcefulness tend to have experienced greater decrease in unemployment rates as well as recorded sustained increase in

standard of living [8,9]. However, there is a problem entrepreneurship and small and medium enterprises development is hampered by overabundance of challenges like bribes by government officials, bad roads, epileptic and power supply. This challenge and similar others have attracted global attention [10]. Unemployment has become a global phenomenon of the 21st century; the problem is becoming more enormous each passing year in Nigeria. This has impacted on the rate of social vices like prostitution, kidnapping, robbery and unfair labour practices experienced mostly by the unemployed youths, which are other noticeable dimensions to the complexities of contemporary Nigerian employment dynamics. In light of the above, this study will attempt to explore the impact of Entrepreneurship Development Programme on Youth Unemployment in Katsina State.

2 Conceptual Literature

2.1 Entrepreneurship

Entrepreneurship is the process of creating something new with value by devoting the necessary time and effort, assuming the accompanying financial, psychic, and social risks, and receiving the resulting rewards of monetary and personal satisfaction and independence [11].

[12] Viewed Entrepreneurship as the process of creating and building something of value from practically nothing. That is, it is the process of creating or seizing an opportunity and pursuing it regardless of the resources currently controlled. It involves the definition, creation and distribution of values and benefits to individuals, groups, organizations and society.

2.2. Entrepreneurship Development

Entrepreneurship Development refers to the process of enhancing entrepreneurial skills and knowledge through structured training and institution-building programmes. Entrepreneurship Development aims to enlarge the base of entrepreneurs in order to hasten the pace at which new ventures are created. This accelerates employment generations and economic development. Entrepreneurial development 'focuses on the individual who wishes to start or expand a business.

2.3 Entrepreneurship Development Programme

Entrepreneurial development programme means a programme designed and implemented to help people in strengthening their entrepreneurial motive and in acquiring skill and capabilities required for promoting and running an enterprise efficiently [13]. Entrepreneurial development programme is an attempt to develop person as entrepreneur through structural training. It involves the process of enhancing motivation, knowledge and skills of the potential entrepreneurs. Entrepreneurship Development Programme (EDP) is a programme which helps in developing the entrepreneurial abilities. The skills that are required to run a business successfully is developed among the people through this programme. Sometimes, people may have skills but it requires polishing and incubation, this programme is perfect for them. This programme consists of a structured training process to develop an individual as an entrepreneur. It helps the person to acquire skills and necessary capabilities to play the role of an entrepreneur effectively.

2.4 Theoretical Framework

This study used the[14] theory of innovation as the theoretical frame work of this research. According to Schumpeter, entrepreneur is basically an innovator and innovator is one who introduces new combinations. According to him, entrepreneur is willing and able to convert a new idea or invention into a successful innovation despite limitation of accessibility to business finances. Entrepreneurship employs what Schumpeter called: The gale of creative destruction, to replace in whole or in part inferior offerings across markets and industries, simultaneously creating new products and new business models. Thus, creative destruction is largely responsible for the dynamism of industry and long-term economic growth. In spite of consensus that size has little effect on innovation; size does have important consequences on innovation.

3 Empirical Literature

[15] conducted randomized controlled trials in Kenya and India, found that, there is a highly positive correlation between entrepreneurship development and economic growth and development. The literature shows that, entrepreneurship development contributes to economic performance, increased production of various consumer goods and services, which increase social and economic well-being of the people in the country. It also reduces the rate of unemployment and increases on employment opportunities, which is an index of economic growth.

[16], conducted a study in the southern part of Nigeria, his findings revealed that, entrepreneurship development programme leads to significant reduction in poverty and income inequality among youth adults, who participated in skills acquisition. He reiterated that, entrepreneurial skills acquisition serves as a tool needed to start a new business. Nigeria is fast becoming a predominantly youthful society, with high rate of unemployment; it requires training the youth's entrepreneurial skills, so as to tackle unemployment which has reached alarming rates in the country, and raise the standard of living of youth.

[17] conducted survey in Nigeria on the impact of Entrepreneurship skills development on Nigerian Economic growth. The result of the survey showed that, entrepreneurial businesses which emerge as a result of entrepreneurship skills development, contributes more than 23% of the country's G.D.P. It also led to the reduction in the unemployment rate and poverty, which have long been the chronic problems of the Nigeria economy. The devastating effects of the resulted unemployment and poverty are in the form of higher rate of crimes which include insurgency, Cattle rustlers, Boko Haram, Niger Delta militants and so on which we are seeing now in Nigeria.
[18] investigated the impact of entrepreneurship development programme on the lively hood of youth, using data from 23 countries collected between the years of 1974 and 2002l. They noted what they referred to as the "refugee" effect where high unemployment rates lead to start-ups of new companies, and this leads to what they referred to as "Entrepreneurial effect" where the livelihood of youth increases after a period of time. They introduced a two equations vector auto regression model to estimate both of those effects. [19] applied this model on Portugal over the period of 1998 - 2000 and discovered that, the rise of entrepreneurship development programme resulted in an increase in self-employment. At the same time the rise of self-employment resulted in increasing the livelihood of youth, resulting to further decrease in unemployment.
[20] performs a Granger-causality test on data from several developed countries, such as Australia, Germany, the United Kingdom and the United States. They realized that there is a bi-directional relationship between the variables for all countries they studied. This suggests not only that does the level of entrepreneurship development programme affect the unemployment rate and the livelihood of youth but high unemployment is promoting more entrepreneurship.
[21] concern with entrepreneurship as a solution to youth unemployment problem. The contribution was built on the hypothesis that, where there is higher rate of youth unemployment, more youth will translate into entrepreneurship; there will be lower level of unemployment.
[22], in their study entrepreneurship development programme and youth unemployment in the kingdom of Saudi Arabia using descriptive statistics analysis and regression model for estimation, data of 31 selected countries from 2008 - 2010 was used, their study found that there is a positive relationship between youth unemployment and entrepreneurship, which signifies that entrepreneurship development programme impacted on the livelihood of youth.
[23] studied Entrepreneurship education as a strategy for boosting human capital development, and employ ability in Nigeria, issues prospects, challenges, and solutions. The study adopts a qualitative research, and use descriptive statistics which found that Entrepreneurship education is the only way to join creation, wealth creation, youth empowerment, peaceful society and economic development.
[5], in their study titled social entrepreneurship as an instrument of curbing youth gangsters in Nigerian urban communities, investigated the effectiveness of social entrepreneurship in providing gainful employment for the teeming youth in Nigeria or communities, they used structured questionnaire on a random sample of 200 entrepreneurs in Lagos Metropolis, their hypothesis tested using Kolmogorov-Smirnov goodness-of-fit test, and the data was analyzed, their findings revealed that, social entrepreneurial activities have helped significantly to reduce the level of unemployment among the teeming youth by improving their livelihood, and by that has contributed positively to the reduction of crime activities of youth in urban areas.
[24], in their paper entrepreneurship education as panacea for youth unemployment. Their paper X-rayed the promotion of entrepreneurship education and vocational counseling in eradicating youth unemployment in the society, they concluded that guiding the youth people to pursue the right types of entrepreneurship education effective and continuous vocational counseling is a sure way of eradicating unemployment.
[25] examined the relationship between entrepreneurship development and youth unemployment reduction in Nigeria. Using the Ordinary Least Square Regression/Correlation models. Their findings revealed that, the regression results show that, an increase in economic activities will improve the level of youth livelihood positively. Their study found that, youth unemployment and rate of entrepreneurship development are related. Their third model strongly supports the need for government to encourage economic activities in order to improve entrepreneurship development that may reduce youth unemployment.
[26] attempted to study the relation between entrepreneurship development programme and youth employment in Nigeria. They used a multiple regression model on the data to examine the need for promoting employment in Nigeria; this study couldn't prove that entrepreneurship reduces unemployment yet its strong recommendation that the government of Nigeria should support the establishment of new entrepreneurship development programme centers.

4 Methodology

This section examines the approach adopted in the process of carrying out this study. It consists of the population of the study, sampling and sampling technique as well as the tool of data analysis used in the study.

4.1 Population of the Study

The population of this study is all the formal Entrepreneurs living in Katsina Metropolis. Formal Entrepreneurs include registered business owners such as restaurants, barbing saloon, retail outlets i.e. shopping centers, supermarkets, welding,

computer repairs, photography, among others. Katsina Metropolis is chosen because of the high concentration of Entrepreneurship development centers and their beneficiaries. There are one thousand six hundred and eighty (1,680) formal entrepreneurs in the study area [27].

4.2 Sample Size

After identifying the targeted population of this study, the next step followed was determining the sample size of this study. In this study, the total sample size used was determined based on Yamane (1967) formula. The formula is given as:

$$n = \frac{N}{1 + N(e)^2}$$

Where,
n = Desired sample size
N = Total population
e = Accepted error limit (0.5 on the basis of 95% degree of confidence) (Garba, 2016).

$$n = \frac{N}{1 + N(e)^2} = \frac{1,680}{1 + 1,680(0.05)^2} = \frac{1,680}{1 + 1,680(0.0025)} = \frac{1,680}{1 + 4.2} = \frac{1,680}{5.2} = 323$$

In order to minimize the problem of low rate of return of questionnaire due to the problem of non-response biased 400 questionnaires are going to be distributed throughout the data collection process. Finally, about 366 filled questionnaires were returned back, which is more than 90% of the total number of the issued questionnaires.

4.3 Sampling technique

The purpose of sampling is to secure a representative group [28]. The proportion of each segment is calculated and the questionnaires were divided on the bases of such proportion estimated in each segment. This study has adopted multi-stage cluster sampling, whereby samples are grouped and clustered on the basis of geographical location areas. In the first stage, the study sampled three local government areas based on the concentration of Entrepreneurs in each of these local governments. The local government areas sampled out include Katsina municipal, Batagarawa and Kaita. In the second stage, two wards were chosen from each of the selected local government areas on the basis of high concentration of Entrepreneurs also. The selected wards include; Kudu III and Yamma II in Katsina municipal. Mallamawa and Cikin gari in Batagarawa, and lastly Kasuwa and Ciromawa in Kaita. This gives a total number of six words to be used in this research. In the third stage, one Entrepreneurs centre where they showcase their businesses each was sampled out from the study. These include Central market from Kudu III and Tsohuwar Kasuwa from Yamma I. Batagarawa, Babbar Kasuwa from Mallamawa and Yar yara from Cikin gari. While, Kaita, Babbar kasuwa from Kasuwa ward and Kasuwar Yan Koli from Ciromawa. In the fourth stage is where the questionnaires were distributed to the respondents based on convenience random sampling. The samples of the questionnaire were shared based on the population of sampled local governments.

4.4 The Empirical Model

The main objective of this study is to assess entrepreneurship development programme as a panacea for youth unemployment in Katsina State, Nigeria. In this case, logistic regression model was employed so as to achieve the stated objectives. The empirical estimated logit model for entrepreneurship development programme is shown explicitly as:

$$Ln\left(\frac{P_i}{1-P_i}\right) = \beta_o + \beta_1 AGE_i + \beta_2 GND_i + \beta_3 EDU_i + \beta_4 SUC_i + \beta_5 TOB_i + \beta_6 LOB_i + \beta_7 TOT_i + \beta_8 FUN_i + \beta_9 CAA_i + \beta_{10} FAB_i + \beta_{11} AMS_i + \beta_{12} LAC_i + \beta_{13} BEX_i + U_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where:

P_i = probability that the youth employment increases.

1– P_i = probability of otherwise

AGE_i	=	Age of the Entrepreneur
GND_i	=	Gender of the Entrepreneur
EDU_i	=	Level of education of the Entrepreneur (i.e. highest qualification)
SUC_i	=	Source of start-up capital of the Entrepreneur
TOB_i	=	Type of business
LOB_i	=	Location of business
TOT_i	=	Type of training
FUN_i	=	Funding
CAA_i	=	Cash assistance
FAB_i	=	Family background
AMS_i	=	Average monthly saving
LAC_i	=	Loan accessibility

BEX_i = Years of business experience

$\beta_1, \beta_2 \ldots \beta_{13}$ are the coefficients of the regressor variables to be estimated. The constant term or intercept of the regression model is denoted by β_o while U_i symbolizes the error term.

5 Discussion of Results

This section provides the discussion of the result obtained from the estimated logistic regression model. However, the result of the variable correlation matrix is presented before discussion on the estimated logit model.

5.1 Correlation Analysis

In this section, a correlation analysis was conducted in order to explore the nature of the correlation that exist among variables used in this study, and also to ascertain whether there are two or more variables that explain the same phenomena (i.e. multicollinearity of variables). Usually, the value of correlation coefficient ranges between 0 - 1. A correlation value of 0.7

Table 1. Variables Correlation Matrix

	MINCOME	PEDPT	BLOCAT	EEMPLOY	MSTATUS	LHOURSW	LAMSAVIN
MINCOME	1.00						
PEDPT	-0.02	1.00					
BLOCAT	-0.04	-0.18	1.00				
EEMPLOY	0.17	0.01	-0.02	1.00			
MSTATUS	-0.09	0.07	-0.22	0.03	1.00		
LHOURSW	0.16	-0.09	-0.12	0.04	0,05	1.00	
LAMSAVING	0.36	-0.09	0.29	0.33	-0.14	0.17	1.00

5.2 Results and Discussion

The main objective of this study is to access entrepreneurship development programme as a panacea for youth unemployment in Katsina State. In this section, the result obtained is presented and discussed. The result of the estimated logit model is presented in Table 2.

Table 2. *Estimated coefficients of Logit Model*

VARIABLES	**Coefficients**	**Marginal effects**
Mincome	-1.32e-05	-1.33e-05
	(1.40e-05)	(0.0000)
Pedptrain	-0.264**	-0.0266357**
	(0.115)	(0.01143)
Blocation	-0.653***	-0.659054***
	(0.235)	(0.02467)
Eemploy	-0.264**	-0.0265852**
	(0.115)	(0.1188)
Mstatus	0.641**	0.0646378**
	(0.312)	(0.03216)
Lhoursw	-0.0765	-0.0077194
	(0.0804)	(0.081)
Lamsaving	0.000190***	0.00192***
	(3.26e-05)	(0.0000)
Constant	1.703	-
	(1.574)	-
Observations	320	

*Source: Computed by the researcher using STATA 14 (2023). Note: the asterisks***, ** and * indicate significance at 1%, 5% and 10% respectively. The figures in parenthesis () are standard errors.*

5.2.1 Participation in EDP Training: This variable represents entrepreneur that participated in entrepreneurship development programme training. This variable was found to be statistically significant at 5% level. Based on the result of the estimated logit model in the above table, the variable has found to have a negative relationship with the dependent variable. The results have shown that an entrepreneur that do not participated in entrepreneurship development programme training tends to have lower log odd ofbeing employed compared to entrepreneur that participated in entrepreneurship development programme training by about 0.3units. This support the finding of study of [29], who found that entrepreneurs

that participated in entrepreneurship development programme training tend to have higher change of getting employment compared to entrepreneurs that failed to participated in entrepreneurship development programme training. This conforms to prior expectation that, when an entrepreneur participated in entrepreneurship development programme training there is high tendency for him to be employed.
Furthermore, estimated marginal effect of this variable shows that the odd of employment of entrepreneurs that do not participated in entrepreneurship development programme training is less compared to entrepreneurs that participated in entrepreneurship development programme training by about 2%

5.2.2 Business Location: The result in Table 2 shows that this coefficient is statistically significantly at 1% level, and found to have a negative relationship with the dependent variable. Based on the estimated result, entrepreneurs that are living in the rural area tend to have lower log odd of being employed compared to the entrepreneurs that are living in the urban area by about 0.65%. This conforms to aprior expectation as those entrepreneurs leaving urban areas tend to have higher opportunity of employment, because there is much concentration of entrepreneurs in the urban area.
This finding is in line with the work of [30], who found that entrepreneurs living in urban areas tend to have a higher chance of employment compared to entrepreneurs living in the rural areas.
Furthermore, estimated discrete effects of this variable shows that the odd of employing of entrepreneurs living in rural areas is less compared to those entrepreneurs that are living in the urban areas by about 0.6%.

5.2.3 Number 0f Employees: This variable represents the number of employees employed by entrepreneur. This variable was found to be statistically significant at 5% level. Based on the result of the estimated logit model, the variable has found to have a negative relationship with the dependent variable and also a negative relationship with the log odds employment. The results have shown that when the number of employees is decreased by the entrepreneur, the log odd of employment decreases by about 0.2 units. The estimated marginal effect of this variable shows that the odd of employment of entrepreneurs living in rural area is less compared to those living in urban areas by about 2%.

5.2.4 Marital Status: The result in Table 2 has shown that, the estimated coefficient of this variable is statistically significant at 5% level and found to have a positive relationship with the dependent variable. On average, a business headed by a married person tend to have higher log odd of being employed by about 0.6 units compared to a business that is headed by a non-married person. This is in conformity with prior expectations that when a business is headed by a married person tend to have higher change in income. This may be because the married entrepreneur had more responsibility on him that makes him to work hard, unlike non-married entrepreneur who did not have much burden on his head. Also it is because a married entrepreneur in some cases tend to be more economically strong, it makes the entrepreneur to strive hard so as to get employment for the betterment of his family unlike unmarried entrepreneur. This is because based on the culture of the people of the study area person usually married when economically can afford the marriage responsibility. This is in line with the findings of [31,32,33], and contradicts the finding of [23].
The estimated marginal effect of this variable shows that the odd of change in employment of entrepreneurs who is married is greater compared to those living in urban areas by about 6%.

5.2.5 Average Monthly Savings: This variable represents the average monthly saving by the entrepreneur. Based on the estimated model, the coefficient of average monthly saving by the entrepreneur was found to be statistically significant at 1% level, and found to have a positive relationship with the dependent variable. The result has shown that increase in the size of monthly saving by an entrepreneur increases the log odd of his being employed by about 0.2 units. This implies that when an entrepreneur increases his savings is as a result of being employed. This conforms to aprior expectation that entrepreneurs that have higher monthly saving tend to be employed, because it's employment that leads to more saving by an entrepreneur. This is in line with the finding of [34,35,36], and contradicts the findings of [37].
Furthermore, the result indicates that the estimated marginal effect in this coefficient is statistically significant at 1% level (Table 2). Based on the estimated result, it increases the odd of employment of an entrepreneur by about 1%.

6 Conclusions and Recommendations

This study was conducted with the main aim of examining entrepreneurship development programme as a panacea for employment generation in Katsina State, Nigeria. Logit regression model was used to achieve the stated objective. The study found that the higher the level of participation in entrepreneurship development programme, the higher the level of employment opportunity for youth in the study area. Similarly, households that are living in the urban areas of Katsina State have more employment opportunities than those living in the rural areas. Number of employees was found to have a positive significant relationship with employment generation. Similarly, the study found that the higher the average monthly saving of entrepreneur is being determined by his employment status. Also, marital status was found to have a positive impact on the youth employment, the households that are headed by a married person have higher tendency of being employed.Therefore, the study recommends policies that ensure increase in the level of entrepreneurship

development programmes centres in the study area, also more awareness should be done to encourage youth participation in entrepreneurship development programme so as to set their businesses that will lead to more job creation in the study area. Government should also put more efforts in equipping entrepreneurship development centers adequately and also to put strict measures in maintaining the centers, this will help in providing adequate training to entrepreneurs.

References

[1] Ogundele, J.K., Akingbade, W. A. & Akinlabi, H. B. (2016). Entrepreneurship training and education as strategic tools for poverty alleviation in Nigeria, American International *Journal of Contemporary Research*, 2(1):148-155.

[2] Sule, M. (2014). The role of entrepreneurship education on job creation among youths in Nigeria. *International letters of social and humanistic sciences.* 4. 87-96.

[3] UNCTAD (2010) Creative economy. Report 2010. UNDP-UNCTAD. Geneva, New York

[4] Bashir, R., & Danlami, A.H. (2022). Gender and loan accessibility among entrepreneurs: empirical evidence from women entrepreneurs in Kano Metropolis. *European Journal of Government and Economics, 11*(1), 97 – 112

[5] Oghojafor, et al. (2011). Unemployment experience in Nigeria: The impact of vocational skills training. *Journal of Pedagogy and Educational. Development*, 10(1-2): 18-25.

[6] Adelekan, S. A., (2017). Impact of entrepreneurship ventures on development of small and medium enterprises in Nigeria case study of three territorial district in Osun state, Nigeria. *International Journal of Economics, Commerce & Management, 6*(9), 423-441.

[7] Ebiringa, O. T. (2013). Entrepreneurship development for sustainable economic transformation: A study of YOUWIN programme in Eastern States of Nigeria, *Journal of Sustainable Development in Africa*, 15(5): 49-59.

[8] Thaddeus A. (2021) Impact of Entrepreneurship Development Programme on Employment Generation. *A Study of Youth Craft villages in Nigeria, 2023.*

[9] Adelekan, S.A, & Tijjani. (2017). Youth Unemployment: Entrepreneurship Development Programme as an Intervention Mechanism. *Afr. J. Bus. Mgt... 4(6):831-835.*

[10] Business Environment and Enterprise Performance Survey (2007) Survey on the performance of Enterprises in Nigeria, 2007.

[11] Hisrich, C. (2005). Growth and distribution impact on entrepreneurial education in the endogenous growth model with human capital accumulation.

[12] Timmons B. (1989). Definition of Entrepreneurship.

[13] Onwubiko, R. (2011). Conceptual definition of Entrepreneurship Development Programme.

[14] Schumpeter J. A. (1939). Innovation and Growth. Long-Cycle Dynamics in the Post-WWII, *American Manufacturing Industries,2003*

[15] Dupas K. & Jonathan K.H. (2015). The role of entrepreneurship in transforming Nigerian economy, seventh conventional lecture. Igbenedian University, Okada. Edo State. 4th December, 2012.

[16] Chen B. (2020). Entrepreneurship regional Development and Job Creation: the case of Portugal, small business economics, 30(1), 49-58.

[17] National Directorate of Employment (2014) Survey on the Impact of Entrepreneurship Skills Development on Nigerian Economic Growth, 2014.

[18] Thurik, K. (2018). The role of entrepreneurship development programme on job creation among youths in Nigeria. *International journal of social and humanistic sciences.* 6. 67-76.

[19] Baptista, S. Preto. (2016). *Improving youth livelihood in SSA: A review of policies and programmes with particular emphasis on the link between sexual behavior and economic well-being.* Report to the International Development and Research Center (IDRC), 2000.

[20] Faria et al. (2016). Entrepreneurship and unemployment. Non-linear bidirectional causality. *Economic modeling, 27(10), 1282-1291.*

[21] Maric et al. (2018). *Youth Livelihoods and Enterprise Activities in Zambia. Report to IDRC Canada. and Management Sciences* (JEEMS) 4 (6): 261-276.

[22] Llisteri, P. & Ishwara P., (2021). Entrepreneurial promotion through entrepreneurship development programme, *Journal of entrepreneurship development, 5(1), 61- 68.*

[23] Sofoluwe, K., (2020). The Heart of Entrepreneurship*", Harvard Business Review, June-July. pp. 77-85.*

[24] Abosede, R. et al, (2017). The Impact of Oil Subsidy Removal on Infrastructural Development in Nigeria (2000/2012). *Journal for Canadian Center of Science and Education.*

[25] Oshua, K. & Helen, J., (2013). *Entrepreneurship Development Programme: A yardstick for Development. Mehtah publishers limited.*

[26] Saheed, D. (2019). A perspective on Entrepreneurship, *Harvard Business Review*.

[27] Mugenda, J. (2007). Impact of Sampling Techniques in a Research work. *A publication of Chedih publishers.*

[28] Youth Craft Village (2023) Statistical Analysis of Entrepreneurial Centers in Katsina State. *A publication of Ministry of Commerce and Industries, Katsina State, 2023.*

[29] Umaru, K., Shuaibu, K. (2009). *Pedagogical Methods of Teaching Entrepreneurship: An Historical Perspective.* Gaming and Simulation, 25(3), 67-7.
[30] Safiriyu, A.M & Njogo, B.O. (2017). Impact of small and medium scale enterprises in the generation of employment in Lagos State. *Kuwait Chapter of Arabian Journal of Business and Management Review. Vol 1, No1.*
[31] Obi, K. (2010). *Stimulating youth entrepreneurship Development skills problems and prospects to enterprise start-ups by young people*, International Labour Organization.
[32] Sule, K. (2019). *Entrepreneurship Development Programme: An Entrepreneurial Perspective.* AUK, 27(5), 57-73.
[33] Oladekunni, E., (2017). *Entrepreneurship Education: A panacea for Development. Royal publishers limited.*
[34] Aribaba, F. O., Asaolu, T. O., & Olaopa, O. (2011). An evaluation of the impact of technological innovative entrepreneurial development programmes on the performance of small scale business in Nigeria. *Global Journal of Business Management and Accounting*, *1*(1), 001-009.
[35] Bennell, P. (2000). *Improving youth livelihood in SSA: A review of policies and programmes with particular emphasis on the link between sexual behavior and economic well-being.* Report to the International Development and Research Center (IDRC), 2000.
[36] Efi, A. E., & Akpan, S. S. (2018). Impediments to entrepreneurship development in the Niger Delta Region of Nigeria. *Canadian Social Science*, *8*(6), 102.
[37] Wooldridge P., (2012). Impact of Entrepreneurship development Programme on Employment Generation, *Journal of Social Sciences AUK, 6(1), 62- 77.*

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp.132-145, November 13-16, 2023

Using Spatial Technology to Identify Environmental Problems in the Deployment of Alternate Economic Base into the Progression of the Coastal Areas

Dipo Theophilus Akomolafe[1], Oluwatoyin Mary Yerokun[2]
{dt.akomolafe@oaustech.edu.ng[1]}

Dept. of Computer Science, Olusegun Agagu University of Science and Technology, Okitipupa[1], Dept. of Computer Science Education Federal College of Education (Technical) Asaba[2], Dept. of Software Engineering and Cyber Security, Wellspring University Benin-City[2].

Abstract
Some of the major problems being faced in the coastal areas of Nigeria are flooding and pollution. These two problems have consistently stood as serious impediments to the area's economic growth. Pollution is the introduction of harmful materials into the environment. To achieve progressive economic goals, it is necessary to identify pollution in its entirety through the use of spatial technology. Geospatial technology is used for the geographic mapping and analysis of the Earth and human. It is inclusive of Geographic Information System, Remote Sensing, and Global Positioning System that are used to capture, analyze, and display data related to positions on the earth. In this paper, geospatial technology was used to obtain relevant data on coastal areas in Ondo State, generate its digital map, identify areas prone to pollution, and suggest likely solutions to ensure and facilitate the deployment of an additional economic base.

Keywords: Flooding, Pollution, Pollutants, GIS, Geo-Spatial Technology, Geodetic Data, Coastal areas, Remote Sensing, Global Positioning System

1 Introduction

Globally, coastal areas are an important abode for the populace, ecosystems, and natural resources [7]. While coastal areas encompass most of the world's most important and diverse economic activities, global warming, population growth, pollution, and poor coastal management and practices are serious problems facing these landforms [1]. The proximity of the coastal areas to the seashas made the areas to be vulnerable and always affected by **sea-level rise**, which is one of the adverse effects of climate change. This has resulted in creating the problems of beach erosion, flooding, coastal inundation, habitat destruction, saltwater intrusion into groundwater aquifers, and ecosystem imbalance.

The coast is one of the dynamic parts of the earth's surface which is an area where land meets the ocean or sea or as a line that forms the boundary between the land and the ocean or a lake. Coastal areas are local administrative units (LAUs) that are bordering or close to a coastline. A coastline is defined as the line where land and water surfaces meet (border each other). In the coastal areas, the wet season is warm and overcast, the dry season is hot and partly cloudy year-round, and the temperature is typically from 72°F to 90°F and is rarely below 6°F or above 93°F. Apart from oil found in the area, other mineral/ raw materials available in the area include glass sand salt, Tar sand/Bitumen, quartz, and clay. Agricultural products such as fish, Poultry, piggery, Maize, Palm oil, Vegetables, Timber, Raffia, Poultry, Copra, Cocoyam, Bananas, and Cassava are also found and grown in the area. The coastal areas in Nigeria are majorly populated by the Ijaws [12]. The natural environment of the area is particularly suitable for the development of large-scale rice plantations and the salt industry. It is obvious the means of sustenance in the areas without government intervention is primarily fishing and agricultural-related activities. Some cash crops do thrive well substantially in some areas and this too has contributed immensely to the economic growth of the coastal areas. However, [4] [13] examined the likely contribution of a blue economy if adopted in the coastal areas but found out that the challenges confronting the area are overwhelming and too enormous for the adoption of that type of economy. However, [4], [5], [6], [(8] suggested likely solutions to the problems.

The coastal areas are facing several problems and these problems can be traced and categorized into geomorphological agents and anthropogenic activities. [2] had early carried out the morphometric analysis of the coastal areas of Ondo State while [3], [4] had adopted geospatial technology in road transportation. These problems had previously been enumerated, classified, and discussed from different perspectives by [11], [14], [10] What is common to this identification is the effects of the associated problems on the coastal areas; the severity of the effects has been one of the major hindrances to the adoption of the workable type of economy that can transform the development and growth of the area.[9], [15], [16] Consequently, this research is based on using geospatial technology to identify in detail the major environmental issues confronting the coastal areas of the country with emphasis on coastal areas of Ondo State being the longest coastal line in the country.

2 Data Collection

The steps involved in data collection are the downloading of Landsat satellite images, Ikonos Image, and Aster SRTM DEM from USGS online data archives (www.glovis.usgs.gov); clipping of the area of interest, data processing, generation of the colour composite images and vegetation cover (VC) images, generation of Normalized Differential Vegetation Index (NDVI) map, generation of digital elevation model (DEM) and creation of the cadastral map.

2.1 Data Types and Sources

The datasets for this research were acquired from primary and secondary sources. The primary data used for this study includes the round Control Points (GCPs) of some landmarks in Ilaje LGA were acquired using Garmin handheld GPS 78sin the Longitudinal and Latitudinal degrees unit of the Geographic Coordinate System (GCS).

The secondary data used in the research are listed below

i. The topographic map (1967) of Ilaje was obtained from the Cartographic Section of the Centre for Space Research and Applications (CESRA) and the GRID-3 website.
ii. Landsat TM 1984, Landsat ETM+ 2001 and Landsat OLI 2022 were acquired from the digital web of the United States Geological Survey (USGS) Earth Explorer.
iii. Administrative map of Ondo State.

2.1.1 Software packages

The software packages used in processing the acquired datasets are:

a) *ArcGIS 10.7* – This was used to create map boundary of the study area in this project, also the power option of Interpolated Distance Weighted (IDW) is used to interpolate the results and its reclassification to obtain Spatial Pattern maps. NDVI calculations and their images are also done from the software.

b) *Erdas Imagine 2015* – this is used for displaying and clipping areas of interest from the downloaded imageries for it to be imported into Ilwis environment for further processing.

c) *ENVI 5.3* – This is used to perform the band staking in order to obtain the color composite and image classification.

d) *Microsoft Office* is used for statistical analysis, report writing, and production of charts and graphs.

2.1.2 Materials

The study made use of Landsat TM (1984), ETM (2001), OLI (2022), and SRTM imagery from the United States Geological Survey (USGS).
The dataset and their descriptions are summarized below

Table 1 Description of datasets

S/N	DATA	DATA FORMAT	SOURCES OF THE DATA	DESCRIPTION
1	GPS coordinates of landmarks in the study area	Numerical	Field Survey	The coordinates were used to locate the positions of landmarks
2	Topographic map (1967)	Digital Map	Osun state Ministry of Lands and Survey	The streams, rivers and lake in the Study Area were digitized from it.
3	Landsat TM (1984)	Digital Map	Digital web	Was used to determine the Landuse/Landcover of Ilaje LGA in 1984
4	Landsat ETM+ (2001)	Digital map	Digital web	Was used used to determine the Landuse/Land cover of Ilaje LGA in 2001
5	Landsat 8 (2022)	Digital map	Digital web	Was used to determine the Landuse/Landcover of Ilaje LGA in 2022
6	Shapefile of the study area	Digital Map	GRID-3	To delineate the extent of the study area
7	SRTM (30m)	Digital Map	Digital web	The Digital Elevation Model was created from it.

2.2 Generation of the NDVI

The NDVI calculation was performed to find out the changing pattern of the vegetation during the selected period of this study due to satellite data available (1984, 2001 and 2022).
The following algorithm was used for the analysis.

$$\text{NDVI} = \frac{NIR-Red}{NIR+Red}$$

where *NIR* and *R* is the reflectance in the near-infrared and red portion of Electromagnetic spectrum respectively. The NDVI is the most widely used index in studying vegetation related issue. It can also be used to indicate deficiencies/improvement in rainfall and portray drought/flood event impact on vegetation in a particular geographical location both timely and spatially. NDVI is an important factor in flood risk analysis and the technique is used for analyzing the response of vegetation cover to flooding characteristics. The NDVI is calculated from two bands in the Landsat images: the near infra-red (NIR) band and the Red band. The NDVI takes advantage of the feature of these two bands that is the high reflectance for plants materials of the NIR band and the chlorophyll pigment absorption of the red band to produce an image that presents greenness or relative biomass. In order to generate Greenness Index (GI) map, the resulted NDVI maps were classified in ArcGIS 10.7 environment using the threshold NDVI values in the Table.

2.3 Land use/Landover (LULC) classification

The different LULC classes of the study area were grouped into six for easy analysis and assessment. The LULC classification includes the Water Bodies, Sparse Vegetation, Dense Vegetation, Grass/Bare

Lands, and Built-Up Areas. The landcover classes are described according to Anderson *et al.* (1976) in the tables below.

Table 2 Description of land use / land cover classes

Landuse/landcover class	**Description**
Built-up Areas	Built-up land is composed of areas of intensive use mostly covered by structures. They include cities, towns, villages, strip developments along highways, transportation, power, communications facilities, areas occupied by shopping centers, industrial and commercial complexes, and institutions that may, in some instances, be isolated from urban areas.
Water Bodies	Water is defined as areas within the land mass that persistently are water covered. Waterbodies include streams, canals, lakes, reservoirs, bays and estuaries.
Dense Vegetations	Dense vegetation is dominated by woody vegetation, also comprise seasonally flooded bottomland hardwoods, mangrove swamps, shrub swamps, and wooded swamps. They are separated from other categories of forest land because of their usefulness in many environmental planning activities.
Sparse vegetation	The sparse vegetation refers to dispersed vegetation. Vegetation is mostly widely spaced and scrubby. They include areas of soil with less nutrition that may be natural or human induced.

Source: (Anderson et al., 1976)

2.2.1 Accuracy Assessment

The accuracy assessment works by comparing classification with ROI or ground-truth data to evaluate how well the classification is representative of the real world. The Accuracy assessment of the classes was done using the confusion matrix technique. This was to be sure of a high level of accuracy in pixel selection and was shown in tables in square metres and percentages. Confusion matrix is given as:

3 Results and Discussion

3.1 Normalized Difference Vegetation Index (NDVI)

The NDVI results reveal the rapid degradation of the vegetation within the study area between the years. The vegetation growth over the area has played important role in preventing coastal hazards such as flood and coastal inundations. The vegetation form a resistance to the free flow of water from the swamps into the residential area whenever there is heavy rainfall. However, due to the urbanization and the growing population of the study area, there has been a high reduction in vegetation as well as sand filling of wet lands across the study area from 1984 to the year 2022.
The NDVI maps (as shown in figures 4.3(a-c)) has shown the vast degrading vegetation cover in the area, despite the efforts of reforestation and green policies in recent time.

3.2 Vegetation Analysis

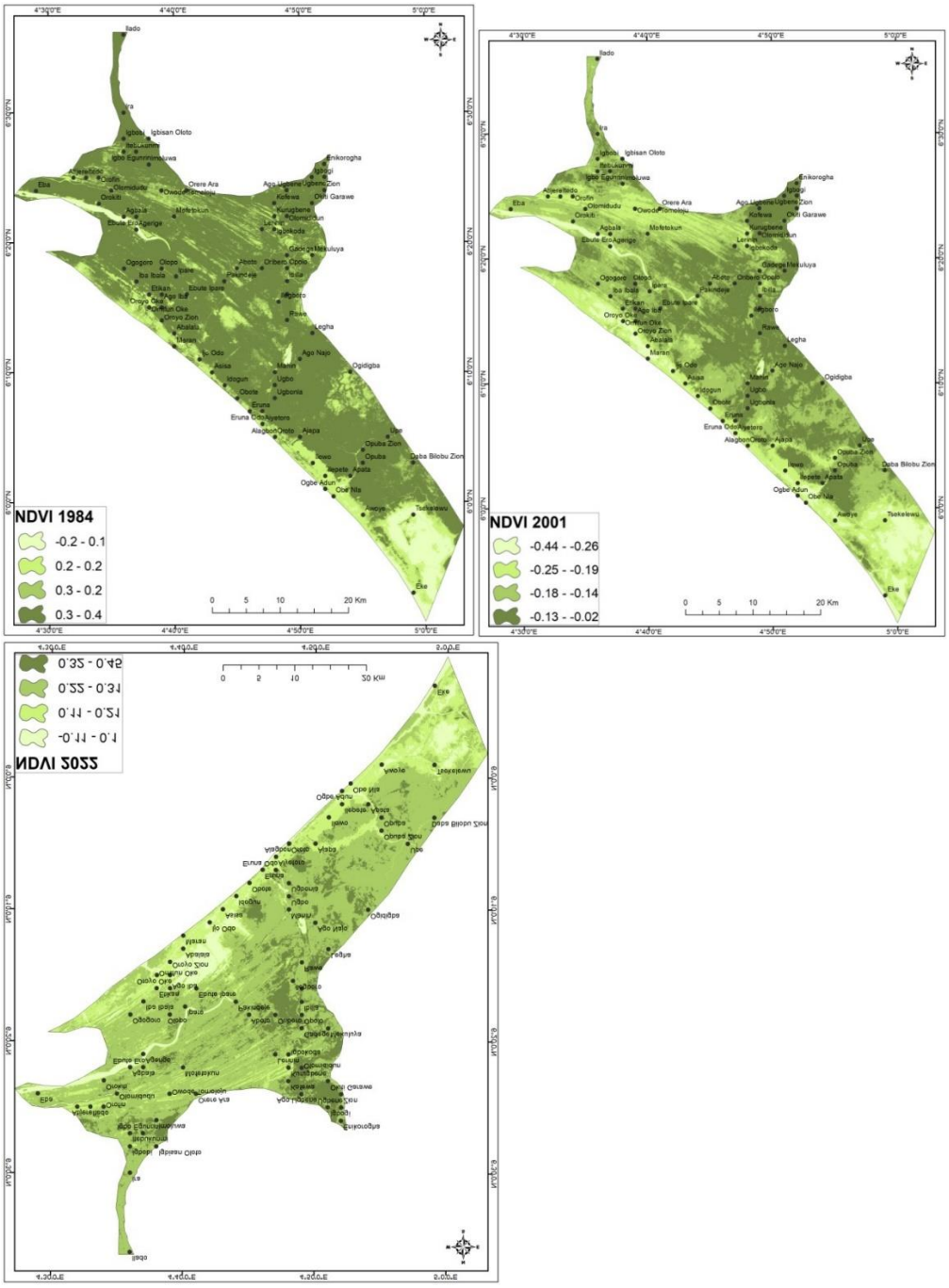


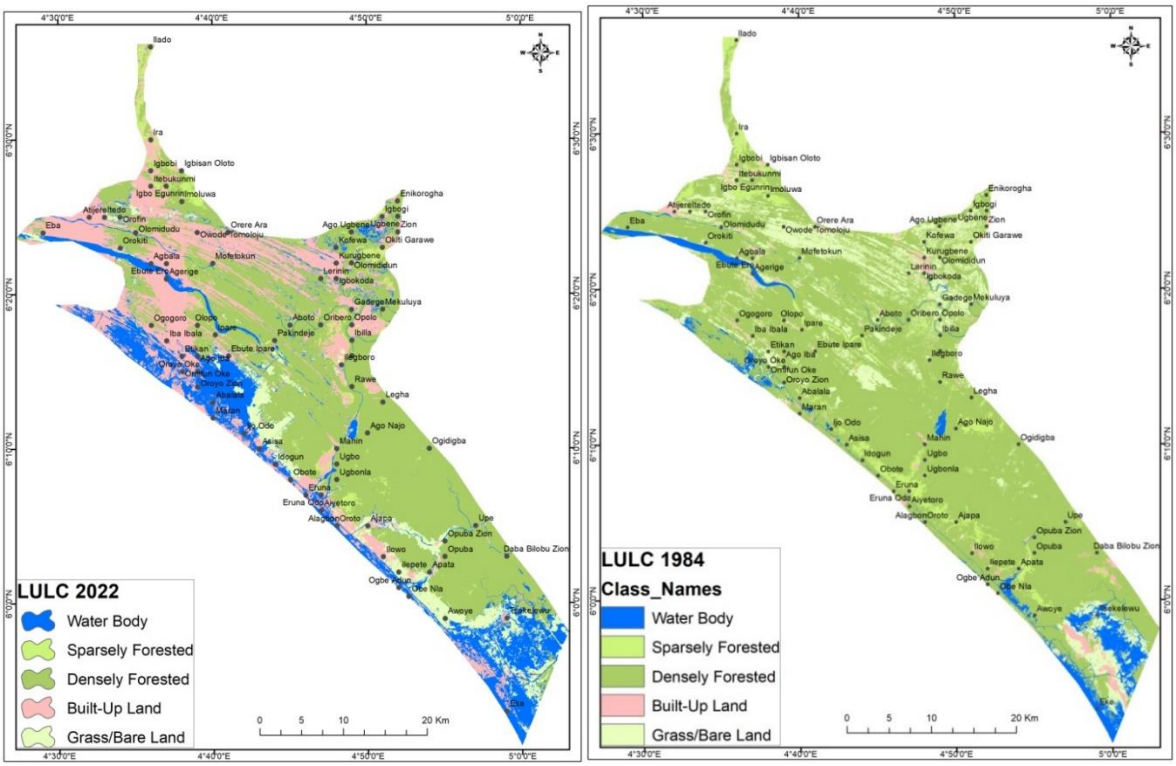
Fig.1a-c NDVI maps for Ilaje LGA for 1984, 2001 and 2022

3.3 Land Use Analysis

Land use refers to the current use of the land, whether for agriculture or non-agriculture. Vegetation and land use plays a major influence in the rate of soil erosion along the Ilaje coastline. Land cover such as water body and rock outcrops have the least potential for soil erosion. Vegetation covers also slower soil erosion process while surfaces; and open land agricultural land are more prone to soil erosion by water. The Figure shows the land use land cover of the study area.

The five (5) major classes of land use land cover were extracted from the satellite image for the period of 38 years ranging from 1984, 2001 and 2022 respectively (Figure .a-c). The maximum likelihood classification of the study area feature reveals that vegetation has been experiencing a downward trend from the year 1984 to 2022. Dense Vegetation is being taken over by the Sparse vegetation and other land uses. However, the Built-Up areas were continuous due to urban expansion and human-induced factors in the area.

The increase in the built-up area may have emerged due to the migration of people from rural to semi-urban ilaje communities in search of better livelihood. The semi-urban migration of people has led to the expansion of urban areas and an increase in social and economic activities along flood plains thus increasing the risk of urban dwellers and infrastructures to natural disasters such as floods. This expansion is indicated by an increase in the population of people living in the area which has also caused a rapid degradation of the vegetated areas, while the built-up witnessed a rapid expansion. It is therefore noteworthy that a built-up area is evident in the fact that many buildings, industries, companies, institutions, and religious structures sprang up in response to the rapid developments of the area.



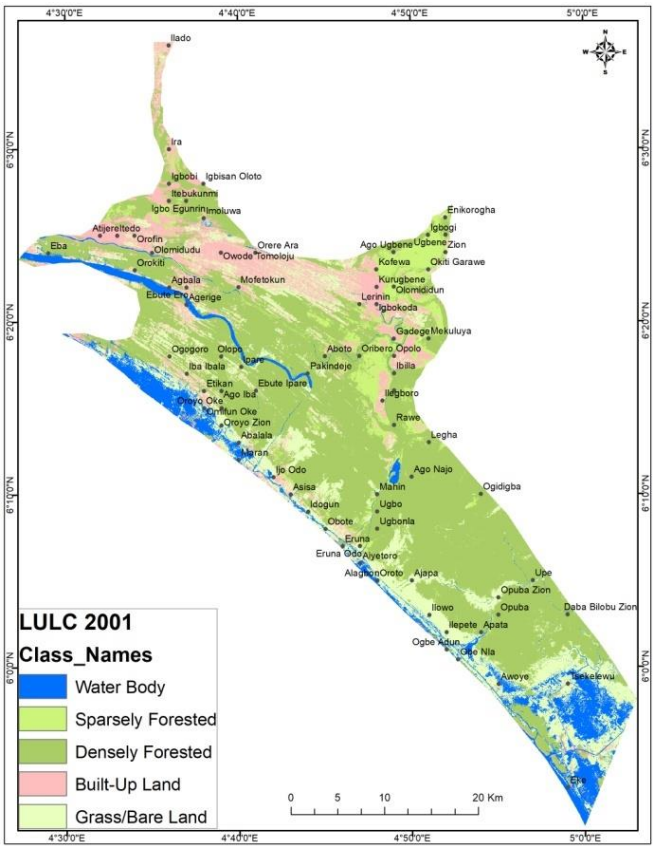


Fig.2a-c LULC maps for Ilaje LGA for 1984, 2001 and 2022

3.4 Digital Terrain Analysis

The spatial analysis and interpretation of the terrain features in Ilaje and its environs demonstrates efficiency of GIS tools in mapping for coastal vulnerability and assessment of terrain characteristics. The contour map (shown below) displays an output isoline data set showing the varying heights of the study area. The value of each line represents all contiguous locations with the same height, magnitude, or concentration of whatever the values on the input data set represent. Based on the topographic map of the study area, which has contour interval (10 m), the upper parts and environs have the highest elevation, while the bottom parts are low land-terrain areas with steepness down the coastline. The general topographic pattern of study area was found to be decreasing down the coastlines, and increasing up the inland, with a land terrain ranging between -16 m and 70 m (shown below).

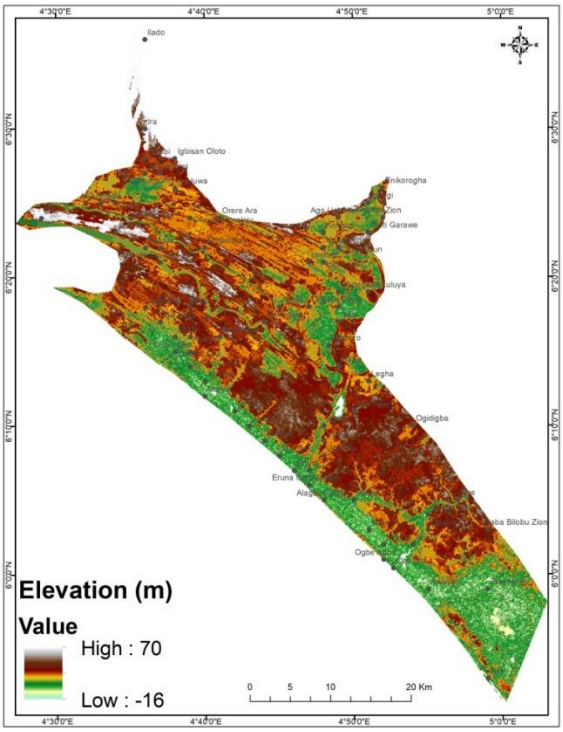


Fig.3a Digital Elevation Model map of Ilaje LGA

3.5 Slope Analysis

From the Slope map below, steep land has more potential for water erosion than flat land such that erosive forces transport and deposit soil particles in a distant place. Therefore, from the study area analysis, land cover with a slope > 20 is considered to be steep to very steep while 10-20 are sloping to strongly sloping; and less than 10 are flat to gently sloping (FAO 2006). The study area is characterized by varying degrees of slope ranging from flat to gently sloping to very steep topography. Ilaje and its environs are categorized under steep slope and more than 50% of the basin area is flat to gentle sloping (Figure 5b).

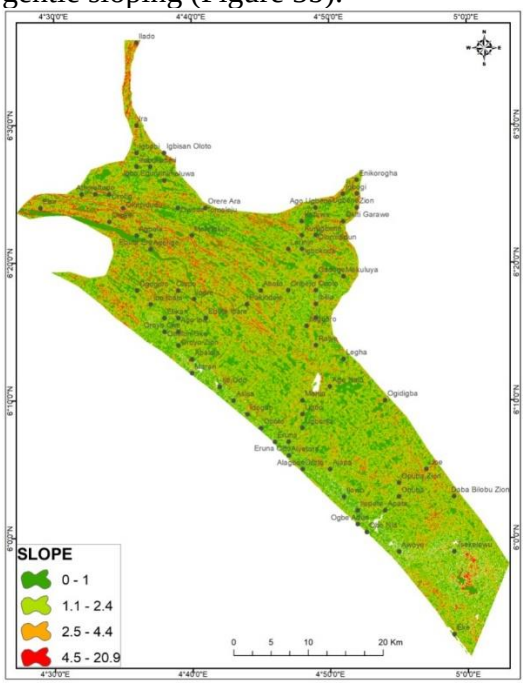


Fig.3b Slope map of Ilaje LGA

The Shuttle Radar Topography Mission (SRTM) image was used to generate the slope map for Imo state using Digital Elevation Model. Slope influences the direction of and amount of surface runoff or subsurface drainage reaching a site. Slope has a dominant effect on the contribution of rainfall to stream flow. Slope controls the duration of overland flow, infiltration and subsurface flow. Steeper slopes are susceptible to surface runoff, while flat terrains are susceptible to water logging and inundations in the area. The slope distribution within the study area ranges from 0^o to 24.2^o. Water from rainfall tends to flow from regions of steep slopes as runoff to flat regions where the water gathers to become a flood. The slope factor was ranked based on its impact on causing floods. Areas with lower slope values i.e. flat or almost flat areas were ranked highest because they support flood by allowing water to gather in them. Areas with gentle slopes are ranked next as they have little impact in causing floods. Steep slopes are ranked lowest as they do not allow water to gather thereby they do not support flooding.

3.6 Soil Analysis

The soil analysis was obtained from scanned processed soil map of Nigeria sourced from NGSA, and the Harmonised World Soil Database (HWSD) viewer. The data was pre-processed to a format that could be used for the analysis using ArcGIS. The data was digitised and then converted to a raster format.

The five (5) major soil classes for the Ilaje and its environs include Gleysols, Aeronosols and Acrisols with very deep-poorly sandy soils along the coastline. This is the dominant soil composition, covering about 61% of the entire study area. The other soil types are pre-dominant at the upper parts consisting of deep drained sandy soils, both amounting the remaining 39%. The geological formation, showing the distribution of various types of bedrock in the area, was obtained from the Nigeria Geological Survey Agency (NGSA). The presence of alluvium and deltaic basins at shallow depths, rock outcrops and environmental degradation over time has led to a serious reduction in soil depth and arable land surface edging and opening for excess surface runoff and stream flows. The result shows that the geological and geomorphologic characteristics of the study area control the system of flow and several other associated surface processes (e.g. flow direction,
infiltration rate, water accumulation, etc.).The seasonal flooding in the study area makes the alluvial soils of the area experience rock weathering, flowing down the terrain towards the southern parts, leading to sheet erosion of the soil with deposition.

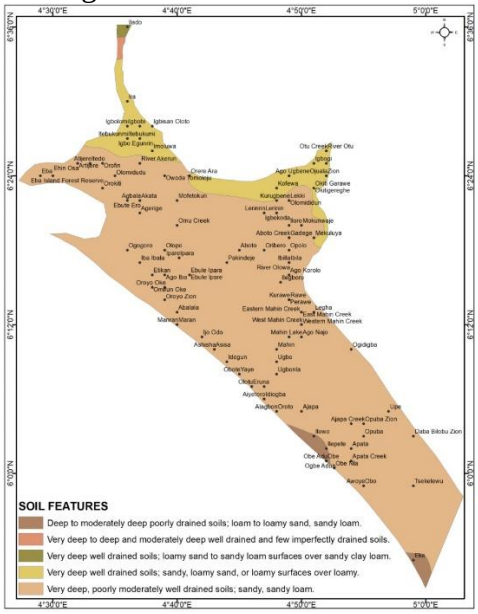


Fig. 3c Soil map of Ilaje LGA

3.6.1 Rising Sea Levels and Coastal Inundation

The study adopts the GIS-based inundation model to produce both land use and inundation maps for several scenarios of coastal sea level rises at 1m, 2m, and 5m, and their impacts on the coastal communities.

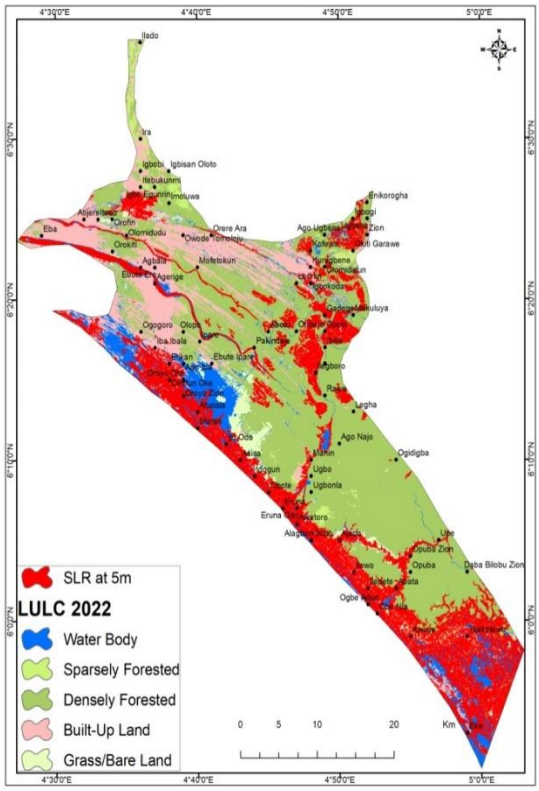
As shown in Fig. 7a-c, the sea level rise at the local level depends on many local factors among which the fact that the sea-level response to global warming will not be globally uniform, since factors like changes in ocean currents and the changing gravitational pull of continental ice affect the local rise. Secondly, superimposed on the climatic trend is natural variability in sea level, which regionally can be as large as the climatic signal on multi-decadal timescales.

Following these observations, the study took into account other severe possibilities that could cause local perturbations, such as previously unheard-of anthropogenic activity in the study area or potential catastrophic sea level rise in the future.

The findings of this study, however, highlighted the necessity and significance of coastal planning and management to improve local residents' capacity for adaptation. Despite the fact that fishing is primarily the main source of income for rural residents in the area, there have been reports of a decline in fishing activities as a result of several factors, including rising waters and marine pollution, which is primarily brought on by oil spills in some parts of the region.

Due to the danger to the main source of income in rural coastal settlements and the consequent rise in poverty, the recent decline socio-economic activities among rural people has resulted in a high rate of rural-to-urban migration. a severe problem that coastal residents in the area experience that is made worse by manmade actions such as climate change. There have been occasional reports of sediment accumulation in the area.

Due to the high degree of vulnerability of the region anticipated by this study, environmental agencies must implement coastal adaptation techniques as preventative measures to avert the losses related to an elevated sea level. In addition, this study serves to provide information to aid coastal planners and create awareness for coastal inhabitants.



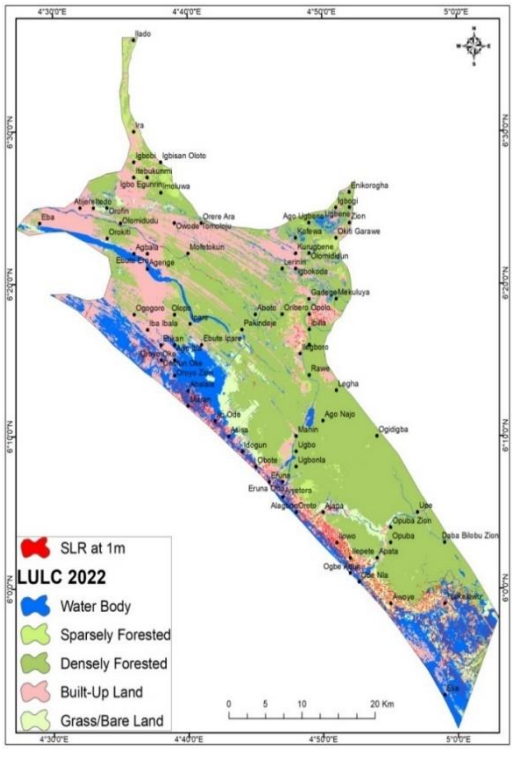


Fig.4a-c SLR Inundation maps of Ilaje LGA at 1m, 2m and 5m levels.

2.1.1 3.6.2 Rainfall Pattern of Ondo

2.1.2

Communities

Double peaks rainfall pattern was observed for Ilaje LGA with peaks around June and September (Figure 8a) and a relatively drier August besides sliding into the dry months between December and February. The rainfall pattern over the study area is typical of rainforest/coastal transition zone, onset is at the early months of the year and it retreats towards the end of the year. Figure 8b shows the averaged temporal pattern of rainfall for an averaging period of 30 years (1992 - 2021). Rainfall peaks in July, with a little break in August referred to as the Little Dry Season (Figure 8a) and the least monthly rainfall amount is in the dry seasons (December to February). Implications of high rainfall amount in months like July is in the likelihood of excessive wash – away of topsoil due to aggressive runoffs and flood events.

Peak value of around 2730 mm/year was observed between 1992 and 2021 (Figure 8b), while minimum values of around 2030 mm/year was recorded around a long term annual mean rainfall of 2305 mm/year.

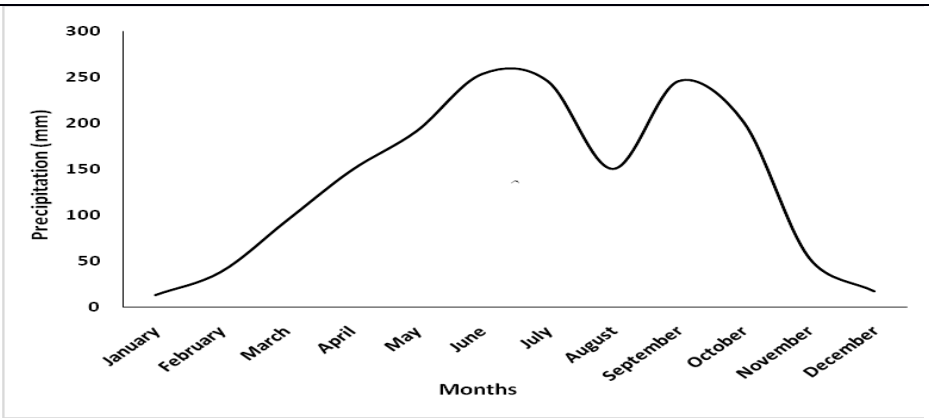


Figure 5 Monthly pattern of rainfall for Ilaje LGA

Data Span / Unit:	**Type:**
Climatology	Time series plot

Fig. 5a Time series plot for Rainfall trend over Ilaje LGA

Table 3.1 Monthly observation of average precipitation in Ilaje LGA (1992 - 2021**)**

Months	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Rainfall (mm)	13.2	38.2	93.6	148.8	191.7	253.7	246.1	150.4	245.8	201.6	53.9	17.2

Table 3.2: Statistical of historic annual precipitation dataset for Ilaje LGA

Statistics	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
	2305	295.80	2030	2730

2.2

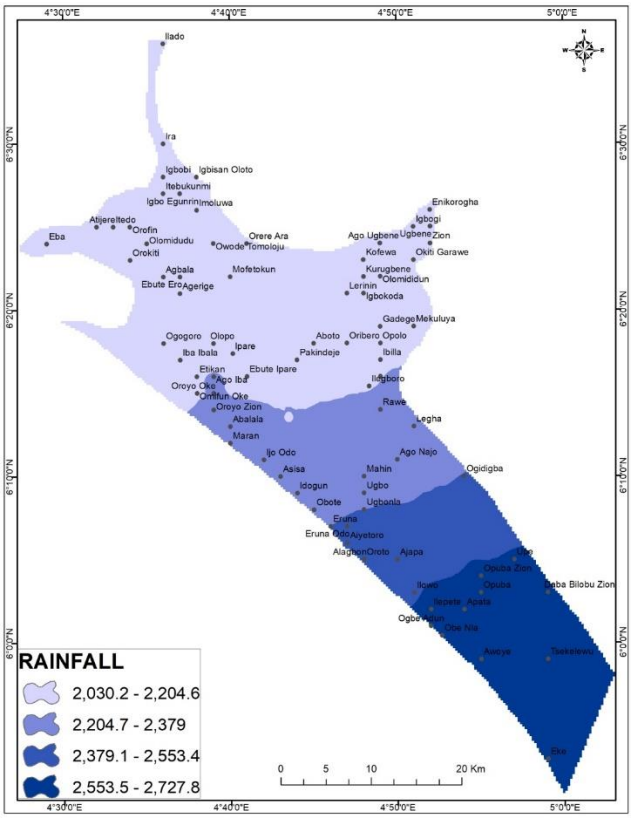


Fig.5b Rainfall map of Ilaje LGA

Figure 8b shows stepwise changes in annual rainfall being received in Iljae LGA due to a changing climate, based on the ecological effect of climate change along the Nigerian coast, is seen in the disturbed patterns of rainfall, a decrease in some regions and an increase in other regions, and sea level rise.

Quantitatively, a forward jump in the climatic pattern as seen in RCP 6.0 and 8.5 (Table 4.3) between 2021 to 2050 means that Ondo coastal communities would receive more annual rainfall under these two radiative forcing scenarios. The implication of increasing annual rainfall is bogus, as it may impact the number of extreme weather events and flood occurrences.

Table 3.3 Climatology of Rainfall Amount changes for Ilaje LGA through the time slices

	1992-2021	**2021 - 2050 (RCP 6.0)**	**2021 - 2050 (RCP 8.5)**
Mean	2510.9	2605.2	2635.4
Standard Deviation	230.9	256.0	277.3
Minimum	2305	2465.2	2550.5
Maximum	2730	2805.1	2860.2

4 Conclusions

The environmental problems confronting the coastal areas have been a danger to the main source of income in rural coastal settlements and the consequent rise in poverty,Furthermore, even though fishing is primarily the main source of income for rural residents in the area, the various reports of a

decline in fishing activities as a result of several factors, including rising waters and marine pollution, which is primarily brought on by oil spills in some parts of the region are problems to be solved.

The findings of this studyshow that even though the people in the coastal areas rely heavily on fish farming as a major source of earnings, other types of agricultural systems can still be conveniently practiced. The area is blessed with fertile land and other mineral resources aside from petroleum, the necessity and significance of coastal planning and management to improve residents' capacity for adaptation and practice of other agricultural systems is the paradigm shift required.The recent decline in socio-economic activities among rural people has resulted in a high rate of rural-to-urban migration. a severe problem that coastal residents in the area experience that is made worse by manmade actions such as climate change. There have been occasional reports of sediment accumulation in the area.
This study has identified the numerous problems confronting the coastal areas using geospatial technology and suggested proper coastal planning and management as a way to solve the problems.

References

[1] Adger, W.N., et al. (2005). Social-Ecological Resilience to Coastal Disasters. Science, 309, 1036-1039.
[2] Akomolafe, D.T. (2022). Morphometric Analysis of the Coastal Areas of Ondo State. Computer Networks, 212, 108585.
[3] Akomolafe, D.T., Adekayode F.O., Gbadeyan J.A., Ibiyemi, T.S. (2009). Enhancing road monitoring and safety through the use of geospatial technology. International Journal Physical Sciences, 4(5), 343-348.
[4] Akomolafe, D.T., Yerokun, O.M., Akande, S. (2022). Challenges and Prospects of the Deployment of Blue Economy in the Coastal Areas of Ondo State. Journals of Production, Operation Management and Economics, 02(03).
[5] Bethel, B.J., Buravleva, Y., & Tang, D. (2021). Blue Economy and Blue Activities: Opportunities, Challenges, and Recommendations for The Bahamas. Water, 13, 1399. **https://doi.org/10.3390/w13101399**
[6] Bethel, B.J., Buravleva, Y., & Tang, D. (2021). Blue Activities: Opportunities, Challenges, and Recommendations for The Bahamas. Water, 13, 1399. **https://doi.org/10.3390/w13101399**
[7] Bird, E.C.F. (2008). Coastal Geomorphology: An Introduction (2nd ed.). John Wiley & Sons.
[8] Boonstra, W.J., Valman, M., & Björkvik, E. (2018). A sea of many colors—how relevant is blue growth for capture fisheries in the Global North, and vice versa? Marine Policy, 87, 340–349.
[9] Creel, L. (2003). Ripple Effects: Population and Coastal Region. Population Reference Bureau, 1-9. **https://books.google.com.br/books/about/Ripple_Effects.html?id=8qcltwAACAAJ&redir_esc=y**
[10] Vermunt, D.A., Negro, S.O., Verweij, P.A., Kuppens, D.V., Hekkert, M.P. (2019). Exploring barriers to implementing different circular business models. Journal of Cleaner Production, 222, 891-902. **https://doi.org/10.1016/j.jclepro.2019.03.052**
[11] Oyewo, E.O., Ajayi, T.O., Dublin-Green, C.O., Ajao, E., & Awosika, L.F. (1999). Anthropogenic activities and their impact on aquatic resources in the Nigerian coastal zone. In Impact of pollution on aquatic living resources in Africa (pp. 79-102). Lagos (Nigeria).
[12] Hay Mele, B., Russo, L., & D'Alelio, D. (2019). Combining marine ecology and economy to roadmap the integrated coastal management: a systematic literature review. Sustainability, 11(16), 4393.
[13] Holma, M., Lindroos, M., Romakkaniemi, A., & Oinonen, S. (2019). Comparing economic and biological management objectives in the commercial Baltic salmon fisheries. Marine Policy, 100, 207–214.
[14] Hunt, B., & Vincent, A.C.J. (2006). Scale and Sustainability of Marine Bioprospecting for Pharmaceuticals. AMBIO: A Journal of Human Environment, 35, 57-64. **http://www.bioone.org/doi/abs/10.1579/0044-7447%282006%2935%5B57%3ASASO%20MB%5D2.0.CO%3B2**
[15] Lee, K., Noh, J., & Khim, J.S. (2020). The and the United Nations' sustainable development goals: challenges and opportunities. Environmental International. **https://doi.org/10.1016/j.envint.2020.105528**
[16] Romero-Colmenares, L.M., Reyes-Rodríguez, J.F. (2022). Sustainable entrepreneurial intentions: Exploration of a model based on the theory of planned behavior among university students in north-east Colombia. The International Journal of Management Education, 20(2), 100627. **https://doi.org/10.1016/j.ijme.2022.100627**.

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp.146-150, November 13-16, 2023

The Assessment of Business Intelligence Tools and Review of its Evaluations

Rabiu Ibrahim[1], Shamsiyya Adam Muhammad[2], Joshua Mamman[3]
{rabiu.ibrahim@aun.edu.ng[1], shamsiyyamadam@gmail.com[2], joshua.mamman@aun.edu.ng[3]}

Giant Horse Int. American University of Nigeria[1], Giant Horse Int.[2], American University of Nigeria

Abstract
Business intelligence (BI) is a set of techniques and tools used to collect, analyze, and transform data into information that can be used to make informed business decisions. With the rise of big data analytics, the landscape of BI tools has become more complex and diverse. This report investigates five different tools used for business intelligence: Tableau, Power BI, QlikView, SAP BusinessObjects, and MicroStrategy. The methodology used for evaluating the tools includes a comparison of features and functionalities, user interface and ease of use, data integration capabilities, and cost. The analysis of the findings includes a discussion of the strengths and weaknesses of each tool, as well as the identification of relevant models, theories, and frameworks used in the evaluation process. The results of the evaluation indicate that Tableau and Power BI are the most comprehensive and user-friendly tools, with strong data integration capabilities and affordable pricing. However, the final recommendation will depend on the specific needs and budget of each organization.

Keywords: Business intelligence, tools, techniques, QlikView, SAP, Tableau, Power BI, MicroStrategy, BusinessObjects

1 Introduction

Business intelligence (BI) is the process of collecting, analyzing, and transforming data into information that can be used to make informed business decisions (Gangadharan & Swami, 2004; Bhardwaj & Baliyan, 2019; Biagi & Russo, 2022; Carlisle, 2018). The goal of BI is to provide stakeholders with insights into the performance of the business, identify trends, and detect patterns that can inform strategic and operational decisions (Niu, Ying, Yang, Bao, & Sivaparthipan, 2021) (Zhao & Strotmann, Information science during the first decade of the web: An enriched author cocitation analysis, 2008). The increasing availability of data and the rise of big data analytics have led to the development of more sophisticated BI tools that can handle larger volumes and more complex types of data (Xia & Gong, 2014; Hamad, Al-Aamr, Jabbar, & Fakhuri, 2021). BI tools are used by organizations of all sizes and across all industries, from finance and healthcare to retail and manufacturing (Raj, Wong, & Beaumont, 2016).

2 Review

Tableau: Tableau is a data visualization tool that allows users to connect to a wide variety of data sources and create interactive dashboards and reports (Praveena & Bharathi, 2017; Hoelscher & Mortimer, 2018; Gangadharan & Swami, 2004) (Reddy, Sangam, & Srinivasa Rao, 2019) (Xia & Gong, 2014). Tableau's strength lies in its ease of use and user-friendly interface, which makes it accessible to non-technical users (Carlisle, 2018). Tableau offers a wide range of visualization options, including charts, graphs, and maps, as well as the ability to perform complex calculations and create custom calculations using its intuitive drag-and-drop interface (Hilbert & Redmiles, 2000). Tableau also offers a robust set of data integration features, including the ability to connect to data sources such as Hadoop, Amazon Redshift, and Salesforce, among others (Saraiya, North, & Duca, 2005). Tableau's pricing is based on a subscription model, with options for both individual and enterprise users.

Power BI: Power BI is a business analytics service provided by Microsoft that allows users to connect to various data sources and create interactive dashboards and reports (Mitra, Pal, & Mitra, 2002) (Carlisle, 2018). Power BI offers a range of visualization options, including charts, graphs, and maps,

as well as the ability to perform complex calculations and create custom calculations using its DAX language (Biagi & Russo, 2022). Power BI's strength lies in its integration with other Microsoft products, such as Excel and SharePoint, as well as its collaboration features, which allow multiple users to work on the same report or dashboard (Hilbert & Redmiles, 2000; Al-Okaily, Teoh, Al-Okaily, Iranmanesh, & Al-Betar, 2023; Crawley, Hand, Kummert, & Griffith, 2008). Power BI also offers data integration features such as the ability to connect to data sources such as Hadoop and Salesforce (Niu, Ying, Yang, Bao, & Sivaparthipan, 2021). Power BI is available as a cloud-based service or as an on-premises installation, with pricing based on a subscription model (Richardson, Sallam, Schlegel, Kronz, & Sun, 2020; Murphy, 2013)

QlikView: QlikView is a data discovery and visualization tool that allows users to connect to various data sources and create interactive dashboards and reports (Drake & Walz, 2018). QlikView's strength lies in its associative data model, which allows users to explore data and discover insights in real-time (Murphy, 2013; Moss & Atre, 2003). QlikView offers a range of visualization options, including charts, graphs, and maps, as well as the ability to perform complex calculations and create custom calculations using its expression language (Niu, Ying, Yang, Bao, & Sivaparthipan, 2021). QlikView's pricing is based on a perpetual license model, with options for both individual and enterprise users (Richardson, Sallam, Schlegel, Kronz, & Sun, 2020).

SAP BusinessObjects: SAP BusinessObjects is a suite of business intelligence tools that includes reporting, data visualization,and data integration capabilities (Richardson, Sallam, Schlegel, Kronz, & Sun, 2020). SAP BusinessObjects offers a range of visualization options, including charts, graphs, and maps, as well as the ability to perform complex calculations and create custom calculations using its formula language (Hamad, Al-Aamr, Jabbar, & Fakhuri, 2021; Olszak, Ziemba, & Koohang, 2006). SAP BusinessObjects also offers a robust set of data integration features, including the ability to connect to various data sources and transform data into meaningful insights (Reddy, Sangam, & Srinivasa Rao, 2019). SAP BusinessObjects is available as both a cloud-based service and on-premises installation, with pricing based on a subscription or perpetual license model (Drake & Walz, 2018; Kapoor, 2010).

MicroStrategy: MicroStrategy is a business intelligence platform that offers a range of reporting, data visualization, and data integration capabilities (Hilbert & Redmiles, 2000). MicroStrategy's strength lies in its scalability and ability to handle large volumes of data, as well as its comprehensive set of data integration features (Ozdemir, Eyüp Emre, & YILDIZ). MicroStrategy offers a range of visualization options, including charts, graphs, and maps, as well as the ability to perform complex calculations and create custom calculations using its formula language (Saggi & Jain, 2018; Wu, Zhao, Zhu, Tan, & Zheng, 2011). MicroStrategy's pricing is based on a perpetual license model, with options for both individual and enterprise users (Xia & Gong, 2014).

3 Methodology

The methodology used for evaluating the tools includes a comparison of features and functionalities, user interface and ease of use, data integration capabilities, and cost (Von Landesberger, et al., 2011; Parenteau, et al., 2016). These criteria were chosen based on their relevance to the needs of organizations that use BI tools (Biagi & Russo, 2022; Zhao, University of Alberta, 2012). The evaluation process involved the following steps (Lavanya, Sindhuja, Gaurav, & Ali, 2023):

Identifying the key features and functionalities of each tool based on their documentation and user reviews.

Evaluating the user interface and ease of use of each tool by conducting a hands-on test of their dashboard and report creation features.
Assessing the data integration capabilities of each tool by testing their ability to connect to various data sources and transform data into meaningful insights.
Comparing the cost of each tool based on their pricing model and available subscription or licensing options.

4 Analysis from the Findings

The analysis of the findings reveals the following strengths and weaknesses of each tool:

Tableau: Tableau's strength lies in its ease of use and user-friendly interface, which makes it accessible to non-technical users. Tableau offers a wide range of visualization options and data integration features, as well as affordable pricing options. However, Tableau's data modeling capabilities are not as robust as some other tools, and its security features may be lacking for some organizations (Hoelscher & Mortimer, 2018).

Power BI: Power BI's strength lies in its integration with other Microsoft products, such as Excel and SharePoint, as well as its collaboration features. Power BI offers a range of visualization options and data integration features, as well as affordable pricing options. However, Power BI's data modeling capabilities may not be as sophisticated as some other tools, and its customization options may be limited for some organizations (Hyman, 2022).

QlikView: QlikView's strength lies in its associative data model, which allows users to explore data and discover insights in real-time. QlikView offers a range of visualization options and data integration features, as well as a perpetual licensing model that may be more cost-effective for some organizations. However, QlikView's user interface may be less intuitive and user-friendly than some other tools, and its collaboration features may be lacking for some organizations (Niu, Ying, Yang, Bao, & Sivaparthipan, 2021).

SAP BusinessObjects: SAP BusinessObjects' strength lies in its comprehensive set of business intelligence tools, including reporting, data visualization, and data integration capabilities (Praveena & Bharathi, 2017). SAP BusinessObjects offers a range of visualization options and data integration features, as well as both cloud-based and on-premises installation options. However, SAP BusinessObjects' licensing model may be more expensive for some organizations, and its user interface may be less intuitive and user-friendly than some other tools.

MicroStrategy: MicroStrategy's strength lies in its scalability and ability to handle large volumes of data, as well as its comprehensive set of data integrationfeatures (Richardson, Sallam, Schlegel, Kronz, & Sun, 2020). MicroStrategy offers a wide range of visualization options and data modeling capabilities, as well as a perpetual licensing model that may be more cost-effective for some organizations. However, MicroStrategy's user interface may be less intuitive and user-friendly than some other tools, and its collaboration features may be lacking for some organizations.

Overall, each tool has its strengths and weaknesses, and the choice of tool will depend on the specific needs and priorities of the organization.

5 Result Discussion

Based on the findings of the evaluation, Tableau and Power BI are the most user-friendly and affordable options, making them ideal for organizations with limited resources or non-technical users. QlikView and MicroStrategy are better suited for organizations with more sophisticated data modeling needs and large volumes of data. SAP BusinessObjects offers a comprehensive set of business intelligence tools, but may be more expensive and less user-friendly than some other options.

6 Recommendation

Based on the findings, the final recommendation for a business intelligence tool would depend on the specific needs and priorities of the organization. For organizations with limited resources or non-technical users, Tableau or Power BI may be the best options. For organizations with more sophisticated data modeling needs and large volumes of data, QlikView or MicroStrategy may be better suited. For organizations looking for a comprehensive set of business intelligence tools, SAP BusinessObjects may be the best option.

Reference

[1] Al-Okaily, A., Teoh, A. P., Al-Okaily, M., Iranmanesh, M., & Al-Betar, M. A. (2023). The efficiency measurement of business intelligence systems in the big data-driven economy: a multidimensional model. Information Discovery and Delivery.

[2] Bhardwaj, P., & Baliyan, N. (2019). Hadoop based analysis and visualization of diabetes data through Tableau. 2019 Twelfth International Conference on Contemporary Computing (IC3), 1–5.

[3] Biagi, V., & Russo, A. (2022). Data Model Design to Support Data-Driven IT Governance Implementation. Technologies, 10, 106.

[4] Carlisle, S. (2018). Software: Tableau and Microsoft Power BI. Technology| Architecture+ Design, 2, 256–259.

[5] Crawley, D. B., Hand, J. W., Kummert, M., & Griffith, B. T. (2008). Contrasting the capabilities of building energy performance simulation programs. Building and Environment, 43, 661–673.

[6] Drake, B. M., & Walz, A. (2018). Evolving business intelligence and data analytics in higher education. New Directions for Institutional Research, 2018, 39–52.

[7] Gangadharan, G. R., & Swami, S. N. (2004). Business intelligence systems: design and implementation strategies. 26th International Conference on Information Technology Interfaces, 2004, 139–144.

[8] Hamad, F., Al-Aamr, R., Jabbar, S. A., & Fakhuri, H. (2021). Business intelligence in academic libraries in Jordan: Opportunities and challenges. IFLA journal, 47, 37–50.

[9] Hilbert, D. M., & Redmiles, D. F. (2000). Extracting usability information from user interface events. ACM Computing Surveys (CSUR), 32, 384–421.

[10] Hoelscher, J., & Mortimer, A. (2018). Using Tableau to visualize data and drive decision-making. Journal of Accounting Education, 44, 49–59.

[11] Hyman, J. A. (2022). Microsoft Power BI For Dummies. John Wiley & Sons.

[12] Kapoor, B. (2010). Business intelligence and its use for human resource management. The Journal of Human Resource and Adult Learning, 6, 21.

[13] Lavanya, A., Sindhuja, S., Gaurav, L., & Ali, W. (2023). A Comprehensive Review of Data Visualization Tools: Features, Strengths, and Weaknesses.

[14] Mitra, S., Pal, S. K., & Mitra, P. (2002). Data mining in soft computing framework: a survey. IEEE transactions on neural networks, 13, 3–14.

[15] Moss, L. T., & Atre, S. (2003). Business intelligence roadmap: the complete project lifecycle for decision-support applications. Addison-Wesley Professional.

[16] Murphy, S. A. (2013). Data visualization and rapid analytics: Applying Tableau Desktop to support library decision-making. Journal of Web Librarianship, 7, 465–476.

[17] Niu, Y., Ying, L., Yang, J., Bao, M., & Sivaparthipan, C. B. (2021). Organizational business intelligence and decision making using big data analytics. Information Processing & Management, 58, 102725.

[18] Olszak, C. M., Ziemba, E., & Koohang, A. (2006). Business intelligence systems in the holistic infrastructure development supporting decision-making in organizations. Interdisciplinary Journal of Information, Knowledge & Management, 1.

[19] Ozdemir, M., Eyüp Emre, Ü. L., & YILDIZ, K. (n.d.). Analysis and Comparison of Business Intelligence Tools Most Preferred by Companies in Turkey. Balkan Journal of Electrical and Computer Engineering, 11, 144–155.

[20] Parenteau, J., Sallam, R. L., Howson, C., Tapadinhas, J., Schlegel, K., & Oestreich, T. W. (2016). Magic quadrant for business intelligence and analytics platforms. Retrieved from **https://www.gartner.com/doc/reprints**.

[21] Praveena, M. A., & Bharathi, B. (2017). A survey paper on big data analytics. 2017 International Conference on Information Communication and Embedded Systems (ICICES), 1–9.

[22] Raj, R., Wong, S. H., & Beaumont, A. J. (2016). Business Intelligence Solution for an SME: A Case Study.

[23] Reddy, C. S., Sangam, R. S., & Srinivasa Rao, B. (2019). A survey on business intelligence tools for marketing, financial, and transportation services. Smart Intelligent Computing and Applications: Proceedings of the Second International Conference on SCI 2018, Volume 2, 495–504.

[24] Richardson, J., Sallam, R., Schlegel, K., Kronz, A., & Sun, J. (2020). Magic quadrant for analytics and business intelligence platforms. Gartner ID G00386610.

[25] Saggi, M. K., & Jain, S. (2018). A survey towards an integration of big data analytics to big insights for value-creation. Information Processing & Management, 54, 758–790.

[26] Saraiya, P., North, C., & Duca, K. (2005). An insight-based methodology for evaluating bioinformatics visualizations. IEEE transactions on visualization and computer graphics, 11, 443–456.

[27] Von Landesberger, T., Kuijper, A., Schreck, T., Kohlhammer, J., van Wijk, J. J., Fekete, J.-D., & Fellner, D. W. (2011). Visual analysis of large graphs: state-of-the-art and future research challenges. Computer graphics forum, 30, 1719–1749.

[28] Wu, K., Zhao, Y., Zhu, Q., Tan, X., & Zheng, H. (2011). A meta-analysis of the impact of trust on technology acceptance model: Investigation of moderating influence of subject and context type. International Journal of Information Management, 31, 572–581.

[29] Xia, B. S., & Gong, P. (2014). Review of business intelligence through data analysis. Benchmarking: An International Journal, 21, 300–311.

[30] Zhao, D. (2012). University of Alberta. Dept. of Medical Microbiology and Immunology., Function of myeloid dendritic cells during chronic hepatitis C virus infection.

[31] Zhao, D., & Strotmann, A. (2008). Information science during the first decade of the web: An enriched author cocitation analysis. Journal of the American Society for Information Science and Technology, 59, 916–937.

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp.151-155, November 13-16, 2023

Exploratory Data Analysis (EDA) and its Importance in Data Analytics

Joshua Alli Mamman[1], Rabiu Ibrahim[2]
{joshua.mamman@ aun.edu.ng[1], rabiu.ibrahim@aun.edu.ng[2]}

American University of Nigeria[1], Giant Horse Int., American University of Nigeria[2]

Abstract
Exploratory Data Analysis (EDA) provides a set of simple tools to achieve a basic understanding of a dataset. The results of data exploration are very useful in understanding connections and the structure of the dataset, the distribution of the values, the presence of extreme values, and interrelationships within the dataset. In Data Analytics, EDA is the first or main step used to understand, evaluate, and visualize data to obtain important information from the beginning or to identify patterns or key areas that you can dig deeper. It uses a combination of automated tools and manual methods such as charts, visuals, and reports to help clarify and comprehend datasets. With EDA we get a lot of details from the data, reveal its basic structure, detect any external, error data, and confusion if there is data, evaluate the basic assumptions, and determine the appropriate feature settings. Using data exploration tools and methods such as dashboards, reports, and point-to-point datasets users can understand the big picture and can find information on it easily.

1 Introduction

Data is often collected in vast and unstructured formats and stored in different data types such as structured, unstructured, and semi-structured from various sources, it becomes necessary for data analysts to first view, understand, and develop a comprehensive view of the data before extraction of the data for further analysis (Giudice, Musarella, Sofo, & Ursino, 2019).
Data analysis is an aspect of data science and data analytics that is all about analyzing data for different kinds of purposes (Siddiqui, Alkadri, & Khan, 2017). The data analysis process involves inspecting, cleaning, transforming, and **modeling data** to draw useful insights from it (Provost & Fawcett, 2013). Data analysis can be categorized into different types which include: Exploratory Data Analysis (EDA), Descriptive Data Analysis, Inferential Data Analysis, and Predictive Data Analysis (Cao, Chychyla, & Stewart, 2015; Jones & Linder, 2015).
However, EDA is the primary step to understand the data in depth and to learn the different characteristics of dataset (Jones & Linder, 2015). This means that the data scientist must understand the structure and pattern of the available data as well as the values of the data. EDA, therefore, is the first step in data analysis, which involves the use of data visualization tools and statistical techniques to explore data set characteristics and initial patterns. During exploration, raw data is typically reviewed with a combination of manual workflows and automated data-exploration software to visually explore data sets, look for similarities, patterns, and outliers, and identify the relationships between different variables (Cao, Chychyla, & Stewart, 2015; Myatt, 2007). This helps data scientist knows the basic characteristics of the data sets, e.g., the structure, the size, completeness, and the relationships between different parts of the data (Myatt, 2007).
EDA is a broad process that is performed by business users and an increasing number of citizen data scientists with no formal training in data science or analytics, but whose jobs depend on understanding data trends and patterns (Myatt, 2007). Visualization tools help this wide-ranging group to better export and examine a variety of metrics and data sets (HOLLYLYNNE, MOJICA, THRASHER, & Baumgartner, 2022). By visualizing patterns and finding commonalities in complex data flows, data exploration helps enterprises make data-driven decisions to streamline processes, better target their ideal audience, increase productivity, and achieve greater returns (Laffan, et al., 2016).

2 Why Exploratory Data Analysis

Data exploration helps to ensure:

i. **Data understanding:** EDA provides a comprehensive overview of each attribute or variable in the dataset and the pattern and relationship between the attributes (Henke & Jacques Bughin, 2016).
ii. **Data preparation:** Before embarking on further analysis of the dataset, data exploration helps to detect anomalies in the data. These anomalies include outliers, missing values, or highly correlated attributes. Some data science algorithms do not work well when input attributes are correlated with each other. Therefore, correlated attributes need to be identified and removed (Henke & Jacques Bughin, 2016).
iii. **Data science tasks**: Exploring basic data can sometimes replace the entire data science process. For example, scatterplots can identify clusters in low-dimensional data or can help to develop regression or classification models with simple visual rules (Henke & Jacques Bughin, 2016; Ratner, 2010).
iv. **Interpreting the results**: By visualization, data exploration is used to understand the prediction, classification, and clustering of the results of the data science process. Histograms help to comprehend the distribution of the attribute and can also be useful in visualizing numeric prediction, error rate estimation, etc. (Bobek, et al., 2021).

2.1 Important Steps in EDA

Steps in data exploration play an important role because the quality of input is directly proportional to output quality. Following are the steps involved in preparing, understanding, and cleaning data for predictive modeling (Cavallo & Demiralp, 2018):

i. **Variable Identification:** In variable identification, we need to identify a predictor that is the input variable and output variable for further data exploration. Based on our needs we can change the data type of the variable (Cavallo & Demiralp, 2018).
ii. **Univariate Analysis:** In the univariate analysis, we need to explore the variables one after another. To perform univariate analysis, it depends on the variable type, that is if the variable is continuous or categorical (Cavallo & Demiralp, 2018).
iii. **Bi-variate Analysis:** The bi-variate analysis aids in determining how two variables are related. This analysis can be applied to any form of categorical and continuous variable combination. During the analysis process, a variety of strategies are utilized to address this kind of variable combination (Cavallo & Demiralp, 2018). Variables can be combined in the following ways: continuous & and continuous, continuous & and continuous, and continuous.
iv. **Missing values treatment**: Missing values in a dataset must be addressed because failure to do so will lead to incorrect classifications and predictions in the future. There are numerous ways to handle these missing values in the data, including mean mode, median imputation, and deletion of pairs or lists that contain missing values (Cavallo & Demiralp, 2018). Prediction models are among the sophisticated methods for using and operating missing values in the data. KNN imputation is another method for treating missing values; in this method, missing values of an attribute are imputed using the given number of attributes that are similar to the attribute whose values are missing in the dataset.
v. **Outlier treatment:** Abnormal observations in the data can cause outliers in the data. Data analysts and scientists need to identify these outliers before they will result in severely wrong estimations (Cavallo & Demiralp, 2018; Swamynathan, 2017). There are different types of an outlier such as data entry errors, measurement errors, intentional outliers, experimental outliers, sampling errors, data processing errors, and natural outliers. Outliers can be detected using Box-plot, histogram, and scatterplot during visualization. To remove the outliers from the data some techniques are used such as deleting the observation, imputing, transforming, and binning the values, and treating them separately.
vi. **Variable transformation:** This refers to replacing variables with the function. There are three types of variable transformation Logarithm, Binning, and Square or Cube root (Cavallo &

Demiralp, 2018; Swamynathan, 2017). The variable transformation changes the relationship or distribution of the variable with the others. This is used when we need to change the scale of a variable or standardize the variables for good understanding, when we can transform the complex non-linear relationship into linear ones, symmetric distribution is favored over the skewed distribution as it is easier to generate inference, interpret, and variable transformation is also done from the implementation viewpoint.

vii. **Variable or Feature creation:** This is the process of generating new variables from existing or old variables as input variables in the data set (Cavallo & Demiralp, 2018). This is used to highlight the relationship between the hidden variables. There are different techniques to create the variables or generate new features such as creating derived variables and creating dummy variables (Swamynathan, 2017).

2.2 How EDA Works

Data exploration works by:

i. **Understanding the Variables:** The basis of any data analysis begins with an understanding of variables. Understanding what each field in a data set stands for and identifying missing or incomplete data can be accomplished by looking through data catalogs, field descriptions, and metadata (Siddiqui, Alkadri, & Khan, 2017).

ii. **Detect Any Outliers:** A dataset's reality can be distorted by outliers or anomalies, thus it's critical to spot them beforehand. The most popular techniques for finding outliers include data visualization, numerical methods, interquartile ranges, and hypothesis testing (Lu, Garcia, Hansen, Gleicher, & Maciejewski, 2017). A z-score provides information on how far from the mean a particular data point is, while a boxplot, histogram, or scatterplot makes it simple to identify points that are beyond the expected range. An analyst can investigate, modify, omit, or ignore the outliers after they have been identified. Whatever the decision, it needs to be recorded in the analysis (Abhishek, 2022).

iii. **Examine Patterns and Relationships:** Finding and examining patterns and correlations between variables is made simpler by plotting a dataset in a variety of ways. For instance, a company analyzing data from several retailers would have knowledge of a location's population, weather, and per capita income (Bagozi, Bianchini, Antonellis , Marini, & Ragazzi, 2017). They need to choose which variables to include in their predictive model in order to estimate sales for a new site.

3 Exploratory Data Analysis tools

EDA tools make data analysis easier to present and understand through interactive, visual elements, making it easier to share and communicate key insights. Some of the most common data science tools used to create an EDA include (Lu, Garcia, Hansen, Gleicher, & Maciejewski, 2017):

I. **Python:** An interpreted, object-oriented programming language with dynamic semantics. Its high-level, built-in data structures, combined with dynamic typing and dynamic binding, make it very attractive for rapid application development, as well as for use as a scripting or glue language to connect existing components together. Python and EDA can be used together to identify missing values in a data set, which is important so you can decide how to handle missing values for machine learning (Jones & Linder, 2015).

II. **R:** An open-source programming language and free software environment for statistical computing and graphics supported by the R Foundation for Statistical Computing (Jones & Linder, 2015). The R language is widely used among statisticians in data science in developing statistical observations and data analysis.

3.1 EDA Importance in Data Analytics

EDA in data analysis gives the utmost value to any business by helping analysts or scientists understand if the results that they have obtained are correct. The following are some important of data exploration in data analysis (HOLLYLYNNE, MOJICA, THRASHER, & Baumgartner, 2022):

1. Spotting missing data and errors in the data set.
2. Identifying the valuable and important variables in a dataset
3. Understanding and uncovering the underlying important variables in a dataset
4. Checking assumption or testing the hypothesis of the specific model
5. Creating a parsimonious model, the model that can explain your data using minimum variables.
6. Figuring the margins of errors and estimating parameters
7. EDA provides the context needed to develop a correct and appropriate model to interpret the insights correctly and efficiently.
8. It enables us, to unexpected discoveries in the dataset Gives a deeper understanding of the data as an important fundamental thing for successful and efficient data science projects.
9. With the user-friendly interface, anyone across an organization can familiarize themselves with the dataset, generate thoughtful questions that may spur on deeper, discover the patterns or trends, and gain valuable analysis to make decisions later.
10. It empowers users to explore data in any visualization.

4 Conclusion

The better an analyst or data scientist knows the data they are operating on or working with, the better their analysis will be. In data analysis, EDA is the most important step in the whole process and getting insights from data. By laying a solid foundation for the further analysis process data exploration plays a crucial role that you should focus on for understanding the characteristics of a dataset. The main use of EDA is, to assist in the analysis of the data before making any assumption or decision regarding something important. Most data analysts and data scientists employ data exploration to ensure that the results they produce or obtain are accurate and acceptable for any desired business goals and outcomes. Though data exploration might take some significant amount of effort that is it might involve large datasets of data that are being identified and sorted using various tools and techniques, these techniques may require a lot of effort and time to understand and adopt. But this surely results in better models than bad ones. In the whole world, a significantly large amount of data is accumulated, structured and unstructured volumes from sources across the whole globe so we must understand and comprehensive, complete view of the data.

Successfully extracting the data will ensure organizations or businesses will not miss out on any opportunities to leverage web data and will not be left behind due to incomplete data access, erroneous data, poor quality data, unreliable data, out-of-date data, high costs, or any uncertain business risks and give better insights for decision making.

Reference

[1] Abhishek, S. (2022). Importance of Data Exploration in Data Analysis A Review Paper. *Internationa Journal of Advanced Research in Science, Communication and Technology*.

[2] Bagozi, A., Bianchini, D., Antonellis , D., Marini, A., & Ragazzi, D. (2017). Summarisation and Relevance Evaluation Techniques for Big Data Exploration: the Smart Factory case study. *International Conference on Advanced Information Systems Engineering* , (pp. 264-279).

[3] Bobek, S., Tadeja, S. K., Struski, Ł., Stachura, P., Kipouros, T., Tabor, J., . . . Kristensson, P. O. (2021). Virtual reality-based parallel coordinates plots enhanced with explainable ai and data-science analytics for decision-making processes. *Applied Sciences, 12*, 331.

[4] Cao, M., Chychyla, R., & Stewart, T. (2015). Big data analytics in financial statement audits. *Accounting Horizons, 29*, 423–429.

[5] Cavallo, M., & Demiralp, Ç. (2018). Clustrophile 2: Guided visual clustering analysis. *IEEE transactions on visualization and computer graphics*, *25*, 267–276.
[6] Giudice, P. L., Musarella, L., Sofo, G., & Ursino, D. (2019). An approach to extracting complex knowledge patterns among concepts belonging to structured, semi-structured and unstructured sources in a data lake. *Information Sciences*, *478*, 606–626.
[7] Henke, N., & Jacques Bughin, L. (2016). The age of analytics: Competing in a data-driven world.
[8] HOLLYLYNNE, L. E., MOJICA, G. E., THRASHER, E. M., & Baumgartner, P. (2022). Investigating data like a data scientist: Key practices and processes. *Statistics Education Research Journal*, *21*, 3–3.
[9] Jones, Z., & Linder, F. (2015). Exploratory data analysis using random forests. *Prepared for the 73rd annual MPSA conference*.
[10] Laffan, S. W., Rosauer, D. F., Di Virgilio, G., Miller, J. T., González-Orozco, C. E., Knerr, N., . . . Mishler, B. D. (2016). Range-weighted metrics of species and phylogenetic turnover can better resolve biogeographic transition zones. *Methods in Ecology and Evolution*, *7*, 580–588.
[11] Lu, Y., Garcia, R., Hansen, B., Gleicher, M., & Maciejewski, R. (2017). The state-of-the-art in predictive visual analytics. *Computer Graphics Forum*, *36*, pp. 539–562.
[12] Myatt, G. J. (2007). *Making sense of data: a practical guide to exploratory data analysis and data mining.* John Wiley & Sons.
[13] Orr, L., Suciu, D., & Balazinska, M. (2017). Probabilitics Databasse Summarization for Interactive Data Exploration. *Proc. of the VLDB*, (pp. 1154-1165).
[14] Provost, F., & Fawcett, T. (2013). *Data Science for Business: What you need to know about data mining and data-analytic thinking.* " O'Reilly Media, Inc.".
[15] Ratner, B. (2010). Variable selection methods in regression: Ignorable problem, outing notable solution. *Journal of Targeting, Measurement and Analysis for Marketing*, *18*, 65–75.
[16] Rutuja , M. (2022). What is Data Exploration? and its Importance in Data Analysis. *International Research Journal of Engineering and Technology*.
[17] Siddiqui, T., Alkadri, M., & Khan, N. A. (2017). Review of Programming Languages and Tools for Big Data Analytics. *International Journal of Advanced Research in Computer Science*, *8*.
[18] Swamynathan, M. (2017). *Mastering machine learning with python in six steps: A practical implementation guide to predictive data analytics using python.* Springer.

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp.156-162, November 13-16, 2023

The Impact of the New Naira Redesign and Cashless Police from the Business Intelligent Prospective

Rabiu Ibrahim[1], Shamsiyya Adam Muhammad[2]
{rabiu.ibrahim@aun.edu.ng[1], Shamsiyyamadam@gmail.com[2]}

Giant Horse Int. American University of Nigeria[1], Giant Horse Int

Abstract
In today's rapidly evolving business landscape, the effective use of business intelligence has become crucial for predicting and capitalizing on economic growth opportunities. With the introduction of a new Naira redesign and cashless policy in Nigeria, businesses need to adapt and leverage business intelligence tools and techniques to accurately predict the potential impact on economic growth.The application of business intelligence in predicting economic growth potential involves data collection, data analysis, and data visualization. Data collection involves gathering relevant data from various sources, such as financial statements, market research reports, and government publications. Data analysis entails processing and analyzing the collected data to identify patterns, trends, and correlations. Data visualization techniques, such as charts, graphs, and dashboards, are employed to present the findings in clear and concise manner.The results of applying business intelligence to predict the potential of economic growth with regards to the new Naira redesign and cashless policy can provide businesses with valuable insights. Businesses can use these insights to make informed decisions, develop strategic plans, and allocate resources effectively. For instance, businesses can identify opportunities in the digital payment sector, develop marketing strategies to promote cashless transactions, and invest in technologies that enable seamless online transactions.The effective application of business intelligence can provide businesses with a competitive advantage by accurately predicting the potential of economic growth with regards to the new Naira redesign and cashless policy. By leveraging data-driven insights, businesses can adapt to the changing business environment, capitalize on growth opportunities, and drive economic success.

Keywords*: Business Intelligent, Naira Redesign, Policy, Financial Ecosystem, Implementation*

1 Introduction

In today's dynamic business environment, organizations require data-driven insights to make informed decisions and stay competitive (Arner, Buckley, & Zetzsche, 2018). Business intelligence (BI) is a powerful approach that involves the collection, analysis, and utilization of data to drive strategic decision-making and optimize operations (Bharadiya, 2023). Nigeria, a country located in West Africa, has been actively embracing BI as part of its efforts to modernize its financial ecosystem, which includes the redesign of its national currency, the Naira, and the implementation of a cashless policy (Chizoba & Anthony, 2016; Emilia, Neha, & Amlan, 2019) Business intelligence (BI) has gained significant importance in recent years as organizations across industries recognize the value of data-driven decision-making. With BI, organizations can collect, process, and analyze vast amounts of data to identify patterns, trends, and insights that can inform strategic decisions (Ibe & Ode, 2018). BI tools and technologies enable organizations to transform raw data into meaningful information, visualize data in intuitive ways, and generate actionable insights to enhance performance and drive growth (Ibrahim R. , Hilles, Adam, Jamous, & Yafooz, 2016).

The Nigerian government has recognized the potential of BI in driving economic growth and has been taking steps to promote its adoption in the country (Ibrahim R. , Hilles, Adam, & El-Ebiary, 2017). This includes initiatives such as the redesign of the Naira, the official currency of Nigeria, to incorporate advanced security features and enhance its durability (Ifechukwu, 2022). The Naira redesign aims to address issues of counterfeiting and fraud, and promote trust and confidence in the currency, both domestically and internationally (Kharakhash, 2023).

In addition to the Naira redesign, Nigeria has also been promoting a cashless policy as part of its efforts to modernize its financial system (LAWAL, 2023). The cashless policy aims to reduce the country's reliance on cash transactions and promote digital payments through various channels such as mobile banking, online banking, and card-based transactions (Lateef & Kelkhosroklanl, 2022). The policy

seeks to improve transparency, reduce corruption, and drive financial inclusion by making financial services more accessible and convenient to the population (Michael & Nyong, 2022). The combination of business intelligence, Naira redesign, and the cashless policy in Nigeria has the potential to transform the country's financial landscape and drive economic growth (Monye, 2023). These initiatives are expected to enhance the efficiency and transparency of financial transactions, promote digital literacy and financial inclusion, and position Nigeria as a progressive and competitive player in the global financial market. However, there are also challenges that need to be addressed, such as infrastructure limitations, regulatory frameworks, and cultural barriers, to ensure the successful implementation of these initiatives (Ndukwe, 2023).

In this paper, we will delve into the significance of business intelligence, the Naira redesign, and the cashless policy in Nigeria, their potential benefits and challenges, and their overall impact on Nigeria's business and financial ecosystem (Nwakpa & others, 2023). We will explore how these initiatives are reshaping the financial landscape in Nigeria and driving the country towards a more modern, efficient, and transparent financial ecosystem (OBILOR, 2023).

2 Methodology

The research is based on a descriptive research design which was applied in picking the literatures reviewed on currency redesign and monetary policies in Nigeria and all over the globe (Obasa, 2022). The targeted studies are based on all research conducted across the globe on the subject matter which is reviewed for this study. Accordingly, the literature review was compiled from a variety of sources available on multiple online platforms and on print media (Odior & Banuso, 2012).

Business intelligence (BI) can play a crucial role in predicting the potential economic growth with regards to the new Naira redesign and cashless policy in Nigeria (Ndukwe, 2023; Nwakpa & others, 2023). Here's how it could be applied in detail:

1. Data Collection: The first step in utilizing BI for economic growth prediction is to gather relevant data (Ibe & Ode, 2018; Osazevbaru & Yomere, 2015). This includes data related to the new Naira redesign, such as the design elements, security features, and circulation plans. Additionally, data related to the cashless policy, such as transaction volumes, types of transactions, adoption rates, and user behavior, would also be collected. Data can be collected from various sources, such as government agencies, central banks, financial institutions, payment processors, and other relevant stakeholders.
2. Data Integration: After collecting the data, the next step is to integrate it into a centralized data repository (Ibe & Ode, 2018). This involves cleaning, transforming, and consolidating the data from different sources into a unified format. Data integration enables the creation of a single source of truth for analysis and prediction, eliminating inconsistencies and redundancies in the data.
3. Data Analysis: Once the data is integrated, BI tools and techniques can be applied to analyze it. Descriptive analytics can be used to understand historical trends and patterns, while predictive analytics can be employed to forecast future outcomes (Ibe & Ode, 2018). For instance, using data on transaction volumes and types of transactions, predictive analytics can forecast the potential impact of the cashless policy on various industries, such as retail, hospitality, and transportation. Similarly, data on the new Naira redesign, such as its design elements and security features, can be analyzed to predict its potential impact on counterfeiting and overall public perception.
4. Visualization and Reporting: BI also involves visualizing and reporting the analyzed data to make it more understandable and accessible to decision-makers. Dashboards, charts, and reports can be created to present the findings of the analysis in a visually appealing and easy-to-understand format (Ibe & Ode, 2018). For instance, a dashboard can be designed to display key performance indicators (KPIs) related to the adoption rate of the cashless policy, the

impact of the new Naira redesign on counterfeiting incidents, and the overall economic growth trend.

5. Scenario Planning: BI can also be used for scenario planning, where different scenarios can be simulated and their potential impacts on economic growth can be analyzed (Ibe & Ode, 2018). For example, using BI tools, various scenarios can be simulated, such as the impact of increased adoption of cashless transactions, the impact of changes in the design of the Naira, or the impact of changes in government policies related to the cashless policy. These scenarios can help decision-makers assess the potential risks and benefits of different policy options and make informed decisions accordingly.
6. Continuous Monitoring and Optimization: BI is not a one-time process but requires continuous monitoring and optimization. As new data becomes available, it can be integrated into the BI system to update the analysis and predictions (Ibe & Ode, 2018). This helps decision-makers stay informed about the changing dynamics of the economic growth potential related to the new Naira redesign and cashless policy and take appropriate actions in a timely manner.

As with any policy or implementation, if the new redesign of the Naira and the cashless policy are not implemented properly, it could have potential consequences for businesses (LAWAL, 2023; Simeon & Bamidele, 2012). Let's explore some of them in detail:

1. Confusion and Lack of Acceptance: If the new redesign of the Naira notes and coins, as well as the cashless policy, are not communicated clearly and effectively to the public, it may lead to confusion and lack of acceptance (Emilia, Neha, & Amlan, 2019). People may struggle to understand the changes, leading to difficulties in recognizing and accepting the new currency design. This could result in delays and errors in transactions, as well as potential rejection of the new currency by businesses and consumers alike.
2. Counterfeiting and Fraud: A poorly implemented redesign of the Naira and the cashless policy may open up opportunities for counterfeiters and fraudsters to take advantage. If the new currency design lacks proper security features or if the cashless policy is not accompanied by robust authentication measures, it may become easier for counterfeiters to produce fake currency notes and coins (Emilia, Neha, & Amlan, 2019). This could result in an increase in counterfeit currency circulating in the economy, leading to a loss of confidence in the currency and undermining the overall effectiveness of the cashless policy.
3. Economic Disruption: The implementation of a new redesign of the Naira and the cashless policy could potentially disrupt the economy if not executed properly. If the transition process is not well-managed, it could result in delays in transactions, difficulties in accessing funds, and disruptions in supply chains, leading to economic inefficiencies and losses for businesses and consumers (Emilia, Neha, & Amlan, 2019; Ifechukwu, 2022; Kharakhash, 2023). Moreover, if the cashless policy is not supported by adequate technological infrastructure, such as reliable electronic payment systems and digital financial services, it may hinder the smooth functioning of the economy and limit financial inclusion, particularly for those who rely heavily on cash transactions.
4. Social Impact: The wrong implementation of the new redesign of the Naira and the cashless policy may also have social consequences. For instance, if the redesign does not take into consideration cultural or social factors, it may face resistance from certain segments of the population who may feel disconnected from the new currency or the cashless policy (Ibrahim R. , Hilles, Adam, & El-Ebiary, 2017; Ifechukwu, 2022). Additionally, if the cashless policy is not accompanied by proper financial literacy and education programs, it may result in confusion and misunderstandings among consumers, particularly those who are not familiar with digital payment methods. This could potentially exacerbate existing inequalities and exclude vulnerable populations from participating fully in the economy.
5. Cost and Resource Implications: Implementing a new redesign of the Naira and the cashless policy requires significant resources, including printing new currency notes and coins, updating

technology infrastructure, training personnel, and conducting public awareness campaigns. If the implementation process is not well-planned and executed, it may result in cost overruns, inefficiencies, and wastage of resources (Ibrahim R. , Hilles, Adam, & El-Ebiary, 2017) (Ifechukwu, 2022). This could strain the financial resources of the government, central bank, and other stakeholders involved in the process, potentially leading to budget shortfalls and fiscal challenges.

The wrong implementation of the new redesign of the Naira and the cashless policy could have various consequences. It is imperative that any changes to the currency design and cashless policy are carefully planned, communicated, and executed to minimize potential negative consequences and ensure a smooth transition for all stakeholders involved (Monye, 2023; Pillah, 2023).

3 Findings after some Analysis

Let's consider the use of synthetic data and Excel to factor the impact of the Nigerian naira redesign andcashless policy.Synthetic data are based on assumptions and may not fully capture real-world complexities and risks associated with the implementation of the naira redesign and cashless policy (Kharakhash, 2023). The synthetic data consists of 200 inputs and is used to make visualizations in Excel data to factor out potential negatives of the said redesign and cashless policy (Sokari, 2017; Vassakis, Petrakis, & Kopanakis, 2018).

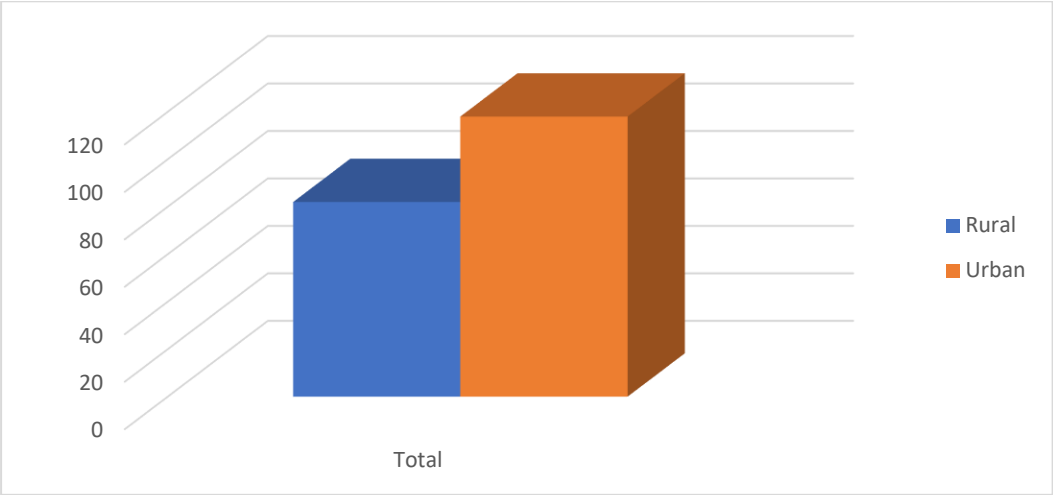


Figure 1: The statistics of people with active accounts in some rural and urban areas of the country

Table 1: This shows the number of people with active accounts in some rural and urban areas of the country.

	Rural	**Urban**	**Grand Total**
Count of bank_account	**82**	**118**	**200**

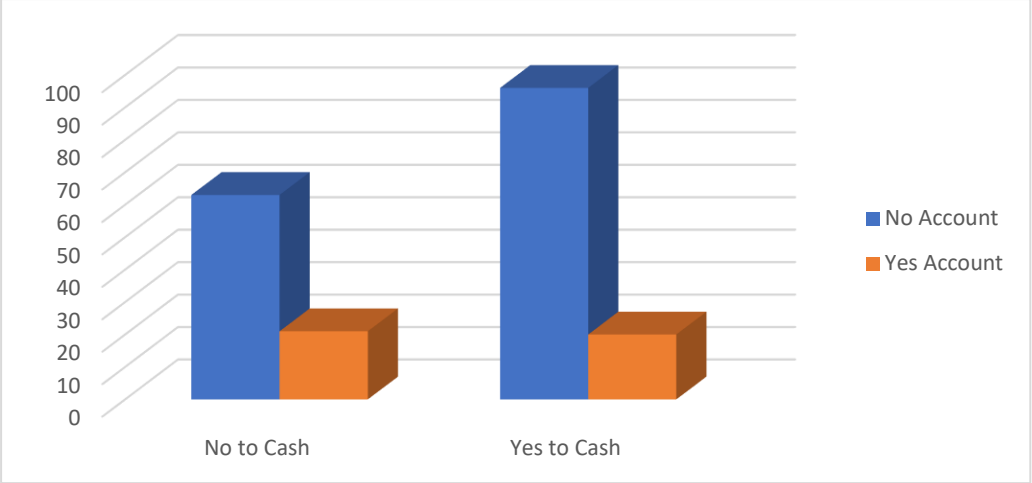


Figure 2: The statistics of people with active accounts and needs cash for their day-to-day activities in the country.

Table 2: This shows the number of people with active accounts and needs cash for their day-to-day activities in the country.

Count of row_id	**Have Bank Account**		
Need Cash	**No Account**	**Yes Account**	**Grand Total**
No to Cash	63	21	84
Yes to Cash	96	20	116
Grand Total	**159**	**41**	**200**

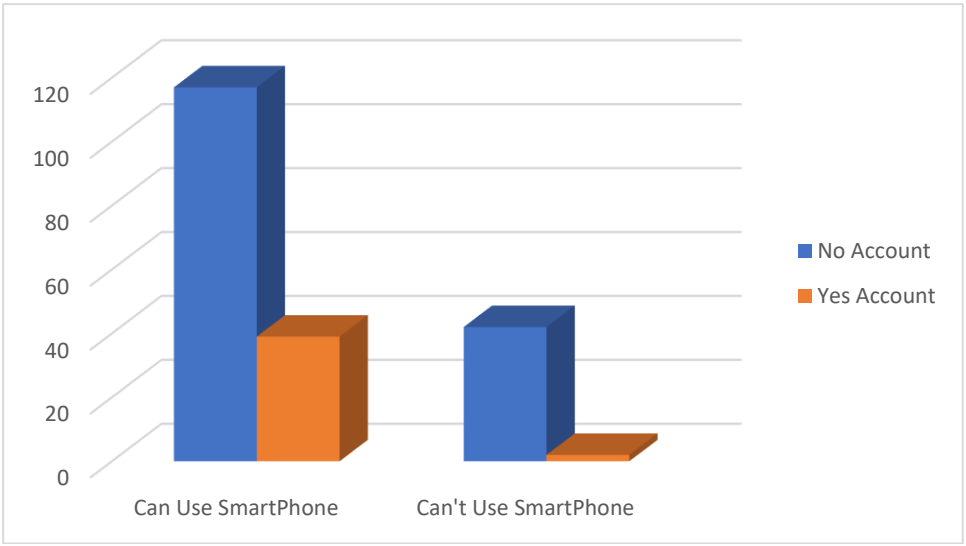


Figure 3: The statistics of people with active accounts and can or can't operate a smart phone.

Table 3: This shows the number of people with active accounts and can or can't operate a smart phone.

Count of row_id	Have Bank Account		
Smartphone	**No Account**	**Yes Account**	**Grand Total**
Can Use SmartPhone	117	39	156
Can't Use SmartPhone	42	2	44
Grand Total	**159**	**41**	**200**

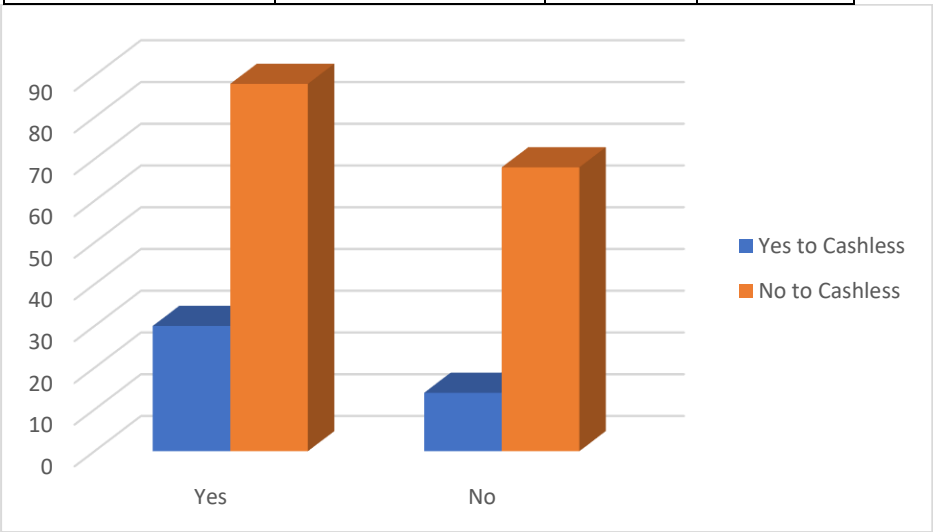


Figure 4: The statistics of people that think the cashless policy will thrive and have the infrastructure to make it work in Nigeria.

Table 4: This shows the number of people that think the cashless policy will thrive and have the infrastructure to make it work in Nigeria.

Count of row_id	Cashless Economy		
Literate	**Yes to Cashless**	**No to Cashless**	**Grand Total**
Yes	30	88	118
No	14	68	82
Grand Total	**44**	**156**	**200**

Synthetic data may not fully capture the diversity of the Nigerian population, including those who may face accessibility issues, such as the elderly or people with disabilities. Excel may not fully account for these factors, resulting in potential negative impacts on financial inclusion and equity in accessing and using the redesigned currency or digital payment systems. Technical glitches or failures in digital payment systems could disrupt transactions and impact businesses and consumers negatively. Additionally, cyber-security risks associated with digital payments and data privacy concerns could also pose challenges to the successful implementation of the policy.

In conclusion, the use of synthetic data and business intelligence tool can be valuable tools to analyze and model the potential impact of the Nigerian naira redesign and cashless policy. However, it's important to consider the limitations and potential risks associated with these tools and ensure that real-world complexities, such as accessibility issues, technological risks, and behavioral changes, are carefully evaluated to maximize the positive impacts and mitigate potential negative impacts of the policy.

Reference

[1] Arner, D. W., Buckley, R. P., & Zetzsche, D. A. (2018). Fintech for financial inclusion: A framework for digital financial transformation. *UNSW Law Research Paper*.

[2] Bharadiya, J. P. (2023). Leveraging Machine Learning for Enhanced Business Intelligence. *INTERNATIONAL JOURNAL OF COMPUTER SCIENCE AND TECHNOLOGY*, *7*, 1–19.

[3] Chizoba, A. E., & Anthony, R. (2016). Cashless Policy in Nigeria and Its Socio-Economic Impacts. *Public Policy and Administration Research*.

[4] Emilia, B. V., Neha, S., & Amlan, C. (2019). Data management, analytics and innovation. *Data management, analytics and innovation*. Singapore: Springer Nature Singapore Pte Ltd.

[5] Ibe, R. C., & Ode, E. R. (2018). Cashless Policy Models of Economic Growth: The Nigeria Evidence. *International Journal of Business & Law Research*.

[6] Ibrahim, R., Hilles, S. M., Adam, S. M., & El-Ebiary, Y. (2017). Electronic government Services Usage, Adoption and Evaluation: A Review Paper. *International Journal of Contemporary Computer Research, 1*, 6–13.

[7] Ibrahim, R., Hilles, S. M., Adam, S. M., Jamous, M. M., & Yafooz, W. M. (2016). Theoretical framework formation for e-government services evaluation: Case study of Federal Republic of Nigeria. *Indian Journal of science and technology, 9*, 1–7.

[8] Ifechukwu, A. (2022). Regulating Fintech in Developing Economies: Examining The Risks, Policies and Nigeria's Path to Financial Prosperity. *Policies and Nigeria's Path to Financial Prosperity (December 26, 2022)*.

[9] Kharakhash, O. (2023). DATA VISUALIZATION: TRANSFORMING COMPLEX DATA INTO ACTIONABLE INSIGHTS. *Automation of Technological & Business Processes/Avtomatizaciâ Tehnologiceskih i Biznes-Processov*, *15*.

[10] Lateef, M., & Kelkhosroklanl, P. (2022). Predicting Critical Success Factors of Business Intelligence Implementation for Improving SMEs' Performances: a case study of Lagos State, Nigeria. *Knowledge Economy*.

[11] LAWAL, S. A. (2023). An Evaluation of the Scarcity of New Naira Notes and Slow Business Growth in Nigeria. *Central Asian Journal of Innovations on Tourism Management and Finance*, *4*, 110–118.

[12] Michael, U. E., & Nyong, C. E. (2022). Digital Currency and Financial Inclusion in Nigeria: Lessons for development. *Emerald Insight*.

[13] Monye, O. (2023). Cashless policy initiative in Nigeria: outline of crucial socio-economic and regulatory considerations. *Journal of Money Laundering Control*.

[14] Ndukwe, J. (2023). Naira Redesign and Cashless Policy in Nigeria. *Research Gate*.

[15] Nwakpa, J. N., & others. (2023). Evaluation of Nigerian Government's New Cashless Policy: Insights from Select National Dailies. *British Journal of Marketing Studies*, *11*, 1–16.

[16] Obasa, O. S. (2022). *Effect of Information and Communication Technology on the Financial Performance of Money Deposit Banks in Nigeria*. Ph.D. dissertation, University of Abuja (Nigeria).

[17] OBILOR, N. M. (2023). COPING STRATEGIES ADOPTED BY INFORMAL TRADER DURING NAIRA SCARCITY IN 2023. *UNILAG Journal of Business*, *9*, 85–96.

[18] Odior, E. S., & Banuso, F. B. (2012). Cashless banking in Nigeria: Challenges, benefits and policy implications.

[19] Osazevbaru, H. O., & Yomere, G. O. (2015). Benefits and Challenges of Nigeria's Cashless Policy. *Kuwait Chapter of Arabian Journal of Business and Management Review*.

[20] Pillah, T. P. (2023). Currency Redesign and Monetary Policy of Nigeria: An Evaluation. *International Journal of Public Administration and Management Research*.

[21] Simeon, E. O., & Bamidele, F. B. (2012). Cashless Banking in Nigeria: Challenges, Benefits and Policy Implications. *European Scientific Journal*.

[22] Sokari, I. E. (2017). *Technology innovation management in the Nigerian banking industry: integrating stakeholders' perspectives, an exploration of strategy and policy implications.* Ph.D. dissertation.

[23] Vassakis, K., Petrakis, E., & Kopanakis, I. (2018). Big data analytics: Applications, prospects and challenges. *Mobile big data: A roadmap from models to technologies*, 3–20.

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp.163-178, November 13-16, 2023

An Overview of the Trends in E-democracy: Based on Assessment of Electronic Voters Registration and Verification in Literature

Aishatu Shuaibu[1], Samuel C. Avemaria Utulu[2], Abel Adeyemi Ajibesin[3]
{aishatu.shuaibu@aun.edu.ng[1], samuel.utulu@aun.edu.ng[2], abel.ajibesin@aun.edu.ng[3]}

Abstract
The systematic literature review explores recent research trends in e-democracy, focusing on voter registration and verification in e-election procedures. The research seeks to reveal scholars' disciplinary affiliations and the philosophical assumptions underpinning study in the field. Scholars, however, have paid little attention to e-voter registration and verification in e-democracy. The study was driven by the question: what kinds of studies dominate the e-democracy literature? The SLR approach evaluated 41 publications from four databases on electronic voting, e-democracy, and Sub-Saharan Africa. The studies identified four distinct e-democracy themes related to electronic voter registration and verification. The findings show that political scientists and international relations specialists dominate the sector. Though the interpretivism stance dominated the e-democracy research domain, more research in e-voter registration and verification is required. We recommend boosting the number of IS-based scholars studying e-voter registration and verification, contributing IS-based insights to ongoing theorizing of this phenomenon.

Keywords: e-democracy, current research trends, e-voting, e-voter registration, e-voter verification, review, sub-Saharan Africa

1 Introduction

Democracy has been defined as the government of the people, by the people, and for the people [74, 124, 91]. This seemingly ageless definition of democracy opens up a critical view of what democracy is all about. Although one may argue that, the definition is not fully explicit, however, it provides grounds for scholars to see the totality of democracy in principle and practice [119, 75]. This is to say that it explicates the notion that democracy revolves around what people want, what they do to get what they want, and the extent the machinery of government allows them to participate in what they need to do to get what they want [28, 37]. Given this, democracy is a set of rules and values for managing conflict in an institutionalized way [79, 140].

According to insights in the extant literature, the phases of democracy include, assumptions, perceptions, individuals' common experience and their freedom, voters, information, political aspect, and living together [127, 122]. These phases are either traditional (direct) democracy or indirect democracy. In traditional democracy where democracy is practiced as direct democracy, all that is required to attain democracy in principle and practice is allowing the people to participate in processes of decision-making, dialogue, and public communication [109, 72]. However, in situations where democracy is practiced as indirect democracy, the requirements include participation in elections through which government officials serve as representatives of the people voted for by the people [114, 44, 55]. Given the negative implications of direct and indirect democracy, researchers have proposed the use of information systems to reduce public and government distrust [89, 20]. Hence, the emergence of what has come to be known as e-democracy due to the use of ICT devices for delivering democratic services.

Electronic democracy refers to the use of information systems tools and applications to increase government accountability and transparency [60, 95, 71] E-democracy is the way citizens actively participate in the governing process through transparent access to government information, services and policies via various ICT platforms, most notably the internet [8, 60, 108, 53, 96]. It is critical to understand that e-democracy aims to not only educate citizens about major issues but also to express citizens' perspectives to improve political decisions and therefore strengthen democracy [89, 107, 71]. E-democracy started by increasing public service delivery, access to government information, and

public governance. [107, 32, 8]. It has been determined that e-democracy addresses the general discord among citizens and representatives to make political democratic processes transparent and more inclusive by fostering new forms of participation, collaboration, and deliberation [52].

The difficulties associated with the implementation of e-democracy have become apparent in developing countries as a result of the technological transformation of political institutions [22, 60, 81, 94, 131]. Other evidence suggests that e-democracy initiatives around in some nations frequently fail to meet expected levels of uptake. Instances from the literature show that the systems created for citizen input and communication frequently fail to meet governments' anticipated goals and levels of uptake. Different types of challenges fail the system: those that are typical of information systems projects, those resulting due to the context of the public sector, and particular difficulties resulting from the intricate democratic participation context which makes them prone to failure [131]. In another study, most government agencies' employed e-democracy only as strategies for their objectives. These have resulted in the failure and replication of implementation efforts [52]. The research therefore concentrated on the e-electoral process as one of the main types of e-democracy.

There is currently no agreed standard definition of electronic election (e-electoral) processes based on reviewed literature. From various angles, different definitions of "e-election" have been developed. Some definitions tend to emphasize how the election has changed as a result of new technological advancements by using information and communications technology (ICT) applications, such as the internet, as tools to enable people to vote effectively and efficiently [82, 102, 12, 99, 139] define it as a system for casting, recording, or counting votes in political elections that uses information and communication technologies (ICTs). It is ICTs that is employed by the government in many nations to enhance the electoral process and frequently raise voter turnout. [76], On the other hand, claimed that an electronic device was used to record votes in place of paper ballots and boxes, which were previously used in traditional voting, and that this implied that an e-election was nothing more than a machine, which both poll workers and voters could easily operate.

The adoption of information and communication technology is seen as a significant step forward in the fight against corruption and declining voter turnout [46, 7]. Based on several definitions of the e-electoral process by different scholars, the researchers define the e-electoral process as the use of ICTs in electoral processes to enhance efficiency and transparency for credible election outcomes. Different ICT are used at different stages of the electoral process. In countries around the world, various forms of electronic voter identification (biometric) and registration are used for new democracy [6, 29, 18, 33, 41]. There are several stages involved in the e-election process. These stages are a structured and systematic process that includes registration, voter registration revision, the distribution of voter identification cards, verification of voters, voting, election supervision, vote counting, and the declaration of election outcomes. This network of stages in the election process is controlled electronically, which increases speed and efficiency while allowing for the least amount of human subjectivity-related error or distortion [11, 135, 102]. The primary focus of the study is on electronic voter registration and electronic voter verification in the electoral process.

The electronic registration and verification of voters during elections involve biometric technologies [43, 18]. The process of capturing body traits with biometric devices (such as fingerprint scanners and digital cameras) and storing them on smart cards or databases is known as registration [87, 85, 42, 43]. The electronic registration process prevents multiple identifications of a specific voter in the biometric database, whereas the verification process checks a voter's identity for authorization to use a service in the electoral process [43]. Similarly, the involvement of biometric technologies in the process makes it distinct from the existing or manual process [61, 19].

The electronic voter registration technologies enhance the traditional paper-based voter registration technique [41, 85, 61, 6] In the traditional (manual or paper-based) process, voters complete a paper application [83], which is then presented to election officials, who check for validity and enter the information from the paper application into the registration system [123]. The two systems of voting are similar, only that, electronic voter registration acquires information by utilizing electronic technologies, which includes biometric identification, and subsequently saved it electronically [56]. In most cases, the voter's information is examined electronically [6] and if it is found to be accurate, the new registration is added to the voter's registration list [112]. The first process of electronic voter's registration is that Individuals' personal qualities are recorded and associated with a unique number or code and then stored in a database [58, 85, 59, 40, 106].

Despite apparent efforts from e-democracy, the electoral process still faces several challenges in delivering efficient and effective electoral outcomes. Among the challenges are system failures that lead to voting manipulation and violations of users' data, putting democracy at risk [47]. Moreover, Africa lacks the implementation capacity for deploying ICT for elections [62]. These weak implementation capacity includes roads to deliver biometric kits, reliable mobile networks to transmit data for de-duplication, electricity to power scanners and card readers; and to submit results, a robust data system to store, verify, and tally the data received, and trained staff to operate the equipment and troubleshoot if problems arise [49]. As a result, there is not enough proof of the efficiency of e-democracy interventions needed to guide the e-election process [60, 131]. Hence, some scholars argue that the effectiveness of e-democracy in the electoral process remains debatable; pointing to a gap in existing e-democracy research at both the technical and societal levels [47].

In the case of Nigeria's recent elections, problems with biometric voter verification were highlighted, including the failure to authenticate the incumbent President's fingerprint [49]. The malfunction of infrastructures and the inefficiency of some technologies added to the problems of electronic registration and verification of voters in Nigeria [87]. It was reported that 91 percent of the machines failed to consistently validate voter identity in the presidential election in Nigeria as many components of the electronic technologies for verification did not work as anticipated [35, 100]. In Southern Nigeria, the smart card reader (SCR) failed miserably to read biometric data included in the permanent voters' cards (PVCs) and to verify voters. As a result, manual accreditation became unavoidable in many areas [100]. While the use of electronic devices can help with some of the issues associated with voter registration and verification, they cannot prevent fraud or manipulation completely. However, little is known in the information systems literature about the social actors accountable for these issues in Africa.

While many e-democracy studies have been incorporated into the electoral process, the majority of research investigations have been carried out from non-IS perspectives. According to our findings, there is no IS-based study in the review of e-democracy in the electoral process. Research on e-democracy and electoral processes, particularly voter registration and verification, is currently understudied in the IS discipline. The IS-based studies will reveal the factors that contribute to the successful adoption of IS artifacts in Nigeria to promote credible election outcomes.

In our review of the literature on e-democracy in the electoral process, we found a single conceptual study on the registration and authentication of voters [78] published in a scholarly journal on security and communication networks. The study proposed a novel concept known as "traceable attribute-based anonymous authentication" which achieves complete anonymity once credentials are released and messages are verified [78].

2 Findings of Major Themes from the Reviewed Studies

Each of the 41 studies chosen for the review was actively read and reread by the authors [113]. It was carried out to become better acquainted with the chosen studies and to explain any inconsistencies that may have arisen through the process of selection. As a result, the broad themes and study patterns were extracted for the categorizing of the study as shown in figure 1. This section delves deeper into four distinct themes identified for researching e-democracy in the electoral process. The goal was to find research on voter registration and verification during the electoral process and the barriers that prevented ICT adoption for voter registration and verification during the electoral process to achieve a credible electoral outcome.

2.1. Adoption and Implementation

The actual application of electronic technologies in the electoral process is referred to as e-democracy implementation [1, 54, 60]. This could include using electronic voting machines, online voter registration, and other digital tools to make voting and counting easier, as well as disseminating election-related information [18, 125]. The adoption of e-democracy, on the opposite side, refers to how far individuals and institutions accept and use e-democracy technologies in the electoral process [60]. This involves voter willingness to use electronic voting machines, the use of online campaigning and social media by political parties and candidates, and the extent to which electoral management bodies incorporate digital tools into their operations [97, 115].

Adoption and implementation of e-democracy into the electoral process could indeed increase voter turnout, minimize the risk of fraud, and encourage a higher level of accountability and transparency in elections [64, 77]. The successful adoption and implementation of e-democracy projects in electoral processes depend on several factors, including stakeholder engagement and involvement, technological readiness, voting system security and integrity, and legal and regulatory frameworks [5, 70, 130]. Election officials and policymakers should consider this when designing and implementing e-democracy programs to guarantee their success. After thoroughly reviewing the literature, it is possible to conclude that the concept of e-democracy in the electoral process has huge potential for transparency and accountability in the electoral process. It may, however, not materialize if governments, non-governmental organizations, citizens, and technology companies' skills or inspiration to act are lacking [27]. This is especially important in democratic settings, where electoral processes are driven by the government, citizens, and non-governmental organizations.

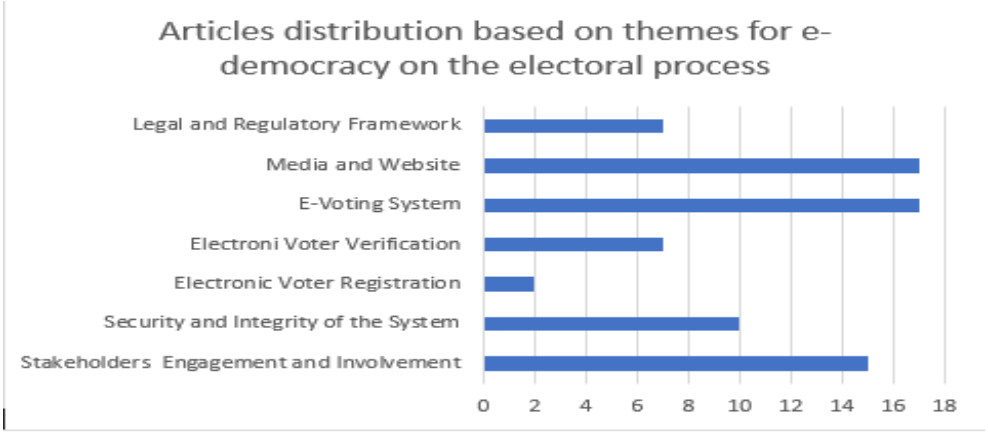


Figure 1. Articles based on themes for e-democracy on the electoral process

The findings of this review in the focus area of e-democracy implementation/adoption in the electoral process found that, the majority of studies were based on e-voting, which encompasses the entire election process from registration to after-voting [3, 2, 4, 30, 45, 128]. However, while some scholars considered electronic registration and verification, the studies undertaken were not based on information systems research [6, 9] leaving a lacuna in electronic voter registration and verification. Voter registration and verification affects the effectiveness of the electoral process, as well as interventions throughout the election process if credible electoral outcomes are to be ensured. While e-democracy has the potential to transform the electoral process, voter registration and verification during the electoral process in order to achieve a credible electoral outcome is critical and fundamental stage and is a major challenge in ensuring transparency and accountability. These impede the effective use of ICT for credible electoral outcomes.

2.2. Success and Failure of e-democracy to Electoral Process

The success or failure of e-democracy in the electoral process is determined by several factors, including the technology's design, the context in which it is implemented, and the larger social conditions and political under which it operates [7, 65, 68]. The literature highlights some factors for the successful adoption and implementation of e-democracy projects in electoral processes. These factors include stakeholder engagement and involvement, technological readiness, voting system security and integrity, and legal and regulatory frameworks [12, 120, 121]. Election officials and all policymakers should take this into account when designing and implementing e-democracy programs to guarantee their success. The success of e-democracy can lead to increased participation, transparency, and accountability in the electoral process [21, 80]. E-voting systems, for example, can make it easier for people to vote, while online forums can give citizens a place to discuss and debate political issues. E-democracy can also help political candidates reach out to voters and educate voters about candidates' positions and platforms [21, 118]. However, it has limitations and potential drawbacks.

2.3. Challenges in e-democracy

The challenges in e-democracy to the electoral process include cyber security risks as well as the need to ensure that all citizens have equal access to information and technology [18, 41, 111]. Other factors such as software issues or system failures and privacy of voter information could cause voting delays or errors, potentially undermining voter confidence in the election's outcome [42, 50]. It is critical to tackling these problems to guarantee that e-democracy is implemented to encourage transparency, trust, and inclusivity in the process of election [38].

In summary, even though e-democracy initiatives could provide numerous advantages, it has not been widely embraced in developing nations [20, 131, 107] Moreover, a lot of research shows results regarding the adoption of e-democracy that are in conflict [131, 101, 90, 62]. Furthermore, the majority of the literature on e-democracy concentrates on socio-technical actors about its failure while little research has been done to look into the categories of social factors influencing the implementation of this technological innovation. Notably the electronic registration and verification process which is a major and fundamental component of the e-Democracy. There is paucity of information on IS -based studies on voter registration and verification in electoral process. Similarly, due to paucity of information on IS based studies, reviews on the field are equally scanty. Therefore, this study aims to address this gap in the literature.

2.4. Citizen Participation

The term "citizen participation in e-democracy" refers to citizens actively participating in political decision-making via electronic channels such as online forums, social media, and other digital channels

[51, 80]. E-democracy in the context of the electoral process gives citizens more chances to engage in democratic activities such as campaigning, voter registration, and voting [80, 129]. Electronic voting systems and online voter registration can help citizens vote more efficiently and conveniently [38, 50]. This can boost voter turnout and ensure that all eligible voters participate in the election [18, 38]. Furthermore, e-democracy can enable citizens to participate in political debates and discussions [18]. People can use online forums and social media platforms to share their thoughts, concerns, and concepts with others and engage in a productive discussion about issues that are important to them [34]. This can contribute to a more educated and involved electorate, as well as provide useful feedback to parties and political candidates, thereby prevention of corruption and the holding of fair and free elections [31, 36] Broadly speaking, citizen participation in e-democracy can help electoral processes by making the voting system easier, encouraging dialogue and engagement, and facilitating accountability and transparency.

2.5. Electoral Reforms

Electoral reforms are the process of enhancing the electoral system to improve its effectiveness, transparency, and efficiency [24, 67]. Electoral reform in the context of e-democracy may entail using technology to improve electoral processes, such as voter turnout on registration or electronic voting [48, 86]. It seeks to increase voter turnout, enhance the voting process's integrity and accuracy as well as encourage accountability and transparency [25, 137]. Electoral authorities could make the voting system more accessible and convenient by applying technology, especially for participants who may have problems accessing physical polling places [15, 66]. For instance, electronic voting has the potential to reduce election costs while also allowing for real-time vote counting, which has the potential to speed up and improve the accuracy of election results [93]. Moreover, electoral reform in e-democracy necessitates a careful evaluation of possible challenges and risks, such as privacy concerns, the possibility of technological failures, and cyber security threats [54, 131]. It is crucial to guarantee that every change to the electoral process is reliable, trustworthy, and secure to maintain the legitimacy and integrity of the election outcome [18].

3 Research Methodology

The systematic literature review (SLR) method was adopted to answer the research questions. It entails applying a rigorous and well-defined procedure to a body of previously published literature [104]. According to [103, 57, 104] SLR is a systematic, explicit, comprehensive, and repeatable method used for identifying, assessing, and synthesizing the body of completed existing and recorded research work. Therefore, this review focuses on e-Democracy in relation to e-registration and e-verification of voters for credible electoral outcomes to strengthen the body of evidence for e-electoral research in the IS discipline. The purpose of this study is to review the methodology used by researchers to study e-democracy about e-elections specifically registration and verification of voters, as well as the philosophical assumptions and theoretical implications of those assumptions. This type of classification allows us to recognize repeated themes and key points in the debates that emerge from actual electronic election processes. Knowing the type of research being done in this area is crucial, as is spotting theoretical and methodological holes that might attract the attention of the research community in this field. The researchers believe that explaining the gaps in the literature will be useful to the increasing number of researchers interested in investigating and evaluating e-democracy in place of e-registration and verification of voter projects with credible election outcomes.

The data source and strategy used in the search for the SLT are critical components of the review of existing literature [104]. A good review establishes a solid foundation for knowledge advancement [103, 136]. It aids theory creation, identifies places where more study is needed and fixes gaps where there is a lot of research. [136, 104, 134, 13, 110]. This study followed [103, 136] recommendations

and guidelines for conducting an SLR study in IS discipline to answer the research questions posed by the researchers.

Different studies utilize different terminology to describe the phenomena of digital democracy, this research was conducted using a combination of phrases such as ("electronic voting" OR “electronic voting”) AND (“e-democracy” OR "electronic democracy") AND "Sub-Saharan Africa.". At first, the study was limited to the title, abstract, and keywords of each paper to limit our review to papers that highlight digital democracy or electronic voting as the primary topic. After that, there was a search from each of the papers to find out relevant information about the African country, such as the goal, philosophical assumption, concepts, methodology, study design, framework/model, findings, strengths, and limitations. Zotero referencing software was used because the databases lacked characteristics for indicating study titles, journals/conferences, abstracts, dates, and references. 338 references, abstracts, dates, and titles were extracted and stored in Zotero. The Zotero reference software was used by other scholars for both review and other academic research as it is in [23, 63, 138]. The study search occurred between November and December 2021, encompassing all of the selected journals' available timeframes in the databases ACM, JSTOR, Science Direct, and ProQuest.

3.1. Selection criteria

The eligibility criteria specify which studies will be included in the systematic review and which will be excluded [88, 73, 84, 10]. The inclusion/exclusion criteria are summarized in Table 1

Table 1. Inclusion and exclusion criteria.

Inclusion Criteria	**Exclusion Criteria**
Should involve electronic democracy or electronic voting processes in Africa	Articles on democracy or voting that do not involve information systems or technologies.
Should involve technology or an information system.	Voting or democracy processes that are used in contexts other than information systems or technologies and Africa.
Articles are written in English.	Articles are written in languages besides English.

Inclusion Criteria:

The inclusion criteria are based on the research questions being investigated [126, 117]. Therefore, the review covered articles written in English and published between 2011 and 2021 that studied electronic democracy or electronic voting systems in Africa and were all stored in Zotero reference software in different folders.

Exclusion Criteria: Articles not on electronic voting and electronic democracy as a tool for African political systems, as well as articles not on, IS to electoral systems, were removed from this review. Articles not written in the English language were as well excluded. This is in line with the work of other IS scholars as in [73, 10] Review papers, books, reports, editorials, letters, meetings, and a manual were also removed, and the information structured in a table as shown in table 2.

Selection for the Study: Following the removal of duplicates, the study selection screening that was adopted from [69] began with a review of the title and abstract, followed by a review of the full-text record. All of the writers independently assessed the titles and abstracts of the publications in order to select appropriate titles and abstracts related to e-democracy. The discussion was used to settle disagreements on items that met the requirements. The title and abstract of each study were examined to see if they fit the inclusion criteria. Following that, full-text papers were retrieved and evaluated,

and studies were chosen based on the above-mentioned inclusion and exclusion criteria. Eleven full-text articles could not be retrieved and were consequently excluded. An annotated bibliography was created to organize the findings.

4 Results and Discussion

There were 338 articles discovered from our search in total from the four selected databases. The search result was obtained for ten years (2011 to 2021) of published articles from the four selected databases. However, 17 of the articles with the same title were excluded as duplicates during the initial search as shown in figure 2, and we were left with 321 articles. 68 articles were deleted following the exclusion criteria, these were excluded as a result of the title not being relevant, reports, meetings, and non-English articles and we were left with 253 records of publications. Only 253 articles were left, based on the relevance of the titles. The researchers retrieved the abstract of 253 articles for inclusion and relevance to the topic of the review. The authors reviewed the titles and abstracts of all identified sources against the predefined inclusion criteria. The Inclusion Criteria were based on articles written in English and published between 2011 and 2021. The articles involved studies that used ICT for democracy or electronic elections, electronic democracy, and e-voting in Africa and were indexed in one of the databases listed were included. Reports that were not focused on electronic democracy or electronic voting, as well as those written in languages other than English were omitted from the title and abstract. Those from outside of Africa, as well as those published before 2011, were also omitted.

After reviewing the abstract, 201 publications were removed and 52 articles from conferences and journals met the inclusion criteria. Furthermore, 9 items were excluded going by the contents of the full text as relevant to the topic. The 9 items were excluded because they did not originate from African countries; these include publications from South Korea, Estonia, the United States, Canada, the Netherlands, and India. We were finally left with 41 conferences and peer-reviewed journals that met the inclusion criteria as shown in figure 2. For the full review and analysis, the full text of relevant publications was searched using the Zotero software and manually retrieved from digital online sources.

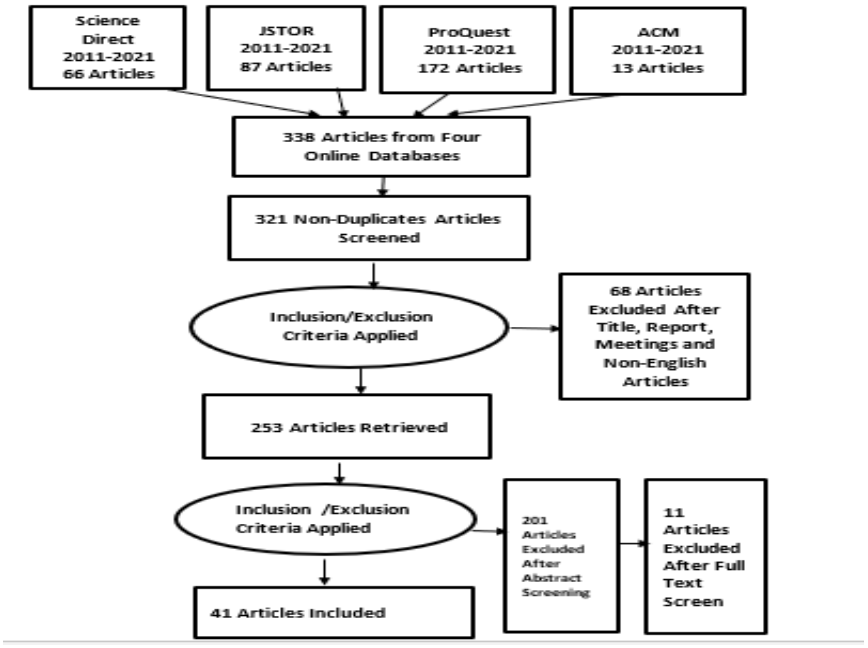


Figure 2. Flowchart for the identified articles selection inclusion/exclusion criteria

Abstraction of key terms from the articles: Each article was compiled into an Excel spreadsheet. Each article's columns were labeled with the following categories of data: S/N, author, title, nations, aim, philosophical assumption, concepts, study design, framework/theory, findings, strength, and limitations. For convenience, the papers were reviewed and arranged in columns**.** This is done with relevance to the topic in mind and IS to election processes (registration and verification process).

Data Analysis: The authors carefully analyzed and compared the features of each study and separated them into units to synthesize the features of information systems in electoral processes across the reviewed studies. The findings of the study confirmed that e-democracy/e-election research in Nigeria, a nation located in the West African continent, has received a lot of attention from researchers investigating e-democracy or electronic voting systems. It is revealed from the literature as twenty-two (22) researches were conducted in Nigeria. Results from other countries on e-democracy/e-election revealed that Kenya (2), Ghana with (3), Northern Africa (1), Togo (1), Namibia (2), South Africa (4), Egypt (1), Uganda (2), Botswana (1), Guinea-Bissau (1), and Zimbabwe (1). figure 3 depicts a graphical representation of publications per country, in terms of number, as depicted in figure 3.

	NUMBER OF PUBLICATION
Nigeria	22
Kenya	2
Ghana	3
Northern Africa	1
Togo	1
Namibia	2
South Africa	4
Egypt	1
Uganda	2
Botswana	1
Guinea Bissau	1
Zimbabwe	1
Total	41

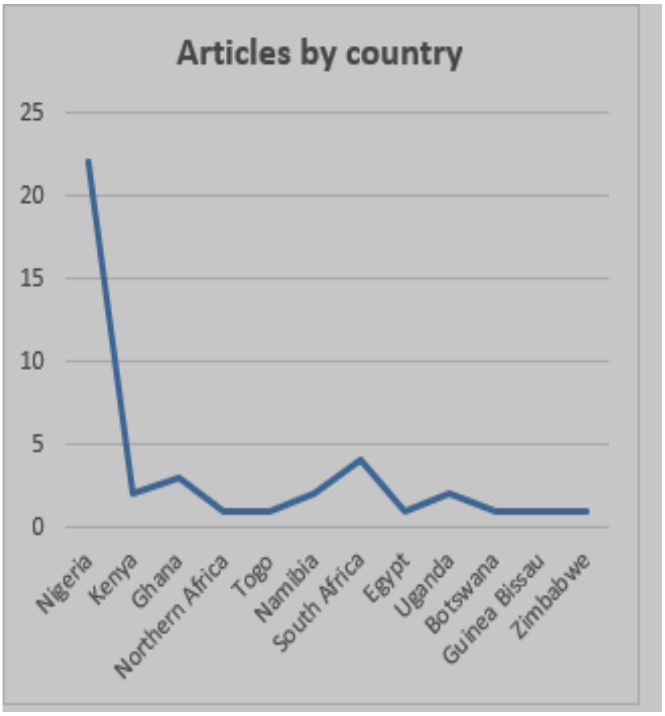


Figure 3. Articles by Country

5 Research Theories/Models/Framework and Philosophies Driving e-Democracy in Electoral processes

In terms of IS theories/models/frameworks used to study the implementation of e-democracy/e-electoral processes, some of the current research trends are hampered by a lack of theory/framework/model applicability. This evidence can be found in the work of [122, 123]. Some researchers extensively used e-government models/frameworks as an IS model in studying e-democracy/e-voting implementation [92, 105, 30]. However, this has been criticized for being theoretically weak, not well grounded, and descriptive in empirical evidence [39]. These critiques are

commonly related to the beliefs of some researchers that some models for e-government intentionally divert away from the basics of how information technology is used within organizations and for the outside world [39]. The findings further shows that some articles used unified modeling language, flow charts, and database models to design and develop an electronic voting system while ignoring the social actors, which causes system impediment [1, 3, 14, 116].

This review shows that, the philosophies used on e-Democracy in e-voting process research are categorized into four. These categorizations are adopted from both information systems and non-information system research. The four categories of philosophies include interpretivism, pragmatism, positivism, and critical realism. However, some of the authors did not clearly state the type of philosophical stance they work within their research. We derived some of their philosophical stance from the type of data presentation and research methodology used in their studies. The researchers discovered pragmatism due to its integration of quantitative and qualitative philosophical perspectives. Furthermore, The SLR determined that nine (9) of the articles under review used pragmatic approach.

The research investigated the role of the interconnectedness of experience, knowledge, and action as one of the methodological principles of pragmatism inquiry. The review's findings indicate that interpretivism is the prevailing philosophical stance used in e-Democracy based on the voting process. This shows that eighteen (18) of the articles used in this systematic literature review employed interpretivism. To identify the interpretivist studies, thematic qualitative findings from the perspectives of study participants were used. This is followed by positivism which adopted fourteen (14) of the studies used in this review. The use of statistical representations in some of the findings aided in identifying positivist research articles with a large number of study participants and their population generalization *as presented in figure 4*. There has been no study that investigates e-Democracy in the voting process from a realist standpoint.

PHILOSOPHICAL STANCE	NUMBER OF PUBLICATIONS
Pragmatism	9
Interpretivism	18
Positivism	14
Critical Realism	0
Total	41

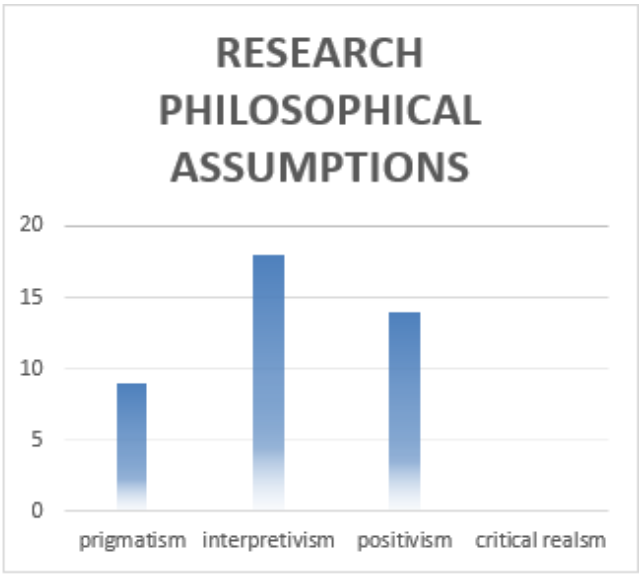


Figure 4. Number of Articles Sorted by Philosophical Assumptions used

5.1. Scholarly Research Discipline

According to the review search results, the majority of scholars' studies that dominated the literature on e-democracy in the election process are from political science and international relations as depicted in figure 5. This was acquired by examining the details presented by the authors on each of the articles

incorporated for reading the full text. The researchers discovered that only one information systems academic studied e-democracy during the review. The study provided a model for the deployment of local e-democracy (e-government) in Uganda that applies to other developing countries [92]. Even though the scholar is an IS expert, the study is not on electronic voter registration and verification in the electoral process. There is a paucity of IS researchers studying the application of e-democracy to the electoral process in Sub-Saharan Africa.

Socio-cultural norms are among the challenges restricting the use of e-government services, failing numerous e-government systems [26]. This argument is compatible with our contention that IS scholars may make significant contributions to e-democracy, particularly in the socio-technical realm. This is based on findings from the discipline's literature on how socio-technical aspects of IS implementations are embedded and socially created, as well as the way IS accomplishments are attributed to varied interpretations at various stages of assessment [17, 18, 16]. One of the main critiques made towards scholars investigating e-democracy and electronic voter registration and verification in particular is the lack of socio-technical knowledge in the discipline, an area that is important in IS scientific inquiry [22, 54].

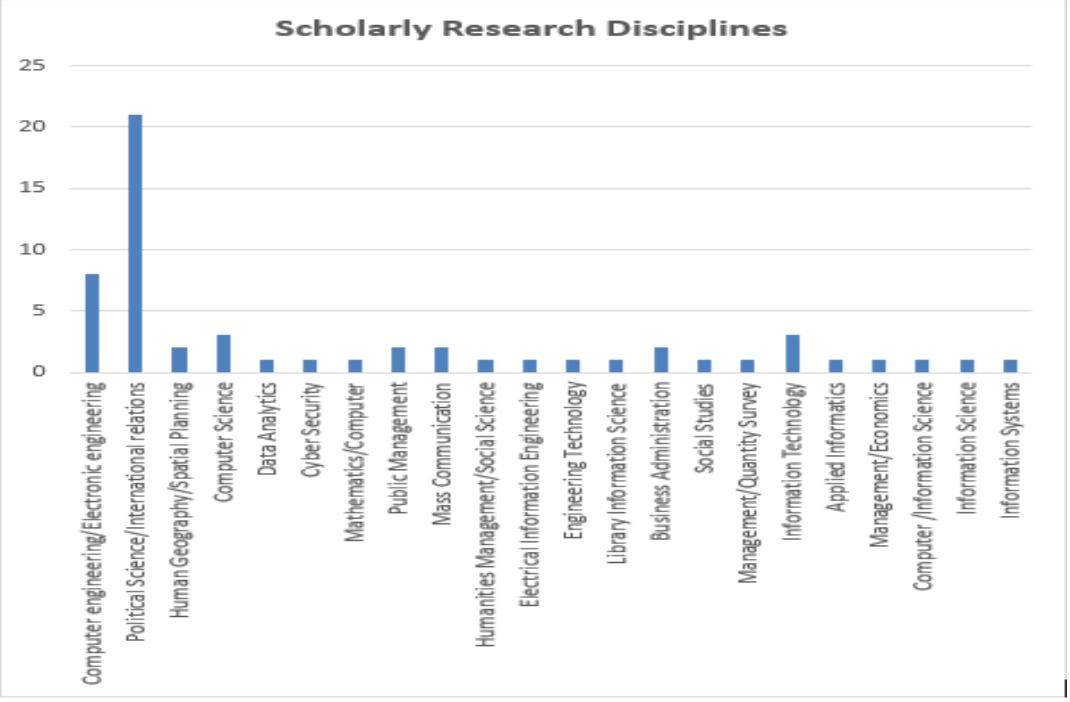


Figure 5. Scholarly Research Disciplines

6 Conclusion

The systematic literature review synthesized the literature on e-democracy with emphasis on electronic registration and verification in Sub-Saharan Africa over the last decade. The researchers discovered that the dominant philosophical stance used by scholars studying electronic registration and verification in Sub-Saharan Africa is interpretivism and positivism. It was also discovered that although eleven African countries reportedly use electronic voter authentication/validation as a security measure for credible electoral outcomes, several pilot studies from seventeen African countries in sub-Saharan African region have been conducted. This emphasizes the requirement for further findings from electronic registration and verification in the electoral process in other African countries to better understand the practice in Sub-Saharan Africa. Our findings also emphasize the

significance of further research for the e-electoral process, particularly voter registration and verification, with a broader philosophical underpinning, particularly interpretivism. our study results have helped the development of a body of evidence for e-democracy in the Sub-Saharan African electoral process, which is frequently undervalued in the literature. To develop new perspectives on e-democracy in Sub-Saharan Africa, we additionally hope to draw the attention of the researchers and practitioners in the IS field. Using the full potential of e-democracy in the e-electoral process could help SSA countries grant legitimacy to the electoral process, avoid electoral fraud, and guarantee that each registered voter can vote only once in an election.

7 Limitations and future studies

We acknowledge that this study has some limitations, which necessitates additional research in e-elections and in particular electronic registration and verification. The main drawback of this review is that it is restricted to Sub-Saharan Africa. The second limitation stems from the electoral process's constraints. The SLR is limited to the electoral registration and verification process. The timeframe is another constraint; it should be expanded to include a more extensive period of IS research. This expansion would allow for the evaluation of other e-electoral processes used in several IS articles. The assertions and inferences are primarily aimed at explaining the complexities and benefits of studying e-democracy in the e-electoral process using interpretivist philosophy. As a result, the scope of the review is reduced. Future research may examine and assess the quality of findings from e-democracy in e-electoral processes interventions in Sub-Saharan Africa, consisting of findings from the literature review.

References

[1] Abdulhamid, S. M., Adebayo, O. S., Ugiomoh, D. O., & AbdulMalik, M. D. The Design and Development of Real-Time E-Voting System in Nigeria with Emphasis on Security and Result Veracity. *International Journal of Computer Network and Information Security*, 2013; *5*(5): 9–18. https://doi.org/10.5815/ijcnis.2013.05.02

[2] AboSamra, K. M., AbdelHafez, A. A., Assassa, G. M. R., & Mursi, M. F. M. A practical, secure, and auditable e-voting system. *Journal of Information Security and Applications*, 2017; *36*: 69–89. https://doi.org/10.1016/j.jisa.2017.08.002

[3] Adekitan, A. I., Matthews, V. O., John, T. M., & Uzairue, S. Implementation of E-voting System for Student Union Government Elections. *Telkomnika*, 2018; *16*(5): 2155–2164. https://doi.org/10.12928/TELKOMNIKA.v16i5.9739

[4] Adeshina, S. A., & Ojo, A. towards Improved Adoption of E-Voting: Analysis of the Case of Nigeria. *Proceedings of the 8th International Conference on Theory and Practice of Electronic Governance*, 2014; 403–412. https://doi.org/10.1145/2691195.2691255

[5] Adeshina, S. A., & Ojo, A. Factors for e-voting adoption—Analysis of general elections in Nigeria. *Government Information Quarterly*, 2020; *37*(3): 101257. https://doi.org/10.1016/j.giq.2017.09.006

[6] Afolabi, O. S. Biometric Technologies, Electoral Fraud and the Management of Elections in Nigeria and Zimbabwe. *The Strategic Review for Southern Africa*, 2020; *42*(2): 205–229.

[7] Ahmad, S., Abdullah, S. A. J. B. A., & Arshad, R. B. Issues and Challenges of Transition to e-Voting Technology in Nigeria. *Public Policy and Administration Research*, 2015; *5*(4): 9.

[8] Akter, S., Molla, M., Islam, S. M. R., Kabir, R., & Alam, F. Unequivocal ICT in Enhancing the Essence of Democracy and Good Governance. *Journal of Modern Accounting and Auditing*, 2019; *15*(1): https://doi.org/10.17265/1548-6583/2019.01.003

[9] Akwen, G. T., Jooji, I., & Moorthy, R. Smart Card Reader And Electoral Transparency In Nigeria: The Case Of 2015 General Elections. *E-Bangi*, 2018; *15*(2):

[10] Al-Emran, M., Mezhuyev, V., Kamaludin, A., & Shaalan, K. The impact of knowledge management processes on information systems: A systematic review. *International Journal of Information Management*, 2018; *43*: 173–187. https://doi.org/10.1016/j.ijinfomgt.2018.08.001

[11] Aljarrah, E., Elrehail, H., & Aababneh, B. E-voting in Jordan: Assessing readiness and developing a system. *Computers in Human Behavior*, 2016; *63*: 860–867. https://doi.org/10.1016/j.chb.2016.05.076

[12] Alomari, M. K. E-voting adoption in a developing country. *Transforming Government: People, Process and Policy*, 2016; *10*(4): 526–547. https://doi.org/10.1108/TG-11-2015-0046

[13] Asadullah, A., Faik, I., & Kankanhalli, A. Digital Platforms: A Review and Future Directions. *Twenty-Second Pacific Asia Conference on Information Systems*, 2018; 15:

[14] Asafe, Y. N., Okedola, A. A., & Olamide, O. A. Embedded Computer Application Software for Secured Voter Card Transfer: An Approach to Improve Electoral Integrity & Electoral Fraud Prevention Mechanism. *International Journal of Advanced Networking and Applications*, 2017; *9*(1): 3294.

[15] Avgerou, C. Explaining Trust in IT-Mediated Elections: A Case Study of E-Voting in Brazil. *Journal of the Association for Information Systems*, 2013; *14*(8): 420–451. https://doi.org/10.17705/1jais.00340

[16] Avgerou, C., & Bonina, C. Ideologies implicated in IT innovation in government: A critical discourse analysis of Mexico's international trade administration. *Information Systems Journal*, isj. (2019). 12245. https://doi.org/10.1111/isj.12245

[17] Avgerou, C., Hayes, N., & La Rovere, R. L. Growth in ICT uptake in developing countries: New users, new uses, new challenges. *Journal of Information Technology*, 2016; *31*(4): 329–333. https://doi.org/10.1057/s41265-016-0022-6

[18] Avgerou, C., Masiero, S., & Poulymenakou, A. Trusting e-voting amid experiences of electoral malpractice: The case of Indian elections. *Journal of Information Technology*, 2019; *34*(3): 263–289. https://doi.org/10.1177/0268396218816199

[19] Ayeni, T. P., & Omolayo Esan, A. The Impact of ICT in the Conduct of Elections in Nigeria. *American Journal of Computer Science and Information Technology*, 2018; *06*(01): 6. https://doi.org/10.21767/2349-3917.100014

[20] Ayo, C. K., Mbarika, V. W., & Oni, A. A. The Influence of Trust and Risk on Intention to Use E-Democracy in Nigeria. *Mediterranean Journal of Social Sciences*, 2015; *6*(6): 10. https://doi.org/10.5901/mjss.2015.v6n6s1p477

[21] Aziz, M. S., & Hasna, S. The Problem of E-Democracy and its Impact on Political Participation in Indonesia: *Proceedings of the 6th International Conference on Social and Political Sciences (ICOSAPS 2020)*. 2020; 6th International Conference on Social and Political Sciences (ICOSAPS 2020), Surakarta, Jawa Tengah, Indonesia. https://doi.org/10.2991/assehr.k.201219.071

[22] Bannister, F., & Connolly, R. The future ain't what it used to be: Forecasting the impact of ICT on the public sphere. *Government Information Quarterly*, 2020; *37*(1): 101410. https://doi.org/10.1016/j.giq.2019.101410

[23] Basak, S. K. *Reference Management Software: Comparative Analysis of RefWorks and Zotero*. 2014; *8*(11): 4.

[24] Batista Pereira, F., & Porto, N. F. F. Gender Attitudes and Public Opinion Towards Electoral Gender Quotas in Brazil. *Political Psychology*, 2020; *41*(5): 887–899. https://doi.org/10.1111/pops.12655

[25] Benabdallah, A., Audras, A., Coudert, L., El Madhoun, N., & Badra, M. Analysis of Blockchain Solutions for E-Voting: A Systematic Literature Review. *IEEE Access*, 2022; *10*: 70746–70759. https://doi.org/10.1109/ACCESS.2022.3187688

[26] Bindu, N., Sankar, C. P., & Kumar, K. S. From conventional governance to e-democracy: Tracing the evolution of e-governance research trends using network analysis tools. *Government Information Quarterly*, 2019; *36*(3): 385–399. https://doi.org/10.1016/j.giq.2019.02.005

[27] Bisong, D. *E-VOTING, A PANACEA FOR CREDIBLE ELECTION IN NIGERIA*. 2019; *Vol. 06*(12): 5391–5396.

[28] Blais, A., Bol, D., Bowler, S., Farrell, D. M., Fredén, A., Foucault, M., Heisbourg, E., Lachat, R., Lago, I., Loewen, P. J., Nemčok, M., Pilet, J.-B., & Plescia, C. What Kind of Electoral Outcome do People Think is Good for Democracy? *Political Studies*, 2021; 003232172110555. https://doi.org/10.1177/00323217211055560

[29] Bowles, J., Larreguy, H., & Liu, S. How Weakly Institutionalized Parties Monitor Brokers in Developing Democracies: Evidence from Postconflict Liberia. *American Journal of Political Science*, 2020; *64*(4): 952–967. https://doi.org/10.1111/ajps.12515
[30] Brooks, L., & Mohammed, A. B. EVoting in Nigeria: The Case of the Independent National Electoral Commission (INEC). *Proceedings of the 2014 Conference on Electronic Governance and Open Society: Challenges in Eurasia*, 2014; 127–136. https://doi.org/10.1145/2729104.2729106
[31] Carr, P. R., Cuervo Sanchez, S. L., & Daros, M. A. Citizen Engagement in the Contemporary Era of Fake News: Hegemonic Distraction or Control of the Social Media Context? *Postdigital Science and Education*, 2020; *2*(1): 39–60. https://doi.org/10.1007/s42438-019-00052-z
[32] Carter, L., Yoon, V., & Liu, D. Analyzing e-government design science artifacts: A systematic literature review. *Elsevier Ltd. All Rights Reserved* 2022; *62*: 13.
[33] Chaieb, M., Yousfi, S., Lafourcade, P., & Robbana, R. Verify-Your-Vote: A Verifiable Blockchain-Based Online Voting Protocol. In M. Themistocleous & P. Rupino da Cunha (Eds.), *Information Systems* 2019; Vol. 341: pp. 16–30. Springer International Publishing. https://doi.org/10.1007/978-3-030-11395-7_2
[34] Chauhan, P., Sharma, N., & Sikka, G. The emergence of social media data and sentiment analysis in election prediction. *Journal of Ambient Intelligence and Humanized Computing*, 2021; *12*(2): 2601–2627. https://doi.org/10.1007/s12652-020-02423-y
[35] Cheeseman, N., Lynch, G., & Willis, J. Digital dilemmas: The unintended consequences of election technology. *Democratization*, 2018; *25*(8): 1397–1418. https://doi.org/10.1080/13510347.2018.1470165
[36] Chibuwe, A. Social Media and Elections in Zimbabwe: Twitter War between Pro-ZANU-PF and Pro-MDC-A Netizens. *Communication*, 2020; *46*(4): 7–30. https://doi.org/10.1080/02500167.2020.1723663
[37] Dalton, R. J., Shin, D. C., & Jou, W. *Understanding Democracy: Data from Unlikely Places*. 2007; *18*(4): 16. https://doi.org/10.1353/jod.2007.0065
[38] Debrah, E., Effah, J., & Owusu-Mensah, I. Does the use of a biometric system guarantee an acceptable election's outcome? Evidence from Ghana's 2012 election. *African Studies*, 2018; *78*(3): 347–369. https://doi.org/10.1080/00020184.2018.1519335
[39] Debri, F., & Bannister, F. E-government Stage Models: A Contextual Critique. *2015 48th Hawaii International Conference on System Sciences*, 2015; 2222–2231. https://doi.org/10.1109/HICSS.2015.266
[40] Dias, M., & Teles, A. VOTE IN BRAZIL AND GENERAL ELECTIONS 2018: ARE THE PILLARS OF DEMOCRACY IN DANGER? *European Centre for Research Training and Development UK (Www.Eajournals.Org)*, 2018; *6*(6): 15.
[41] Effah, J., & Debrah, E. Biometric technology for voter identification: The experience in Ghana. *The Information Society*, 2018; *34*(2): 104–113. https://doi.org/10.1080/01972243.2017.1414720
[42] Effah, J., & Owusu-Oware, E. From national to sector level biometric systems: The case of Ghana. *Information Technology for Development*, 2020; 1–20. https://doi.org/10.1080/02681102.2020.1818543
[43] Effah, J., Owusu-Oware, E., & Boateng, R. Biometric Identification for Socioeconomic Development in Ghana. *Information Systems Management*, 2020; *37*(2): 136–149. https://doi.org/10.1080/10580530.2020.1732528
[44] Elkjær, M. A., & Iversen, T. The Political Representation of Economic Interests: Subversion of Democracy or Middle-Class Supremacy? *World Politics*, 2020; *72*(2): 254–290. https://doi.org/10.1017/S0043887119000224
[45] Faniran, S., & Olaniyan, K. Strengthening Democratic Practice in Nigeria: A Case for e-Voting. *Proceedings of the 5th International Conference on Theory and Practice of Electronic Governance*, 2011; 337–340. https://doi.org/10.1145/2072069.2072132
[46] Fidelis, D. O. O. ELECTRONIC VOTING SYSTEM: A CREDIBLE ALTERNATIVE FOR TRADITIONAL PAPER-BASED VOTING IN NIGERIA. *BINGHAM JOURNAL OF ECONOMICS AND ALLIED STUDIES*, 2020; *4*(2): 8.
[47] Fornoni, T. M. Why e-democracy is not a possible reality (yet): A literature review on the challenges to the applicability of e-democracy. *Kommunikation.Medien Open-Access-Journal*, 2019; *10*: 1–10. https://doi.org/10.25598/JKM/2019-10.14
[48] Garnett, H. A., & James, T. S. Cyber Elections in the Digital Age: Threats and Opportunities of Technology for Electoral Integrity. *Election Law Journal: Rules, Politics, and Policy*, 2020; *19*(2): 111–126. https://doi.org/10.1089/elj.2020.0633
[49] Gelb, A., & Diofasi, A. Biometric Elections in Poor Countries: Wasteful or a Worthwhile Investment? *Washington, DC: Center for Global Development.*, 2016; 30.
[50] Gibson, J. P., Krimmer, R., Teague, V., & Pomares, J. A review of E-voting: The past, present and future. *Annals of Telecommunications*, 2016; *71*(7–8): 279–286. https://doi.org/10.1007/s12243-016-0525-8
[51] Gohari, S., Baer, D., Nielsen, B. F., Gilcher, E., & Situmorang, W. Z. Prevailing Approaches and Practices of Citizen Participation in Smart City Projects: Lessons from Trondheim, Norway. *Infrastructures*, 2020; *5*(4): 36. https://doi.org/10.3390/infrastructures5040036
[52] Gunawong, P., & Gao, P. Understanding e-government failure in the developing country context: A process-oriented study. *Information Technology for Development*, 2017; *23*(1): 153–178. https://doi.org/10.1080/02681102.2016.1269713
[53] Gupta, D. K., & Biswas, A. K. The Institutionalization of e-Democracy: Challenges, Risks and Future Directions in an Indian Context. *JeDEM - eJournal of eDemocracy and Open Government*, 2021; *13*(1): 127–143. https://doi.org/10.29379/jedem.v13i1.622
[54] Hasan, H., & Linger, H. Letting the public in: Dialectic tensions when local governments move beyond e-government to e-democracy. *Australasian Journal of Information Systems*, 2020; *24*: 31.
[55] Heinisch, R., & Werner, A. Who Do Populist Radical Right Parties Stand for? Representative Claims, Claim Acceptance and Descriptive Representation in the Austrian FPÖ and German AfD. *Representation*, 2019; *55*(4): 475–492. https://doi.org/10.1080/00344893.2019.1635196
[56] Helm, J. E. Distributed Internet voting architecture: A thin client approach to Internet voting. *Journal of Information Technology*, 2021; *36*(2): 128–153. https://doi.org/10.1177/0268396220978983

[57] Henriette, E., Feki, M., & Boughzala, I. The Shape of Digital Transformation: A Systematic Literature Review. *MCIS 2015 Proceedings*. 2015; *Paper 10*, 15: http://aisel.aisnet.org/mcis2015
[58] Herman, J. L. *The Potential Impact of Voter Identification Laws on Transgender Voters*. 2012; 11.
[59] Herman, J. L., & Brown, T. N. T. *The Potential Impact of Voter Identification Laws on Transgender Voters in the 2018 General Election*. 2018; 9.
[60] Hujran, O., Abu-Shanab, E., & Aljaafreh, A. Predictors for the adoption of e-democracy: An empirical evaluation based on a citizen-centric approach. *Transforming Government: People, Process and Policy*, 2020; *14*(3): 523–544. https://doi.org/10.1108/TG-03-2019-0016
[61] IDEA, I. *Introducing Biometric Technology in Elections*. 2017; 66.
[62] Idowu, H. A. Biometric technologies and the prospect of sustainable democracy in Africa. *Journal of African Elections*, 2021; *20*(1): 23–43. https://doi.org/10.20940/JAE/2021/v20i1a2
[63] Idri, N. Zotero Software: A Means of Bibliographic Research and Data Organisation; Teaching Bibliographic Research. *SSRN Electronic Journal*. 2015; https://doi.org/10.2139/ssrn.2843984
[64] Igwe, S. C. *Mitigating Electoral Discontents in Nigeria: A Case for SMS Enabled Vote-*. 2021; 27.
[65] Isma'ila, Y., & Othman, Z. Challenges of Electoral Processes in Nigeria's Quest for Democratic Governance in the Fourth Republic. *Research on Humanities and Social Sciences*, 2015; *Vol.5*, No.22: https://core.ac.uk/download/pdf/234674783.pdf
[66] James, T. S., & Clark, A. Electoral integrity, voter fraud and voter ID in polling stations: Lessons from English local elections. *Policy Studies*, 2020; *41*(2–3): 190–209. https://doi.org/10.1080/01442872.2019.1694656
[67] Jibia, M. S., Zake, P. M., Ajiji, D. Y., & Kareyo, D. M. ACCEPTANCE OF ELECTRONIC VOTING TECHNOLOGY AND PERFORMANCE OF ELECTIONS IN SELECTED STATES IN NIGERIA. *Ijisrt.Com*. 2018; https://ijisrt.com/assets/upload/submitted_files/1581057529.pdf
[68] Keramidis, P., & Charalabidis, Y. Decisive Factors for Success or Failure of e- Democracy Initiatives in the Information Era. *Ceur-Ws.Org*, 2021; *Vol-3049*(1): https://ceur-ws.org/Vol-3049/Paper1.pdf
[69] Kgoroeadira, R. *Promoting entrepreneurship as a means to foster economic prosperity: A Review of market failure and public policy*. 2010; Cranfield University.
[70] Khan, K. M., Arshad, J., & Khan, M. M. Investigating performance constraints for blockchain based secure e-voting system. *Future Generation Computer Systems*, 2020; *105*: 13–26. https://doi.org/10.1016/j.future.2019.11.005
[71] Kim, J. A model and case for supporting participatory public decision making in e-democracy. *Group Decision and Negotiation*, 2008; *17*(3): 179–193. https://doi.org/10.1007/s10726-007-9075-9
[72] Kim, J. H. *Replication Data for: Direct Democracy and Women's Political Engagement* [dataset]. Harvard Dataverse. 2019; https://doi.org/10.7910/DVN/SZ9YXZ
[73] Kim, M., Zoo, H., Lee, H., & Kang, J. Mobile financial services, financial inclusion, and development: A systematic review of academic literature. *The Electronic Journal of Information Systems in Developing Countries*, 2018; *84*(5): e12044. https://doi.org/10.1002/isd2.12044
[74] Koenig-Archibugi, M. Who Are the People? Defining the *Demos* in the Measurement of Democracy. *Political Studies*, 2020; 003232172096648. https://doi.org/10.1177/0032321720966481
[75] Komariah, K., Prastowo, F. A., & Sumartias, S. Millennials' Perception of the Practice of Democracy. *Proceedings of the First International Conference on Literature Innovation in Chinese Language*, 2022; *LIONG 2021, 19-20 October 2021, Purwokerto, Indonesia*. Proceedings of the First International Conference on Literature Innovation in Chinese Language, LIONG 2021, 19-20 October 2021, Purwokerto, Indonesia, Purwokerto, Indonesia. https://doi.org/10.4108/eai.19-10-2021.2316596
[76] Kumar, M. S., & Walia, Dr. E.. *ANALYSIS OF ELECTRONIC VOTING SYSTEM IN VARIOUS COUNTRIES*. 2011; *3*(5): 6.
[77] Leininger, A., & Meijers, M. J. Do Populist Parties Increase Voter Turnout? Evidence From Over 40 Years of Electoral History in 31 European Democracies. *Political Studies*, 2021; *69*(3): 665–685. https://doi.org/10.1177/0032321720923257
[78] Li, P., Lai, J., & Wu, Y. Publicly Traceable Attribute-Based Anonymous Authentication and Its Application to Voting. *Security and Communication Networks*, *2021*. 2021; https://doi.org/10.1155/2021/6611518
[79] Lieberman, R. C., Mettler, S., Pepinsky, T. B., Roberts, K. M., & Valelly, R. The Trump Presidency and American Democracy: A Historical and Comparative Analysis. *Perspectives on Politics*, 2019; *17*(02): 470–479. https://doi.org/10.1017/S1537592718003286
[80] Lindner, R., & Aichholzer, G. (Eds.). *"E-democracy: Conceptual foundations and recent trends."* 2020; https://doi.org/10.1007/978-3-030-27184-8
[81] Liu, S. M., Pan, L., & Lei, Y. What is the role of New Generation of ICTs in transforming government operation and redefining State-citizen relationship in the last decade? *Proceedings of the 12th International Conference on Theory and Practice of Electronic Governance*, 2019; 65–75. https://doi.org/10.1145/3326365.3326374
[82] Loeber, L. Use of Technology in the Election Process: Who Governs? *Election Law Journal: Rules, Politics, and Policy*, 2020; *19*(2): 149–161. https://doi.org/10.1089/elj.2019.0559
[83] Mann, C. B., & Bryant, L. A. If you ask, they will come (to register and vote): Field experiments with state election agencies on encouraging voter registration. *Electoral Studies*, 2020; *63*: 102021. https://doi.org/10.1016/j.electstud.2019.02.012
[84] Maramba, I., Chatterjee, A., & Newman, C. Methods of usability testing in the development of eHealth applications: A scoping review. *International Journal of Medical Informatics*, 2019; *126*: 95–104. https://doi.org/10.1016/j.ijmedinf.2019.03.018
[85] Marjorie, O. P., & Mwikya, D. J. *BIOMETRIC VOTER REGISTRATION AND ELECTRONIC VOTER IDENTIFICATION SYSTEM ON CREDIBILITY OF THE ELECTORAL SYSTEM IN KENYA; A CASE STUDY OF NAIROBI COUNTY*. 2020; *8*(7): 21.
[86] Mathe, L. Party nominee or independent candidate? Examining Electoral Reforms and the Use of Digital Technologies for Voter Participation in South Africa. *Journal of African Elections*, 2021; *20*(2): 120–140. https://doi.org/10.20940/JAE/2021/v20i2a7

[87] McGrath, K. Identity Verification and Societal Challenges: Explaining the Gap Between Service Provision and Development Outcomes. *MIS Quarterly*, 2016; *40*(2): 485–500. https://doi.org/10.25300/MISQ/2016/40.2.12
[88] Meline, T. Selecting Studies for Systemic Review: Inclusion and Exclusion Criteria. *Contemporary Issues in Communication Science and Disorders*, 2006; *33*(spring): 21–27. https://doi.org/10.1044/cicsd_33_S_21
[89] Mishra, S. S. Testing the antecedents to e-democracy towards citizens' happiness: A structural equation modelling approach to 'MyGov' initiative, India. *International Journal of Public Administration*, 2020; *43*(15): 1293–1303. https://doi.org/10.1080/01900692.2019.1669051
[90] Moss, G., & Coleman, S. Deliberative Manoeuvres in the Digital Darkness: E-Democracy Policy in the UK. *The British Journal of Politics and International Relations*, 2014; *16*(3): 410–427. https://doi.org/10.1111/1467-856X.12004
[91] Mukti, H. H., & Rodiyah, R. Dynasty Politics in Indonesia: Tradition or Democracy? *Journal of Law and Legal Reform*, 2020; *1*(3): 531–538. https://doi.org/10.15294/jllr.v1i3.38090
[92] Nabafu, R., & Maiga, G. *A model of success factors for iplementing local e-government in Uganda.* 2012;
[93] Najam, S., Shaikh, A. Z., & Naqvi, S. A Novel Hybrid Biometric Electronic Voting System: Integrating Finger Print and Face Recognition. *Mehran University Research Journal of Engineering and Technology*, 2018; *37*(01): 59–68. https://doi.org/10.22581/muet1982.1801.05
[94] Naranjo-Zolotov, M., Oliveira, T., & Casteleyn, S. Citizens' intention to use and recommend e-participation: Drawing upon UTAUT and citizen empowerment. *Information Technology & People*, 2019; *32*(2): 364–386. https://doi.org/10.1108/ITP-08-2017-0257
[95] Nchise, A. C.. An Empirical Analysis of the Theory of Planned Behavior: A Review of Its Application on E-democracy Adoption Using the Partial Least Squares Algorithm. *JeDEM - eJournal of eDemocracy and Open Government*, 2012a; *4*(2): 171–182. https://doi.org/10.29379/jedem.v4i2.129
[96] Nchise, A. C. *The trend of e-democracy research: Summary evidence and implications*. 2012b; 8: https://dl.acm.org/doi/pdf/10.1145/2307729.2307756
[97] Nelimarkka, M., Laaksonen, S.-M., Tuokko, M., & Valkonen, T. Platformed Interactions: How Social Media Platforms Relate to Candidate–Constituent Interaction During Finnish 2015 Election Campaigning. *Social Media + Society*, 2020; *6*(2): 205630512090385. https://doi.org/10.1177/2056305120903856
[98] Neshkova, M. I., & Kalesnikaite, V. Corruption and citizen participation in local government: Evidence from Latin America. *Governance*, 2019; *32*(4): 677–693. https://doi.org/10.1111/gove.12401
[99] Nu'man, A. *A Framework for Adopting E-Voting in Jordan*. 2012; *10*(2): 14.
[100] Nwangwu, C. BIOMETRIC VOTING TECHNOLOGY AND THE 2015 GENERAL ELECTIONS IN NIGERIA. *Electoral Institute*, 2015; 28. https://inecnigeria.org/wp-content/uploads/2019/02/Conference-Paper-by-Chikodiri-Nwangwu2

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp.179-195, November 13-16, 2023

Understanding the Defensive Approaches to Organization Cybersecurity Threats in the Fourth Industrial Revolution

Maharazu Kasim[1], Samuel C. Avemaria Utulu[2]
{maharazu.kasim@aun.edu.ng[1], samuel.utulu@aun.edu.ng}

American University of Nigeria, Yola Bye-Pass, Yola, Adamawa State, Nigeria[1,]
American University of Nigeria, Yola Bye-Pass, Yola, Adamawa State, Nigeria[2]

Abstract
The fourth industrial revolution, with its numerous advantages, has brought up a number of cyber security issues that prevent it from reaching its full potential. The internet lays the groundwork for its expansion of the fourth industrial revolution. In the future, it will be possible for people to control the contents of their refrigerators through their mobile devices. If an unwanted attacker obtains access to these devices, the consequence is dire. As a result, researchers and industry professionals have suggested a number of cybersecurity protection methods. Adopting proactive security measures against cyber-attacks is an important strategy. Organizations are more often using ethical hacking as a preventative strategy to spot vulnerabilities early and keep one step ahead of prospective attackers by applying upgrades and cybersecurity protections as soon as possible. It's important to note that social ethical hacking's significance in identifying delicate actions and activities connected to cybersecurity threats has only been acknowledged in a small number of studies. We did a conceptual review through an extensive literature review of papers in this area. Our study has highlighted the necessity for an integrated framework that incorporates both technical ethical hacking and social ethical hacking methods in order to close this gap. To do this, we created an extensive model that fully explains our idea and provides insightful recommendations for enhancing cybersecurity throughout the fourth industrial revolution. Since the study was not done using empirical data, we suggest that future studies should look into the cybersecurity issues in the fourth industrial by collecting empirical data.

Key words: Cyber security, Fourth Industrial Revolution, Ethical hacking, Social ethical Hacking,

1 Introduction

Information and communication technology (ICT) use has grown significantly through time, taking on many different forms that have had a significant influence on both human existence and the environment. The way people connect, participate, and conduct themselves has fundamentally changed as a result of this ubiquitous shift, which has also transformed the way businesses produce goods and services, obtain an edge over competitors, and pursue their strategic objectives.

ICT development has traversed through the four stages of the industrial revolution. The developments associated with the stages of the industrial revolution have enhanced our everyday lives and caused us a lot of ease and convenience. However, it has ushered in a number of cybersecurity risks that we have to deal with. Its presence is having a strong influence on virtually every aspect of our lives, thereby becoming an integral part of our daily activities. Despite this strong connection to our daily lives, we still have to deal with the cybersecurity challenges it has caused us. This recognition is crucial given that ICT now permeates all aspects of human existence. Consequently, there arises an urgent need to comprehend and implement cybersecurity defense mechanisms associated with the challenges posed by the fourth industrial revolution.

ICT users are required to cope with a wide range of cybersecurity risks in the fourth industrial revolution. Cybersecurity vulnerability refers to security flaws that enable cybercriminals to gain unauthorized access to an organization's cyberspace. It leads to intentional distortion, illegal access, and manipulation of information, causing information to lose its values and credibility [48]. The consequences of cybersecurity breaches can encompass financial losses, damage to an organization's reputation and credibility, and, in extreme cases, complete dissolution [1,26,44]. Cybersecurity breaches show themselves in a variety of ways, including hacking, phishing, taken-for-granted actions

and behaviors, unwarranted trust, password sharing, and others. Cybersecurity is one of the pillars of the fourth industrial revolution that that organizations cannot overlook. This is because system vulnerabilities may create major disruptions and unforeseen effects. This is particularly true given that cyber security is a feature of cyberspace, which includes the internet, individuals who use the internet, and the infrastructure that allows diverse organizations to connect [37]. Ignoring the imperative of cybersecurity in this digital era would be a perilous oversight.

Cybercriminals are out there seeking for any opportunity to orchestrate cybercrimes. Cybercrime is a term used to refer to the intentional breach of an individual's or organization's ICT with the aim of stealing critical information, ruining reputation, cyberbullying, and many others [28,42]. Fourth industrial revolution is not free from the shackles of cybercrime. In fact, cybercrime is an integral part of it. We will explain this later in the article.

The Fourth Industrial Revolution (4IR) is the current industrial revolution in information and communication technology, often known as Industry 4. [46], that represents the ongoing industrial transformation within the realm of information and communication technology. It necessitates the integration of various cutting-edge technologies, such as the Internet of Things, cyber-physical systems, and cloud computing, driven by the growing quest to harness the convergence of these advancing technologies. As mentioned in the opening paragraph, 4IR is the most recent industrial revolution that intertwines single systems in order to make systems a part of human existence. Although 4IR is significant for our topic, it is the result of earlier work documented in the preceding three revolutions. Understanding the history of revolutions will aid our understanding of the fourth industrial revolution and the cyber security challenges that surround it.

2 The Emergence of the fourth Industrial Revolution

2.1 *First Industrial Revolution*

The rise of ICT advancement is traced back to the earlier industrial revolution period. This is a transformative period sparked by the advent of steam power. This technological marvel has seen the era of mechanized industries where people effortlessly conduct their day-to-day activities through the introduction of machinery. The development unfolded during the latter part of the eighteenth century and the early years of the nineteenth century.

As traditional production methods proved inadequate to meet the burgeoning demand for goods and services, the first industrial revolution saw a shift from manual labor to mechanized systems [18,39]. With the groundbreaking inventions of steam engine, spinning machines, coke refining, rolling for iron production, the era witnessed a profound transformation in labor and technology [33].

Furthermore, the first industrial revolution served as a basis for revitalizing production, enhancing consumer spending and global economic growth. It witnessed the growth stemming from crucial logistical communication networks, comprising canals, roads, and railways. Financial systems, such as banking, passed through constant enhancements to facilitate more efficient operations for businesses and industries. Genetically, fertility rates experienced a swift rise, while child and infant mortality rates declined, leading to significant shifts in population reduction.

However, it is essential to acknowledge that the first industrial revolution was not without its dark aspects. It was marred by key issues such as forced labor of children and women as well as the enormous number of youngsters who aren't in school while they are too busy supporting their impoverished families [33].

2.2 Second Industrial Revolution

The quest to engage in mass production of goods and enhance corporate competitiveness became the stimulator behind the second industrial revolution (IR2). This new trend transpired during the latter part of the nineteenth and early twentieth centuries which was propelled by the introduction of so many pioneering technologies, including electricity and internal combustion engines, among others [32]. This technological advancement is often referred to as the American Industrial Revolution [34] and has fostered a symbiotic relationship between science and technology, permeating modern technologies into the daily lives of the middle and working classes like never before. Living standards and the purchasing power of money improved considerably.

Despite the fact that IR2 repressed many difficulties during the first industrial revolution, it left many other problems unresolved and of interest to scholars. Electricity, communication networks, sophisticated transportation network systems, educational facilities, and economic reform were all brought about by IR2 [33]. In spite of that, a significant section of the work still relied on manual labor, causing a considerable necessity for workforce to operate the machinery designed to facilitate mass production and economic growth. Relying on human labor gave rise to various problems, including poor working conditions for employees, environmental pollution generated by the industrial facilities, increasing a huge issue associated with global warming due to emissions, substantial rural-urban migration, and a slew of other challenges. These issues eventually set the ground for the advent of the third industrial revolution.

2.3 Third Industrial Revolution

The third industrial revolution (IR3) became the mother of the ICT evolution. In spite of the effort of the second industrial revolution (IR2) in addressing challenges arising from the first industrial revolution, it also had created certain issues, necessitating adaptations and measures to mitigate the ensuing crises. This eventually was the reason for the emergence of IR3. IR3 witnessed a transformative era that spanned from 1969 to 2000 [18].

IR3, often referred to as the "green industrial revolution," the "efficiency revolution," or "green capitalism," represents a breakeven technological advancement, that involves advancement in information and communication technologies (ICTs), microelectronics, innovative materials, cleaner technologies, the internet, and mobile telecommunications, among others [22]. The high ubiquity of computer systems caused the automation of processes that were once reliant on manual operation [18, 32].

Although IR3 was designed to overcome the faults of IR2, and although it resulted in the automation of production and day-to-day operations throughout the globe, it still left certain holes that the fourth industrial revolution had to fill. As gas emissions and other environmental degradation persist, global warming challenges remain unaddressed. The fourth industrial revolution simplifies life by allowing users to communicate across several systems with a single click, rather than forcing them to traverse via different systems.

Despite the effort to overcome the shortcomings of IR2 and its achievement in automating production and global day-to-day operations, IR3 left certain gaps that the fourth industrial revolution would have to attend to. Issues associated with greenhouse gas emissions and ongoing environmental degradation persisted that accounts for the challenges in the realm of global warming. With the fourth industrial revolution, people witnessed the cross-system communication leading to bridging the gaps from the prior IRs. This era no longer necessitates the cumbersome navigation of diverse systems, making life more efficient and interconnected.

2.4 Fourth Industrial Revolution

The fourth industrial revolution became a sound ground for the coming together of interconnected smart technologies [18]. With fourth industrial revolution, people have seen a world where machines seamlessly communicate with each other and with humans, efficiently and effectively perform numerous tasks that were once exclusively within the span of human labor. All this owing much credence to the high advancement in computer speed and functionality, a reduction in both cost and size.

The advent of "Cyber-Physical Systems" (CPS) signaled the inception of the Fourth Industrial Revolution for many people. This revolution is characterized by automation permeating various domains, including workplaces, industrial settings, and the realm of robots. It comprises the growth of intelligence, automation, a decrease in human labor, and the mediation of tools, appliances, and machines into daily operations [39]. In this evolving landscape, highly intelligent CPS can operate independently along the entire value stream.

When we think about intelligent settings, we often imagine common things with embedded software and algorithms that work together to assist us in our daily tasks by adjusting to the environment. In actual fact, thanks to technological advances in miniaturization and wireless transmission, sensors, mobile devices, and apps may now communicate with one another while remaining in our line of sight. Regardless of these wireless sensors and actuators, sophisticated context-aware applications and services have been built that monitor their users' presence and automatically react to an ever-changing circumstance while being attentive to their changing needs and preferences [38].

The fourth industrial revolution saw the convergence of digital, physical, and biological technologies that enhances our quest for a promising transformative shift in how goods are manufactured and consumed. The advent of the Internet of Things (IoT) opened new possibilities in manufacturing, lifestyle enhancement, and risk management which is driven by dynamic information exchanges among interconnected devices [32].

The fourth industrial revolution became an era where the boundaries between the physical and digital worlds is slowly disappearing which opens up exciting ways for innovation and integration across various sectors of life. We envisioned smart homes, connected cities, advanced manufacturing and healthcare, among others. Technological development is constant and it will continue to shape people's daily lives through promising, intelligent, context-aware systems.

We have provided a summary of these revolutions below:

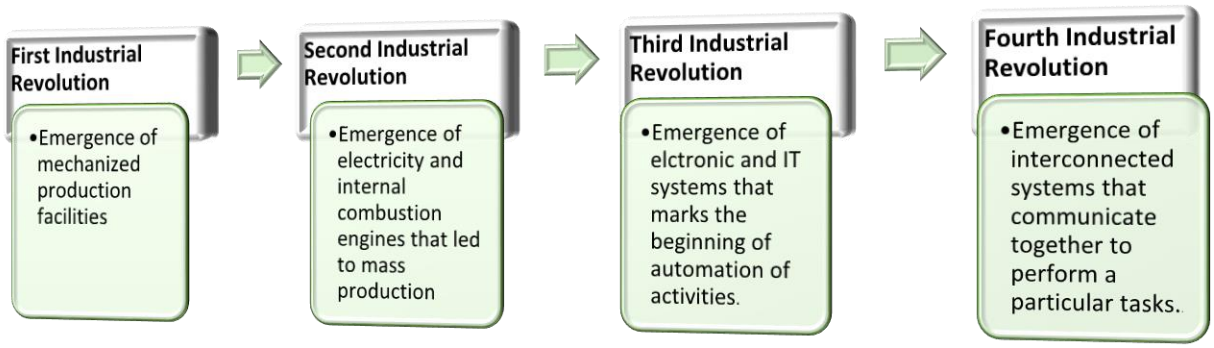


Fig. 1. First, second, third and fourth industrial revolutions

3 Opportunities of the Fourth Industrial Revolution

The advent of the fourth industrial revolution signifies a profound change that is changing our political institutions, corporations, and even our way of life. Scholars have identified three main opportunities provided by the emergence of the fourth industrial revolution [39]:

3.1 Manufacturing Innovation

Global manufacturing methods have undergone significant changes as a result of the fourth industrial revolution, developments that we have seen and continue to see. As a consequence, among other advantages, we have seen a decline in manual labor, extensive use of robotic technology for managing risky activities, supply chain management optimization, and the creation of highly customized products and services.

3.2 Process and industry management

The fourth industrial revolution encompasses several industry operations, including the creation of linked systems that enable autonomous and self-managed teams, real-time planning and monitoring, predictive operating modes, adapting to changes, etc.

3.3 Transformation of Daily Life

In the ordinary lives of people, the fourth industrial revolution is bringing about transformational changes. Wearable technology and smart technologies that speed up, streamline, and save money on interactions across several sectors enable this revolution. Notably, it has transformed home dynamics with the emergence of the Internet of Things (IoT), transformed consumer behavior with the rise of online commerce, and even transformed education, as shown by the COVID-19 epidemic. These examples show how the fourth industrial revolution has had a profound influence on almost every aspect of life.

4 Challenges Introduced by the fourth Industrial Revolution

With the advent of the fourth industrial revolution (4IR), we have been faced with a plethora of new challenges and considerations that must be carefully addressed, especially in the areas of privacy, security, and ethics. We have provided more detailed exploration of these concerns below:

4.1 Privacy Concerns

Having witnessed the proliferation of connected devices, the Internet of Things (IoT), and the constant exchange of data, we cannot the dispel the assumption that individuals' privacy is increasingly at risk [7,45]. Numerous pieces of personal data are gathered by wearable technology, smart houses, and other IoT technologies. It becomes essential to protect sensitive data from abuse and unlawful access. Furthermore, concerns about data ownership and permission come up. The ownership of the data produced by these devices and the methods for obtaining permission to use it become crucial questions [3].

4.2 Cybersecurity Challenges

4IR continues to progress day by day. As it advances, so also the threats to cybersecurity grows much faster and thicker [25]. Cybercriminals have also been observant of the interconnected systems and devices and therefore have expanded their attack surface with sophisticated methods of achieving their ill-intent goal. With this, individuals and organizations have been compelled to fortify the security of their networks, devices, and data to guard against breaches. Safeguarding critical infrastructure, such as power grids and transportation systems, becomes a pressing concern as well.

4.3 Ethical Dilemmas

Today, smart machines are taking over almost all facets of human activities which caused serious ethical dilemma associated with the use of AI, machine learning, and automation in 4IR [27]. As these technologies continue to evolve, human labor is slowly dying. Decisions made by AI algorithms may have ethical implications, such as bias in decision-making processes or the allocation of resources [2]. Additionally, AI-based systems introduced a plethora of challenges to educational system. It has opened up a door for academic misconducts ranging from plagiarism, asking the AI to write a paper, and many other issues. Based on this, experts have spotted a need for ethical frameworks and guidelines to ensure that technology benefits society while upholding fundamental values and fairness.

4.4 Data Governance

Having the interconnectivity of devices causes the enormous generation of data in the 4IR and necessitates robust data governance practices [24]. Data quality, integrity, and accountability become paramount. It is quite essential to ensure that data is used responsibly, ethically, and transparently. Additionally, 4IR enabled the collection and utilization of data across different industries and sectors. This emphasized a need to establish standards for data sharing.

Organizations need to establish a multi-faceted approach involving collaboration between governments, businesses, technologists, ethicists, and society at large. With the Establishment of robust privacy policies, enhancing cybersecurity measures, developing ethical AI guidelines, and fostering digital literacy, we could navigate through the 4IR era responsibly and ensuring its benefits are shared by all.

5 Cybersecurity in the fourth Industrial Revolution

The fourth industrial revolution offers numerous advantages to humanity, however, it has also ushered in a slew of challenges, particularly in the domain of cybersecurity. Within the realm of information and communication technology (ICT), cybersecurity is one of the critical concern which demands active attention from both enterprises and individuals. This is pertinent because attackers are constantly vigil of new opportunities and are perpetually seeking out vulnerabilities in technology and exploiting human weaknesses.

In essence, cybersecurity is concerned about the safeguarding of an organization's computer systems against potential threats, originated from within the organization or externally [10,26]. A fortified cybersecurity framework offers organizations a significant competitive advantage and shields them from the brink of bankruptcy. Conversely, organizations that are highly susceptible to threats are those who disregard cybersecurity despite the possible vulnerabilities within their systems. Most businesses today are increasingly relying on online payment methods and store sensitive client information such as credit card details. It is actually dangerous operating without cybersecurity measures in place. This negligence not only jeopardizes an organization's integrity but also places it at significant risk in an environment where digital threats are prevalent and evolving constantly.

It is important to highlight that cyber security is one of the nine pillars of the fourth industrial revolution, though the precise number appears debatable [45,46]. Precisely, some scholars hold a viewpoint wherein they identify merely three core pillars of 4IR [40]. Most important here is recognizing that the classification of these pillars is fundamentally a matter of perspective and preference. Comprehensively, the nine pillars that collectively underpin 4IR encompass diverse facets including big data analytics, autonomous robots (in whatever forms they appear), simulation, horizontal and vertical system integration, the Internet of Things (IoT), cyber security and cyber physical systems, the cloud, additive manufacturing, and augmented reality through innovative

technologies [46]. These pillars collectively form the bedrock upon which 4IR is based on, guiding its transformative stages and impact on various domains of human endeavor.

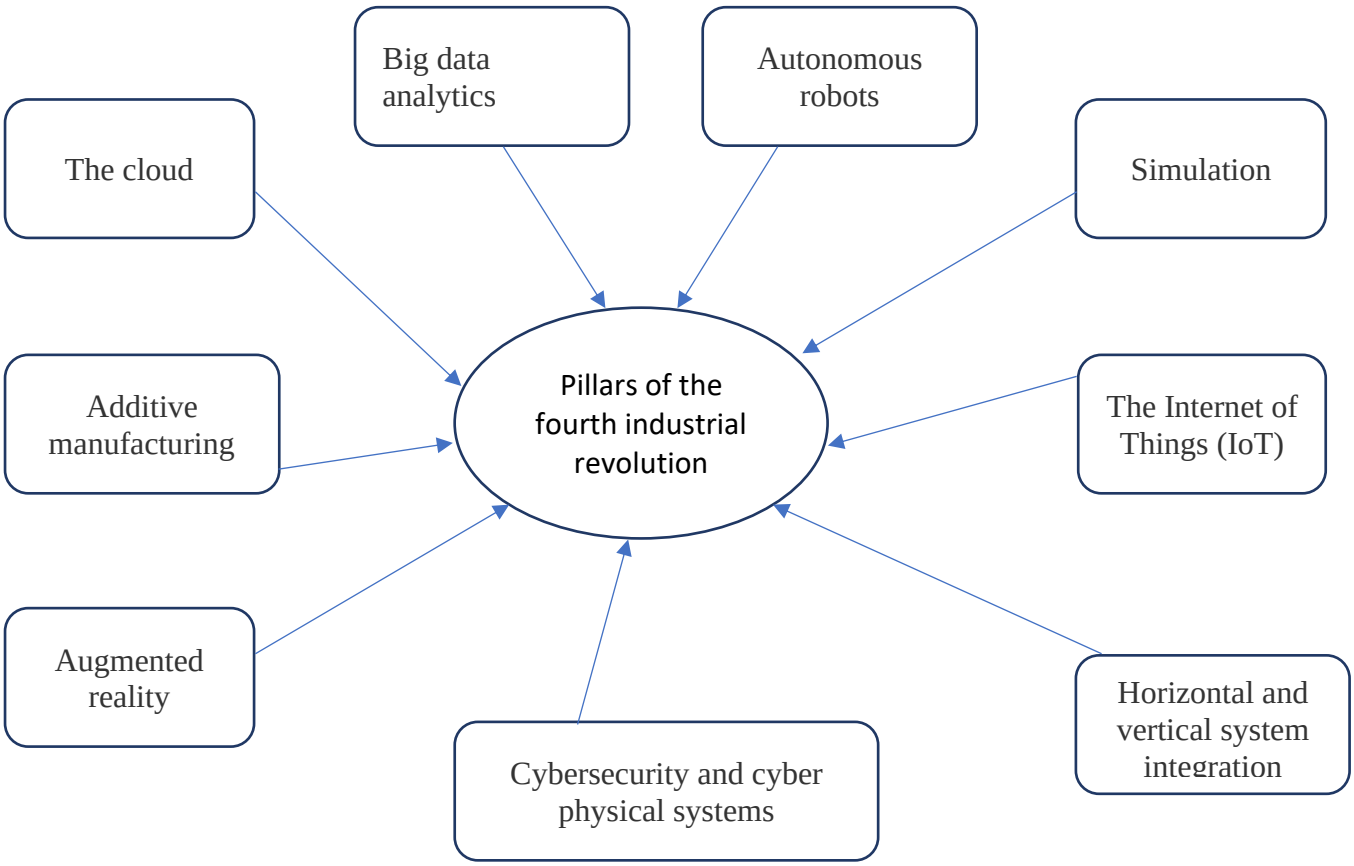


Fig. 2. The nine pillars of the fourth industrial revolution as outlined by [46]

The Fourth Industrial Revolution (4IR) is identified with its extensive interconnectedness and the widespread utilization of industry-based communication protocols. Safeguarding these critical industrial systems and production lines against cybersecurity threats is a precious task and not to be ignored. Consequently, it's imperative to deploy intelligent and robust systems for identifying both machines and users, complemented by robust access control measures, while concurrently establishing secure and dependable communication channels. Amalgamating the physical, service-oriented, and digital domains, holds significant potential for augmenting the quality of information indispensable for the strategic planning, optimization, and efficient operation of manufacturing processes [35].

Advocates of the 4IR movement have been forthright in recognizing the inherent risks associated with its advancements, with cybersecurity emerging as a foremost concern. Try to describe a scenario wherein remote management of your home's security cameras, control over the contents of your refrigerator, closet, television, and supervision of your heating and kitchen systems—all accomplished via your smartphone. consider the dire consequences when an unauthorized person gains access to these embedded systems. Most attacks are done to achieve monetary value. But it is pertinent to know that the risks transcend mere financial incentives; a malevolent intruder could harbor sinister intentions, potentially placing lives in jeopardy. The manipulation of your refrigerator's contents, interference with your cooling systems, or disruption of the gas supply in your kitchen might all result

in devastating results in the case of a hostile break into your cyber systems, all without a physical presence.

There are several hazards associated with these embedded technologies in homes and workplaces when cybersecurity safeguards are either absent or insufficient. As a result, the creation of meticulously planned frameworks targeted at protecting these infrastructures from cybersecurity attacks becomes a crucial need. These frameworks are crucial for reducing the possibility of antagonistic occurrences brought on by manipulation and illegal access.

6 Approaches to Cybersecurity Threat Defense

When we talk about strategies to defend against cybersecurity threats, we are essentially interested in exploring the defense mechanisms that organizations employ to protect their systems, be it reacting to active threats or taking proactive measures. Organizations use two primary strategies to safeguard their systems: the technical approach and the human-induced approach. Each approach attends to a particular set of vulnerabilities independently. Cybersecurity attackers may exploit these vulnerabilities to gain control over critical operations within an organization. For instance, an attacker could spot a technical weakness in an organization's cybersecurity and capitalize on it, leading to significant damage on their key working areas. Conversely, an organization might establish a robust technical cybersecurity system that poses formidable challenges for attackers. In response, attackers may need to devise new strategies to breach such strong defenses. They achieve that by trying to break through the weakest link of cybersecurity- the human factor. Organizations have to worry about this human factor because it renders all cybersecurity effort futile. This is because the presence of this human element has the potential to compromise even the most advanced technical cybersecurity systems in place. Neglecting this vulnerability is risky to any organization. Based on this, we will provide a comprehensive explanation of each of these defense strategies:

6.1 Technical cybersecurity approach

One of the key mechanisms for protecting cybersecurity systems against threats is to fortify the technical infrastructures of the security system and making it robust that almost proves impossible to break. This method is highly adopted by organizations. This is true given their strong trust and dependence on technological systems. organizations spend a lot of money trying to purchase the best technological cybersecurity system to deny any malicious access into their systems. Technological cybersecurity involves the acquisition and deployment of advanced tools and technologies that are capable of combating cybercrime. This approach is widely recognized and commonly employed in both theoretical and practical contexts. Many organizations have focused on fortifying their defensive tools through technological means but often shy away from the significant risks associated with cybersecurity issues involving human factors.

Most popular defense mechanisms in this category are the development of different penetration testing mechanisms such as ethical hacking. Ethical hacking involves deliberately hacking into one’s own systems [17,20] or hired to hack into another person’s or organization’s systems with the aim of detecting the technical flaws that are inherent in the system [16,31]. Hackers who are engaged in this kind of hacking activity are referred to as white hats [17].

Ethical hackers are a group of trained hackers who have been certified to carry out hacking activities with the permission of the client organizations. This exercise mostly come after the organizations have established a strong cybersecurity system for guarding against external intrusion. Organizations could do this in two ways. They could either make general announcement inviting hackers across the globe to hack into their systems whenever they spot a vulnerability. This is a practice largely adopted by

international organizations who have held ground in their cybersecurity preparations. Most of these organizations place bounties for any successful intruder. This intruder is referred to as gray hat or bug bounty hacker. Gray hats or bug bounties are those attackers who have the permission of an organization to hack into their systems. The striking difference between ethical hacker and bug bounty hackers is preparing a report after the incidence [17, 20]. The general picture is not about the bounty but about testing the formidability of their systems and trying to see how they could first detect these vulnerabilities before a malicious attacker does that.

Cybercriminals are out there snipping for vulnerabilities that they could capitalize on and inflict pain on their victims. As organizations research them and make an effort to create a formidable cybersecurity system that could lower cybercriminals' success in their operations, these cybercriminals are also working tirelessly to develop sophisticated cybersecurity tools for their cybercrime [30,42]. Most of whom have to take on different identities to hide and to reduce any chance of tracing the attack back to them. Sometimes they form a network of like-minded attackers that have virtual cognizance, and have different nationals, with different levels of skills. Each member is trying to share with others his skills and how he had successfully sabotaged a system [28].

As stated earlier, cybersecurity threat is categorized into two distinct perspectives: technical cybersecurity threats and human-induced cybersecurity threats. Organizations could address these threats reactively, where organizations respond to existing threats that jeopardize their cybersecurity [14]. In this situation, organizations must have to prepare incident response plans, disaster recovery strategies, and other measures aimed at mitigating the extent of damage once an attack has occurred. Meaning, reactive measure is aimed at containing the scope of the damage to a certain area by quickly abating the attack. Common practice here is shutting the systems down and taking the attacker offline and quickly polluting the information therein. Most organizations have their disaster recovery plan to recuperate from any form of disaster, be it physical disaster or cyber. This is not the goal of the discussion.

Alternatively, organizations can adopt a proactive approach to safeguard their systems by implementing various measures, including vulnerability identification and patching [4,26,44]. Users who take proactive measures such as identifying technical vulnerabilities (software loopholes, and others) and detecting human-induced vulnerabilities such as human factors have a high possibility of abating a targeted attack on their systems [29]. Both of these strategies are applicable to technical cybersecurity threats.

6.2 Human factor cybersecurity approach

When organizations are able to fortify their technological cybersecurity infrastructures, they have to face a greater and lethal threat associated with human factor. This threat, the human factor, is important because all other efforts to safeguard the system is shouldered upon the formidability of this aspect of the security system. Human factor refers to the actions and behaviors of individuals that pose a significant cybersecurity risk to themselves or their organizations [8,14,26,41. These enacted behaviors and actions create vulnerabilities that malicious actors may exploit, causing a significant harm to individuals or businesses [4,26,44]. With this, we have acknowledged the critical role of technical cybersecurity measures. However, it's essential to recognize that safeguarding against the challenges posed by the fourth industrial revolution (4IR) goes beyond purely technical cybersecurity.

Human-driven cybersecurity safeguards are equally crucial. In reality, human-caused vulnerabilities may be the core reasons for attacks that are capable of undermining the finest cyber security procedures in place to repel attacks. Often, businesses prioritize bolstering their technical cybersecurity and focus on external threats, overlooking the fact that a substantial portion of cybersecurity incidents originates from within. Furthermore, whether deliberately or not, insiders assist orchestrate the bulk of external

incursions [14,19,26,47]. This might be initiated by demonstrating particular acts and behaviors that could disclose technical flaws in a company's cyber security. Understanding these tendencies will prepare you to battle them and keep you one step ahead of the hacker community as a whole.

Like the earlier defense mechanism, human factor vulnerabilities encompass a range of proactive cybersecurity defense strategies, starting with the formulation of comprehensive cybersecurity policies that provide guidelines for the use of organizational information systems assets (Ajibesin et al., 2022; Ejigu et al., 2021; Hong & Furnell, 2022). With these policies, one will learn about the acceptable practices, ensuring data security, and regulating access to sensitive information.

Programs for training and awareness are additional essential components of proactive cybersecurity. They are designed to provide organizational actors the necessary expertise to spot hacking operations and successfully deal with them. It follows that people who have little to no expertise of the software or any other important technical component for managing everyday operations of a business are often the victims of cybersecurity assaults [29]. Organizations may promote a culture of alert and proactive defense by improving the cybersecurity literacy of workers and stakeholders.

We divided this section into two major divisions. We view this hacking activity from the perspective of the attacker manipulating the victim (social engineering), or the victim exhibiting certain actions and behaviors that lures the attention of the attacker into capitalizing on them and making significant damage on the organization (enacted actions and behaviors).

6.2.1 Social Engineering

Social engineering is the practice of persuading individuals or groups of people, usually with malevolent intent, to carry out tasks or reveal private information. Rather than depending solely on technical flaws, it is a psychological manipulation approach used by attackers to take advantage of human behavior. To earn the confidence of their targets and persuade them to expose sensitive information, take activities that undermine security, or allow illegal access to systems or data, social engineers often utilize a variety of strategies, including deception, persuasion, impersonation, and manipulation [5,10,44].

There are different attack mechanisms that attackers use to manipulate their targets into achieving their goals. Notable amongst them is phishing. Phishing refers to the malicious messages that an attacker sends to organizational actors through emailing, messaging on message inbox, and sometimes using voice messaging in order to lure the organizational actor into revealing the information he needs for his attack [6,23]. Through phishing, an attacker solicits passwords, monetary requests, critical organizational information, and many more. If one unfortunate actor is able to succumb to the fraudulent act, his cyber security will be breached and by extension, organizational cyber security too.

Phishing is achieved through the following vectors:

- *Emails*: email is the popular vector for exacerbating social engineering attack through phishing. This involves an attacker sending a deceptive fake email to manipulate the recipient (targeted individual or organization) into revealing critical information, mostly by making him click on a malicious link. Attackers try to provide a pseudo-email account similar to one's organizational email domain. This vector has caused so many organizations or individuals to become victim of cybersecurity attacks.
- *Smishing*: this is another vector of phishing attack that is conducted through text messages. The social engineer sends SMS to his intended victim and tries to manipulate him into performing the action that will harbor his ill-intent.

- *Vishing*: this is a phishing vector that allows an attacker to manipulate his victims through voice messaging. Today voice messaging has been made easier with the rapid advancement in social media activities. Many attackers are using this vector to subdue their prospective victims into the requisite actions and behaviors for aiding their hacking activities.

Today, many studies have stressed a need for organizations to deliberately test these social engineering manipulation techniques with a view to detecting these vulnerabilities [19,36,43,44,47]. Like the technical ethical hacking, practicing social engineering techniques will help organizations fortify the human aspect of cybersecurity, thereby making penetration difficult for social engineers. This does not mean the social engineers are defeated permanently. No matter the effort put forward by organizations, social engineers will devise new attacking mechanisms to achieve their ill-intent goal. However, organizations would have to constantly think like the social engineer not to discriminate their organizational rather to strengthen their resilience for any form of social engineering manipulation.

Many studies have been undertaking on phishing, ranging from general phishing, spear phishing and contextual phishing. General phishing studies looked at phishing from a holistic perspective without paying attention to a particular segment of the phishing exercise. Such studies provided organizations with the overall idea on how social engineers prepare for the attack and how organizations could mimic such procedures with the aim of depending their human aspect of cyber security. For example, we take the effort done by [44] and [8,9].

[44] for instance, showed the different tactics social engineers employ to manipulate unsuspecting individuals into divulging sensitive information related to their organization's information security strategies. These techniques enable the attackers to exploit organizational systems and inflict significant harm. The authors offered a very significant contribution by applying a grounded theory analysis technique to analyze the interviews they conducted with social engineers-repentant and practicing ones. The data gathered from individuals involved in these hacking activities was analyzed to reveal crucial insights, as illustrated in the figure below:

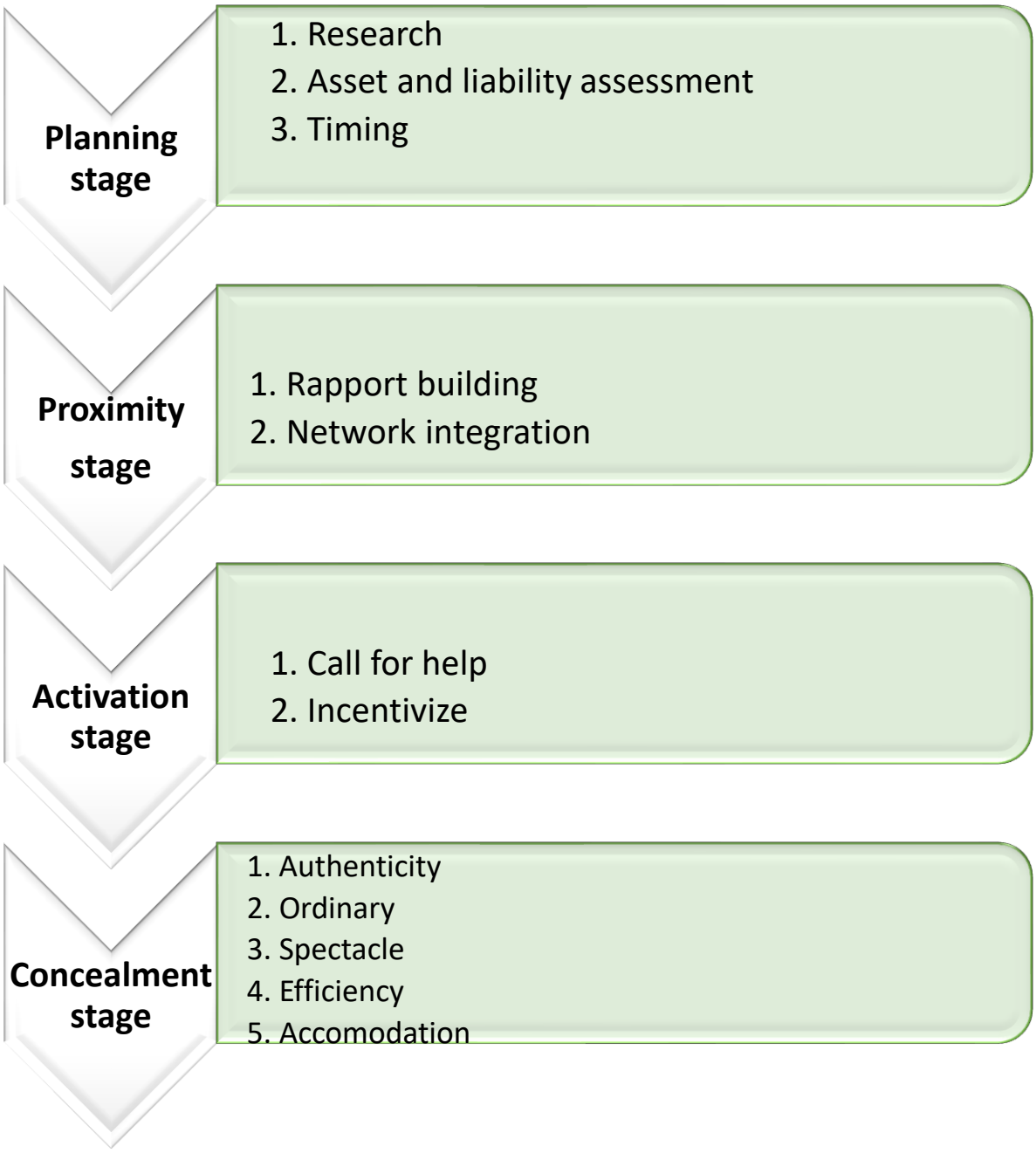


Fig. 3. A framework for social engineering technique by [44]

The framework details the stages that social engineers take to identify their target (an individual or organization), formulate detailed and quick plans, execute the plans, and ensure they conceal their tracks in the event of discovery. However, one of the framework's shortcomings is that it is based on what the social engineers say and may not reflect their real methods of recruiting their victims.

Human penetration testing is one of the most significant contributions of social penetration testing. [8] made another mind-blowing contribution by developing a human pentester to deliberately detect human-induced vulnerabilities. The authors created a human pen-tester to measure their personnel's resilience and ability to detect and resist human-targeted attacks. This was created to assist small and medium-sized organizations (SMEs) in identifying possible risks to their cybersecurity by increasing their personnel's understanding of social engineering strategies. To achieve this, the authors conducted a systematic review of the literature that discussed about social engineering approaches. However, the

research lacks a defined empirical technique for gathering the information required for the construction of the framework. After the thorough systematic review into the tactics social engineers apply in manipulating their prospective victims, the authors were able to reduce their entire effort into three major steps. This framework was not in a form of a model. For easier navigation, we have formed it into a figure:

Fig. 4. Refined POINTER Framework by [8]

Other studies have focused on a specific area of the phishing. For example, many studies have been conducted to look at spear phishing and testing the procedures on organizational actors with the aim of testing their resilience to manipulation of social engineers. Spear phishing refers to targeted and personalized attacks aimed at specific individuals or entities [36].Spear phishing is a highly advanced kind of attack that targets certain people, companies, or other entities in an effort to trick them into doing things like disclosing sensitive information or clicking on dangerous links. Spear phishing is a precisely designed and individualized kind of phishing, as opposed to generic phishing efforts that cast a broad net in the hopes of snagging unwary victims. So, organizations could particularly target a particular group of actors whom they feel pose significant threats to their cybersecurity effort. This is particularly useful in order to strengthen their resolve with respect to resilience to any form of social engineering attacks.

Consequently, there are other studies, few to be precise, that have looked at the contextual phishing exercise. Contextual phishing is a kind of specialized phishing where the attacker sends a phishing email taking cognizance of the context of the victim [19]. Context could mean the physical environment where the victim is situated or a specific time with a particular event taking place. For example, if your targets are students, contextualized phishing could target examination time and send a message that will force the hands of the students into believing in the message and getting easily subdued. [19] conducted a contextualized test of phishing emails on undergraduate students. The aim of the study is to understand how contextualizing phishing emails for certain groups of individuals affects those groups' vulnerability to phishing, as opposed to many other studies that concentrated on people's susceptibility to generic phishing emails. In order to analyze the responses that the 7,225 undergraduate students gave to the phishing emails, the researchers sent them out in context. The study's findings showed that contextualized emails that are pleasing to the eye make a person more vulnerable to phishing. Additionally, expecting positive outcomes from the contextualized emails makes them more susceptible to fraud and phishing attacks.

6.2.2 Human-Enacted Actions

Another aspect of the human factor is the negligence springing from the enacted actions and behaviors of organizational actors. The striking difference between social engineering and human negligence is where the action is initiated. While social engineering involves manipulation coming from the attacker's end, this one is springing from the prospective victims. Organizational actors enact actions and behaviors detrimental to their organizational cybersecurity. This is what [26] called social ethical hacking. Social ethical hacking refers to deliberately enacting actions and behaviors of organizational actors with a view to detecting human vulnerabilities detrimental to organizational cybersecurity.

[26] created a proposal for social ethical hacking based on an empirical investigation of the daily life practices of undergraduate students of an organization. These daily activities result in the enactment of specific behaviors and actions that are exposed to cybersecurity risks. Organizational actors are mostly uninformed of the potentially devastating effects of their activities for organizational cybersecurity. Attackers could snip for these enacted actions and behaviors and inflict a significant damage on the organization. The authors created the framework through understanding the social actors as a community of practice with which members interact and engage in comparable activities. This community is recognized through forming a defined *competence*. This competence is formed based on the formation of domains, mutual engagement, and shared repertoires, which facilitate the performance of these sensitive behaviors and activities. On this basis, the authors created a framework for their proposal.

We have included the original structure they created below:

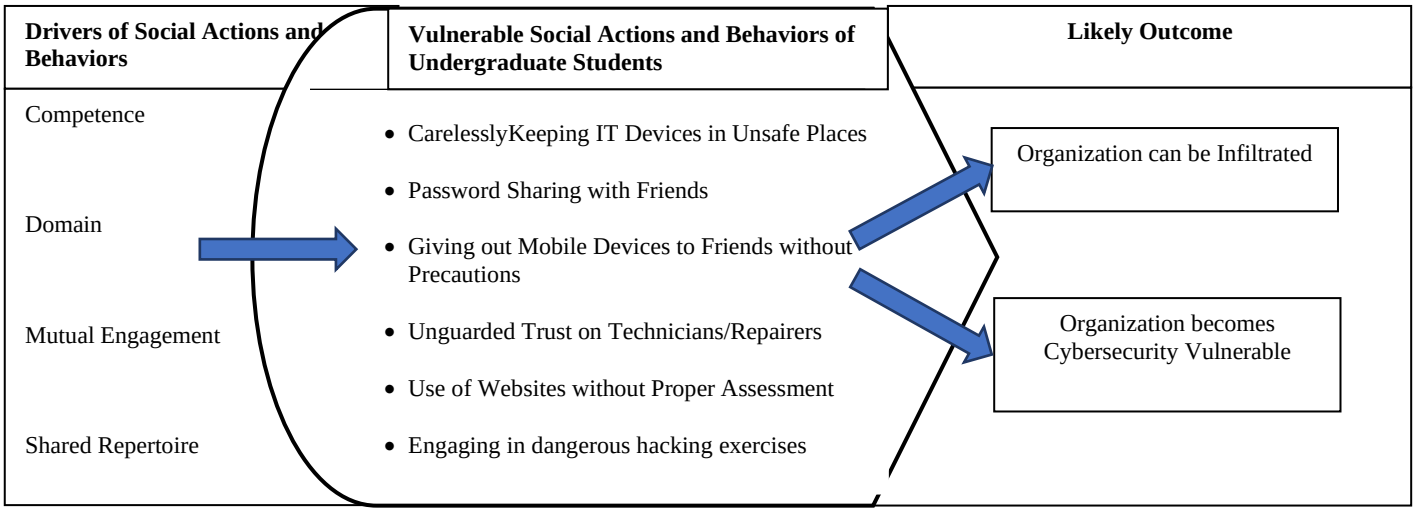


Fig. 5. Proposed social ethical hacking framework developed by [26] in its original form (consent of the authors has been sought)

7 Integrated framework

Having understood the dire need for each of the preventive approaches to cybersecurity threats, we advocate for harmonizing the two aspects of the security system. If you rely on one aspect while neglecting the other aspect, the consequence is waking up one day to receive the news of a cybersecurity attack on your system. It is pertinent for organizations to understand that they need to have the best cybersecurity infrastructure that will prevent technological exploitation and equally fortifying the human factor by constant training and awareness, policy to guide the overall behavior towards their information systems, deliberately testing each aspect of the security system through

ethical hacking and social ethical hacking. Thus, this article advocates for enterprises to cope with cybersecurity risks by using both technological and social ethical hacking defensive measures in order to achieve substantial cybersecurity in their operations. We have supplied a model describing our idea below:

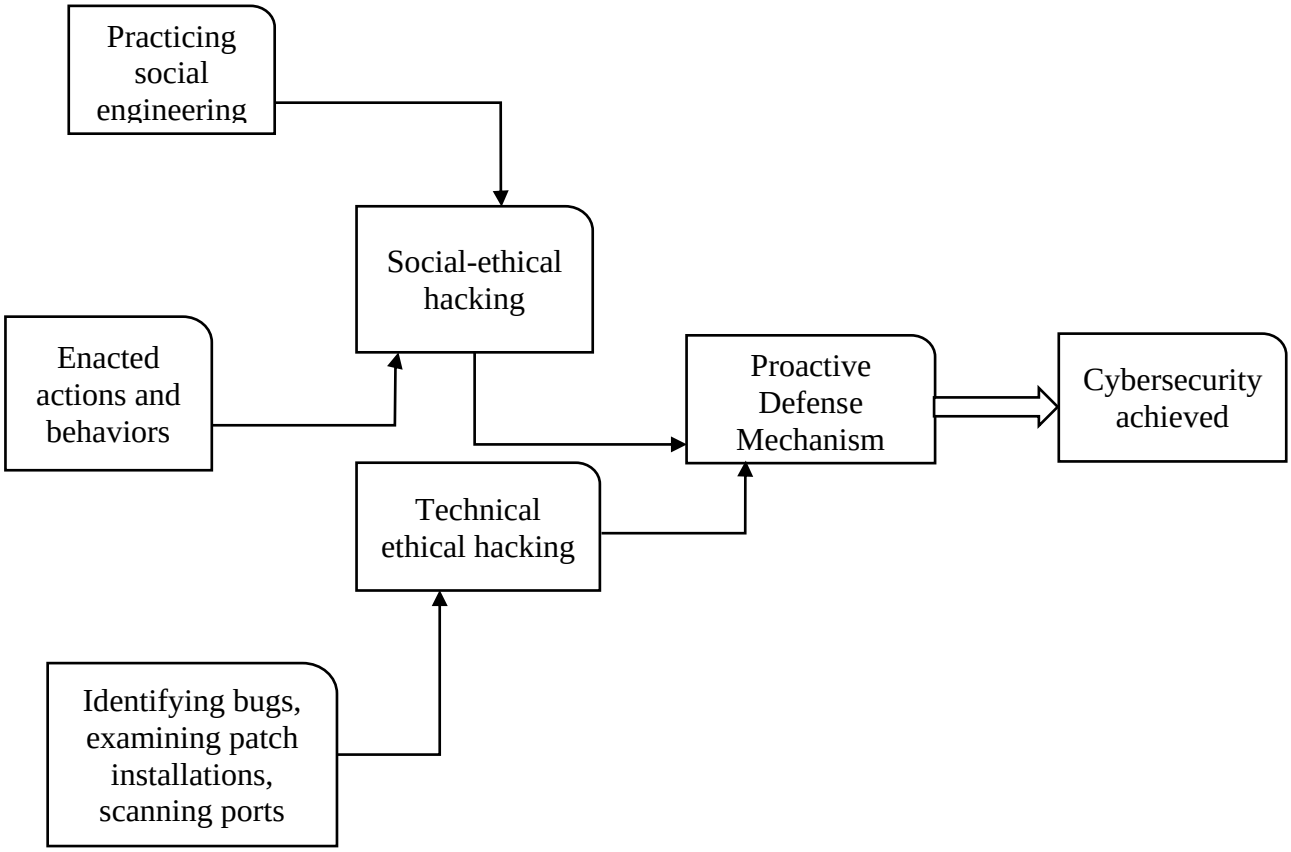


Fig. 6. Integrated organizational cybersecurity defense mechanism

8 Conclusion

The purpose of this research is to learn more about the defense mechanisms that organizations develop in order to abate the cybersecurity dangers posed by the fourth industrial revolution. We were able to conduct a conceptual analysis through extensive literature review of the literature within the domain of fourth industrial revolution, ethical hacking, and human penetration testing. Adopting extensive literature review signifies non-subscription to the rigor associated with narrative review or systematic review. Our review of literature in this area showed that cybersecurity is exploited through the presence of cybersecurity vulnerabilities. These vulnerabilities are all inherent within the technological cybersecurity infrastructures and the human-induced vulnerabilities. Most studies have focused their attention in detecting technical cybersecurity vulnerabilities while neglecting the human aspect. Because many organizations have ventured into new technological innovations, it is equally important that we look at the vulnerabilities that may occur as a result of organizational actors, as well as have a grasp on the new integrated defensive mechanisms for cybersecurity in the fourth industrial revolution. To protect embedded systems from cybersecurity vulnerabilities, the research advises using an integrated framework that encompasses both technical ethical hacking and social ethical hacking frameworks. Ethical hacking is the intentional compromise of a company's cybersecurity system in order to find flaws. It is usually done with prior knowledge of the company and even involves payment

for the services [11,12]. The enacted actions and behaviors that are seen to represent flaws in organizational cyber systems emanating from human factor is referred to as social-ethical hacking [26].

Reference

[1] Abawajy, J. User preference of cyber security awareness delivery methods. Behaviour & Information Technology. 2014; 33(3): 237–248. **https://doi.org/10.1080/0144929X.2012.708787**

[2] Agbaji, D., Lund, B., Mannuru, N. R. Perceptions of the Fourth Industrial Revolution and Artificial Intelligence Impact on Society. 2023; **https://doi.org/10.48550/ARXIV.2308.02030**

[3] Ahmad, K., Maabreh, M., Ghaly, M., Khan, K., Qadir, J., Al-Fuqaha, A. Developing future human-centered smart cities: Critical analysis of smart city security, Data management, and Ethical challenges. Computer Science Review. 2022; 43: 100452. **https://doi.org/10.1016/j.cosrev.2021.100452**

[4] Ajibesin, A. A., Kasim, M., Ogundapo, O. Information security policies in Nigerian institutions: Evaluation and readiness. International Journal of Risk and Contingency Management. 2022 11(1): 1–22. **https://doi.org/10.4018/IJRCM.303103**

[5] Aldawood, H., Skinner, G. Reviewing Cyber Security Social Engineering Training and Awareness Programs—Pitfalls and Ongoing Issues. Future Internet. 2019 11(3): 73. **https://doi.org/10.3390/fi11030073**

[6] Alkhalil, Z., Hewage, C., Nawaf, L., Khan, I. (2021). Phishing attacks: A recent comprehensive study and a new anatomy. Frontiers in Computer Science. 2021; 3: 563060. **https://doi.org/10.3389/fcomp.2021.563060**

[7] Almusaylim, Z. A., Zaman, N. A review on smart home present state and challenges: Linked to context-awareness internet of things (IoT). Wireless Networks. 2019; 25(6): 3193–3204. **https://doi.org/10.1007/s11276-018-1712-5**

[8] Archibald, J. M., Renaud, K. Refining the PoinTER "human firewall" pentesting framework. Information & Computer Security. 2019; 27(4): 575–600. **https://doi.org/10.1108/ICS-01-2019-0019**

[9] Archibald, J., Renaud, K. POINTER: A GDPR-Compliant Framework for Human Pentesting (for SMEs). HAISA. 2018; 147–157.

[10] Atkins, B., Huang, W. A study of social engineering in online frauds. Open Journal of Social Sciences. 2013; 1(3): 23–32. **https://doi.org/10.4236/jss.2013.13004**

[11] Chhillar, K., Shrivastava, S. Vulnerability Assessment of University Computer Network using Scanning Tools. 2021; 13.

[12] Cisar, P., Pinter, R. Some ethical hacking possibilities in Kali Linux environment. Journal of Applied Technical and Educational Sciences. 2019; 9(4); ISSN 25605429. **https://doi.org/10.24368/JATES.V9I4.139**

[13] Dawson, M. Cyber security in industry 4.0: The pitfalls of having hyperconnected systems. Journal of Strategic Management Studies. 2018; 10(1): 19–28. **https://doi.org/10.24760/iasme.10.1_19**

[14] Desolda, G., Ferro, L. S., Marrella, A., Catarci, T., Costabile, M. F. Human factors in phishing attacks: A systematic literature review. ACM Computing Surveys. 2022; 54(8): 1–35. **https://doi.org/10.1145/3469886**

[15] Ejigu, K. T., Siponen, M., Arage, T. M. Investigating the impact of organizational culture on information security policy compliance: The case of Ethiopia. AMCIS 2021: Proceedings of the 27th Americas Conference on Information Systems. 202; **https://aisel.aisnet.org/amcis2021/info_security/info_security/10/**

[16] Engebretson, P. The basics of hacking and penetration testing: Ethical hacking and penetration testing made easy Second Edition. Syngress, an imprint of Elsevier; 2013

[17] Farsole, A. A., Kashikar, A. G., Zunzunwala, A. Ethical hacking. International Journal of Computer Applications. 2010; 1(10): 7.

[18] Fitzsimmons, J. Information technology and the third industrial revolution. The Electronic Library.1994; 12(5): 295–297. **https://doi.org/10.1108/eb045307**

[19] Goel, S., Williams, K., Dincelli, E. Got phished? Internet security and human vulnerability. Journal of the Association for Information Systems. 2017; 18(1): 22–44. **https://doi.org/10.17705/1jais.00447**

[20] Hartley, R. D. Ethical hacking pedagogy: An analysis and overview of teaching students to hack. 2015; 24(4): 11.

[21] Hong, Y., Furnell, S. Motivating information security policy compliance: Insights from perceived organizational formalization. Journal of Computer Information Systems. 2022; 62(1): 19–28. **https://doi.org/10.1080/08874417.2019.1683781**

[22] Janicke, M., Jacob, . Long-term governance for social-ecological change. 1st edition. Routledge; 2013. A third industrial revolution; p. [47–71]

[23] Jansen, J., Leukfeldt, E. Phishing and malware attacks on online banking customers in the Netherlands: A qualitative analysis of factors leading to victimization. International Journal of Cyber Criminology. 2016; 10: 79–91. **https://doi.org/10.5281/zenodo.58523**

[24] Kaginalkar, A., Kumar, S., Gargava, P., Niyogi, D. Stakeholder analysis for designing an urban air quality data governance ecosystem in smart cities. Urban Climate. 2023; 48: 101403. **https://doi.org/10.1016/j.uclim.2022.101403**
[25] Kaloudi, N., Li, J. The AI-based cyber threat landscape: A survey. ACM Computing Surveys. 2021; 53(1): 1–34. **https://doi.org/10.1145/3372823**
[26] Kasim, M., Saidu, M. B., Isa, A., Utulu, S. A proposal for social ethical hacking framework for detecting and managing human-induced vulnerabilities in organizational cybersecurity. UK Academy for Information Systems Conference Proceedings. 2022. **https://aisel.aisnet.org/ukais2022/16**
[27] Krishnannair, A., Krishnannair, S., Krishnannair, S. Learning environments in higher education: Their adaptability to the 4th industrial revolution and the "social transformation" discourse. South African Journal of Higher Education. 2021; 35(3): 65–82. **https://doi.org/10.20853/35-3-4098**
[28] Leukfeldt, E. R. Cybercrime and social ties: Phishing in Amsterdam. Trends in Organized Crime. 2014a; 17: 231–249. **https://doi.org/10.1007/s12117-014-9229-5**
[29] Leukfeldt, E. R. Phishing for suitable targets in the Netherlands: Routine activity theory and phishing victimization. Cyberpsychology, Behavior, and Social Networking. 2014b; 17(8): 551–555. **https://doi.org/10.1089/cyber.2014.0008**
[30] Leukfeldt, E. R., Kleemans, E. R., Stol, W. P. A typology of cybercriminal networks: From low-tech all-rounders to high-tech specialists. Crime, Law and Social Change. 2017; 67(1): 21–37. **https://doi.org/10.1007/s10611-016-9662-2**
[31] Maillart, T., Zhao, M., Grossklags, J., Chuang, J. Given enough eyeballs, all bugs are shallow? Revisiting Eric Raymond with bug bounty programs. Journal of Cybersecurity. 2017; 3(2): 81–90.
[32] Maynard, A. D. Navigating the fourth industrial revolution. Nature Nanotechnology. 2015; 10(12): 1005–1006.
[33] Mohajan, H. The first industrial revolution: Creation of a new global human era. Journal of Social Sciences and Humanities. 2019a; 5(4): 377–387.
[34] Mohajan, H. The second industrial revolution has brought modern social and economic developments. Journal of Social Sciences and Humanities. 2019b; 6(1): 1–14.
[35] Oke, A., Fernandes, F. A. P. Innovations in teaching and learning: Exploring the perceptions of the education sector on the 4th industrial revolution (4IR). Journal of Open Innovation: Technology, Market, and Complexity. 2020; 6(2): 31.
[36] Oliveira, D., Rocha, H., Yang, H., Ellis, D., Dommaraju, S., Muradoglu, M., Weir, D., Soliman, A., Lin, T., Ebner, N. Dissecting spear phishing emails for older vs young adults: On the interplay of weapons of influence and life domains in predicting susceptibility to phishing. Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems. CHI Conference; 2017. p. 6412–6424. **https://doi.org/10.1145/3025453.3025831**
[37] Ottis, R., Lorents, P. (2010). Cyberspace: Definition and implications. International Conference on Cyber Warfare and Security, 267.
[38] Preuveneers, D., Ilie-Zudor, E. (2017). The intelligent industry of the future: A survey on emerging trends, research challenges and opportunities in Industry 4.0. Journal of Ambient Intelligence and Smart Environments. 2017; 9(3): 287–298. **https://doi.org/10.3233/AIS-170432**
[39] Savić, D. Rethinking the role of grey literature in the fourth industrial revolution. Grey Journal (Online). 2018; 14(2018): 7–14.
[40] Schwab, K. The fourth industrial revolution First edition. US: Crown Business; 2017.
[41] Shahbaznezhad, H., Kolini, F., Rashidirad, M. Employees' behavior in phishing attacks: What individual, organizational, and technological factors matter? Journal of Computer Information Systems. 2021; 61(6): 539–550. **https://doi.org/10.1080/08874417.2020.1812134**
[42] Soudijn, M. R. J., Zegers, B. C. H. T. Cybercrime and virtual offender convergence settings. Trends in Organized Crime. 2012; 15(2–3): 111–129. **https://doi.org/10.1007/s12117-012-9159-z**
[43] Steinmetz, K. F. Executing Effective Social Engineering Penetration Tests: A Qualitative Analysis. Journal of Applied Security Research. 2023; 18(2): 246–266. **https://doi.org/10.1080/19361610.2021.2002119**
[44] Steinmetz, K. F., Pimentel, A., Goe, W. R. Performing social engineering: A qualitative study of information security deceptions. Computers in Human Behavior. 2021; 124: 106930.
[45] Tawalbeh, L., Muheidat, F., Tawalbeh, M., Quwaider, M. IoT privacy and security: Challenges and solutions. Applied Sciences. 2020; 10(12): 4102. **https://doi.org/10.3390/app10124102**
[46] Vaidya, S., Ambad, P., Bhosle, S. Industry 4.0 – A glimpse. Procedia Manufacturing. 2018; 20: 233–238. **https://doi.org/10.1016/j.promfg.2018.02.034**
[47] Williams, E. J., Hinds, J., Joinson, A. N. Exploring susceptibility to phishing in the workplace. International Journal of Human-Computer Studies. 2018; 120: 1–13. **https://doi.org/10.1016/j.ijhcs.2018.06.004**
[48] Zwilling, M., Klien, G., Lesjak, D., Wiechetek, Ł., Cetin, F., Basim, H. N. Cyber security awareness, knowledge, and behavior: A comparative study. Journal of Computer Information Systems. 2020; 62(1): 82–97. **https://doi.org/10.1080/08874417.2020.1712269**

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp.196-208, November 13-16, 2023

Geospatial Data Development for Rural Roads Planning, Construction and Management: Case Study of ADRAMP-2 Project

Geoffrey Naphtali[1], Samuel Chinedu Utulu[2], Sunday Ozovehe Amos[3]
{geoffrey.naphtali@aun.edu.ng[1]**,** samuel.utulu@aun.edu.ng[2], Sunday.amos@aun.edu.ng[3]**}**

Adamawa State University Mubi[1], School of Information and Technology Communication
American University of Nigeria[2], School of Information and Technology Communication
American University of Nigeria[3]

Abstract
Geospatial data describe objects and things with relation to geographic space often with location coordinate in a spatial referenced system. Rural roads are geospatial entities which can be captured and stored using geographic information system techniques. Therefore, a geographic information system is an essential tool to be placed on comprehending the information of spatial and non-spatial data over a space and time. Data required for this article include high resolution satellite imageries (QuickBird, SPOTS, IKONOS), Landsat (EOI Hyperion, DEM); local, state, and international boundaries; all Edges of transport routes connecting all settlements in the state, settlement data, stream network data, and terrain data. Roads associated attributes include location of potholes, bumps, drainages, drainage direction, and last date of road repaired, highest point, lowest point, mean elevation, maximum slope, average slope, road tears and wears which is expressed as roads condition. Road geometry data involve length of each road edge, width, and referential measurement. Data on nature of surfacing such as tar, asphalt, concrete, and laterite. Other data on roads are name, type, classification, and Geotagged pictures and video of all roads in Adamawa state. The field survey involves trailing the whole length of the roads from a referenced baseline at a vehicle speed using GPS Waypoint Navigators, handheld GPSs, and RoadLab application in iPad. These devices were used in collecting data on roads roughness index expressed as good, bad, excellent; visual assessment of road condition and drainages were carried out during the field survey. When navigating the roads records taking of roads data, geotagged pictures, videos, and coordinates of event areas were captured. However, the use of RoadLab in assessing road condition was only limited to Trunk A, B AND C roads across the state since they are the most tarred roads in regional road classification. Therefore, rigorous physical/visual surveys and assessment on all other rural roads were conducted. The result of the research indicate that truck B, C and feeder roads are in bad shape and geospatial database of all road network in Adamawa State was developed.

Key words: Geospatial Database, Geographic Information Systems, Data, Rural Roads, Road lap

1 Introduction

Geospatial data describe objects and things with relation to geographic space often with location coordinate in a spatial referenced system [7]. Literatures have confirmed that 80% of data is geographic [4]. Much of the data in this word can be geo-referenced, which indicate the importance of geospatial data.

Rural roads are geospatial entities which can be captured and stored using geographic information system techniques. Therefore, a geographic information system is an essential tool to be placed on comprehending the information of spatial and non-spatial data over a space and time [1]. Geographic information system (GIS) is a computer-based system which can be used for handling the entire geospatial data and help in planning and management of rural roads [3]. GIS can effectively be used to prepare geospatial data of rural roads which can be used for planning, development, and management of rural roads network.

Rural areas play a very significant role in a country development. In Nigeria, most especially in Adamawa state rural roads comprises of 87% of the total road network. Therefore, keeping these roads in good condition is very important for the rural people because they will get access to health facilities, education, and markets etc.

For the past 60 years government at all levels have been trying to improve rural roads accessibility in Nigeria and in Adamawa state in particular using different intervention and programs, but up till now most of these interventions and programs did not yield much positive result due to lack of accurate and comprehensive geospatial database of roads facilities and rural roads in the state. A geospatial database of roads comprises of; roads location, width, length, name age (year of construction). Other information that forms the roads data are culverts, bridges, river crossing on the roads. Some physical and climatic information needed for effective planning, construction and managements of roads also include soil type water bodies such as rivers, streams, lakes, waterlog areas, amount of rainfall, temperature, slope, and geological formations. But all these data are not available to relevant authorities in a comprehensive and in digital format that is easy to manipulate, updated and use for decision making therefore, the need for this paper.

The development of geospatial data of rural roads network in Adamawa State will assist Adamawa rural access and mobility project (ADRAMP-2) in planning, construction, and management of rural roads in the state therefore, this paper aim at using geographic information system in collecting, manipulating, storing, and analyzing geospatial data for better decision making and planning for ADRAMP-2. This can be achieved through the following objectives: 1) to carry out a field survey of all roads in Adamawa state, 2) to collect rural roads data using digital survey equipment, 3) to develop and analyze these data for ADRAMP-2 for better decision making in the organization. The paper, therefore, seek to answer the following questions Q1) What are the geospatial data needed for rural roads planning, construction, and management? Q2) How can the geospatial data be collected, stored, manipulated, and analyzed using Geographic Information System?

2 Literature Review

Various literatures have discussed on the use of geospatial big data and Geographic Information System or planning, construction, managements and impact of rural roads for the economic development of rural areas in different countries of the world for example; big data for geospatial application for rural roads in China by [6], developing big data analysis architecture for spatial data on rural roads in India, [2], rural roads network planning using GIS methodology also in India by [5]. They also added that geographic information system can be used as an effective tool to prepare a geospatial rural roads information system which will be useful for planning and development of rural roads network. [10] also confirms that geographic information system is a computer-based tool which can handle the entire database and help in the management of the entire rural development program.

The potential for the use of GIS and geospatial data in rural roads for both development and management are tremendous [11]. [13] further stress that GIS has been used for planning of rural roads connectivity for a community development and the information system was developed for villages and rural roads. [12] also support the use of geographic information system for maintenance and management of rural roads network. [8] advised that in order to avoid the problems associated with rural roads development, it is better to prepare a rural road plan by building strong data base which consist of village level information and roads inventory. Therefore, by this advice, this paper is geared towards developing a comprehensive and robust geospatial rural roads database for ADRAMP-2.

3 Study Area

Adamawa state is located at the northeastern part of Nigeria, it lies between latitude 7º and 11º N of the equator and between longitude 11º and 14º E of the Greenwich meridian. It shares boundary with Taraba state in the south and west, Gombe State in its Northwest and Borno state to the north. Adamawa state has an international boundary with the Cameroon republic along its eastern border.

The state covers a land area of about 38,741 km with a population of 36,917km2 People according to the 2006 census and a population density 115.1km2. Adamawa state is divided into 21 local government areas. The paper covers the 21 local government areas of Adamawa State.

3.1 Brief introduction of ADRAMP-2 Project

The Adamawa State government through the federal government ministry of infrastructure and rural development applied for financing of the rehabilitation/ construction of rural roads in the state from the World Bank and French development agency (AFD) which is guided by the government's rural travel and transport policy (RTTP). The approval was therefore granted in 2012 and the ministry of rural infrastructure and community development through the state project implementation unit (SPIU) is implementing the program for the Adamawa State, while the federal project management unit (FPMU) and the donor agencies are monitoring the project to ensure total compliance with the World Bank procurement guidelines. The overall objectives of RAMP are to support participating state and local governments in providing improved all-weather access roads in selected and prioritized rural development areas, rehabilitate prioritized river crossings statewide, and support the institutional reforms in the transport sector leading to optimization and improvement of the sector management.

4 Methodology

Research methodology is a philosophical stance of worldview that underlies and informs the style and type of research [14]. Methodology refers to how the researcher goes about practically finding out whatever he or she believes can be known [14]. It is a research strategy that translates ontological and epistemological principles into guidelines that shows how research is to be conducted, and the principles, procedures that govern research [14]

This article adopts the mixed method research methodology which combines the quantitative and qualitative research methods which is underpin by the pragmatic research philosophy.

The mixed method approach employs both quantitative and qualitative approaches in a research work for the purpose of breadth and depth of understanding and partnership (15).

4.1 Philosophy Underpinning

All research is based on some underlying philosophical assumptions about what constitute a valid research and which research method(s) are appropriate for the development of knowledge in a given study [14]. Understanding research philosophy and agreeing to adopt a particular perspective for a proper research paradigm is the step in setting other research parameters and choice to a study.

The philosophical paradigm for this article is pragmatism. This philosophy concerns thinking that choosing between one position (epistemology, ontology, or axiology) and the others is somewhat unrealistic in practice and it is argued that the most important determinant of which position to adopt is the research question [14] Therefore, this philosophy encourages the use of both qualitative and quantitative methods to solve real- world challenge as in this article. There are many research design alternatives that can be applied in research study such as experiments, survey, case study, action research, grounded theory, ethnography, and archival research. Therefore, this article combines both survey and case study.

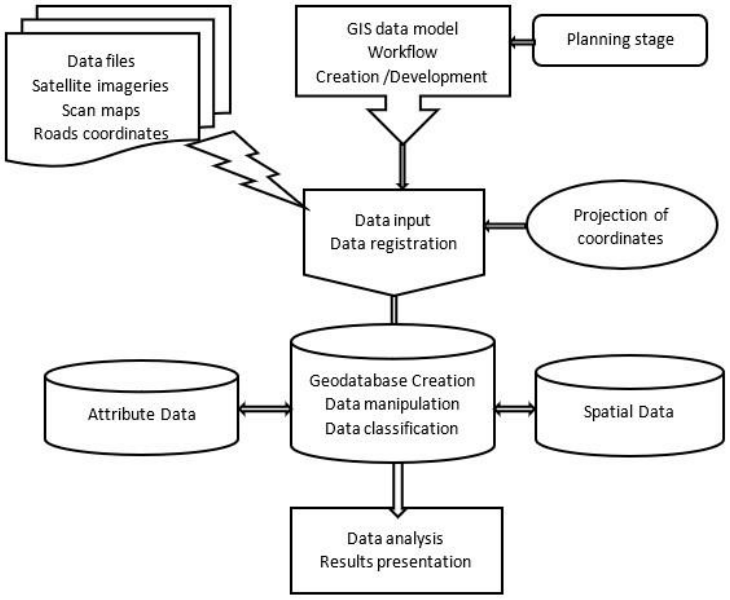


Fig 1. GIS Geospatial Data Model

5 Material and Methods

Data required for this article include high resolution satellite imageries (Quick Bird, SPOTS, IKONOS), Landsat (EOI Hyperion, DEM); local, state, and international boundaries; all Edges of transport routes connecting all settlements in the state, settlement data, stream network data, and terrain data. Roads associated attributes include location of potholes, bumps, drainages, drainage direction, and last date of road repaired, highest point, lowest point, mean elevation, maximum slope, average slope, road tears and wears which is expressed as roads condition. Road geometry data involve length of each road edge, width, and referential measurement. Data on nature of surfacing such as tar, asphalt, concrete, and laterite. Other data on roads are name, type, classification, and Geotagged pictures and video of all roads in Adamawa state.

5.1 Quantitative

Field survey formed the basis for primary data which represent relational attribute of the road segments; this was done through rigorous physical site visitation with the help of contemporary mapping devices. The field survey involves trailing the whole length of the roads from a referenced baseline at a vehicle speed using GPS Waypoint Navigators, handheld GPSs, and RoadLab application in iPad. These devices were used in collecting data on roads roughness index expressed as good, bad, excellent; visual assessment of road condition and drainages were carried out during the field survey. When navigating the roads records taking of roads data, geotagged pictures, videos and coordinates of event areas were captured. However, the use of RoadLab in assessing road condition was only limited to Trunk A, B AND C roads across the state since they are the most tarred roads in regional road classification. Therefore, rigorous physical/visual surveys and assessment on all other rural roads were conducted. Policy statements concerning road provision and nomenclature were sourced from ministry of works.

RoadLab was used to capture data during the survey, such as speed of the vehicle used for survey, category of the road, start latitude and end longitude, IS fixed, international roughness index (IRI), distance covered and suspension of each road

Suspension- suspension indicate the smoothness or roughness of the road, RoadLab measured suspension in two categories of soft and medium. Survey data gotten from the used of RoadLab was converted into Geographic information system shape files.

5.2 Qualitative

Data collected include information from various geoportals, Ministries, departments, and spatial data vendors vested with the responsibility of providing spatial data. Nigeria map and Adamawa state boundary map (shapefiles) was source from the Nigerian boundary commission in connection with the ministry of land and survey Yola.

The high-Resolution satellite images were downloaded online through advanced use of Google Earth Pro, while the Digital Elevation Model (DEM) and Landsat were source from the United States Geological Surveys (USGS) Archive (Earth Explorer). The Google Pro was instrumental in online digitization of all road Edges at high resolution upon which road attributes that were collected during field survey using RoadLab and dual frequency GPS was aggregated and related with the road's geometry. Landsat was used for extraction of water bodies while digital elevation model (DEM) for building stream networks. These are all important data in the planning and management of road assets. Other qualitative data were information gotten from literatures that provide information on the extent to which similar projects have covered the subject of Geospatial data development for planning, construction, and management of rural roads.

5.3 Data Collection and Entry

5.3.1 Hardware- these are physical devices that were used for data collection and entry. These include *Laptop for* inputting, processing, and displaying of spatial data. It was used for storage of roads data collected, and a medium for the installation of software packages which includes ArcGIS Desktop that was used for spatial data assembly, and Google Pro for online digitization of all roads. *Dual frequency GPS* for capturing coordinate locations of event data associated with road edges such as potholes, road tears, wears, drainages, culvert, water crossing and bridges. A *smart phone for* installation of survey and measurement apps and sensors such as RoadLab, Waypoint navigators, and cameras. The smart phone facilitates snapping geotagged images and videos of event sections of the roads and recording information on roads conditions such as good, poor, fair, and excellent.

5.3.2 software-that were used include ArcGIS Desktop, Google Pro, RoadLab application, Waypoint navigators, PostgreSQL/PostGIS, Geo-sever, Microsoft office, and other related web applications. These applications were used for georeferencing, digitization, geodatabase creation, spatial data assembly, network development, linear referencing, road trailing, understanding road directions, road elevation, assessment of road condition, computation of roughness index of trailing paths in international roughness index scale, workflow development, report generation, establishment of geoportal, modeling, and analysis.

5.3.3 Data Generation-Geographic Information System database development are highly sensitive it requires thoroughness and should defy assumptions. The key element in this geospatial database is the absolute geometrical location of all rural roads in Adamawa state. Most open-source road data including the ones in most applications and geoportals were digitized at lower resolutions and should not be completely trusted as base data for a sensitive article like this; hence, the need for a more practical, robust, accurate, and localized method of rural road data generation with high spatial integrity for the state.

For effective rural road inventory, a folder named Adamawa state roads was created at Google Pro table of content, subfolders were also created from the Adamawa state folder depicting different

categories of roads. KML layers were created in each category, folders representing each road feature were created, each road feature was digitized online at the maximum resolution of the high resolution of satellite images (Quickbird and Ikonos) on the globe. The ability of the satellite image to reveal every rural road at a higher resolution within the boundary of the state was adequately spur to capture 100% road networks within the territory necessary for conversion, aggregation, and relating with layers and tables that were generated from the field condition survey using RoadLab, GPSs and other devices. The acquired data on road condition with RoadLab apps were directly linked with the Dropbox account where they were automatically saved. Both the digitized road network from Googlepro and road data from RoadLab were save in KML format and converted to shapefiles, transformed to UTM WGS 84 coordinate system using ArcGIS. This data are the rural road map and geometric attribute of Adamawa State that finally formed the geodatabase. Stream network of the entire state were generated from the DEM while the terrain where be generated from LIDAR data. These data reveal areas on the roads where streams cross.

5.3.4 Spatial Data Assembly (Creation of Geospatial database)-The geospatial database for Adamawa state rural roads was created in a folder after which all features and attribute of the road were modeled and imported into it. The geospatial database storage model was based on a series of simple yet essential relational database concepts that leverage the strengths of the underlying database management system (DBMS). Topological operations were carried out on all road features within the geospatial database to ensure that all road features coincided to each other and that features maintained geometrical integrity. Simple tables and well-defined attribute types of all road assets were used to store the schema, rule, base, and spatial attribute data for each geographic dataset.

This approach provides a formal model for storing and working with the road data. Through this approach, structured query language (SQL) a series of relational functions and operators was used to create, modify, and query tables and their data elements.

5.3.5 Relational Database Creation-The roads geospatial database was implemented using the same multitier application architecture found in other advanced DBMS applications. The multitier architecture of the geospatial database is an object-relational model. The geodatabase objects persist as rows in DBMS tables that have identity, and the behavior is supplied through the geospatial database application logic. Road geometry tables, road condition tables, potholes tables, road category tables, geotagged image tables, and drainage tables were related to a primary key all within the geospatial database. At the core of the geospatial database is a standard relational database schema (a series of standard database tables, column types, indexes, and database object). The schema was used in the collection of geospatial database system tables in the DBMS that defines the integrity and behavior of the geographic information.

5.3.6 Cartographic Finishing-All the roads geospatial database features that were assembled within the Geo-database undergo professional cartographic finishing on the layout view where templates at varying scales were designed. The Maplex labeling engine was used for hi-tech labeling of all roads and their associated attributes; all map accessories such as scale bar, map grids, North arrow, legend, and neat lines were strategically decorated on the map layout.

6 Results and Discussions

This section presents the result and findings of this study in summary form for easy understanding. The results are presented as road class rating, the distance covered using the RoadLab, International Roughness Index (IRI) of the roads surveyed using the RoadLab, summary of both roads surveyed and

captured using satellite imageries and online digitization, others are maps of Adamawa state showing all the road network.

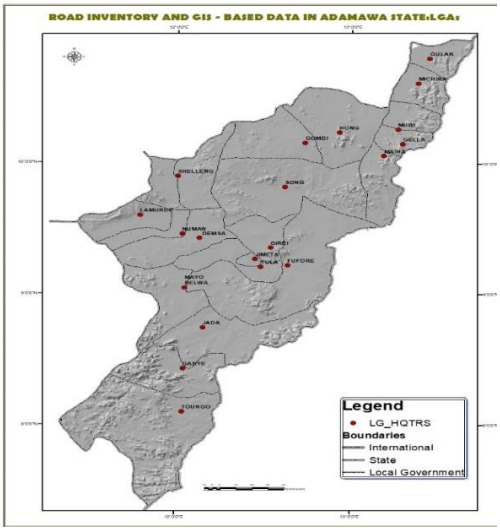


Fig 2: The 21 Local Government Areas of the State

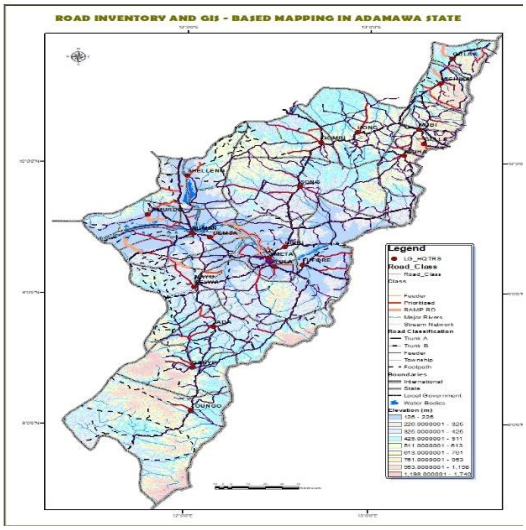


Fig 3: All Road Network in the State

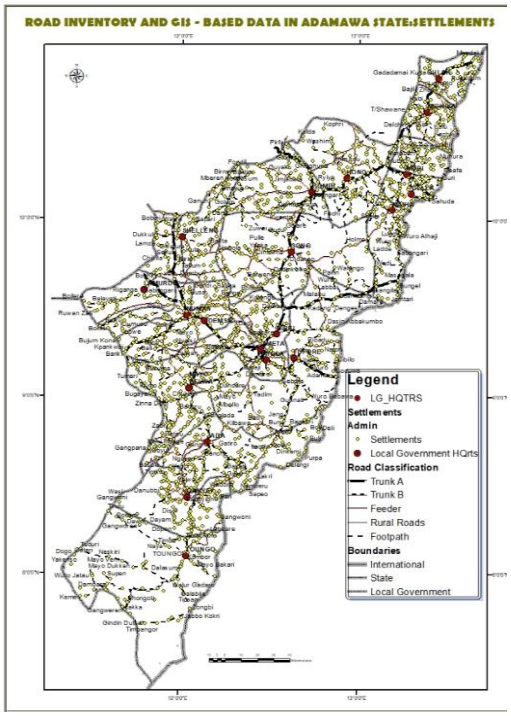


Fig 4: Settlements in the Adamawa state

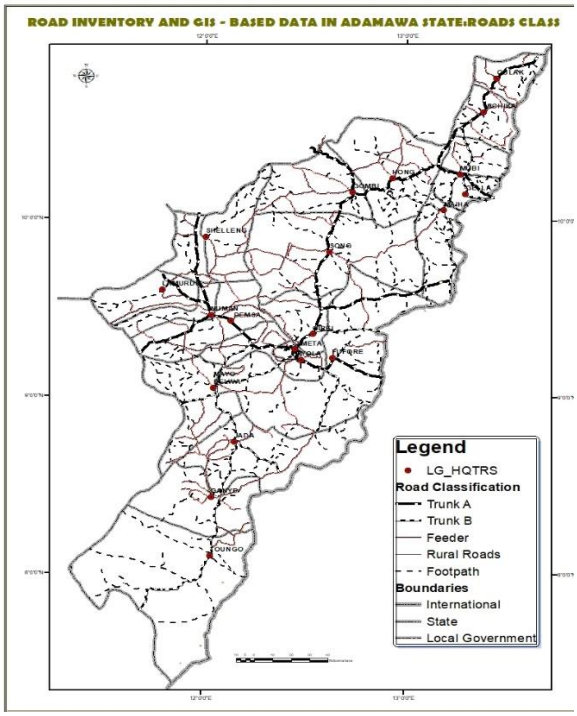


Fig 5: Roads Classification in Adamawa state

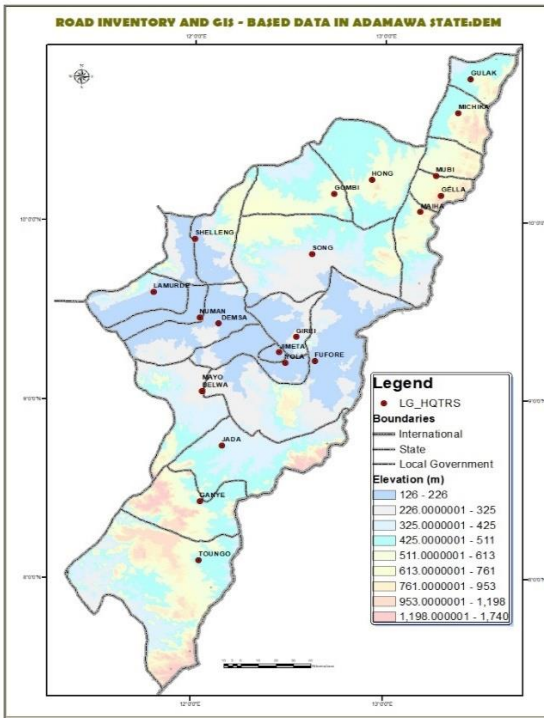


Fig 6: Adamawa state digital elevation model (DEM)

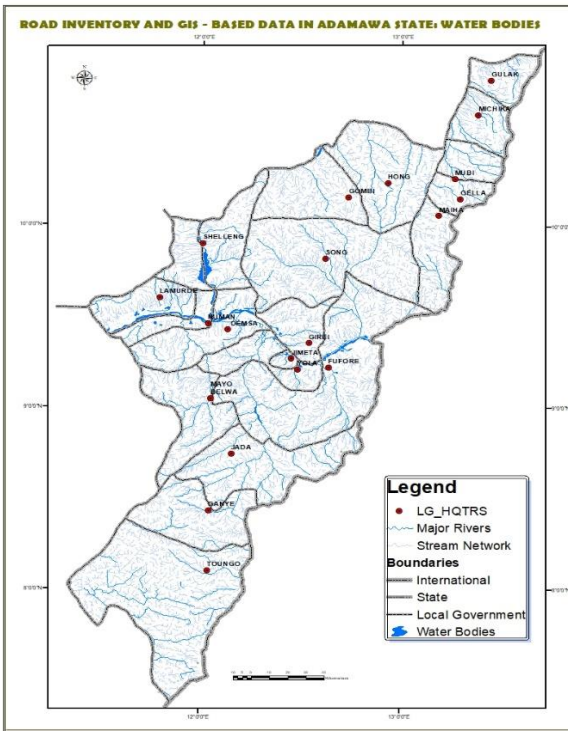


Fig 7: Adamawa state Rivers, Lakes and Streams

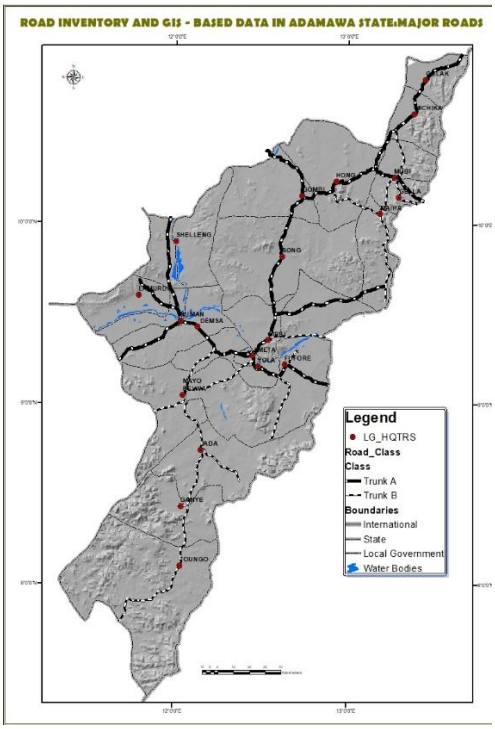


Fig 8: Adamawa state major roads (trunk A, B and C)

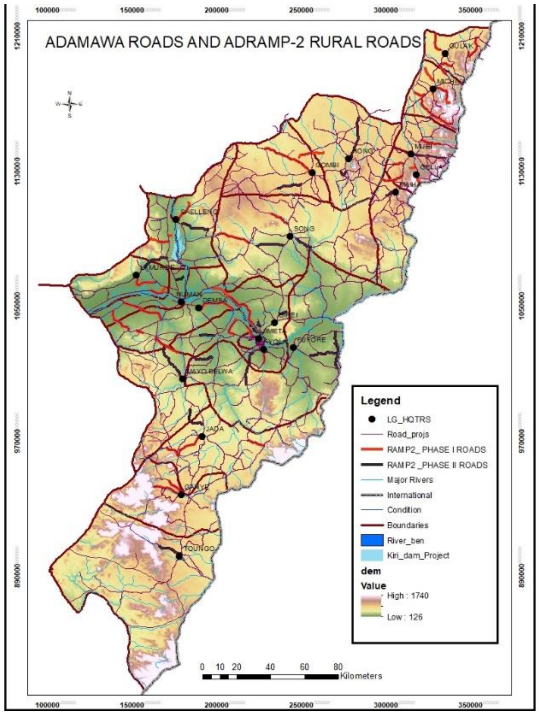


Fig 9: Adamawa state RAMP-2 Rural Roads

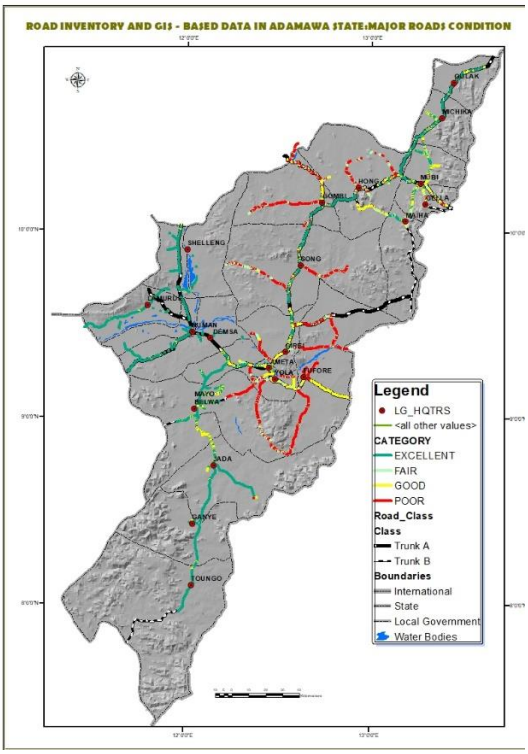


Fig 10: RoadLap Roads Condition Survey on DEM

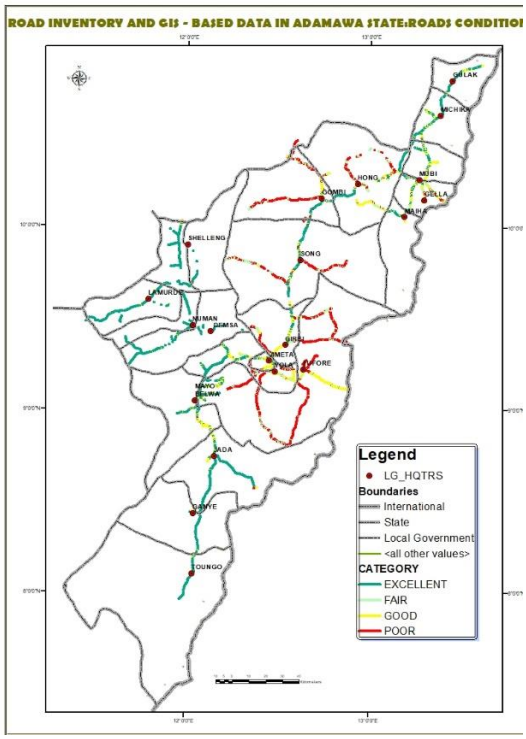


Fig 11: Roads Condition Survey

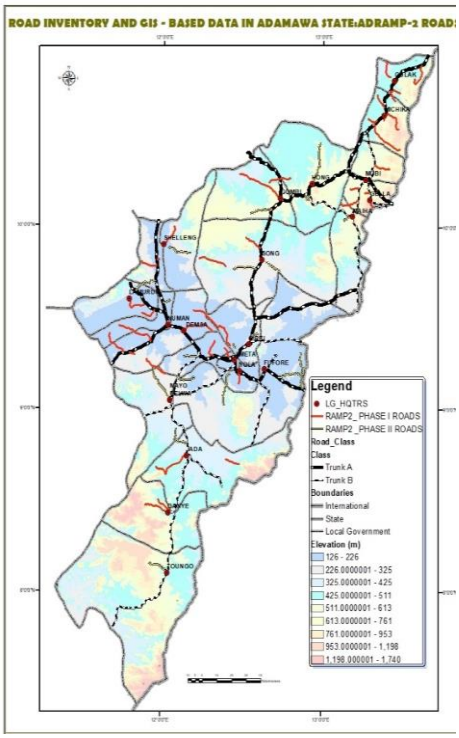


Fig 12: RAMP-2 Phase I and II Rural Roads

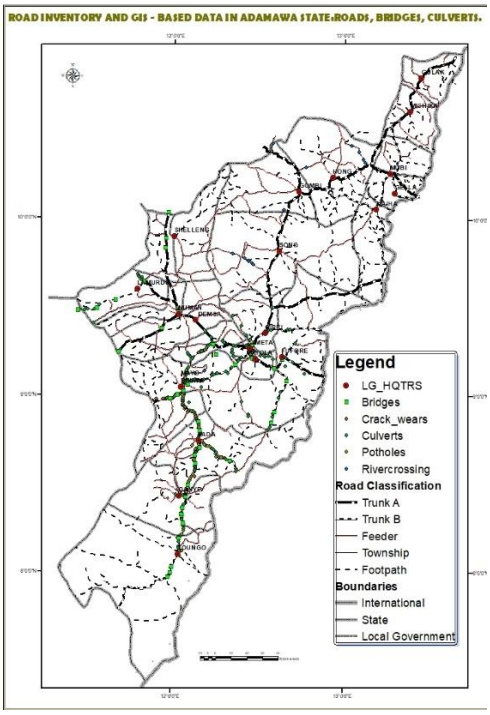


Fig 13: Culverts, Bridges, River Crossings and Potholes

Fig. 1 above represent the geographic information system geospatial database model developed to capture, stores, analyzed and present the results of the roads geodata developed for adamawa state, fig. 2, the 21 local government of adamawa state overlayed on the digital elevation models developed, fig. 3, shows all the road network in adamawa state with more details in table, fig. 5, 8,9 and 12 furthers

shows the roads classifications, major roads, Ramp -2 rural roads and Ramp-2 phase 1 and 2 rural roads in the state. Fig 4 shows all the settlements in the state, fig 7. Is for rivers, lakes, streams, and water courses while fig. 13 shows the bridges, river crossing, culverts, and potholes on the road network in adamawa state.

6.1 RoadLab Survey Summary

Road Class Rating- this table provide a comprehensive data on the different types of roads surveyed using the RoadLap, the RoadLap classify the categories of the nature of the roads into excellent, good, fair, and poor.

Table 1: Road class rating using the RoadLab.

S/No.	Rating	Count (Trunk A)	(Trunk B)	(Feeder)	Township	TOTAL
1	Excellent	1187	4124	1093	129	6533
2	Good	1156	644	868	350	3018
3	Fair	419	107	1241	106	1873
4	Poor	547	33	2962	199	3741
Total		3309	4908	6164	778	

Distance Coverage- this is the distance covered during the road lap survey for the whole roads network in Adamawa state.

Table 2: Distance coverage using the RoadLab.

S/No.	Rating	Count	Min.	Max.	Sum	Mean	Std. Deviation
1	Excellent	6533	100.01	192.39	709223.26	108.560119	6.700456
2	Good	3018	100	166.53	321271.1	106.451657	5.484436
3	Fair	1873	100.02	190.34	198171.74	105.804453	7.430516
4	Poor	3741	100	196.74	392324.08	104.871446	5.190105

International Roughness Index (IRI)-the surface roughness of the roads survey is presented in the table below.

Table 3: International Roughness Index (IRI) using the RoadLab.

S/No.	Rating	Count	Min.	Max.	Sum	Mean	Std. Deviation
1	Excellent	6533	1	2	7942.58	1.215763	0.296614
2	Good	3018	2	4	8677.48	2.875242	0.557057
3	Fair	1873	4	6	9404.95	5.021329	0.585039
4	Poor	3741	6	49.34	35140.81	9.393427	3.643385

6.2 Road Inventory Summary

The entire road network covered in this project is presented in this table, some roads are not accessible, therefore, they were mapped using the online digitization, the table below give the total number of the roads surveyed in the state.

Table 4: Road Inventory Summary

S/No.	Road Class	Length (Km)	Nature (km)		General Condition			
			Tarred	Untarred	Excellent	Good	Fair	Bad
1	Trunk A	970km	970km	Nil	170km	215km	213km	372km
2	Trunk B	1,201km	756km	445km	Nil	326km	460km	415km
3	Feeder	1,902km	452km	1,450km	Nil	156km	307km	1,438km
4	Major Footpath	2,999km	Nil	2,999km	Nil	Nil	Nil	2999km
5	Total	7,072km	2178km	4894km	170km	697km	980km	5,224km

A road network is a valuable Government asset and failure to maintain the roads that form the network will lead to their rapid deterioration which in turn will lead to increases in road user costs and accidents and the need for expensive reconstruction works. Well-maintained roads make a valuable contribution towards the country's economy. This section presents the result of major finding of the project.

Road Classification-In Nigeria roads are classified in the following categories: federal roads, state roads, Feeder roads and footpaths

Federal Roads (TRUNK A)- Federal roads are defined as Highways connecting state capitals with different divisional and old district headquarters, port cities and international highways.

These roads have been categorized as federal roads considering their national importance and geographical positions.

The federal roads in the state covered using the roadlap include the following:

Mubi Sahuda Road, Maraba Michika Road, Michika Madagali Road, Lafiya Gombe Road, Numan Jalingo Road, Numan Bui Road, Others are Ngurore Mayobelwa Road, Galadima Aminu Road, Jimeta Bye Pass, Mayobelwa Zing Road, Mayobelwa Jada Road, Yola Fufore Road, Fufore Gurin Road, Yola Numan Road, Yola Mubi Road, Jada Ganye Road, Dashen Ganye Road, Ganye Toungo Road, Gombi Bui Road, Gombi Song Road, Gombi Mubi Road and Numan Guyuk Road.

The following are the state roads covered in this project using the roadlap: Mubi Vimtim Road, Vimtim Muva Road, Muva Mayobani Road, Maiha Gella Road, Mubi Maiha Road, Maiha Bellel Road, Maiha Pella Road, Michika Kurbususu Road, Mubi Digil Road, Kashim Ibrahim Way Others mohammed Mustapha Way, Justice Buba Ardo Road, Atiku Abubakar Road, Ahmadu Bello Way, Jada Kojoli Road, Mayo Inne Road and Maraban Jen Lafiya Road, Labondo-Borrong Road, Bazza-Zah Road, Kayo- Sabon Gari Road, Shuwa –Pallam, Koe-Koppa, New Densa-Kwaine, and Bille-Woro Bobbo Roads

Local Government Feeder Road (Trunk C)

Feeder Roads are defined as Roads connecting state roads and other important rural centers (growth centers) within the existing Road network. These connecting roads are defined as Feeder Roads. There are two types of Feeder roads. Feeder road - Type A and Feeder road - Type B. This project was able to identify and cover the following trunk C roads in the state using the roadlap:

Muchalla Road, Prambe Road,Zumo Road, Mai Tulare Bilachi Road, Wuro Boki Malabu Road, Jabbi Lamba Farang Road, Vunoklang Road, Nepa Road, Gimba Road, Bishop Stree, Hospital Road, Jimeta Riverside Road, Garaha Mugwalar Road, Dzangwala Road, Bibiji Road, Dumne Road, Dirma Road, Bokki Tawa Road, Gaanda Road, Ngurore Mbilla Farm Road, Mayo Belwa Ndikong Road, Mayobelwa Wuro Jombe Road, Mayobelwa Mayo Inne Road, Mayobelwa Linringo Road, Rock Heaven Avenue, Grand View Terrance, Yolde Pate Yadem Rijiya Road, Rijiya Larlahi Road, Njoboliyo Rugange Road, Jada Gangwuso Tola Road, Jada Gidanmutuwa Road, Kojoli Shigari Road, Kojoli Ganye Road, Mayo Belwa Mapio Road, Fufore Dashin Road, Dashin Bwatiy Road, Fufore Ribadu Road, Kwanan Waya Namtari Road, Ring Road Malkohi Road, Forest Toungo Road, Bonghe Ganye Road, Sanga Somen Gurum Road, Police Station Road Ganye, Others Are , Bulo LCCN Road, Gyawana Lamurde Road, Kwah Maraban Waduku Road, Boshikiri Road, Bobini Road, Chikila Road, Numan Kikon Road, Maraban Dakanta Maliki Road, Ndwam Road, Old Demsa Road, Imburu Road, Kpasham Road, Mararaban Dong Dong Road, Guyuk Dukul Road, Mararaban Kiri Shelleng Road, Mugwalar Gashala Road, Kwamla Mubi Road, Gashala Mubi Road, Banshika Road And Garaha Road,jambuto- kofare road,

7 Summary and conclusion

In this study the RoadLab software was used, the results on road classification presented as excellent, good, fair and poor. The results indicate that feeder roads in the state are in poor condition while truck A roads are mostly in good condition. The distance covered in the survey and data collection of roads in adamawa state are, excellent 6,533km, good 3,018km, fair 1,873m and poor is 3,741km, the reason is that RoadLab software are mostly used where the surface of the roads is flat. The areas where the RoadLab was used are truck A roads and B roads which are mostly flat terrain. The international roughness index (IRI) of roads in adamawa state indicates that, truck A roads are in good condition, truck B, C and feeder roads are in bad conditions.

8 Recommendation and Further Research

This research was able to capture all the present road network in adamawa state, it is recommended that attention should be given to construction, rehabilitation, management and maintenance of truck B, C and feeder roads in the state. These roads are the once linking the local government areas, the villages and farm settlements. Further research is needed in carrying out an in-depth analysis of the settlement that are linked with these roads and how the roads impact their lives. It is also recommended that further studies should be carried out on the socio-economic importance and benefits of RAMP -2 roads to the benefiting communities in Adamawa State.

Acknowledgment
We will first acknowledge the contribution and support of *ADRAMP-2* staff for providing the relevant information on all the rural roads they constructed, we will also acknowledge the staff of *GN TSUNDASS NIGERIA LIMITED* for their help in data collection, special thanks to the state ministry of rural infrastructure and rural development, ministry of land and survey adamawa state and ministry of works adamawa state.

Reference

[1] Chen, J., Wu, H., Li, S., Chen, F., & Han, G. Service-oriented dynamic computing for land cover big data. Journal of Geomatics Science and Technology. 2013, 30(4), 369–374.

[2] Chen, X., Li, S., Li, L., & Li, M. Object-event-process-based spatiotemporal data model and its application into sea-ice dynamics. Geography and Geo-Information Science. 2013. 29(3), 10–16.
[3] Li, S., & Yan, W. Mashing up geospatial data services: implications of acceptable use policies. Geomatica. 2010, 64(1), 111–122.
[4] Chen, X., Li, S., & Zhu, J. Database model based on spatio-temporal ontology. Geography and Geo-Information Science. 2010, 26(5), 1–6.
[5] Chen, X., Li, S., & Zhu, J. Spatiotemporal data model related concepts and its classifications. Hydrographic Surveying and Charting. 2009, 29(5), 74–76.
[6] Chen, X., Li, S., Zhu, J., & Chen, J. Spatiotemporal data models and their extensions: a review. Progress in Geography. 2009,28(1), 9–17.
[7] Li, S., & Coleman, D. Modeling distributed GIS data production workflow. Computers, Environment and Urban Systems. 2005, 29(4), 401–424.
[8] Li, S., & Coleman, D. A web-based collaboration system for managing distributed GIS data production. Geomatica. 2003, 57(1), 59–67.
[9] Huang, W., Li, S., Liu, X., & Ban, Y. Predicting human mobility with activity changes. International Journal of Geographical Information Science. 2015, 29(9), 1569–1587.
[10] Liu, X., Chen, M., Claramunt, C., Batty, M., Kwan, M. P., Senousi, A. M., ... Li, S., ... & Lü, G. Geographic information science in the era of geospatial big data: A cyberspace perspective. The Innovation. 2022,3(5), 100279.
[11] Xu, S., Li, S., Huang, W., & Wen, R. Detecting Spatiotemporal Traffic Events using Geosocial Media Data. Computers, Environment and Urban Systems. 2022, 94, 101797.
[12] Sattar, S., Li, S., & Chapman, M. Developing a near real-time road surface anomaly detection approach for road surface monitoring. Measurement. 2021,185, 109990.
[13] Sattar, S., Li, S., & Chapman, M. Road Surface Monitoring Using Smartphone Sensors: A Review. Sensors. 2018, 18(11), 3845.
[14] Paulinus, I. W., & David, E. The pragmatic research approach: A framework for sustainable management of public housing estate in Nigeria. Journal of US-China Public Administration. 2013, 10.
[15] Creswell, J. W. Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research (4th ed.). Boston, MA: Pearson. 2012.

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp.209-224, November 13-16, 2023

Using Causal Constraints to Achieve Diverse Feasible and Actionable Counterfactual Explanations Predictions with SENSE-EGRA Dataset

Gabriel Terna Ayem[1], Abel Ajibesin[2], Aamo Iorliam[3], Augustine Shey Nsang[4],
{gabriel.ayem@aun.edu.ng**[1],** abel.ajibesin@aun.edu.ng**[2],** aamo.iorliam@aun.edu.ng**[3],** augustines.nsang@aun.edu.ng**[4]}**
Computer Science Department, School of Information Technology and Computing, American University of Nigeria, Yola, Nigeria[1,2,3,4]

Abstract.
This work presents a framework tiled – DiFACE-SCM, which stands for **Di**verse, **F**easible, and **A**ctionable **C**ounterfactual **E**xplanations (CE) with **S**tructural **C**ausal **M**odel constraints. The background knowledge obtained from the data generation process is employed to design a structural causal model (SCM), which is further used to identify variable features which can be used to constrain and sparse a black-box machine learning (ML) predictive model and ensues it produces feasible and actionable counterfactual explanation during the model prediction process, to identify features in the dataset that will require improvement for each student in the next intervention program. The designed SCM is tested for correctness using the conditional independence test (CIT) criteria. Further, it uses a real-life intervention dataset of the American University of Nigeria (AUN) called "Strengthening education in northeast Nigeria (SENSE) early grade reading assessment (EGRA) - (SENSE-EGRA) dataset. A maximum of 4 counterfactual explanations (CEs) are generated for each test dataset instance, and the result shows feasible and actionable CEs for all test dataset instances for the categorical variables features as compared to similar previous frameworks. Albeit, with the numeric variables, the framework sometimes generates CEs that are infeasible and non-actionable. This challenge is however resolved by further introducing non-causal constraints adopted from a previous framework. Also, the constrained sparse ML black-box predictive model led to a reduction in the model's F1 and accuracy scores. However, the focused of this work is on feasible and actionable CEs and so we cannot tradeoff feasible and actionable CEs on the altar of high accuracy and F1 scores with meaningless CEs.
Keywords structural causal model. counterfactual explanation. diverse feasible and actionable. causal models. machine learning models.

1 Introduction

Explanation of ML or artificial intelligence (AI) tasks is imperative and considered a sin-quo-non nowadays since they are employed to inform decision-making in societally critical domain areas such as healthcare, finance, the justice system, education, etc. These domain areas require no gambling as an implementation of a wrong prediction result may be fatal. Imagine a case scenario of a predictive model in the area of cancer that predicts that one is positive for cancer, whereas it is false. Another scenario is where a suspected criminal is predicted to commit a crime that the sentencing is capital in nature and turn out to be false upon further investigation after the person has already been executed. Thus, since most of these predictive models are back-box or at best grey boxes by nature, applying them in the aforementioned domain areas would require the users to have a working knowledge of their "thought decision-making process", to increase users' or experts' trusts in the systems and to enhance decision-making in the domain areas [1-3]. Laws, principles, and guidelines that require that ML/AI models be explainable or interpretable are now already in existence [4-7].

Many methods and forms of generating explanations classifications for ML/AI algorithms exist [8-13], albeit, the counterfactual explanation or contrastive explanation is of vital importance and is the focus of this study. Counterfactual explanations are counter to fact, and they are an opposite or alternative perturbation of the individual data instance features of that individual instance prediction in a classifier to obtain an alternative or opposite prediction of the same individual data instance. Further, counterfactual explanations provide a human interpretation for ML/AI predictions and allow stakeholders to explore the scenario of "what-if", similar to the way children learn through potential realities that have no facts [8, 14-17]. Imagine a scenario where an ML/AI prediction is employed to determine the suitability or not of the applicants who made a loan request from a bank. The individual whose loan was rejected may desire an actionable explanation of what to do next time to obtain a positive prediction from the system. Thus, a counterfactual explanation will suffice in helping the

applicant obtain the requisite knowledge of what to do next time to get his/her loan request approved. Thus, a counterfactual explanation from the loan process and predictions such as "*your loan request is rejected but if you increase your annual income to $12,000, you might be considered next time*". In another scenario in education where stakeholders seek to understand why a particular student performed poorly in an exam, a counterfactual explanation such as "*if the student's study hours are increased to 3 or 4 hours in a day as against the 1 or 2 hours, his/her grades may improve*". These explanations which are not real (but are potential realities), and are counter to facts (counterfactual) in the dataset can go a long way to helping the individual with the right knowledge on what to do next time to get a positive prediction from the system. Interpreting counterfactuals is not rocket science. If a data instance feature values are perturbed in line with the counterfactuals, the prediction is changed to the predefined prediction. No extra assumptions or magic are required at the backend. Thus, making them easier to implement, than other explanation methods such as the local Interpretable Model-Agnostic (LIME) method proposed by Ribeiro, Singh [8], where it is not clear to which extent one can extrapolate the interpretation of a local model in the region of concern.

The diversity of different counterfactual explanations on the same data instance is crucial (usually called the Rashomon effects – i.e., every counterfactual explains a different "story" of how a certain output was attained)[18] as it is capable of providing stakeholders with a pool of alternative positive counterfactual predictions to enable them to make the best choice to implement in a decision. Thus, the study by Russell [34] recognizes the essence of diversity in counterfactuals and further proposes an approach for counterfactuals with a linear ML classifier using integer programming. The work of Mothilal, Sharma [19] constructs a problem of optimization that looks at generating counterfactual diversity from the same data instance with proximity to the original input. Their work tries to solve the problem of optimization, which counterfactuals are known for by basically considering the diversity and proximity tradeoff. This framework which is a general solution to optimization problems is an extension of the study by Wachter, Mittelstadt [14]. Further, it is capable of generating any number of counterfactual examples for a given data instance input and uses an objective evaluation metric for the evaluation of the counterfactuals that are generated. Finally, the study points to causal models, that could provide constraints for the generation of feasible and actionable counterfactuals from which gap our proposed framework seeks to bridge.

1.1 Background of Study and Comparison with Similarly Related Works

Thus, our study is an extension of these two methods by Wachter, Mittelstadt [14] and Mothilal, Sharma [19]. Wachter, Mittelstadt [14] proposed the novelty of counterfactual explanation and suggested the inculcation of causal constraints in the generating of feasible and actionable counterfactuals but lack the technical know-how on how to create, and validate the causal model due to their subjective nature. The study by Mothilal, Sharma [19] extended Wachter, Mittelstadt [14] work by introducing diversity and proximity and also suggested causal constraints in future work. We closed these gaps suggested in these two studies by creating an SCM that describes the dataset and helps identify the causal constraints to introduce in our sparse ML black-box predictive model, which would enable feasible and actionable CE predictions. The objective evaluation check on the subjective SCM developed to ascertain its correctness, which is suggested in the works of Wachter, Mittelstadt [14] is performed on the model by our previous work which can be accessed in reference [20]. Our DiFACE-SCM framework is implemented for the first time on a real-life dataset of SENSE-EGRA dataset in the area of letter identification task for grade 2 students. This educational intervention program is an initiative of the American University of Nigeria, Yola under the sponsorship of the United States Agency for International Development (USAID). See Table 1 for the comparison analysis of our framework with that of Wachter, Mittelstadt [14] and Mothilal, Sharma [19].

Table 1. presents a comparison analysis of our framework and that of Wachter, Mittelstadt [14] and Mothilal, Sharma [19].

Differences Between Wachter, Mittelstadt [14], Mothilal, Sharma [19] and Our Study			
COMPARISON INDICES	**Wachter, Mittelstadt [14] study**	**Mothilal, Sharma [19] study**	**Our Study**
Explanation Framework employed	Local example-based post-hoc explanation	Local example-based post-hoc explanation	Local example-based post-hoc explanation
Type of explanation used	Counterfactual explanations	Counterfactual explanations	Counterfactual explanations
Framework Major Building blocks	counterfactual explanations, with proximity to original input features.	counterfactual explanations, with proximity to original input features, and the incorporation of diversity in CE outputs.	counterfactual explanations, with proximity to original input features, the incorporation of diversity in CE outputs, and the creation of a sparse ML model constrained by a causal model (SCM) for feasible and actionable CE.outputs.
Causal constraints used [Y:Yes/N: No]	N: No causal constraints were used, only suggested if it can be validated.	N: No causal constraints were used, only suggested in future work, rather a non-causal constraint approach using Python programming codes is employed.	Y: Yes, used SCM to provide causal constraints for the sparse ML model, which produces CEs which are feasible and actionable for all test dataset instances.
Causal Structure correctness Proven [Y:Yes/N: No]	N: No causal structure was used so no need to prove it.	N: No causal structure was used so no need to prove it.	Y: Yes, SCM was used and its correctness was proven using the conditional independent

			test (CIT) criteria. See our work in reference[20].
Evaluation method employed	Uses objective and subjective evaluation of the CE outputs. I.e., objective evaluation from the predictive model accuracies matrix and End-user interpretation of CE-generated	Uses objective evaluation from the predictive model and suggested objective evaluation in future work	Uses both objective evaluation, i.e., the accuracy/F1 matrix generated, and the CIT validation of the SCM[20]; and subjective evaluation, i.e. End-users' interpretation of the result, and the design of the SCM from the background knowledge.

1.2 Study Aims & Question

The goal of the study is to find diverse feasible and actionable counterfactual explanations for each student in the SENSE-EGRA intervention program dataset under the letter identification task that answers the following question: What are the likely perturbed key input features or predictors (counterfactual features) from a sparse black-box predictive ML model constrained by a causal model (SCM), that is required to obtain an opposite performance prediction of 1 (passed mark above 40%) on the stated SENSE-EGRA task, instead of an actual predicted 0 (failed mark below 40%)?

1.3 Study Objectives & Contributions

The following narrative explicates the main objectives and contributions of this study.

1.3.1 Study Objectives

The following objectives are elicited from this study:

1. To design an SCM framework that describes the data generation process for a real-life dataset (the SENSE-EGRA intervention dataset) and use the same to identify the necessary causal constraints that will make possible, feasible, and actionable diverse counterfactual explanations of a black-box ML prediction model.
2. To create a sparse explainable predictive model for a black-box ML model with causal constraints obtained from the created SCM and use the same to offer diverse feasible and actionable counterfactuals for a real-life intervention dataset (the SENSE-EGRA dataset).

1.3.2 Study Contributions

The following research contributions are evinced from this study.

i. ***Model Design.*** We designed and implemented for the first time a novel application-based SCM that describes the causal structure of the SENSE- EGRA dataset in the area of the letter

identification task, and used the same to identify causal constraints for the ML black-box predictive model.

ii. ***Feasible & Actionable Diverse Counterfactual Explanations Generation.*** Our DiFACE-SCM framework which incorporates causal constraints for a sparse ML black-box predictive model is used to empirically implement diverse counterfactual explanations which are feasible and actionable for the test dataset set (SENSE-EGRA dataset)

For the rest of the work, in section 2, we present the definitions and theoretical foundation of the methods and frameworks applied to this work, i.e., the SCM and the previous frameworks on counterfactual explanations from which our framework is developed. Section 3 introduces the SENSE-EGRA dataset experiment and explains how the methodology of an SCM is used to design the model. Further, the identification of the causal constraints and the feasible and actionable criteria in the dataset is obtained. In section 4, we present and interpret the results of the DiFACE-SCM framework experiment with some dataset instances. Section 5 presents some of the challenges of the framework and how they are addressed. In section 6 we conclude the study.

2 Definition and Theoretical Foundations to the Study

In this paper, just like is common with papers in the field, capital letters such as X represent a variable set. While their lower case counterpart x, would represent instances of the variable set X. Also, characters such as $T, Y, and\ X_i$would stand for single variables and their associates lower cases such as $t, y,$ and x_i would stand for their values respectively. Also, we use F_X or for a function on a variable set X and an instance of such a function would be represented by F_x or $f(x)$. The calligraphic upper characters such $\mathcal{G}, \mathcal{V},$ and $\mathcal{E}$ stand for graph, node set, and edges or vertices sets respectively. For graphs family relations, $Pa(V_i)$ stands for a set of parent nodes of a set of variables (V_i) found in the graph and $pa(V_i)$ is an instance of $Pa(V_i)$. Similarly, the character $Ch(V_i)$, would stand for children node set in the graph $\mathcal{G}$ and the $ch(V_i)$ is an instance of $Ch(V_i)$. The letter$T$ (its lowercase indicating its instance) is used as the treatment variable and we assume the treatment to be binary and univariate. Similarly, the variable$X$ is also used as a set of covariates in the graph. While the variable Y denotes the outcome variable with lower case, or lower case with subscript as an instance of it, or y with a bracketed binary digit such as $y_i(0), y_i(1)$ denotes instances of the treatment subscribed to them.

2.1 SCM Theoretical Background

SCM model enhances the articulation of causal theory in a given observational dataset [11]. SCM models are made up of two components. Viz. (i) DAGs and (ii) Non-Parametric structural equations (NPSEM). The DAGs are factorized based on the Bayesian network factorization with respect to the Markov condition (MC), with arrowheads showing the causal relations amongst variables. And no arrows showing the conditional independence among variables. The variables formation of a DAG may include, the treatment variable, the outcome variable, and sometimes observed and even unobserved variables. Thus, in this study, we will only consider the directed acyclic graph and not the directed cyclic graphs where the path returns to the same node.

Definition 1: Causal graphs. A graph $\mathcal{G}$ with a set of node $\mathcal{V}$ and a set of edges $\mathcal{E}$, written as $\mathcal{G} = (\mathcal{V}, \mathcal{E})$ is said to be a causal graph if the set of edges $\mathcal{E}$ linking the node set $V$is directed based on the MC. Hence, describing the causal effects between the variables set V. Thus an edge from the treatment variable t to an outcome variable y describes a causal effect of t on y.

Definition 2. The Markov Condition (MC). The MC is also called the truncated factorization (TF) [16, 17], and it states that a variable node is conditionally independent of its non-descendant, given its

parents in a joint probability distribution. This can be expressed mathematically as shown in equation 1.

$$P(X) = \prod_{x_i \in X} P(x_i | pa(x_i)) \quad (1)$$

Where $pa(x_i)$denotes the parent of the variable (x_i) and $i = 1 \ldots . n$
Based on the MC, the estimand for the SCM model in Fig. 1 (a) factorizes as in Equation 2, instead of as in Equation 3.

$$P(X, Y, Z) = P(x)P(z|x)P(y|z) \quad (2)$$
$$P(X, Y, Z) = P(x)P(z|x)P(y|z, y, x) \quad (3)$$

Since the MC is not a sufficient assumption to empirically determine conditional dependencies (or independencies) encoded in SCM, which are the basis for confounding biases, Pearl's [21, 22] popular adjustment criteria that is hinged on, d-separation (dependency) technique is imperative to de-confound the confounders in a dataset. However, the emphasis in this work is not on estimating treatment effects for the SENSE-EGRA dataset, which requires adjustment but rather on determining the causal structure from the SCM, we shall not discuss the adjustment criteria in this work. Readers who are interested in the adjustment criteria for estimating the causal effect of an SENSE-EGRA SCM can check up our other work on it in reference [20].

In an SCM, the chain, the fork, and the collider are identified as the three sources of confounding biases that can be found in an observational dataset, as shown in Fig. 1. Thus, to create or design an efficient SCM, one must consider these three building blocks carefully, and apply them appropriately based on the knowledge obtained from the data generation process. Otherwise, one is bound to create an SCM that may not reflect the correct causal relations amongst variables.

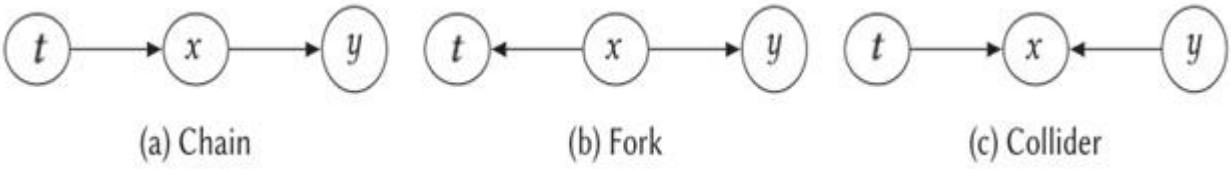


Fig. 1. The three basic sources of confounding structures in an observational dataset

Non-parametric structural equation (NPSEM). This is the second part of the SCM and it enables us to specify the causal effects depicted by the directed edges in the causal DAG. Equation 4 expresses the NPSEM of Fig. 2(a) as shown below.

$$x = \mathrm{F}_x(U_x), \; t = \mathrm{F}_t(x, U_t), \; y = \mathrm{f}_y(x, t, U_y) \quad (4)$$

In equation 4 the terms U_x, U_t, and $U_y$depict the noise terms from the variables observed and they are exogenous or mutually independent sources of variation that are not measured. Hence, it should be noted that the variables on the right-hand side (RHS) (usually called the endogenous variables) affect the variable on the left-hand side (LHS) and not a converse it since it is a matter of causation. Therefore, equation 4 provides a quantitative or parametric way of representing intervention for the corresponding causal DAG (Fig 2(a)). Intervention in SCM is defined by the use of the do-calculus, proposed by Pearl [21]. The do-calculus uses the do-operator which is expressed as $do(T = t)$, which shows the intervention of setting treatment T to some value t' as shown in Equations 5 and 6.

Definition 5. The Interventional distribution with the do-operator. The interventional distribution sometimes called post-intervention [17] is expressed mathematically as $P(y|do(t'))$ which is the

distribution of y when the data generation process is modified by setting the value of the variable t to t'. Therefore, the SCM of Fig. 2(a) under an intervention is shown in the SCM of Fig. 2(b), and the NPSEM for the intervention of Fig. 2(b) can be expressed as shown in Equations 4, 5, and 6.

$$x = \mathrm{F}_x(U_x),\ t = t',\ y = \mathrm{F}_y(x, t, U_y) \quad (5)$$

$$P(y|do(t') = \mathrm{F}_y(x, t, U_y) \quad (6),$$

It should be noted that with SCM the intervention distribution, written as $P(y|do(t))$ is different from the observed probability distribution, written as $P(y|t)$ and the difference is a result of the presence of confounding which is occasioned by the covariate set X. Thus, equation 6 is the basis for simulating an A/B in datasets that ensures confounding biases are removed to carry out causal impact analysis
.

(a) An SCM without intervention. (b) An SCM under the intervention $do(t)$.

Fig. 2. Showing Intervention (b) and non-intervention (a) SCM

2.2 Example-based Explanation with Counterfactual Approach

As discussed in related works and the comparison of our work with other approaches to explanation, example-based explanation frameworks of both Wachter, Mittelstadt [14] and Mothilal, Sharma [19] in Table 1, are building blocks for this work. Wachter, Mittelstadt [14], proposed counterfactual explanations as a way to advance an alternative perturbation strategy that could change the prediction of a model to a desired prediction class. In ML, most of the regular classifiers such as neural networks, random forest, SVM, etc., are trained by obtaining the optimal weight set w that minimizes an objective function over a training dataset set. Written in equation 7 as:

$$arg\min_{w} l(f(x), y + \rho(w) \quad (7)$$

Where $f(.)$ is the predictive model, y is the label or outcome for x_i set of input features or predictors, and ρ(·) is considered a regularizer over the weights w. Thus, for counterfactual, Watcher suggested the following formula, expressed in equation 8, such that a counterfactual explanation can be obtained by perturbing the input feature x to generate a set of counterfactual features x', that is closed to the original features x, and that would be used by the same model $f(.)$ to generate a different and opposite prediction class y' that is desirable. The following formulation of equation 8 by Wachter, Mittelstadt [14] is applicable.

$$l(x, x', y', \lambda) = \lambda.(f(x') - y')^2 + d(x, x') \quad (8)$$

Where $d(\cdot,\cdot)$ is a distance function that determines how far the synthetic or counterfactual generated features x' and the original features x are from each other. The parameter λ is used as a balancer or stabilizer in reducing the distance in prediction between the original input feature x and the counterfactual or synthetic feature set x' and the model $f(.)$. Thus, optimizing for a given λ loss and returning a counterfactual x', the λ whose value is higher infer a preference for counterfactuals that come close to the desired outcome y'. While a λ whose value is low entails a preference for a counterfactual x' that is similar to the original feature x. In the event where λ is large, the instance whose prediction is close to the desired prediction y' will be considered irrespective of whether it is significantly different from the original input feature x. Overall, the user must determine how to stabilize the prediction and determine how the synthetic feature x' matches the desired outcome y', and how close the synthetic feature x' is with the original input set x.

2.2.1 Diverse Counterfactual Generation Framework

As implemented in the work of Mothilal, Sharma [19], we consider a trained black-box ML model $f(.)$, and a dataset instance feature x_i. We desire to generate a counterfactual example set m, such that $m = \{x'_1, x'_2, \ldots, x'_m\}$, and all amounts to the desired output y' with different explanation decisions. Thus, the data instance feature x_i and all the concomitant counterfactual examples $\{x'_1, x'_2, \ldots, x'_m\}$ are considered d-dimensional, with a static and differentiable mode for ML models, and a binary output, assumed for the model. Thus, Mothilal, Sharma [19] employed equation 9 for the diversity generation and optimization process of the counterfactual explanation $C(x)$.

$$C(x) = \underset{x'_1,\ldots,x'_m}{arg\,min} \frac{1}{m}\sum_{i=1}^{m} \lambda.(f(x') - y')^2 + \frac{\lambda 1}{m}\sum_{i=1}^{m} d(x,x') - \lambda 2\, dpp_{diversity}(x'_1, \ldots, x'_m) \quad (9)$$

where $dpp\_diversity(.)$ is the diversity metric and $\lambda 1$ and $\lambda 2$ are hyper-parameters balancers that stabilizes the three parts of the loss function.
Also, $dpp\_diversity(.)$ Is further defined as:

$$dpp_{diversity(.)} = \det(M), \quad (10)$$

Where $\det(.)$, stands for determinantal point processes (DPP), and $M_{i,j} = \frac{1}{1+\mathrm{d}(x'_i,\ x'_j)}$ and $\mathrm{d}(x'_i,\ x'_j)$ stand for the distance metric between two different counterfactual examples.

2.2.2 Inculcating Model Sparsity via Causal Constraints (our Framework).

Proximity as explained and implemented by Wachter, Mittelstadt [14] and Mothilal, Sharma [19] is essential for generating the right set of counterfactual features and getting the desired opposite prediction. Albeit model sparsity is also sin-qua-non if one desires feasible and actionable counterfactual explanations, especially in datasets with many feature variables (e.g. 15 or more) and having multiple categories. Thus, we posit that the black-box predictive model $f(.)$ be made sparse, or be reduced, or kept fixed in the original input features. These features that are fixed or removed do not need to change or altered during counterfactual generation, to obtain the desired opposite prediction, y'. Thus, in the real sense of it, a counterfactual will be more feasible if it requires minimal perturbation on a few features in the predicted model $f(.)$. Therefore, for the dataset used (SENSE-EGRA), the causal knowledge is known and employed. We propose some causal constraints in the predicted model $f(.)$ to make it sparse as $f(.)_{scc}$ which will constrain the original feature set x and the concomitant counterfactual set x', where the non-feasible and actionable features will be kept constant (i.e., made to be statics in the model during prediction). We know that the feature manipulation will not have a significant impact on the prediction, but rather it will help in obtaining diverse counterfactual features x' that are feasible and actionable for the SENSE-EGRA intervention program. Thus, inculcating the constrained predicted model $f(.)_{scc}$ in the formula of equation 9, we can rewrite it as in equation 11 below.

$$C(x) = \underset{x'_1,\ldots,x'_m}{arg\,min} \frac{1}{m}\sum_{i=1}^{m} \lambda.(f_{scc}(x') - y')^2 + \frac{\lambda 1}{m}\sum_{i=1}^{m} d(x,x') - \lambda 2\ \det(M)\,(x'_1, \ldots, x'_m) \quad (11)$$

Where $f(.)_{scc}$ stands for the sparse causal constrained predictive model.
Equation 11 is our DiFACE-SCM framework for the production of diverse, feasible, and actionable counterfactual explanations that would be implemented on the SENSE-EGRA dataset task of letter identification. This framework can be applied in similar intervention datasets where the causal structure of the dataset is known.

3 Experiment Design

In this section of the experiment design, we shall discuss our SENSE-EGRA dataset background, initiate the CIT criteria for the design of the SCM, and point to our other works on how the CIT on the SENSE-EGRA SCM correctness is performed. Further, we will identify the required constraints to implement in our DiFACE-SCM framework and discuss the results.

3.1 Dataset Background

An early grade reading assessment (EGRA) educational intervention program tagged 'Strengthening Education in Northeast Nigeria' – (SENSE-EGRA), of the American University of Nigeria (AUN), Yola, Adamawa State sponsored by the USAID aimed at improving the literacy of over 200,000 primary school pupils targeting two northeastern states of Adamawa and Gombe in Nigeria, that were affected by terrorist conflicts that span a period of two decades[23]. The SENSE-EGRA intervention program's impact on the task of letter identification was evaluated using statistical methods[24], and the SCM framework [20], and it showed a positive effect in the subtask under study for both frameworks. Albeit using the dataset for ML prediction to determine the root causes of a student's performance and what features are important in accelerating a student's performance in the subtask for the next intervention is what is required to undertake a follow-up intervention program. Hence in this work, we desire to use the causal knowledge of SENSE-EGRA SCM to build our DiFACE-SCM framework of a sparse ML predictive model to obtain diverse feasible, and actionable CE for the students. The causal constraints from the SCM will help us identify the relevant features to focus on and the ones to jettison or focus less on, in the next intervention. The implementation of this framework (DiFACE-SCM) is novel as far as we can check.

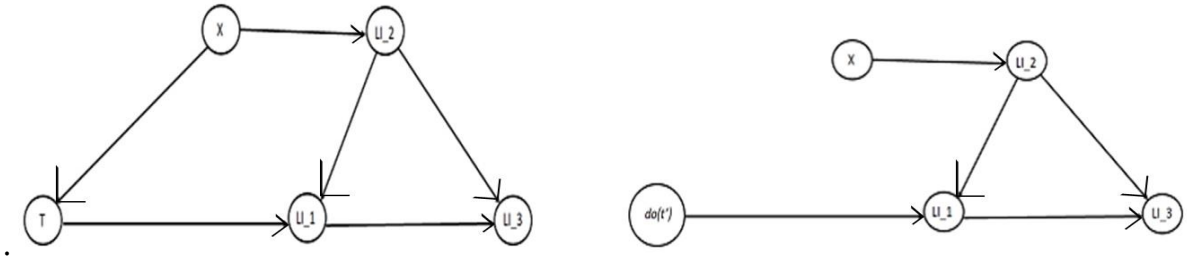
3.2 SENSE-EGRA SCM Design

The SENSE-EGRA dataset on the subtask of letter identification for grade 2 students of two northeast states of Nigeria under study is made of 1,114 records, collected from a population of over 200 primary schools in the said states. 19 columns are of interest for our design of the SCM and analysis. These columns are further grouped into 4 distinctive groups which are. A set of input features or covariates $(X)$where instances x stand for $State, LGA, Gender, Age,$ etc.; the output feature $LI\_3\,(Y)$, the treatment variable $T(Treament)$ and two other assessment or evaluation criteria features ($LI\_1,$ and LI_2) respectively.

Thus, based on the above-discussed methodology in section 2 we designed the SENSE-EGRA SCM of Fig. 3 using the dataset background knowledge. The following conditional independence criteria are observed and identified in the SENSE-EGRA SCM as shown in Equation 12. This SENSE-EGRA SCM correctness validation process and its results can be found in our work of reference [20].

$$\begin{aligned} P(&LI\_1 \perp X | LI\_2, T \\ &LI\_2 \perp T | X \\ &LI\_3(Y) \perp T | LI\_1, LI\_2, \\ &LI\_3(Y) \perp X | LI\_2, T, \\ &LI\_3(Y) \perp X | LI\_1, LI\_2) \end{aligned} \tag{12}$$

Further, for how the estimand for the adjustment of the set of covariates can be obtained, the corresponding NPSEM, and the causal estimation of the SENSE-EGRA SCM, also see reference [20].



(A) An EGRA SCM without intervention (b) An EGRA SCM with an intervention

Fig. 3. Showing our EGRA- SENSE- SCM with (b) and without (a) intervention

3.3 Identification of Constraints from SENSE-EGRA SCM for Implementation with Diface-SCM

The ML prediction model employed in this framework is a binary classification problem where the task is to classify whether or not students passed their reading task in letter identification (A classification of 1, shows a performance for the outcome (LI_3) $\geq$ 40 is a passed mark) and a classification of a 0, with an outcome performance (LI_3) $\leq$ 40 is a failed mark, according to the SENSE-EGRA dataset. We understand the structure of the dataset as shown in Figure 3, where the dataset is made up of 4 main sets of features, which are (i) the Treatment variable (T), (ii) the students attributes variable (X), i.e., State of origin, Gender, local government area (LGA), etc., (iii) the two assessment variables (LI_1, and LI_2), and the (iv) the outcome variable (LI_3). Thus, we can be able to identify the feature variables that cannot be changed or that are infeasible (e.g., a pupil's state, gender, age, etc. See Table 2 for the features that cannot be changed), and also features that have causal relations (e.g., assessment features such as LI_1, LI_2, etc., cannot precede pupil's attributes features such as Q4, Q5, etc., as causal arrows do not go back in time. See Figure 3. Hence, we remove them or make them statics during the counterfactual generation to ascertain the features that affect the pupils so that stakeholders can focus on the next follow-up intervention program. Table 2 summarizes the features and identifies the features that are feasible, actionable, and infeasible in the dataset in the 19 features of interest (note the feature containing the student's ID/name has been removed).

Table 2. Identification of the features that are feasible, actionable, and infeasible in the SENSE-EGRA dataset for the chosen task

Variable name	Variable meaning	Feasibility [Feasible A: Actionable, I: Infeasible]	Variable type in SCM model	Variable type in the dataset
$State$	Students state of origin/residence:	I – non-changing feature	Input feature (X)	Binary Nominal
LGA	Local Government Area of origin/residence	I –non-changing feature	Input feature (X)	Multiple Nominal
$School$	Name of primary school where pupils were selected from	I – non-changing feature	Input feature (X)	Multiple Nominal
$Treatment$	Whether or not a school received the SENSE-	F & A	Treatment variable (T)	Binary Nominal

	EGRA intervention			
$Gender$	Gender or sex of a student	I – non-changing feature	Input feature (X)	Binary Nominal
Age	Ages of students	I – non-changing feature	Input feature (X)	Scalar
$Q4$	Whether or not a student lives with his/her parents	F & A	Input feature (X)	Multiple Nominal
$Q5$	Language spoken at home by the pupil	F & A	Input feature (X)	Multiple Nominal
$Q6\_0$	For other languages spoken at home, option 1	F & A	Input feature (X)	Multiple Nominal
$Q6\_1$	For other languages spoken at home, option 2	F & A	Input feature (X)	Multiple Nominal
$Q6\_2$	Other languages spoken at home, option 3	F & A	Input feature (X)	Multiple Nominal
$Q6\_3$	Other languages spoken at home, option 4	F & A	Input feature (X)	Multiple Nominal
$Q7$	Number of people living with pupil (with pupil included)	F & A	Input feature (X)	Scalar
$Q8$	Parent reading and writing literacy level	F & A	Input feature (X)	Multiple Nominal
$Q9$	Number of books at parent house	F & A	Input feature (X)	Multiple Nominal
$Q10$	Whether a pupil has gone for a whole day in a week without eating	F & A	Input feature (X)	Multiple Nominal
LI_1	Number of letters identified correctly	I – due to causal relations	Assessment variable	Scalar
LI_2	Number of letter items attempted	I – due to causal relations	Assessment variable	Scalar
LI_3	Number of letters identified correctly per minute (outcome marks recorded)	Outcome variable	Outcome variable (Y)	Scalar

From Table 2, which is obtained from the SCM background knowledge, we have constrained all the infeasible features labeled [I] which are causally related and cannot be altered during the generation of counterfactual explanations. Thus, they shall not be passed into our constrained ML prediction model, since they cannot be changed as far as the next follow-up intervention is concerned. Only the feasible and actionable features labeled [F & A] in Table 2 would be passed as alterable features during the counterfactual generation process for our DiFACE-SCM framework. Thus a sparse ML predictive model containing 12 F & A features will be employed for the DiFACE-SCM framework instead of the initial 19 features of the dataset

4 Results Presentation and Interpretations for the DiFACE-SCM Framework

In this section, we present and interpret the results from our DiFACE-SCM framework.

4.1 Results Presentation

Implementing the constraints in Table 2 to get a sparse ML predict model $f(.)_{scc}$ which is infused into equation 12, we generate a maximum of 4 counterfactuals each for every test data instance. These 4 CEs generated is the most suited for the DiFACE-SCM framework. We focused on counterfactuals with the desired class of 1., i.e., the original outcomes classified as 0, which we seek a counterfactual generation of a 1 in their stead. We used a Gaussian Naïve Bayes (GNB) model as our black-box predictive model with a binary class. The task is to classify whether a student's performance in the task of letter identification assessment outcome labeled LI_3 in the dataset is a passed mark (i.e., 1 when LI_3 $\geq$40) or a failed mark (i.e., 0 when LI_3$\leq$40). The model recorded a prediction accuracy of 91% and an F1 accuracy score of 70% (which is one of the objective evaluation methods). The result is displayed in Table 3.

Table 3. The result of our DiFACE-SCM Framework for 5 data instances with failed outcome, with 1 prediction for the CEs.

S/No.		SENSE-EGRA Variables Treatment	Q4	Q5	Q6_0	Q6_1	Q6_2	Q6_3	Q7	Q8	Q9	Q10	LI3
1	Original input/output		1	0	3	0	0	1	1	7	0	1	0	0
	DiFACE – SCM input/output	1)	-	-	-	1	-	0	-	-	-	-	-	1
		2)	-	5	0	-	-	-	-	-	-	-	-	1
		3)	-	-	-	1	-	-	0	-	-	-	-	1
		4)	**-**	**-**	**-**	**1**	**-**	**-**	**-**	**-**	**-**	**-**	**1**	**1***
2	Original input/output		0	0	2	0	0	1	0	7	1	0	1	0
	DiFACE – SCM input/output	1)	1	-	-	1	-	-	-	-	-	1	-	1
		2)	1	5	1	-	-	-	-	-	-	-	-	1
		3)	1	5	-	-	-	-	-	-	-	-	-	1
		4)	**1**	**5**	**-**	**1**	**-**	**-**	**-**	**-**	**-**	**-**	**1**	**1***
3	Original input/output		0	0	2	0	0	1	1	5	0	1	1	0
	DiFACE – SCM input/output	1)	1	5	-	-	-	-	-	-	-	-	-	1
		2)	1	-	-	1	-	-	-	-	-	-	-	1
		3)	1	3	-	-	-	-	-	-	-	-	-	1
		4)	**1**	**-**	**-**	**-**	**1**	**-**	**-**	**-**	**-**	**-**	**-**	**1***
4	Original input/output		0	0	2	0	1	0	0	15	0	0	1	0
	DiFACE – SCM input/output	**1)**	**1**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**1***
		2)	1	1	-	-	-	-	-	-	-	-	-	1
		3)	1	3	-	-	-	-	-	-	-	-	-	1
		4)	1	5	-	-	-	-	-	-	-	-	-	1
5	Original input/output		1	0	2	0	0	1	1	5	0	1	0	0
	DiFACE – SCM input/output	**1)**	**-**	**3**	**0**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**1***
		2)	-	5	-	1	-	-	-	-	-	-	-	1
		3)	-	5	-	-	-	-	-	-	-	-	-	1
		4)	-	5	1	-	-	-	-	-	-	-	-	1

4.1 Result Interpretations - Understanding the Variable Features and their Options

In Table 3, the results of DiFACE-SCM are presented, where the sparse model contains 11 input features and 1 output feature is presented. The treatment variable is a categorical variable with two binary classes. A 1 means the student received the intervention (treated), while a 0 means the student didn't receive the intervention (untreated). The second variable labeled Q4 is also a categorical variable with 5 classes, and it seeks to know whether a student lives with their parents or not. Thus, a 0 class value means the student lives with both parents, a 1 class value means the student lives with his father, a 2 class value means the student lives with his/her mother, a 3 value means the student does not live with neither of his/her parents and a 4 means, the pupil doesn't know or not sure whether her/she lives with parents. Variable Q5 is also a categorical variable and it seeks to know which language a student speaks at home. A 0 means the student speaks the English language at home, a 1 means the student speaks the Fufulde language at home, a 2 means the student speaks the Hausa language at home a 3 means the student speaks other languages aside from the 3 other language options. Variables Q6_0, Q6_1, Q6_2, and Q6_3 are all an extension of Q5, and they seek to ascertain whether a pupil speaks more than one language at home. Thus, the same options for the variable Q5 still hold for these variables. Variable Q7 seeks to ascertain the total number of individuals (with pupil inclusive) living with pupils at home, and it is a scalar variable. Variable Q8 seeks to know whether a pupil's parents can read and write, and it is also a categorical variable with 3 classes. A 0 class value means parents can read and write, a 1 means they cannot read and write. A 2 means the student doesn't know or is not sure. Variable Q9 is a follow-up question for Q8, it seeks to know the number of books in the

parent's library at home. 0 means between 1-5 books are at the library of the parents, a 1 means between 6-10 books are present at the library of the parents, a 2 means between 11-20 books are present at the library of the parents, a 3 means between 21-50 books are available at the library of the parents, a 4 means more than 50 books are present at the parent's library. The last variable Q10 is also categorical and it seeks to ascertain whether the pupil went a whole day without eating a meal. A 0 means yes, the student went a whole day without eating a meal, a 1 means no, the student didn't go a whole day without eating a meal, and a 2 means he/she doesn't know or is not sure. The outcome variable is labeled LI_3, and it is the outcome for the assessment of each student on the letter identification task, it is a categorical variable with two classes. A 0 means the student failed the assessment with less than 40 points, while a 1 means a student passed the assessment with 40 points or above in the task under review.

4.2 Selecting Optimal Options for the Generated CE Features (An Objective Evaluation Approach)

Thus, the goal of this experiment is to ascertain through our DiFACE-SCM framework the student's feature variables that affects their performance in the task under review. Thus, to understand the result evinced in Table 3, only the cells where a value change is recommended by the counterfactual generator that we show in the counterfactual section of Table 3. The dash (-) in most of the cells showed that no change of value is affected by such a cell, so the original value for such a cell still stands and is assumed. Further, the most reliable and trusted counterfactuals would be the one(s) that recommend first and foremost that a student be treated, if the original data instance was not treated. Thus, option 1 for Treatment is the best counterfactual to expect in such an instance. In the case where the original outcome showed that the student received treatment, and yet failed the assessment test, then other variables counterfactuals would further be of interest. Thus the following counterfactual options for the other variables would be essential: (i) the student lives with both parents or either of them (options 0, 1, 2 for Q4 is acceptable), (ii) that a student speaks a maximum of three or less languages, with the English language being a must (options 0,1,2,3, with 0 dominating for variables Q5, Q6_0, Q6_1, Q6_2, and Q6_3 is good), (iii) the student should live with less number of people in his/her home (so a numeric quantity between 3-10 for Q7 is best for the student), (iv) The student parents should be able to read and write (option 1 for Q8 is the most appropriate, with any option for Q9 but better with increasing class values), and (v) the student should not go a whole day without missing a meal (option 1 for Q10 is the most appropriate).

4.3 Selecting the Best-generated CE Options for Each Data Instance

Furthermore, we affirm that diversity is an advantage, as it presents you with multiple options to choose the best, especially in education initiatives such as the SENSE-EGRA intervention program, which seeks the best counterfactual solution to determine why some students performed poorly in their assessment tasks. Thus, putting Table 3 result of our DiFCAE-SCM framework into perspective, we can select the best counterfactual for each of the failed students in Table 3 for the 5 data instances as follows: For S/No.1, the best counterfactual is no. 4. For S/No.2, the best counterfactual is also number 4. For S/No.3, the best counterfactual is also number 4. For S/No.4, the best counterfactual is number 1, and lastly, the best counterfactual for S/No.5 is number 1. These preferred counterfactuals are bolded and asterisked as shown in Table 3.

5 DiFACE-SCM Framework Challenges

Highly sparse predictive models can lead to a reduction in the model's accuracy and F1 score accuracy. Thus, our DiFACE-SCM framework prediction accuracy and F1 score accuracy are also affected. In the test dataset, the prediction accuracy is 91% and 70% for the F1 score, as against other similar frameworks such as Wachter, Mittelstadt [14] and Mothilal, Sharma [19], where the accuracy is between 99% and 98 respectively, and their concomitant F1 scores are also equivalent to the accuracy

score. However, we cannot trade off feasible and actionable counterfactuals for just a high prediction accuracy model. It is better to have low predictive accuracy but more feasible and actionable counterfactuals than very high predictive accuracy but many meaningless or infeasible counterfactuals and non-actionable counterfactuals. Finally, another challenge to our framework is how the counterfactual generator handles scalar quantities such as the Q7 variable in our test datasets. The counterfactual generator sometimes recommends that a student increase the number of people living in their home to 90 or more persons to improve their performance. This kind of counterfactual is absurd and opposite to reality (a small family leads to better performance for a student, and the converse is true for a student with a large family size). Thus, to overcome this challenge, further constraint to keep the number to an acceptable one (such as between 3 to 10) is required. Hence, we employed the non-causal constraints of the diverse counterfactual explanations (DiCE) framework proposed by Mothilal, Sharma [19] to overcome this challenge.

6 Conclusion and Future Work

This section concludes the study.

6.1 Conclusion

In this work, we presented a framework for diverse, feasible, and actionable counterfactual explanation generation called DiFACE-SCM. This framework employed the use of the background knowledge from the data generation process for the design of an SCM, which can help in the identification of the requisite causal relations in the dataset (we used the SENSE-EGRA dataset as our test dataset). Thus, using the SCM, we identified and created a sparse-constrained ML black-box prediction model, which we used for the generation of diverse, feasible, and actionable CEs for the desired dataset instances. The framework which is an extension of the counterfactual generation approach from Wachter, Mittelstadt [14] emphasized proximity in the generated counterfactuals to the original feature value. Also, the work of Mothilal, Sharma [19] (DiCE), aside from the proximity of the generated counterfactual introduced diversity alongside proximity. Our framework inculcates the sparsity of the ML model via causal constraints that are obtained from the causal knowledge of the SCM of the dataset. The results of our DiFACE-SCM framework which focuses on a classification task for student assessment under the letter identification task of the SENSE-EGRA dataset; where the focus is on determining the features that affect a student's failure (i.e., students with less than 40 points in the task), and how the counterfactual generator can recommend features that can be worked upon or improved to obtain a passed mark (40 points or more) in the next intervention. The framework which generates a maximum of 4 counterfactuals for each dataset instance evinced some feasible and actionable counterfactuals for almost all the allowable and 'perturbable' features in the constrained sparse model. A little deviation in feasible CE generated is with the scalar variable Q7 in the dataset (continuous numeric feature), which sometimes recommends infeasible counterfactuals explanation for a dataset instance. However, this issue was resolved by further enforcing non-causal constraints adopted from the DiCE framework. Also, the sparse ML model introduced led to a diminution in the prediction accuracy and F1 scores, as compared to Wachter, Mittelstadt [14] and DiCE frameworks. However, a tradeoff between having a low predictive accuracy with many feasible and meaningful counterfactual explanations is better than taking the path of having a very high predictive accuracy but many infeasible and meaningless counterfactual explanations.

Declarations

Ethical Approval

Not applicable

Competing interests

All authors have no financial or proprietary interests in any material discussed in this work

Authors' contributions

Author 1 initiated the study, designed, analyzed the results, and wrote the manuscript. Authors 2, 3 and 4 reviewed the study's design and analysis and edited the manuscript.

Funding
Not applicable.

Reference

[1] Doshi-Velez, F., & Kim, B. (2017). Towards a rigorous science of interpretable machine learning. arXiv preprint arXiv:1702.08608.
[2] Kusner, M. J., et al. (2017). Counterfactual fairness. Advances in neural information processing systems, 30.
[3] Lipton, Z. C. (2018). The mythos of model interpretability: In machine learning, the concept of interpretability is both important and slippery. Queue, 16(3), 31-57.
[4] Council, U.P.P. (2017). Statement on algorithmic transparency and accountability. Communications of the ACM.
[5] Gunning, D. (2017). Explainable artificial intelligence (XAI). Defense Advanced Research Projects Agency (DARPA), 2(2), 1.
[6] Prabhakar, A. (2017). Powerful but limited: A DARPA perspective on AI. In Proceedings of DARPA.
[7] Goodman, B., & Flaxman, S. (2017). European Union regulations on algorithmic decision-making and a "right to explanation". AI magazine, 38(3), 50-57.
[8] Ribeiro, M. T., Singh, S., & Guestrin, C. (2016). "Why should I trust you?" Explaining the predictions of any classifier. In Proceedings of the 22nd ACM SIGKDD international conference on knowledge discovery and data mining.
[9] Ribeiro, M. T., Singh, S., & Guestrin, C. (2018). Anchors: High-precision model-agnostic explanations. In Proceedings of the AAAI conference on artificial intelligence.
[10] Baehrens, D., et al. (2010). How to explain individual classification decisions. The Journal of Machine Learning Research, 11, 1803-1831.
[11] Simonyan, K., Vedaldi, A., & Zisserman, A. (2013). Deep inside convolutional networks: Visualizing image classification models and saliency maps. arXiv preprint arXiv:1312.6034.
[12] Zeiler, M. D., & Fergus, R. (2014). Visualizing and understanding convolutional networks. In Computer Vision–ECCV 2014: 13th European Conference, Zurich, Switzerland, September 6-12, 2014, Proceedings, Part I.
[13] Sundararajan, M., Taly, A., & Yan, Q. (2017). Axiomatic attribution for deep networks. In International conference on machine learning.
[14] Wachter, S., Mittelstadt, B., & Russell, C. (2017). Counterfactual explanations without opening the black box: Automated decisions and the GDPR. Harvard Journal of Law & Technology, 31, 841.
[15] Beck, S. R., Riggs, K. J., & Gorniak, S. L. (2009). Relating developments in children's counterfactual thinking and executive functions. Thinking & Reasoning, 15(4), 337-354.
[16] Buchsbaum, D., et al. (2012). The power of possibility: Causal learning, counterfactual reasoning, and pretend play. Philosophical Transactions of the Royal Society B: Biological Sciences, 367(1599), 2202-2212.
[17] Weisberg, D. S., & Gopnik, A. (2013). Pretense, counterfactuals, and Bayesian causal models: Why what is not real really matters. Cognitive Science, 37(7), 1368-1381.
[18] Molnar, C. (2018). Interpretable machine learning: A guide for making black box models explainable.
[19] Mothilal, R. K., Sharma, A., & Tan, C. (2020). Explaining machine learning classifiers through diverse counterfactual explanations. In Proceedings of the 2020 conference on fairness, accountability, and transparency.
[20] Ayem, G. T., et al. (2023). Structural Causal Model Design and Causal Impact Analysis: A Case of SENSE-EGRA Dataset. In International Conference on Communication and Computational Technologies.
[21] Tian, J., & Pearl, J. (2002). A general identification condition for causal effects. eScholarship, University of California.
[22] Pearl, J., & Verma, T. S. (1995). A theory of inferred causation. In Studies in Logic and the Foundations of Mathematics (pp. 789-811). Elsevier.
[23] (AUN), A.U.o.N. (2022). SENSE PROJECT EVALUATION: READING PROFICIENCY ASSESSMENT, RESULTS OF THE HAUSA EARLY GRADE READING ASSESSMENT (EGRA) IN ADAMAWA AND GOMBE.
[24] Bhaskaran, S., & Marappan, R. (2023). Enhanced personalized recommendation system for machine learning public datasets: generalized modeling, simulation, significant results and analysis. International Journal of Information Technology, 15(3), 1583-1595.

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp. 225-232, November 13-16,

Combatting Drug Menace in Northern Nigeria: Roles of Non-Governmental Organizations (NGOs)

BM Magaji
{bello.magaji@aun.edu.ng}

School of Law, American University of Nigeria, Yola Nigeria. +234(0) 8036011782

Abstract
The problem of drug abuse among young people in Northern Nigeria is a serious issue that requires a comprehensive approach. NGOs play an essential role in combating drug abuse by providing education and awareness campaigns, treatment and rehabilitation services, and advocacy. However, there is a need for more resources and support to enable NGOs to continue their important work and reach more young people affected by drug abuse. The government and other stakeholders must collaborate with NGOs to address the issue of drug abuse comprehensively.

1 Introduction

Drug abuse is a significant problem in Nigeria, with an estimated 14.3 million drug users in the country. The Northern region of Nigeria has been particularly affected by drug abuse, with a high prevalence of drug use among young people. The use of drugs such as marijuana, cocaine, and heroin is widespread, and the problem is compounded by the lack of basic social amenities, high unemployment rates, and poverty

1.1 What is Drug Abuse

Drug abuse refers to the excessive and persistent use of any substance, such as alcohol, opioids, cannabis, cocaine, stimulants, and other drugs, that leads to physical, psychological, and social harm to the user. It involves the continuous use of drugs even when the user is aware of its negative consequences. Drug abuse is a form of addiction that affects a person's health, relationships, and productivity. It can also lead to other severe consequences, such as substance dependency, mental illness, and physical harm, and can even result in death.

1.2 Drug Abuse Situation in Nigeria

i. The drug abuse situation in Ni,geria is a significant public health concern. According to the National Bureau of Statistics, nearly 15 million Nigerians abuse drugs such as cannabis, codeine, tramadol, and other opioids. The prevalence of drug abuse is highest among young people aged 15-39 years old.
ii. Drug abuse in Nigeria has led to numerous negative consequences such as mental illness, physical harm, and addiction. It also contributes to high rates of crime, violence, and insecurity. Additionally, drug trafficking and production are major issues in the country, affecting the national economy negatively, and fueling corruption.
iii. Efforts to address the drug abuse problem in Nigeria include the establishment of drug rehabilitation centers, awareness campaigns in schools and communities, and collaborations with international organizations to combat drug trafficking. However, more needs to be done to address the root causes of drug abuse and provide adequate support and resources to those affected by it.

2 Statistical Prevalence of Drug Abuse Amongst Youths in Northern Nigeria

According to a scoping review of drug abuse in Nigeria, a prevalence of 20-40% and 20.9% of drug abuse was reported among students and youths, respectively1. The UNODC World Drug Report 2021 also states that drug use prevalence in Nigeria is significantly higher than the global average at 14.4%2. 14.3 million Nigerians between 15 and 64 years engage in drug abuse Says one out of four drug users is a woman-NDLEA boss, Buba Marwa
Drug abuse is a serious problem among youths in northern Nigeria, and there are several statistics available that demonstrate the extent of the problem. Here are some statistics on drug abuse by youths in northern Nigeria:

i. According to a 2018 survey conducted by the United Nations Office on Drugs and Crime (UNODC), the prevalence of drug use among young people in northern Nigeria is higher than the national average. The survey found that 14.4% of young people in northern Nigeria had used drugs in the past year, compared to the national average of 10.6%.
ii. A 2019 report by the National Bureau of Statistics (NBS) found that Kano state, one of the northern states in Nigeria, had the highest prevalence of drug use among young people in the country. The report found that 9.5% of young people in Kano state had used drugs In the past year.
iii. The most commonly abused drugs among young people in northern Nigeria are cannabis, codeine-containing cough syrup, tramadol, and other opioids.
iv. According to a 2017 report by the Nigerian National Drug Law Enforcement Agency (NDLEA), the agency arrested 2,205 drug offenders in northern Nigeria, with 1,835 of them being youths aged between 18 and 35.
v. A 2018 report by the European Monitoring Centre for Drugs and Drug Addiction (EMCDDA) found that Nigeria is the largest producer of cannabis in West Africa, and that cannabis is often smuggled from Nigeria to other countries in the region.

These statistics highlight the need for more effective drug abuse prevention and treatment programs for young people in northern Nigeria.

2.1 Causes of Drug Abuse Amongst Northern Nigerian Youths

According to a scoping review of drug abuse in Nigeria, some of the reasons why Nigerian youths engage in drug misuse include peer pressure, curiosity, ignorance, frustration, and lack of parental care1. The abuse of drugs in Nigeria is also caused by many factors including love for money by peddlers, disobedience to the laws of the country, proliferation of the market with individuals who sell medicines, lack of control of prescription in the healthcare facilities and lack of control of dispensing among dispensers

2.2 Consequences of Drug Abuse Among the Youths in Northern Nigeria

i. Physical health problems: The use of illicit drugs can lead to various physical health problems, including respiratory problems, heart disease, liver damage, and brain damage. Some drugs, such as heroin, can also cause infections, abscesses, and other health problems associated with injecting drugs.
ii. Mental health problems: The use of drugs can lead to mental health problems such as depression, anxiety, and psychosis. Some drugs, such as methamphetamine and cocaine, can cause paranoia and hallucinations.

iii. Addiction: Drug abuse can lead to addiction, which is a chronic and relapsing disease characterized by compulsive drug seeking and use. Addiction can have a significant impact on a person's life, Including their relationships, education, and employment.
iv. Social and economic consequences: Drug abuse can have significant social and economic consequences, including increased crime rates, reduced productivity, and increased healthcare costs. Drug abuse can also lead to family breakdown and homelessness.
v. Legal implications: The use of illicit drugs is illegal in Nigeria, and drug-related offenses can lead to imprisonment and fines. Drug use can also limit a person's opportunities for education and employment.
vi. Infectious diseases: The use of drugs can increase the risk of contracting infectious diseases such as HIV/AIDS and hepatitis, particularly among those who inject drugs.
vii. Death: The use of drugs can lead to overdose and death, particularly when combined with other substances such as alcohol.

In conclusion, the harmful effects of drug abuse among youths in Northern Nigeria are numerous and can have long-lasting consequences. It is essential to raise awareness about the dangers of drug abuse and provide support and resources for those affected by drug addiction.

3 Drug Abuse and the Nigerian Law

In Nigeria, there are several laws that criminalize drug abuse and prescribe punishments for offenders. Some of these laws include:

i. The National Drug Law Enforcement Agency (NDLEA) Act: This is the primary law that regulates drug control in Nigeria. It criminalizes the possession, sale, and use of narcotic drugs and psychotropic substances. The punishment for drug possession ranges from a fine of not less than ₦50,000 to imprisonment for a term of not less than two years and not more than five years, depending on the quantity of the drug involved.
ii. The Criminal Code Act: This law criminalizes drug abuse and trafficking. Under this law, the punishment for drug possession is imprisonment for a term of not less than six months and not more than three years.
iii. The Indian Hemp Act: This law criminalizes the possession, sale, and use of Indian hemp, also known as marijuana or cannabis. The punishment for possession of Indian hemp is imprisonment for a term of not less than two years and not more than five years.
iv. The Psychotropic Substances Control Act: This law regulates the manufacture, distribution, and use of psychotropic substances in Nigeria. It criminalizes the possession, sale, and use of psychotropic substances without a valid prescription. The punishment for drug possession ranges from a fine of not less than ₦50,000 to imprisonment for a term of not less than two years and not more than five years.
v. The Counterfeit and Fake Drugs and Unwholesome Processed Foods (Miscellaneous Provisions) Act: This law criminalizes the production, sale, and distribution of counterfeit and fake drugs, as well as unwholesome processed foods. The punishment for drug-related offenses under this law ranges from fines to imprisonment for a term of not less than five years.

It Is important to note that the severity of punishment for drug offenses in Nigeria can vary depending on several factors, including the type and quantity of the drug involved, as well as the criminal history of the offender.

4 Leading Nigerian Cases on Drug Abuse and their Outcomes

Here are some leading Nigerian cases on drug abuse and their outcomes:

1. NDLEA v. Olatunde Abiodun Williams (2008): In this case, the accused was found guilty of trafficking 2.66 kg of cocaine. He was sentenced to life imprisonment.
2. NDLEA v. Okonkwo Chukwuka (2013): The accused was found guilty of trafficking 1.3 kg of cocaine and was sentenced to life imprisonment.
3. NDLEA v. Okechukwu Ogebe (2015): The accused was found guilty of possession of 1.1 kg of cannabis and was sentenced to five years in prison.
4. NDLEA v. Okonkwo Obiora Jude (2016): The accused was found guilty of trafficking 2.7 kg of cocaine and was sentenced to life imprisonment.
5. NDLEA v. Eze Stephen (2017): The accused was found guilty of trafficking 2.7 kg of cocaine and was sentenced to life imprisonment.

These cases demonstrate the severity of punishment for drug-related offenses in Nigeria, particularly for offenses involving trafficking in large quantities of drugs like cocaine. It is important to note that drug-related offenses carry serious penalties in Nigeria, and offenders can face long prison sentences and hefty fines.

4.1 Drug Fight: Governmental Intervention Efforts

The Nigerian government has taken several intervention actions to address drug abuse among youths in Northern Nigeria. These interventions include:

i. Drug Demand Reduction Program: The National Drug Law Enforcement Agency (NDLEA) has implemented a Drug Demand Reduction Program that focuses on prevention, treatment, and rehabilitation services. The program aims to reduce the demand for drugs by providing education and awareness campaigns, treatment and rehabilitation services, and support to families affected by drug abuse.
ii. Law Enforcement: The government has increased efforts to combat drug trafficking, including increasing the number of drug enforcement officers, improving border control, and implementing stricter penalties for drug-related offenses.
iii. Rehabilitation Centers: The government has established rehabilitation centers across the country to provide treatment and rehabilitation services to individuals struggling with drug addiction.
iv. Community Engagement: The government has engaged communities in the fight against drug abuse by providing education and awareness campaigns and encouraging community involvement in drug prevention and treatment efforts.
v. International Cooperation: The government has cooperated with international organizations such as the United Nations Office on Drugs and Crime (UNODC) to enhance drug control measures and improve drug enforcement efforts.
vi. Research and Monitoring: The government has conducted research and monitoring of drug abuse trends and patterns to inform drug prevention and treatment efforts.
vii. Interagency Collaboration: The government has encouraged interagency collaboration between agencies such as the NDLEA, the National Agency for Food and Drug Administration and Control (NAFDAC), and the Nigerian Customs Service to improve drug control measures and enhance law enforcement efforts.

4.2 Drug Fight: NGOs and Non State Actors

A NON-GOVERNMENTAL ORGANIZATION (NGO) is a type of organization that is independent of any government and operates primarily for the purpose of serving a social or political goal.

NGOs can be not-for-profit and may operate at the local, national, or international level. NGOs focus on a wide range of issues such as human rights, environmental conservation, health, education, and economic development, among others.
NON-STATE ACTORS, on the other hand, are a broader category that includes NGOs as well as other non-governmental entities such as multinational corporations, religious organizations, civil society groups, and even individuals who may wield significant influence in a particular context. Non-state actors are typically not directly accountable to any government, but they can have a significant impact on political, economic, and social outcomes.
Here are some examples of NGOs and non-state actors:
NGOs:

i. Amnesty International: A global human rights organization
ii. Greenpeace: An environmental organization focused on biodiversity conservation and climate change
iii. Doctors Without Borders: An international medical humanitarian organization
iv. Oxfam: A confederation of 20 NGOs working on issues related to poverty and social injustice
v. Human Rights Watch: A non-profit, non-governmental organization that conducts research and advocacy on human rights

Non-state actors:

i. Facebook: A multinational corporation that operates a social media platform used by billions of people worldwide
ii. The Catholic Church: A religious organization with a global presence and significant influence on social and political issues
iii. The International Olympic Committee: A non-governmental organization responsible for organizing the Olympic Games
iv. Al-Qaeda: A non-state actor known for its involvement in numerous terrorist attacks around the world
v. Anonymous: A loosely associated international network of activists and hacktivists

5 NGOs and the Fight Against Drug Abuse Amongst Youths in Northern Nigeria

NGOs play a significant role in the fight against drug abuse in Nigeria. They provide drug education and awareness programs, counseling services, and rehabilitation services for drug addicts1. NGOs also work with the government to develop policies and programs aimed at reducing drug abuse among youths. They also provide support for drug addicts and their families. Drug abuse has become a major social problem in Nigeria, particularly among young people. The situation is particularly acute in the Northern region of the country, where poverty, unemployment, and social inequality have contributed to the rise of drug use among young people. In response to this crisis, Non-Governmental Organizations (NGOs) have been at the forefront of efforts to combat drug abuse and raise awareness about its dangers. This paper examines the role of NGOs in combating drug abuse among the youths of Northern Nigeria.

Role of NGOs:
NGOs play a crucial role in combating drug abuse among young people in Northern Nigeria. They have taken on various roles, including providing education and awareness campaigns, treatment and rehabilitation services, and advocacy. NGOs work in collaboration with government agencies, communities, and other stakeholders to address the issue of drug abuse.

Education and Awareness Campaigns:
NGOs conduct education and awareness campaigns to inform young people about the dangers of drug abuse. These campaigns are aimed at raising awareness about the negative effects of drugs, including physical and mental health problems, social and economic consequences, and legal implications. The campaigns also provide information on how to prevent drug abuse and promote healthy lifestyles.

Treatment and Rehabilitation Services:
NGOs provide treatment and rehabilitation services for young people who are struggling with drug addiction. These services include counseling, detoxification, and medication-assisted treatment. The NGOs also provide support to families of those affected by drug abuse, including financial assistance, counseling, and social support.

Advocacy:
NGOs engage in advocacy efforts to influence policies and programs aimed at addressing drug abuse among young people. They work with government agencies and other stakeholders to develop policies and programs that promote drug prevention and treatment services.

5.1 Some NGOs and the Fight Against Drug Abuse in Northern Nigeria

i. Youth Empowerment and Development Initiative (YEDI): YEDI is an NGO that provides drug abuse prevention and rehabilitation programs for young people in northern Nigeria.
ii. Kano Youth Organization for Drug Abuse Prevention (KYODAP): KYODAP is an NGO that focuses on drug abuse prevention and education among youth in Kano state, northern Nigeria.
iii. Drug-Free Arewa Initiative (DFAI): DFAI is an NGO that provides drug abuse prevention and rehabilitation programs for individuals and communities in northern Nigeria.
iv. The International Society of Substance Use Prevention and Treatment Professionals (ISSUP Nigeria): ISSUP Nigeria is an NGO that provides training and capacity building for professionals involved in drug abuse prevention and treatment in northern Nigeria.
v. The Initiative for Substance Abuse and Addiction Awareness (ISAAC): ISAAC is an NGO that provides drug abuse prevention and education programs for young people and communities in northern Nigeria.
vi. The Centre for Research and Information on Substance Abuse (CRISA): CRISA is an NGO that conducts research on drug abuse and provides drug abuse prevention and education programs in northern Nigeria.

5.2 Impact of Some NGOs in the Fight Against Drugs Abuse in the Northern Nigeria

i. Youth Empowerment and Development Initiative (YEDI) – YEDI is an NGO that aims to educate, equip and empower youths through health education and life skills development. They have played a significant role in the fight against drug abuse amongst youths in northern Nigeria by providing education on the dangers of drug abuse, as well as counseling and support services for those affected.
ii. Neem Foundation – The Neem Foundation is a non-profit organization that focuses on empowering communities affected by conflicts and terrorism in Nigeria. They have been involved in the fight against drug abuse amongst youths in northern Nigeria through their rehabilitation and reintegration program for drug addicts.
iii. House of Refuge Foundation – HRF is an NGO that provides support and rehabilitation services for drug addicts and other disadvantaged groups in northern Nigeria. They have played a vital

role in the fight against drug abuse amongst youths by offering counseling and rehabilitation services, as well as educating communities on the dangers of drug abuse.

iv. Safe Space Foundation – The Safe Space Foundation is an NGO that works to provide safe spaces for youths to learn, grow, and develop life skills. They have been involved in the fight against drug abuse amongst youths in northern Nigeria by providing education on the dangers of drug abuse, as well as counseling and support services for those affected.

v. Partnership for Advocacy in Child and Family Health (PACFaH) – PACFaH is an NGO that advocates for policies and programs that promote child and family health in Nigeria. They have played a role in fighting drug abuse amongst youths in northern Nigeria by supporting advocacy efforts to address the root causes of drug abuse, as well as promoting policies that support prevention and treatment initiatives.

6 Concluding Remarks

In conclusion, the harmful effects of drug abuse among youths in Northern Nigeria are numerous and can have long-lasting consequences. It is essential to raise awareness about the dangers of drug abuse and provide support and resources for those affected by drug addiction.

In conclusion, the Nigerian government has implemented several intervention actions to combat drug abuse among youths in Northern Nigeria. These interventions focus on prevention, treatment, and rehabilitation services, law enforcement, community engagement, international cooperation, research and monitoring, and interagency collaboration. However, there is still a need for more resources and support to address the complex issue of drug abuse comprehensively.

References

[1] "Drug Abuse among Youths in Northern Nigeria: Addressing the Elephant in the Room." International Journal of Innovative Research and Advanced Studies, vol. 6, no. 5, 2019, pp. 10–17.

[2] "Prevalence and factors associated with drug abuse among youths in Northern Nigeria." Journal of Substance Use, vol. 20, no. 4, 2015, pp. 307–312.

[3] "A Study of the Causes and Effects of Drug Abuse among Youths in Northern Nigeria." Journal of African Studies and Development, vol. 11, no. 1, 2019, pp. 21–28.

[4] "Drug use among young people in northern Nigeria: a qualitative study." Harm Reduction Journal, vol. 16, no. 1, 2019, pp. 1–9.

[5] "Youth drug abuse and its impact on development in northern Nigeria." Journal of Public Health Research, vol. 7, no. 1, 2018, pp. 29–36.

[6] "The Role of Parental Monitoring in Preventing Drug Abuse among Youths in Northern Nigeria." Journal of Community Medicine and Primary Health Care, vol. 31, no. 1, 2019, pp. 27–32.

[7] "Drug Use and Risky Sexual Behaviors among In-School Youths in Northern Nigeria." African Journal of Reproductive Health, vol. 20, no. 1, 2016, pp. 139–147.

[8] "Correlates of drug use among male youths in northern Nigeria: implications for drug prevention programs." Journal of Health Education Research and Development, vol. 6, no. 2, 2018, pp. 1–8.

[9] "Knowledge, Attitude and Practice of Drug Abuse among Secondary School Students in Rural Areas of Northern Nigeria." International Journal of Public Health and Epidemiology, vol. 6, no. 4, 2017, pp. 49–55.

[10] "Barriers to treatment-seeking for drug abuse among youths in northern Nigeria." Journal of Substance Use, vol. 23, no. 4, 2018, pp. 391–397.

[11] "The Role of NGOs in Combating Drug Abuse among Youths in Northern Nigeria." Journal of Addiction Research and Therapy, vol. 8, no. 3, 2017, pp. 1-7.

[12] "NGOs' interventions towards youth drug abuse prevention and control in northern Nigeria." International Journal of Social Sciences and Humanities Research, vol. 5, no. 1, 2017, pp. 123-136.

[13] "The Contribution of NGOs in the Fight Against Drug Abuse Among Youths in Northern Nigeria." International Journal of Scientific Research and Development, vol. 4, no. 2, 2016, pp. 195-200.

[14] "The Role of NGOs in Combating Drug Abuse Among Adolescents in Rural Communities in Northern Nigeria." Journal of Social Science and Humanities Research, vol. 5, no. 2, 2017, pp. 101-112.

[15] "The Impact of NGOs in Response to Drug Abuse among Youths in Northern Nigeria." American Journal of Social Sciences and Humanities Research, vol. 2, no. 1, 2018, pp. 1-9.

[16] "The Effectiveness of NGOs' Interventions in Combating Drug Abuse among Youths in Northern Nigeria." European Journal of Social Sciences and Humanities Research, vol. 1, no. 1, 2017, pp. 12-19.
[17] "NGOs and the Fight Against Drug Abuse Among Youths: A Case Study of Northern Nigeria." African Journal of Criminology and Justice Studies, vol. 10, no. 1, 2017, pp. 1-13.
[18] "Combating Drug Abuse Among Youths in Northern Nigeria: The Role of NGOs." Journal of Social and Behavioral Sciences, vol. 4, no. 2, 2016, pp. 89-96.
[19] "Youth Drug Abuse Issues and the Role of NGOs in Northern Nigeria." International Journal of Psychology and Psychological Therapy, vol. 19, no. 1, 2019, pp. 1-15.
[20] "The Contribution of NGOs in Fighting Drug Abuse Among Youths in Northern Nigeria: A Systematic Review." International Journal of Mental Health and Addiction, vol. 16, no. 3, 2018, pp.720-736.

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp.233-236, November 13-16, 2023

Harnessing Legal Research for National Development and Innovation in 21st Century Nigeria: Opportunities and Challenges

BM Magaji
{bello.magaji@aun.edu.ng}

School of Law, American University of Nigeria, Yola Nigeria
+234(0) 8036011782

Abstract:
This paper aims to explore the pivotal role of legal research as a tool for national development and innovation in 21st century Nigeria. It delves into the significance of research in shaping the legal landscape, promoting socio-economic growth, and fostering innovation. The paper also discusses the challenges faced in conducting legal research and provides recommendations for maximizing its impact on national development in Nigeria.
The paper aims to explore the role and relevance of modern technology in legal education and training in Nigeria. It highlights the benefits and opportunities that technology brings to legal professionals, as well as the challenges and considerations that need to be addressed for its effective integration. The paper concludes with recommendations for leveraging technology in legal education and training to enhance the legal profession in Nigeria.

1 Introduction

The 21st century presents Nigeria with a range of complex legal issues and societal challenges. This paper highlights the importance of legal research as an invaluable tool for driving national development and fostering innovation. It also emphasizes the role of legal research in addressing contemporary legal and socio-economic issues.
The legal profession in Nigeria is witnessing significant advancements in technology, thereby transforming legal education and training. Modern technology plays a pivotal role in enhancing the quality, accessibility, and efficiency of legal education. This paper examines the role of technology in contemporary legal education and its relevance in the Nigerian context.

2 Significance of Legal Research for National Development

Policy Formulation: Legal research provides a solid foundation for evidence-based policy formulation, enabling policymakers to enact laws and regulations that meet the needs of a dynamic society. This ensures the establishment of a legal framework conducive to national development.
Access to Justice: Research helps identify gaps and inefficiencies within the legal system, leading to reforms and initiatives that improve access to justice for all Nigerians. Through empirical analysis, legal research can guide the development of efficient and inclusive legal procedures.

Economic Growth and Investment: Sound legal research informs the creation of policies that promote a favorable business environment, attracting both domestic and foreign investments. Efficient legal frameworks can protect business rights, foster economic growth, and enhance overall national development.

Constitutional Development: Legal research contributes to the evolution of Nigeria's constitutional framework by guiding the interpretation and application of the constitution in line with societal values, changing circumstances, and emerging legal trends.

3 Challenges in Conducting Legal Research

Funding and Resources: Inadequate financial support and limited resources pose challenges to conducting extensive and in-depth legal research. Addressing funding constraints and improving access to research facilities and databases is essential.

Availability of Data and Information: The availability and accessibility of legal data and information can be limited in Nigeria. Legal researchers face challenges in obtaining comprehensive and up-to-date data, necessitating improved data collection and management mechanisms.

Collaboration and Networking: Fragmentation in legal research efforts mandates the need for enhanced collaboration and networking among legal academics, researchers, and institutions. Building partnerships and sharing knowledge can drive collective research initiatives and produce impactful outcomes.

Infrastructure and Connectivity: Unequal access to stable internet connectivity and technology infrastructure across Nigeria poses challenges to the effective integration of technology in legal education and training. Addressing these disparities is crucial to ensure equitable access for all legal professionals.

Pedagogical Adaptation: The integration of technology requires pedagogical adaptations in legal curriculum design and teaching practices. Faculty members and legal trainers must receive appropriate training and support to effectively employ technology in their syllabi and training programs.

Cybersecurity and Data Privacy: The increasing reliance on technology necessitates robust cybersecurity measures to protect sensitive legal information and maintain client confidentiality. Policymakers and legal institutions must develop and enforce comprehensive data protection laws and protocols.

4 Opportunity and Benefits of Technology in Legal Research

Enhanced Access to Information: Modern technology provides legal professionals in Nigeria with unprecedented access to vast repositories of legal knowledge, legal databases, and online legal resources. This accessibility amplifies the speed and accuracy of legal research, facilitating efficient and evidence-based legal analysis.

Interactive Learning Platforms: Technology enables innovative and interactive learning experiences through online platforms, virtual classrooms, and simulations. Law students and practitioners can engage in virtual moot courts, online discussions, and collaborative problem-solving activities, thus enhancing their critical thinking, advocacy, and collaborative skills.

Remote Learning and Professional Development: Technology allows legal education and training to transcend geographical barriers. Remote learning initiatives, webinars, and online courses empower individuals in remote areas to gain legal education and remain updated on legal developments, ultimately promoting inclusivity and equal access to justice in Nigeria.

5 Recommendations

Increased Research Funding: The Nigerian government should allocate adequate financial resources to support legal research projects and establish grant programs aimed at fostering innovative research endeavors.

Enhancing Research Infrastructure: Building research centers and libraries, improving access to online legal databases, and establishing shared research facilities can foster a robust research ecosystem.
Encouraging Collaboration: Academic institutions, legal researchers, and policymakers should actively collaborate to share knowledge, resources, and expertise. Establishing research networks and organizing conferences or workshops can facilitate collaboration and further research outputs.

Promoting Dissemination of Research Findings: Initiatives should be undertaken to disseminate research findings through academic journals, policy briefs, and public presentations, ensuring that research reaches a wider audience and directly influences policy-making processes.

Investment in Infrastructure: The Nigerian government and legal institutions should invest in improving internet connectivity and technology infrastructure in both urban and rural areas to ensure widespread access to technology-enabled legal education and training.

Collaboration with Technology Industry: Partnerships between legal institutions and technology companies can foster the development of customized legal software and tools, thereby addressing the unique needs of the Nigerian legal system.

Continuous Training and Support: Regular training programs, workshops, and capacity-building initiatives should be organized for legal professionals to enhance their technological literacy and ensure their competence in utilizing technology effectively.

Legislative Framework: Nigerian authorities should formulate comprehensive cybersecurity and data protection laws to safeguard legal information, maintaining public trust in technology-driven legal education and training.

6 Conclusion

Legal research plays a pivotal role in achieving national development and fostering innovation in 21st century Nigeria. By addressing challenges related to research funding, data availability, and collaboration, Nigeria can fully leverage the power of legal research to shape its legal landscape, drive socio-economic growth, and navigate the complexities of the 21st century. Adopting the recommendations outlined above will enhance the impact of legal research, supporting Nigeria's journey towards national development and Title: Role and Relevance of Modern Technology in Legal Education and Training in Nigeria

Modern technology has a transformative role and immense relevance in legal education and training in Nigeria. It facilitates access to legal knowledge, interactive learning experiences, and remote education initiatives. However, challenges such as infrastructure disparities and cybersecurity concerns need to be addressed. By implementing the recommendations outlined above, Nigeria can harness the full potential of technology to enrich legal education and training, ultimately strengthening the legal profession and promoting access to justice for all Nigerians.

References

STATUTES:
Nigerian Constitution: 1999 (as amended)
Section 16: Economic objectives
Section 17: Social objectives
Companies and Allied Matters Act, 2020
Nigerian Communications Act, 2003
Patent and Design Act, 1970
CASES:
Supreme Court of Nigeria:
Nigerian Bottling Company Ltd v. NAFDAC (2007) 1 NWLR (Pt. 1025), 423.
Olumbe-Bashir v. Yussuf (2014) 14 NWLR (Pt. 1421), 500.
Metuh v. FRN (2017) 9 NWLR (Pt. 1571), 1.
Ifeanyi v. Law Union and Rock Insurance Plc (2018) 2 NWLR (Pt. 1609), 188.
POLICY DOCUMENTS
National Policy on Science, Technology, and Innovation (2012)
National Information Technology Development Agency Act, 2007
National Office for Technology Acquisition and Promotion Act, 1979
National Universities Commission Act, 2004
Federal Ministry of Science and Technology: Strategic Plan (2017-2020)
World Intellectual Property Organization: Innovation for Development Report (2010)

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp.237-247, November 13-16, 2023

Corruption and Governance: Examining the Historical Context of Corruption in Nigeria, It's Impact on Governance and Development and Effort toward Combating Corruption in Present Day

Joy O. Adeboye[1], Kitgak B. Simon[2]
{joyoluwatoyin5@gmail.com[1], kbsimon.ug@atbu.edu.ng[2]}

Adekunle Ajasin University, Akungba Akoko, Ondo State, Nigeria.

Research Aim:
The aim of this research work is to discuss the historical context of Corruption in Nigeria Governances and providing way forward to correcting the Social problem that has eaten deep into Nigeria system.

ABSTRACT
This research delves into the intricate relationship between corruption and governance in Nigeria, examining its historical context, its profound impact on the nation's development, and the ongoing efforts to combat this pervasive issue. Starting with a historical perspective, the research traces the origins of corruption in pre-colonial Nigeria, showcasing how colonial rule exacerbated the problem. It also highlights the key factors responsible for corruption in Nigeria, including greed, market monopolization, and political opacity.
The study emphasizes the multifaceted nature of corruption, categorizing it into administrative, religious, educational, and electoral malpractices, among others. It vividly demonstrates how corruption has hindered good governance and perpetuated inequality, leading to social unrest and even military coups.
To tackle corruption, Nigeria has established anti-corruption agencies like the Economic and Financial Crimes Commission (EFCC) and the Independent Corrupt Practices and Other Related Offences Commission (ICPC). Legislative reforms, international collaborations, and whistleblower protection laws have been implemented to enhance transparency. The research also highlights the importance of civil society organizations and media in raising awareness and advocating for stronger anti-corruption measures.
Nevertheless, the battle against corruption faces substantial challenges, including its institutionalization within the civil service and the divisive influence of tribalism. The research underscores the need for a systemic overhaul, the revitalization of institutions, and the enforcement of strict consequences for corrupt practices. The role of education, historical awareness, and public participation in the fight against corruption is also emphasized.
In summary, the research presents a hopeful outlook for Nigeria, envisioning a future where corruption becomes a relic of the past and the nation can thrive under the principles of transparency, accountability, and good governance.

1 Introduction

Who should be held responsible for the Corruption in Nigeria's governance? For your mind to be librated you must have access to information, information is power, the truth the way and the light. The truth lies in our history and cultural heritage. The deficit of the present day Nigeria can be traced back to our history for that is our identity, without knowing what has happened in the past we won't know where we are going. Today I am setting the tone for the conversation. A child as young as 5 years old knows that Nigeria is corrupt. But what happened? Now let's tell a story. CORRUPTION is not a geographical specific act, corruption is a world global issue, lets come down home as a way of domestication where did we start it all wrong? you would agree with me that corruption has being in existence in Nigeria setting From the pre colonial era, but the inversion of the British into her system make it worst. Corruption in Nigeria is therefore foundational.

When we look at our value system in the pre-colonial era it was founded on strong ethical system, self-dignity, sense of reasoning, hospitality, dignity of labor and money was the last on the list to define prosperity in life, but in the present-day Nigeria money defines prosperity and no longer integrity. Permit me to say a word in Yoruba, Yoruba will say isale oro olegbin, meaning the root of all wealth is questionable. By the time society became more sophisticated by the reason of olaju which is

civilization self-dignity, sense of reasoning, hospitality, dignity took the back stage, wealth became the first on the scale of determining the Social oder, isale oro olegbin the egbin in Yoruba is known as corruption. Corruption is therefore defined as the act of doing something right to be wrong. Anyone that does what is right to be wrong is a corrupt person. And I am sure that you would agree with me.

There is a saying that Those who cannot remember the past are condemn to repeat it by George Santayana. In light of that I shall be examining The historical roots of corruption in Nigeria, including colonial legacies (corrupt practices which were often employed by colonial administrators to exploit resources from Nigeria) and post-independence developments, An historical perspective on corruption in Nigeria, its impact on governance, and the ongoing efforts to combat corruption, How corruption has affected governance, economic development, and social well-being in the country. The evolution of anti-corruption efforts, including key initiatives, legislation, and institutions. (Creation of ICPC, EFCC,) and challenges and successes in the fight against corruption in Nigeria today.

From my topic we shall notice two key words. which are **CORRUPTION AND GOVERNANCE.**

2 Literature Review

Corruption, a persistent challenge that plagues many nations, has been a recurring issue in Nigeria's governance since its pre-colonial era. To comprehend the intricate dynamics of corruption in Nigeria and its impact on governance, it is crucial to examine existing literature spanning historical, political, and sociological perspectives.

2.1 Historical Context

Scholars such as Professor Abraham Sunday have extensively explored the historical roots of corruption in Nigeria. Their research indicates that corruption has deep-seated historical antecedents, dating back to the pre-colonial era. During this time, corruption manifested itself in various forms, including exploitation by traditional leaders, abuse of power by religious authorities, and disputes over land and resources. The British colonial rule further exacerbated corruption by introducing exploitative practices and siphoning off Nigeria's resources for the benefit of colonial powers.

2.2 Impact on Governance:

Corruption's detrimental effects on governance in Nigeria have been widely documented. It undermines accountability, transparency, and the rule of law. The mismanagement of Nigeria's oil revenues during the 1970s oil boom, often attributed to corrupt practices, stands as a striking example. It not only hindered economic development but also perpetuated inequality and social unrest. Moreover, corruption has led to inefficiency in public administration and weakened the enactment of anti-corruption laws.

2.3 Efforts to Combat Corruption:

The literature reveals that Nigeria has taken several measures to combat corruption. The establishment of anti-corruption agencies, such as the Economic and Financial Crimes Commission (EFCC) and the Independent Corrupt Practices and Other Related Offences Commission (ICPC), has been instrumental. These agencies investigate and prosecute corrupt practices, reflecting Nigeria's commitment to tackling corruption head-on.

Furthermore, legislative reforms, international collaborations, and whistleblower protection laws have been enacted to promote transparency and accountability. Civil society organizations and the media have played a vital role in raising awareness and advocating for stronger anti-corruption measures.

2.4 Challenges and Recommendations:

Challenges to combating corruption in Nigeria include its institutionalization within the civil service, tribalism, and the lack of consequences for corrupt practices. Scholars like Professor P.L.O Lumumber have recommended strengthening institutions, promoting good governance hygiene, and addressing privatization of public wealth. The importance of education, historical awareness, and public participation in the fight against corruption is underscored.

In conclusion, the literature review demonstrates the complexity of corruption in Nigeria's governance and its multifaceted impact. While efforts have been made to combat corruption, substantial challenges persist. However, the literature also provides hope, emphasizing the potential for systemic reforms and societal change to address this deeply rooted issue and pave the way for a more transparent and accountable governance system in Nigeria.

3 Research Methodology

In his research work to unravel corruption in governance, we adopted quantitative research methodology by interviewing Historians, philosophers and political analysts who are experts in the study of Nigeria and African history.
From the university at Adekunle Ajasin University Akungba and from CRIMMD Library museum Research and documentation centre of Nigeria History.

4 Definition

4.1 What is Corruption?

Corruption is a form of dishonest and criminal act which is undertaken by a person or an organization which is entrusted in a position in other to acquire illicit benefit on an abuse of power for once personal gain. world bank economist Daniel Kaufman extended the concept of corruption within the Confines of law, as the ability to make laws that favor you. corruption is a complex phenomenon and can occur on different scales from small favor to favor that affect the government on a large scale. corruption is a system of organized crime (systemic corruption), it is Cyclic in nature. It is therefore an anti-social attitude.My Discussion is centered on grand corruption that exist in Nigerian's Governance.

4.2 What Is Governance?

Governance has been defined to refer to structures and processes that are designed to ensure accountability, transparency, responsiveness, rule of law, stability, equity and inclusiveness, empowerment, and broad-based participation. but it quite unfortunate that what truly defines Governance is lacking in Nigeria Administration. An historian, Keith Schopper said bribery was only one of the tools of Top world Corrupt countries. Per R kiltgaard said Corruption will occur if Gain is greater than the penalty multiplied by the likely hood of not being caught or prosecuted. This is a question how many Nigerian public office holders has being prosecuted for a Corrupt act. as we Dive into the historical aspect of corruption In Nigeria you would agree with me that Corruption is foundational.

4.3 World Report on the Causes of Corruption

According to a 2017 survey by the United nation factors responsible Corruption are Greed of money desires, high level of market and political monopolization low level of Democracy, weak Civil participation, gender inequality and low political transparency. Resent Research by world bank suggest that those who make policy decisions, that is the elected officials can be critical in determining the levels of corruption.

4.4 Historical Context of Corruption In Pre-Colonial Nigeria

According to Professor A**braham Sunday from the department of History Adekunle Ajasin university**, Corruption in Nigeria dates back to the pre Colonial era, The Old Oyo Empire as my case study, During this period in the 15th century, slavery system is a prove to once wealth the more slaves you have determines the level of social respect that you will get, slaves are of two categories the Eru and Iwofa (Slaves and prawn), the greatest sin against humanity is failure to respect the dignity of human life.

There are many manifested instances of corruption during the pre-colonial era during, the Sokoto Jihad war by Uthman Danfodio, Borno was invaded out of Greediness of Uthman Dan Fodio. reference to Afonja rebellion against Alaafin Abiodun of oyo. Corruption exists in the precolonial era but the traditional system was highly incorruptible and the social system was communalized. The earth gods sever as fear in the mind of people. not to
do bad things.

On my research and documentation from Crimmd library and Museum Idimu Lagos, I obtained historical facts in picture and interview with DR Raphael James he explained *MEANS OF CORRUPTION IN THE PRE-COLONIAL ERA*. These are:

1. Traditional Leadership and Exploitation:
In many precolonial Nigeria societies, leadership positions were often hereditary or based on lineage. However, leaders sometimes abused their power by imposing heavy taxes or demanding tributes from their subjects under the pretext of providing protection or services. This could be seen as a form of exploitation and misuse of authority.

2. Trade Networks and Influence:
Trade routes crisscrossed Nigeria long before colonial powers arrived. Along these routes, middlemen and traders could engage in corrupt practices, manipulating prices or exploiting information asymmetry. Those in positions of influence within trade networks could gain unfair advantages.

3. Religious and Spiritual Authority:
Spiritual leaders and priests held significant influence in precolonial African societies. Some of these figures exploited their positions for personal gain, extracting offerings or contributions from their followers in exchange for
spiritual blessings or protection.

4. Land and Resource Control:
Land was often communally owned in many precolonial African societies. However, disputes over land ownership and resource allocation could arise. Leaders or elites could manipulate these disputes for their benefit, further deepening inequalities and benefiting themselves or their clans.

5. Tribute Systems and Feudalism:
In some societies, tribute systems were established where subordinate groups or regions were required to provide resources or goods to a central authority. While this could be a legitimate means of redistributing resources, it could also be manipulated by leaders to enrich themselves at the expense of others.

6. Slavery and Human Sacrifice

4.5 Colonial Rule

Corruption was prevalent in the pre colonial era but was kept at manageable level before the inversion of Nigeria by Portugal. Before 1800 Nigera economy system was based on trade by bater there was no use of money or adoption of private property Nigeria economy and social system was communalized and was properly regulated through a central authority apart from the Igbo that were decentralised. In my position the inversion of the Portugal and a Greek modernization is the root cause of corruption. Slave trade was abolish just for the practical need to establish colony.

1800 marked the beginning of colonial rule when Exploitative practices were established by foreign powers, These practices laid the groundwork for a culture of bribery, embezzlement, and nepotism.During the colonial period, many Nigerians were subjected to exploitative practices by European powers. Colonizers often established corrupt systems that siphoned off natural resources, labor, and wealth from Nigeria for the benefit of the colonial powers. This laid the foundation for corrupt practices by fostering a culture of impunity among both colonial administrators and local elites collaborating with them. The subject of corruption is ever green in Nigeria, because corruption has undermine the development of this country. Nigeria is poor because it was poorly governed **according to Prof. P. L. O Lumumber.**

During the trans-Atlantic Slave trade the success of slavery came through compromise with our traditional leader the priest and the debias who were trusted by the people to protect defend and ensure their security as soon as the European had contact with Nigeria our Traditional rulers revealed the strategic corners to the Europeans where the invading trade merchant will have access to Kidnap Nigerian, they exited through the back door and ship Nigeria able body men away .Our traditional leaders will claim that the gods needed the blood of virgins to be sacrificed at the shrines where as it was the blood of animal that was splinted at the shrine, the traditional system that we held uprightly, became a perverted means. Causing damages that scares the citizens Long time ago our traditional rulers had been collecting bribes it grew until we emerged as a country. If our traditional rulers outrightly rejected the trade our own traditional systemic believe won't be perverted this was the foundation of corruption but how would they when slavery system was a social order and a means of wealth before the Europeans came in.

After the Abolition of slave Trade in 1807 our Traditional rulers still involved themselves in selling Nigerias such Rulers such as:

- Kosoko of lagos
- Nana of Isekeri
- Oba of Benin
- Jaja of Opombo

But all of them were all sent to exile.

By History there were report during the colonial era, that the tax collected were not remitted, the native court Authority remit the right amount of money the so called colonial Officials will not remit the right amount of money to the final Authority in Lokoja, in Anger Traditional rulers were removed because they question their authority. The tax collected by the colonial masters were not used to develop Nigeria but to pay colonial officials, anybody that attempt to resist the colonial masters are Killed, in the system of Governace and administration Nigerians were not involved, all her Economic products and sculptures were looted away, there has being several efforts by the Traditional rulers to

recover all Nigeria Artefacts during the post independence. Corruption is not a Nigeria sickness but we have our own fair share and it is affecting deleverages as far as governance to the people is concern. But it is a monster that can be tamed and must be tamed but the corruption in Nigeria today can only be tamed through a deliberate action. The desire to end corruption in Nigeria must be a patriotic desire. The modernization brought by The European was clothed with evils. They trained Nigerians and Nigerians Turn to become a strong object to perpetrate corruption.
slave trade was no longer of interest to the British Colony but the palm oil and kernel of the Niger Delta, and cash Tuber Crops.

The abolition of the sea slave trades in 1807 did not mean an end to internal slavery, in fact the internal slavery increased in the 19th century.

The new situation of British take over into 20th century, firstly the British took over the sovereign power of the kings and reduced there worth to task collectors. they can not collect comey or trade duties rather they were paid subsidies in lieu.

European inversion in to Nigeria was to steal, they claimed to bring civilization and broaden Nigeria outlook, the education was a restricted form of Education. it was channelled to provides clerks to administer trading. the Education introduced in Nigeria was meant to perpetuate there economic ambitious and slow down Nigeria Development as it was done in India and far east.

European foreign Industries killed local industries. local industries cannot compete with fine imported products. Nigerian also lost her great deal of Cultural Heritage.

The Almagation of Nigeria in 1914 was for Economic purpose through the introduction of Indirect Rule System, Nigeria was forcefully merge together without Nigerians representation. This was solely done to establish corruption giving few or no opportunities to Nigeria. All this corrupt practices was established Just to have a totally subversion of Nigeria.

5 Categories of Corruption in the Present Day Time

1. Administrative corruption
2. Religious corruption
3. Educational corruption
4. Examination malpractices
5. Aiding and abetting
6. Electoral malpractices
7. Pen robbery and many more

6 Corruption in the Post Independence Nigeria

World war II gave rise for the agitation of self independence, with that nationalist movement began to come up in Nigeria led by Herbet Macaulay, Obafemi Awolowo, Nnamdi Azikiwe. After gaining independence in 1960, Nigeria experienced series of military coups and a subsequent cycle of civilian governments, often marked by corrupt practices and mismanagement of resources. During the oil boom of the 1970s, Nigeria's oil revenues became a major source of corruption as political elites and government officials siphoned off vast sums of money for personal gain.

But todays discuss is specific corruption and governance, corruption is liked to be a monster that if not tamed the dividence of governance cannot be deliver to people, the pleasure and enjoyment that the

citizens ought to be enjoying, they will never enjoy it or have access to it. corruption is likened to a high headed monster or an octopus that drip an object. Just imagine when a government is choked by corruption, only those who are in charge will enjoy, others are left to suffer. That is what we are facing in our country Nigeria. Let's take a look at the coup taking place in the anglophone and francophone countries it is a result of accumulated corruption, people who are corrupt are not unaware that corruption is evil but because they have deliberately chosen to lose their humanity. The harvest behind corruption is gravious. When Obafemi Awolowo university was built, the contractor monitors the workers with lantern just to ensure that the right work was done, the contractor in charge lost his child through the process but he ensures that the right work was delivered, yet he was focused this is why Obafemi Awolowo structures are still surviving till today. A corrupt system hates people saying the truth They believe that if you cannot beat them you must join them. Nigeria lost his grip by refusing to do the right thing under the civil service commission, there were many commissions in Nigeria to revitalize the civil service commission but all proved abortive (DR Olukayode Adesusyi, Department of Philosophy AAUA).

The causes of corruption in the post independence era as identified by Prof. P.L.O Lumumber:

- Rise of inefficiency in the public Administration.
- Discovery of oil and natural resources.
- Greed, Ostentenious life style customs and people's attitude
- Tribalism
- Weak enactment of laws.

If a university is to be destroyed three people are involved, the Bursar the vice chancellor and the council chairman when the University bursar is compromise the university is finished beyond electing an imam or pastor as a governor or president, if Corruption has been well institutionalized it becomes foundational upon which other houses are built. Corruption became well institutionalized under Babangida regime; other succeeding leadership built on this monstrous edifice and expanded it horizon and that is why we are here today, foundational corruption. (DR Abraham Sunday Dept of history AAUA)

At the Ajaokuta steel company money are being paid to those doing nothing, that is corruption, NNPC, instead of mandating and making our refinery to work they change the name, it was change to NNPCL You were alleged to have killed someone in Kano, you went to Lagos to change your name, but that does not cancel the history. In all our pollical history leadership and governance represent a dark chapter in our effort at building a better nation good for all. It is so difficult for Nigerians outside the country not to be identified with corruption they are not even proud to say I am a Nigerian. Like I have stated earlier corruption exist at every level and part of the world including China and America but they are not institutionalized, there are measure of societal sanity.

Corruption is not until you steal people's money, corruption is when you have a mandate but you fail to give people their mandate of Good governance you promised a good Governance but you failed, that is bad governance. Governors who have prevented their local government from functioning is corruption. Local government was established with the aim to bring government closer to the people but no, masses in Nigeria are suffering. We are suffering because of corruption and not because of poverty.

Corruption has been created as a ministry on itself, our problem is institutional and systematic corruption it has eaten deep in to our fabrics. Governance is everybody's business and not our elected leaders alone there are so many cases of examination malpractices in school, yet we blame our leader

Tinubu is not there, but what our leaders does has in sighted the mind of people to see corruption and all forms of illegal acts as a normal way of life.

Another way that corruption has being perpetuated is through the subversion of constitutional composition **(DR. ADETINJI OGUNYEMI DEPT OF HISTORY OAU),** Nigeria supreme court has become the potent instrument in the hands of political elites to subvert the mandate of the people, corruption is thriving in Nigeria because of Institutional failure, systemic failure. To combat corruption in Nigeria we must have a working system that can identify loopholes and punish anybody that is engaged in corruption. We ought not to be praying for basic amenities, as a philosopher I have found out prayer is not the solution to our problem but a working system. Our talks need to do the working and not just talking alone. The institution must function but a Crique to that is Nigeria is suffering from Tribalism and Division when you're in a position of governance the person in position would prefer to favor an incompetent person because they are from the same tribe, the system will not function well this way.

By history from Tracks of political history In Nigeria, Nigeria was not ready to be granted self-independence. It was corruption that makes the likes of Awolowo not to become the president, he created free education at the south western part of Nigeria which our present leaders enjoyed with. They enjoyed free education but the present government gave student loan to us.

Emefele is one of those that plundered the economy of this country, he his one of the greatest corrupt being in this country trading the economy
of this country with the capitalist inflicting hardship on us. With the report so far, the Nigeria government what to have a play bargain with him because they know that there are more superior and super powers that is above the president using him a tool to mismanage funds, land lords and patrons of corruption. Why settling for bargain why not call out those who he helped to launder Nigeria money and send them all to jail them inclusively. We want emefele to mention names so that the Integrity of our Governing structures can be brought back. Corruption can be fought. Donald Trump was charged it was possible because there are working institutions, if Buhari is charged today the North will say the south west and South east are persecuting their brothers, Nigeria does not come first in Governance Arithmetic.

Governance survival can only be achieved by sane and patriotic elements in power and those in position of Authority. Or Nationalist leaders in 1950s are not saints but they have reproduced themselves as a good example by serving the state.

In recent decades, civil society organizations, media outlets, and activists have played a critical role in raising awareness about corruption's detrimental effects. They have worked to hold governments accountable, push for transparency, and advocate for stronger anti-corruption measures.

7 Impacts of Corruption

1. Corruption denies the people access to social security
2. It takes governance away from the people
3. Corruption encourages restiveness and popular revolt
4. Corruption opens doors for the consideration of military coup. Corruption causes the accumulation of society deficit leading to agitation and worry. Because people are reducing to a state of perpetual poverty lack and inability to access what Citizens should naturally have access to.

5. Corruption will make an elected officer to feel as if they are doing a citizen favor. You are not doing us a favor but you are delivering your supposed mandate to us. We gave you our right in Trust and you must deliver.
6. Corruption has led to the overmonitiaztion of our electoral processes. Such that patriotic Nigerians who have serious and genuine interest in redeeming the country from the precipice, are denied the access because millions of Naira are involved, settlement, corner cutting are involved
7. Compromised judiciary, civil service are all refection of the manifest impact of corruption and so governance has always being on the edge seeking for a space to breath, when governance do not have the space to breath the effect is always on the citizen who will lick to there painful sour and link it for another four years when the cycle is completed they will come back to tell us another story. Corruption is not good for any system.
8. It increase inequalities

8 Efforts to Combat Corruption

African countries, regional organizations, and international partners have taken various steps to combat corruption:

1.Establishment of Anti-Corruption Agencies: The Economic and Financial Crimes Commission, EFCC, was established by an Act of the National Assembly on 12th December, 2002 by the administration of President Olusegun Obasanjo

2. Legislation and Reforms: Nigeria Government have implemented legal reforms to strengthen anti-corruption measures, improve transparency in public procurement, and enhance financial oversight.

3. International Collaborations: Nigeria Government have engaged with international organizations like the United Nations and the African Union to receive support, share best practices, and strengthen cooperation in combating corruption.

4.Whistleblower Protection: Nigeria Government have introduced whistleblower protection laws to encourage individuals to report corrupt practices without fear of retaliation.

5.Technology and Transparency: Digital technologies are being used to increase transparency in government operations, making it harder for corruption to go unnoticed.
6. Police Reformation: Establishment of WAR against in 1983 by Expresident Muhammad Buhari

9 Functions of EFCC as Enacted in 2002 by Ex-President Olusegun

The EFCC Establishment Act was first enacted in 2002 and amended in 2004.

The Act commissions the EFCC to combat economic and financial crimes, thereby enabling the Commission to prevent, investigate, prosecute and penalize economic and financial crimes.

In order to sanitize the system, the agency is also charged with the responsibility of executing the provisions of other laws and regulations that are related to economic and financial crimes. These laws as embedded in Section 7(2) of the Establishment Act 2004 are:

- The Money Laundering Act of 1995
- The Money Laundering (Prohibition) act 2004
- The Advance Fee Fraud and Other Fraud Related Offences Act 1995
- The Failed Banks (Recovery of Debts) and Financial Malpractices in Banks Act 1994
- The Banks and other Financial Institutions Act 1991

- Miscellaneous Offences Act, 1985
- The Criminal Code and the Penal Code
- Terrorism Act, 2011

10 Functions of ICPC as Enacted in 2002 By Ex President Olusegun

The Commission's mandate rests in the investigation, prosecution, and prevention of offences of corruption. It includes the following:

- Investigation
- Prosecution
- Prevention of corruption through the review of lax operational systems in Ministries, Agencies, and Parastatals.
- Education of the public against corruption.
- Enlisting public support for the fight against corruption.

11 Duties of the Commission

Section 6 (a-f) of the ICPC Act 2000 sets out the duties of the Commission as paraphrased in the following:

- To receive and investigate complaints from members of the public on allegations of corrupt practices and in appropriate cases, prosecute the offenders.
- To examine the practices, systems and procedures of public bodies and where such systems aid corruption, to direct and supervise their review.
- To instruct, advise and assist any officer, agency, or parastatal on ways by which fraud or corruption may be eliminated or minimized by such officer, agency or parastatal.
- To advise heads of public bodies of any changes in practice, systems or procedures compatible with the effective discharge of the duties of public bodies to reduce the likelihood or incidence of bribery, corruption and related offences.
- To educate the public on and against bribery, corruption and related offences.
- To enlist and foster public support in combating corruption.

With respect to the prosecution of cases, the Corrupt Practices and Other Related Offences Act 2000 provides that every prosecution for offences under it shall be deemed to be done with the consent of the Attorney-General. Furthermore, it is provided that the Chief Judge of a State or the Federal Capital Territory shall designate a court or judge to hear and determine all cases arising under the Act. Presently, there are two such designated Judges in each State of the Federation and the Federal Capital Territory.

12 Challenges to Combat Corruption in Nigeria

1. Institutionalization of corruption in Nigeria through the Nigeria civil service has make it so difficult for corruption to be combated. corruption has been created as a ministry on itself, our problem is institutional and systematic corruption it has eaten deep in to our fabrics.

Governance is everybody's business. according to D**r Sunday Abraham** from the department of History AAUA

2.Tribalisim.

- In 2016 professor P.L.O lumumber speaks at the Nigerian legislature meeting precribing key ways to Addressing Corruption in Governace.
- We must strengthen institutions
- Hygine must be introduced into out politics.

- Privitilation of public wealth must be frown at.
- Public awareness through behaviour change.
- leadership And self discipline education must be make compulsory in schools.
- Inclusion of History in Nigeria educational curriculum to foster Nationalism In the minds of Citizen
- The civil service must be Revitalized
- Any citizen or public office holder caught in a corruptiful act must be punished within the confined of law
- Our laws must be review for proper legislation.
- The government must create a working system that can empower the citizen an example of a good initiative create by the ex President Muhammad Buhari is the N -Power.
- Judiciary must be well paid to avoid collecting bribes
- The principle of democracy must be properly practiced
- Our local government must function so has to foster nationalism and participation in governance at the grass root.
- Privitilation of public wealth must be frown at
- Public awareness through behaviour change.

13 Conclusion

In conclusion, Nigeria's battle against corruption is far from over. It is a complex, deeply rooted issue that has permeated every facet of society. Yet, the literature review also reveals a profound resilience within Nigeria—a willingness to confront this monster head-on. With systemic reforms, collective societal change, and a steadfast commitment to transparency and accountability, Nigeria can begin to chart a new course towards a more just, equitable, and corruption-free future. It is a challenging journey, but one that holds the promise of a brighter tomorrow for Nigeria and its people.
I, Joy Adeboye, strongly believe that the success and ability of any government to deliver an electoral office is to desire and deliberately ensure administrative discipline, system overall and institutionalism that embraces conscious effort towards building an inclusive nation not for some but for all.

Because corruption has eaten deep into every part. I believe that there is a ray of Light in Nigeria, by killing the high headed monster called corruption which has continue to Diver from Achieving the needed glory that has once being taken from us by this very monster called corruption. I Hope and I believe that we shall experience a new Nigeria back in our time, corruption must be killed in Nigerian Governance. I look forward to a Country where corruption will become an History in Nigeria governance. Where the laws that we enact will be a law that will be observe.

References

[1] Interview session with Dr. Rapheal James at CRIMMID Library and Museum, Idimu, Lagos; Established in 2014.
[2] Lulumber, P. L. O. (2016). How to Address Corruption in West Africa: Speaking at the 2016 Legislative House Meeting.
[3] Groundwork to Nigeria History. (1980). Published by Nigeria Historical Society.
[4] Interview session on "How Corruption Became Institutionalized in Nigeria Governance" with Dr. Sunday Abraham, Department of History and International Studies, AAUA.
[5] Ogunyemi, A., & Adetinji, D. (2016). Historical Evidence of Corruption in Colonial Nigeria: An Analysis of Financial Records in the Decolonization Period, 1950–1960. Journal of Asian and African Studies, 51(1), 60-76.
[6] Interview session with Dr. Olukayode Adesusyi, Department of Philosophy, AAUA. September 5, 2023.

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp. 248-260, November 13-16, 2023

Indigenous Language Films and Promotion of Native Language amongst Children in Nigeria

Nyiyongu Charles Ngusha, Ph.D
{**charles.nyiyongu@aun.edu.ng**}

Department of Communication and Multimedia Design, American University of Nigeria, Yola-Adamawa state – Nigeria

Abstract
The study "Indigenous Language Films and Promotion of Native Language in Nigeria" was conducted to ascertain the aspects of Native Language films which promote local Languages in Nigeria. The study adopted Cultural Learning theory and employed Survey research method to guide the work. Findings from the study revealed that native language is the most aspect in indigenous Language Films that encouraged the children to speak their dialects. The study concludes that; Indigenous Language films are the most effective and efficient means to instill native language in children more than other media of communication. It thus recommends indigenous Language film producers to produce more local language films, but with subtitles in languages that could easily be understood by the children. That is to say; more native language films should be produced and distributed to promote native language amongst children.

Keywords: Indigenous Language film, Culture, Film, Language, Promotion, & Native Language

1 Introduction

The most important aspect of cultural heritage of any racial group is her Language. Indeed, nations preserve their culture through language promotion. In Nigeria, there are various ethnic groups, amongst which the major ones are (Hausa, Yoruba, Ibo and now the Tiv ethnic group) each having her own peculiar Language and dialects which are spoken in different communities (Anyaegbunam, 2019). Thus, the idea of a global village, the aspiration of man at this jet age, is aided by the media. Through the mass media, human can the new trend in language form, fashion, and music. By listening to the radio set or watching indigenous movies on the television set, we could get to do what others are doing or speak the way they do. Therefore, mass media (especially films) are becoming the fast means through which we could get our language promoted (Danbello and Dakogol, 2019).

In fact, the entire range of artifacts constituting traditional oral performances like corpus of songs, oral literature, festivals, rituals, the traditional religion, performing arts, music, and dance amongst others of Nigerian culture are represented in home made movies. And these movies have been used to spread and preserve cultural histories and activities that face the danger of extinction. That is to say, the film industry is undergoing a crucial transition (Sambe, 2005, p.51).

However, certain factors are altering the profile of what could be regarded as the country's culture. For instance, due to the requirements of urban life and many other factors, some Nigerian children tend today to be learning English before their native languages. The question is: Would that make English their mother tongue? The same goes to many children in many parts of North Central Nigeria who learn English language or French as the language of wider communication before their native languages and are indeed more proficient in these languages than their small group mother tongues (MT's). It is unlikely that such children would grow up to claim such languages as their mother tongue (Akpabio, 2013, p.129-143).

Ene (2007) submits that educating the children through the indigenous Language films in Nigeria will stimulate learners (children) for effective productivity more than the foreign languages, and will also make learning more functional (AlubaBari and Somieari, 2014, *p.123-138*). Olafia, observed that many societies are faced with the challenges of language loss, Language shift or even language death and

this to him, may be linked to the fact that a large percentage of the languages are still not properly documented (Opubor, Nwuneli and Oreh, 1979, p.10).
As parts of efforts to forestall the extinction and promotion of mother's languages, UNESCO (1999) launched the International Mother's Language Day, which is observed every February 21 the world over. The celebration is thus designed to promote linguistic diversity and multilingual education, while highlighting the importance of mother tongue education. According to Daura (2014), this is a good development hence Language is the basic and versatile medium of communication which strengthens the foundations of a community (P.4).

A similar process has been developed that requires the transition of oral and written arts to movie or the electronic medium. This is a gigantic multi-billion dollar industry that has generated a very keen competition among different groups and cultures the world over. We have the Hollywood that packages mainly the North American Conquest stories; the Bollywood or Indian movie industry has gone a long way to propagate the Indian culture and of course, the Nollywood industry which appears to promote Nigerian culture at large. Out of which comes the Kano movie industry (Kannywood) which has risen from the rich cultural heritage of the Hausa/Fulani as well as Islamic traditions and is making waves in the ancient city of Kano. Then the Tiv Language film industry tentatively known as "Bennywood films" which through its contents have been able to show case various Tiv cultural practices in material and ideological forms as well as various local languages round the clock (Asemah, 2009, p.97).

Language for instance, has socio-cultural impact in children; as children master language, it becomes a vehicle for building social relationships (Tanes and Cemalcilar 2010, p.84). A child begins to develop language skills even before he/she can use words (for instance, babies cried out to get their needs met). The examples also correspond with how children begin to learn Language by picking up labels and names of what they encounter. Food and body parts rank first on the list. This means that, a delay in language skills can cause frustration for a child as well as miscommunication about what he/she may be trying to convey. Language development is important to a child in order to adequately exchange information with others in a meaningful way (Nwosu& O. Onuzulike, 2017, p. 231 - 242).
It is in regards to this that the study agitates the need to promote Native Language in Nigeria, particularly amongst children through the use of Local Languages. This is so because Language does not only build relationships but also builds people, especially when it is their native Language.

1.1 Statement of Problem

One of the media of communication that attracts a lot of audience (particularly the school children) today is film. Aluba and Somieari (2014) affirm that "the film industry in Nigeria is receiving increasing public patronage, which has led to significant growth and expansion of the industry (p.12). (That is why we now have native Language films). This is largely due to the awareness of the important role films play in socializing our culture and promoting mother tongue in Nigeria. To emphasize on the role of home made movies and Language promotion, indigenous Language films plays a significant role (especially in the area of native language literacy) in the life of most Nigerian children through the documentation of its contents which are represented in audio-visuals form (Olaifa, 2020, p. 32).

Highlighting the importance of indigenous Language films to child education in Nigeria, Bari and Somieari (2014) attest that "indigenous film confers linguistic advantages on children" (p.105). Idegu (2014) attests to the influence of film as medium of communication when he said that "of all the forms of art that which is the longest lasting in the minds of consumers is the audio-visuals. When we read works of art, we can only visualize the characters in action; but when we are exposed to stage performances of the same literary texts because of the practical excitements that we do not just imagine but see, its effect on the viewing audience is by far deeper than the reading audience (p. 174). The

question to ask is: how do indigenous Language films actually promote native Languages amongst children in Nigeria? The broad objective of the study is to ascertain the extent to which home made films have encouraged the children to speak their dialects.

1.2 Objectives of the Study

Specifically, the objectives of this are to:
1. Determine the aspects of indigenous Language films which encouraged the children to speak their dialects.
2. Identify the effects of viewing Local Language films.
3. Investigate the extent to which these indigenous Language films contribute to the promotion of Native Language especially amongst children in Nigeria.
4. Examine the Language patterns contained in local films.
5. Ascertain the possible challenges the children encountered as they view national Language films.

1.3 Research Questions

From the objectives, the following research questions are generated to guide the conduct of this study:
1. What aspect of indigenous Language films encouraged the children to speak local Language?
2. What are the effects of viewing native Language films?
3. To what extent has indigenous Language films contribute to the promotion of local Language amongst Nigerian children?
4. What is the Language pattern contained in native films?
5. What challenge do the children encounter as they view dialects films?

1.4 Significance of the Study

This study is of great importance for a number of reasons. First, it will serve as an eye opener to the producers in the Nigeria film industry on the benefits of showcasing rich and positive indigenous culture while guiding against undue adoption of foreign plots, themes and story lines that may not necessarily project the nation in a good light. Secondly, policy makers will find this study helpful in formulating policies and programmes to promote proactive film production for nation image building and preservation of local cultural heritages. The study will also serve as a wakeup call to the film producers in the country to leave up to expectation in terms of quality local content production and projection of the nation's positive image. Above all, this study will add to the increasing body of knowledge and a veritable source of document from which future researcher could draw background information from.

2 Theoretical Frameworks

The study is anchored on Cultural Learning theory. Though, different scholars like Dennis, and Babatunde have postulated several theories on Home made movies and the promotion of indigenous languages. However the work; ***indigenous Language films and Promotion of native Language in Nigeria***; is fastened by the Cultural learning theory because of its suitability for the study.

3 Cultural Learning theory

Cultural learning which is often refers to "*culture learning theory*" did not emerge from the field of education. Rather it comes from psychology, specifically acculturation psychology, which looks at socio-cultural adaptation. Cultural learning is the way a group of people or animals within a society or culture tend to learn and pass on information (Baran, & Davies, 2006). How learning styles are greatly influenced by and how a culture socializes with its children and young people. Cultural learning

allows individuals to acquire skills that they would be unable to independently over the course of their life times (Strinati, 1995:Pp69-80).
Thus, a modern approach to cultural transmission would be that of the internet (. One example would be Millennia's, which "are both products of their culture as well as influencers." Oftentimes Millennia's are the ones teaching older generations how to navigate the web. The teacher has to accommodate to the learning process of the student, in this case an older generation student, in order to transmit the information fluently and in a manner that is easier to understand. This goes in hand with the Communication Accommodation (Yaroson, 2018).

3.1 Core assumptions

- Cultural novices (new sojourning ELTs) have difficulties managing everyday social encounters
- The culture-specific skills needed to (live and teach abroad) can be acquired through the learning process.

Marshall (1982:25) posited that "societies have always been shaped more by the nature of the media with which people communicate than by the content of the communication." In summary, Marshall was of the opinion that "the medium is the message." This statement could be used as a peg for the reasons indigenous language films has been selected as a medium of encouraging native language amongst Nigerian children.

Many children do not really have a clear cut objective of watching the indigenous Language films, but because he or she believes a friend has viewed local language film and is able to speak in his or her dialect and then maybe through cultural representation understand the culture of his people, it then becomes so interesting for him to view more of native language films so as to acquire the same kills. As the child begins to watch the native language films, he come across new words in his dialect and consequently speak the language more proficiently. This informs our reason for anchoring the study on the cultural learning theory.

3.2 Operational Definition of Significant Terms

3.2.1 Indigenous Language(s)

These are languages spoken by different ethnic groups of a particular nation. In the context of this work, indigenous language is seen as Language of communication in native films that is meant to introduce the children to local Language.

3.2.2 Film

Film is defined as series of motionless images projected into a screen so fast as to create in the mind of anyone watching the screen an impression of continuous motion (Aworo, 2005). In the context of this work, film is viewed as a medium of communication that is meant to educate the children on how to speak native Language

3.2.3 Culture

Culture is defined as the general way of life of a particular ethnic group. It cut across beliefs, norms as well as the tradition a certain group of people. Culture also influences individuals in a recognized society (Enahoro 2009, p. 19).In the context of this work, culture is seen as a method that is used to direct the pattern of thinking and behaviors of children so as to enable them speak native Language.

3.2.4 Language

Language is defined as a unique property of human beings and all the developments of man, be it intellectual, ethical, political, social or economic revolves entirely on the instrumentality of language. In this work therefore, Language is viewed as a communicative medium that introduced the children to local Language.

3.2.5 Promotion

In the context of this work, promotion refers to way of encouraging the children to speak national Language through the use of indigenous Language films. That is trying to retrieve the lost of native language amongst the children in Nigeria.

3.3 Indigenous Language films

In the context of this work, indigenous language films refer to movies that are locally produced within the country by Nollywood in local Language with the aim to encourage the children to speak native Language.

3.3.1 Review of Related Literature

Since the emergence of home made movies at the turn of the twenty-first century, it has had a profound influence on African culture. The Nigerian accents, style of dress, and behavioral idiosyncrasies, all of which are distinctly Nigeria, are now being transmitted as images around the globe. The medium of film has come to be directly associated with the culture industry. For instance, in Nigeria such a role for the film industry is still evolving to the level that it has touched the culture of other nations.

Already, film producers from Nollywood are exporting home made movies to the world with the motive to promoting the indigenous languages, but there is the need to tell more about Nigerian stories that are culturally focused on the diversity and history of the nation. A look at the foreign film industry like Hollywood will reveal a painstaking effort to constantly expose positive aspects of their culture, cities and ideologies through their storylines and imagery (Balabantaray, 2020; Enahora, 2019).

In the words of Mary (2015) there is a need for Africans to take speaking of their Languages seriously, including passing it on to their children, as it is a critical element of preserving their culture and identity as a people "Language gives us worth" (p.10). Accordingly "There is something spiritual about our mother tongue and what we need to do is actually to reinforce that in all of us. It is actually to retrieve our values, retrieve our culture. What stands you out is the language you have that no one else can interpret when you are in danger" (Mary, 2015, p.13).

Sharing related sentiments, Barclays (n.d) stressed that "language expresses the worth of a person and his or her psychological wellbeing.
Similarly, in the words of Akinwunmi (2011);
Language is important because it is the storehouse of culture and knowledge. "That is the centre of controlled culture; so, you can't know a culture without first knowing the language.
Ishola (2005) urges parents to always strive to converse with their children in their mother tongue, adding that mothers should also Endeavour to sing lullabies to their babies in their mother tongue. He says that such actions will enable the children to pick up the language in the home setting.
He added that:

Mother language is also an avenue to showcase the pride and potential of an ethnic group, community or nation. Therefore, we should not allow our local languages to die because if we do, it could lead to a loss of cultural, historical and ecological knowledge of the people (p.87).
Attributing more on the importance of Mother Tongue in Nigeria, Pattanayak (2003) avails that "Mother Language or first language contributes immensely in a child's personal, social, cultural, intellectual, educational and economic lives:

I. Personal, in the sense that a child's first (local) language is critical to his or her identity.
II. Social, in the sense that when the native language of a child is not maintained, important links to family and other community members may be lost.

III. Cultural; in the sense that sustaining a child's mother tongue would help the child to value his or her culture and heritage, which contributes to positive self-concept.

IV. Furthermore, the intellectual aspect of it is that, when students who are not yet fluent in their second/official language such as English or French, but have switched to using only the said official language, would have the tendency of functioning at an intellectual level below their age thereby resulting to academic failure. Educational-wise, students who learn second language and continue to develop their native language would have chances of higher academic achievement in later years than those who learn their second language at the expense of their first language.

V. More so, economically, there are available better employment or job opportunities in Nigeria and in the Diaspora for individuals who are conversant with their official language as well as another language – probably a native language (p.15).

Thus, because of the importance attached to Mother Tongue in Nigeria; every February 21, is set aside to commemorate the world International Mother Language Day as earlier mentioned in the previous chapter (Nwaozor, 2015). The Day was proclaimed by the General Conference of the United Nations Educational, Scientific and Cultural Organization (UNESCO) in November 1999. The date – February 21, represents the day in 1952 when the Pakistani students who demonstrated for recognition of their native language, Bangla, as one of the two national languages of the then Pakistan, were shot and killed by the police in Dhaka – the capital of what is now Bangladesh.

Accordingly, On May 16, 2007, the United Nations General Assembly in its resolution called upon member states to promote the preservation and protection of all languages used by peoples of the world. By the same resolution, 2008 was proclaimed as the 'International Year of Languages', to promote unity in diversity and international understanding through multilingualism and multiculturalism (UNESCO institute for statistics, 2010).
Zhimiko, (n.d), stresses that:

Leaders should encourage the younger generation to take pride in speaking indigenous languages and view them as part of their cultural identity (as cited in the Ward Head of Galadimawa Abuja)
Whatever reasons adduced for or against the use of mother tongue, linguists believe that since culture is strongly connected with language, the mother tongue should be a veritable means of promoting Nigeria's diverse cultures.
Ajala (2017) notes:

The mass media encourage and ginger people to achieve the aims or goals of the society. These goals are promoted by the media, which then stimulate and foster the aspirations and activities of individuals and communities to achieve such goals (p.75).
Nigeria movies are very popular among adolescents and youths, and are gradually gaining wide acceptance among blacks across the world because of their socio-cultural and educational values. From available anthropological and ethnological data the African traditional worldview is characterized by dynamic vitalism, relationality, communion, solidarity, and harmony with nature (Onwubiko, 1991, p. 3-5).

Fayomi (2015) noted that "Nollywood films have been upholding African cultural practices and promoting such among Diasporas living in the various countries in sub-region and in addition re-infusing the African practices and cultures into the original inhabitants of the various countries within the West Africa. To him, this is in line with the ECOWAS cultural integration agenda (p. 35).
What makes film the major cultural force is a combination of different factors which includes the uniqueness of film as an art which is characterized by modern technologies. As such, the principal use

of film as a communication medium is to entertain, instruct, subjugate, persuade and propagate and of course to meet the overall social, political, economic and educational needs of the contemporary word that are deeply dependent on communication in its various forms (Akpabio, 2007).

As noted by Adeiza (1995), most film makers turned to video as a survival option. She added that; Film can contribute immensely to the challenges of our rich cultural heritage and concludes that:
While it may be safe to classify video films produced by private producers for the mass market as commerce driven, the levels of experimentation with popular themes also vary (p.6).
There are some which also try to promote values of a better society and responsible citizenship. Films by Mount Zion Faith Ministries led by Mike Bamiloye are, for instance, devoted to promoting the Gospel using common themes like the eternal battle between the forces of good and evil. In these films, evil is consistently portrayed as unprofitable and dangerous. Such films apart from promoting our cultural heritage have also imparted positively on the lives of viewers especially deviating their minds from evil to doing good.

Enahoro (2009) avers that; Nigeria possesses a culture which reflects the people's way of life just as any other culture. This includes the process of birth, of growing up, of carving riches for oneself, of passing through and fulfilling obligations in the different phases of existence and of pursuing attitudes and attributes that will make one an acceptable member of the society or put one at war with his neighbors depending on the interaction factors. Culture of an individual is dependent on the culture of the society, and or the society to which that individual belongs (p. 4).
What this assertion means according to Elliot (2009) is that:

The cultural ethics theory is based in society and the culture of a nation as opposed to nature...an individual is shaped by his or her culture…and finds that being parts of the culture club provides an ethical security (as cited in Enahoro, 2008, p.19).
Culture influences individuals in the society, it directs their pattern of thinking and behaviors to what it wants them to do. Culture is not limited to music, dance, the law and the morals expectations of the community, the wisdom of their past and the education of the present and the future. Therein the unity or disunity of a people is easily dictated especially through their rituals (Uwah, 2005, p.83).
Comparatively, in an article titled "Promoting Indigenous Language in Nigeria: Issues and Challenges" Ani (2015) noted that:

The appeal of language resides precisely in its capacity to meet the needs of man for self-expression and for communication of experience in his day-to-day engagements with the world around him. Man needs language for the dissection and analysis of material reality and spiritual experience as well as for formulation of hypothetical statements, theories and belief as well as value systems.
In other words, beyond facilitating communication of experience, a language must enhance man's cognitive abilities and functioning, if it is to be of permanent relevance or survive through the ages.
The functional characteristics of language according to Emeka, (2015) are not just restricted to communication or transfer of information. He further posits that language provides means of concealing information as well as unveiling hidden agendas and codes.
The significance of Language in National Development was aptly underscored by Ayodele (2013) when he asserted that:

Language is an important instrument for the development of human beings, as political animals. No meaningful development can take place in a human community without language (p.2).
As an instrument of communication, language makes it possible for the people in any environment to interact and co-exist, thus paving way for the continuity of the society. Human beings get equipped for their maximum self-realization and self-development through the use of language.

Recognizing the place of language in development Olaifa (2014) submits that
Language in any human society is expected to be preserved and rated with the highest priority and attention from both the government and individuals.
Uzochukwu (2017) submits that, *we cannot achieve economic prosperity and technological breakthrough in foreign language*.

Language serves as a vehicle in national development. It holds the power to maintain national and cultural identity (Nwobia, 2015). Language is needed for interaction in the society and to share ideas and experiences with others (Ayeomoni, 2019). Without language, there is bound to be predicament in the society for thoughts, ideas, information, and the society would become incommunicado (Daura, 2014). Language therefore, provides means of accessing our thoughts. It provides a means of showing social relations, coding and decoding, recoding and recording information (Nwobia, 2015).

Thus, it is through the instrumentality of indigenous films that a language of a particular ethnic group or society is promoted and integrated. Hence one of the key functions of home made movies is cultural transmission and integration (Onuzulike, 2017, p. 231 -242). Thus films have the ability to communicate norms, rules and values of any giving society. This function is also regarded as a teaching function of mass media (Essien, 2003).

Notably however, all these reviews do not correspond with the study; *indigenous Language films and Promotion of native Language in Nigeria* which alone necessitated the research work of this nature which is deemed towards the use of local Language films to promote native Language in Nigeria.

3.3.2 Indigenous films and Native Language Promotion

The functional role performed by films affects mans emotion. For instance, Film as an art form or an instrument for persuasion instruction and entertainment is like a bullet, with force to conquer or at least live a mark for the record. That is to say film is a documentary of the consciousness of culture. Galvanizing or fusing all forces into a concrete charger that reconstruct the mind of the people. Film is a custodian of the people's primordial consciousness. Therefore film exposes, liberates, unites, reproaches, reprimands, scorns and can applaud and attract attention, either for positive or for negative reaction (Danbello&Dakogol, 2015).

This makes it stand out as unique from other form of mass media. Our culture is fast eroding into forgetfulness. There is an urgent need to uphold these cultures visually through films to avoid extinction by civilization. Though radio and television may be used for the same purpose, film has an edge over the rest because it has the ability to enter into direct communication with the people and reach the nook and cranny of the country, particularly the children.

Film has an inexplicable bond between itself and the audience as the audience willingly suspends disbelief when viewing a film. It employ's the concepts of ''verisimilitude' or realism in the narratives. This captures the audience mind and value in totality.
A Nigerian in Diaspora, Dzurgba (2018) avers that; indigenous language films have helped so many Nigerians who had left the country for years. That to say, home made films do remind them of how they use to live in Nigeria as well as their cultural heritage (i.e. they serve as reminder tools). To him, home made films reconnect the Nigerians in Diaspora with their reach cultural endowment, thereby making the people to interact fluently in their mother tongue. For example, a Tiv man who was born in London and has no connection with his village people or tribal people will find it difficult to speak his first language (mother tongue) especially when the parents are not communicating to him in the local language (Dzurgba, Akpenpuun, 2003,p.87).

To explain further, indigenous language films plays a significant role in promoting local language in Nigeria, in-that, through viewing of native language films especially when subtitled, most children are able to speak some words in their dialect. They can as well enjoy the local languages songs at their leisure. However, it has been argued that Nigerian films are primarily meant for a Nigerian market, an opinion corroborated by responses indicating that Nigerians usually watch these films at home with family (67.4%) and other compatriots (37.2%) who do not need any explanation to enjoy the viewing. Gathering with Nigerians of other ethnic cultures is then facilitated by the use of Nigerian English, seen as "a unifying force in multicultural Nigeria" (Adegbija 2004, p.126).

Indigenous films also act as conveyors of history; they allow the children to experience past events and most of these movies are produced in local languages. For example, a Nigerian-produced movie directed by Izu Ojukwu is a historical fiction that dramatizes the assassination of General Murtala Mohammed and a coup that happened in 1976.

In addition to history books, such films give the viewer a visual perspective of the political and social history of Nigeria in the 1970s and can help in the appreciation of Nigeria's political history. Indigenous language films also play a descriptive role in the exploration of global societies and culture and have been used to educate youths about the Nigerian culture while dispelling cultural misconceptions (Teutsch, 1995; Oza, 2021).

A very good example of one of the indigenous movies is, *Oleku*, a Nigerian movie produced in 1997 by Tunde Kelani that sparked a fashion revolution home and abroad with the prominent use of the female Yoruba traditional wear, and *Buba,* a wrapper and blouse ensemble (Adbulkareen, 2014, p.44).

Thus, in the era of globalization, films have become a tool of cultural transmission. Supported by online streaming platforms such as Youtube, audio-visual content is becoming readily available to individuals across the world. There is a need to constantly tell the African story and preserve these histories and culture, African characters such as Sango, Oya, MamiWata, Oduduwa and Anubis seem to be downplayed and less celebrated. There is an opportunity for filmmakers to promote such African stories locally and internationally, as films are powerful tools that can promote various ideologies within selected communities. As vehicles of communication films, transport stories and ideas to the audience and can shape global perception on cultural elements such as dressing and language (Sherak, 2011).

4 Findings

In the course of this study**,** the researcher set out the broad objective to examine the extent to which indigenous Language films contribute to the promotion of Native Language in children. Therefore, findings here are discussed in line with the research objectives. Findings from the study revealed that local dialects are the major aspects in indigenous Language films that encouraged the children to speak national Languages. Hence most of these films are produced in local Language with the aim to promote national Languages. This is in consonant with what has been reviewed in the previous literature regarding the use of indigenous films to promote native language where a Nigerian in Diaspora, Terwase (2019) avers that; indigenous language films has helped so many children who had left the country (Nigeria) for years. To him, indigenous language films reconnect the Nigerians in Diaspora with their reach cultural endowment, thereby making the people to interact fluently in their mother tongue. For example, a Hausa man who was born in London and has no connection with his village people or tribal people will find it difficult to speak his first language (mother tongue) especially when

the parents are not communicating to him in Hausa language. This means that native Language as an aspect in indigenous language films promotes national Language in Nigeria.

Findings from the study has also revealed that by watching indigenous Language films children are able to learn new words and greetings in local Language such as; "U ndervee" meaning good morning and "Vayakwagh" which means come and eat in Tiv language . This means that the functional role performed by films affects children's emotion. For instance, Film as an art form or an instrument for persuading instruction, and entertainment is like a bullet, with force to conquer or at least live a mark for the record. That is to say film is a documentary of the consciousness of culture. Galvanizing or fusing all forces into a concrete charger that reconstruct the mind of the children. Film is a custodian of the children's primordial consciousness. Therefore film exposes, liberates, unites, reproaches, reprimands, scorns and can applaud and attract attention, either for positive or for negative reaction. This clearly shows that indigenous Language films are the most viable tools that instill native Language skills in children.

To explain further, indigenous Language films plays a significant role in promoting national languages, in-that, through viewing of local films, most children are able to speak some words in their dialect and can as well enjoy the local languages songs at their leisure. A few years ago, a certain Youngman Mike developed a unique Tiv pop musical genre called (zuulezu/kerewa) in which Tiv children's play songs and lullabies were adapted and recreated into the hip-hop tradition. That became a unique Tiv musical contribution to the promotion of Tiv language in Nigeria.

Agreeing with the research findings on culture and the exposure of children to local Languages, a study was conducted by Femi (1997) who in order to promote Yoruba Language introduced film Sango which particularly dramatizes Yoruba cosmology in its representations of communalistic communications. In this film, the story is told of Sango, the traditional king of the old Oyo kingdom with spiritual powers that helped him win battles. Being an epic film equipped with cultural costumes, deep mystical powers of the gods and evocative sound tracks, this film reveals in great depths the idea of African ontology in its richness in terms of communication between the human and spirit worlds. This is an indication that indigenous Language films contributes to the promotion of native languages and culture especially when projected in artistry way.

To support Femi's statement in above, a study was conducted by Alawode (2007) entitled: "***Home video as ICT-tool for cultural re-alignment*"** regarding the influence of home movies and the culture of people, as reflected in the literature review. The study was a content analysis of eight home movies produced by Tunde to determine whether the values in Yoruba culture are adequately and appropriately portrayed.
The units of analysis in the films were language, costuming, music, song and dance, themes and lessons, relics, folklore and tales, hairdo, fashion, styles, and traditional and religious activities. The findings show that the films studied tremendously portray Yoruba culture or are steeped in Yoruba culture. Although a limitation with the study is that it did not show whether the Yoruba culture is portrayed in a negative or in a positive way by the films (Alawode, 2007, p.12).

The study has also discovered the "Nature of stories" in indigenous Language films as another factor which drew the children's attention like the comedy aspect of indigenous films which is represented by their actors and actresses. A good example of such films is on a movie titled "***Botwev***" a story of a man who was born foolishly with humorous character and Ortoho nyor geri (A.K.A Igboji man Sule) the two comic boys, produced in (2000) and Adam wade koholga which was produced in (2002) Such stories amused the children; thereby draw their minds to indigenous Language films. Hence most

stories in indigenous Language films are told in a humorous manner which in turn draws the minds of Nigerian children.

Findings from the study revealed that native language is the Language of communication in indigenous Language films. This is supported by a statement by Essien (2003) that "it is through the instrumentality of indigenous films that a language of a particular ethnic group or society is promoted and integrated. Hence one of the key functions of home made movies is language promotion. Thus films have the ability to communicate norms, rules and values of any giving society. This function is also regarded as a teaching function of mass media.

In an attempt to support the language of production in home made movies, a similar survey research was carried out by Oyero (2007) in Alimosho Local Government Area of Lagos State to ascertain the degree to which Radio Lagos 107.5FM helped in the promotion of Yoruba Language revealed that the station gives the lion share of the radio airtime to Yoruba programmes. Seventy two percent (72%) of the respondents of the 200 sampled prefer 107.5 FM to other stations due to its presentation of programmes in their Yoruba language, as opposed to 28% of the respondents who do not.

The Radio station is fondly called 'Tiwantiwa', literally meaning, it is ours, because it broadcasts only in two indigenous languages, Ogu and Yoruba, spoken in Lagos State. Similar findings were made by Harrison and Raphael (2006) in their study of the media and the promotion of Yoruba language and culture in African Independent Television (AIT) and Lagos Television (LTV) using questionnaire and direct observation. The result showed that 80% of the 120 respondents watch or listen to Yoruba programmes on AIT and LTV.

They noted that almost all the informants watch Yoruba programmes like, Nnkann'be' (a documentary programme that recounts mysterious happenings around), Sokoyokoto (a life programme that educates viewers on how to prepare different recipes for cooking), Iroyin Agbaye (world news) and Ogaju (it is superfluous) on both stations. While 92% of the respondents see the value of these programmes in the preservation of Yoruba language, 8% of them do not seem to care so long as there are alternatives found in English. This example shows that the language pattern contained in indigenous language films which is "native language" is of great significant to the promotion of native languages in Nigerian children.

Despite the gains, findings from the study has revealed the challenges children encountered in the course of viewing indigenous Language films to include the challenge of uninteresting stories and that of inability to understand the Language of communication as contained in most indigenous Language films that are not subtitled. However, indigenous Language films still remains the major medium of communication amongst other media Nigerians can rely on to promote their Language as well as culture.

5 Conclusion & Recommendations

Based on the findings of this work, the following conclusions are drawn; that indigenous language films are the most effective and efficient means used to instill native language in children more than any other media of communication. And that; Children are meant to learn and understand new words in their dialects as a result of viewing home made movies, most especially when these films are subtitled in English Language.

It is in recognition of the conclusions, the study recommends:

1. The use of indigenous Language films should be adopted in Nigeria along side with other traditional media of communication. This will provide more learning room for the children. Even though each one of these medium have their limitations and strength, they can be harnessed for the promotion of native language in Nigeria.
2. Nollywood film industry should assist the Local language film producers in the production and promotion of more native Language films, but with subtitles in national languages that could be understood by the children. That is to say; more indigenous language films should be produced and distributed in other to promote native language amongst children living in Nigeria.
3. The National Broadcasting Commission (**NBC**) should stand up to her role of directing the media stations to promote the indigenous languages, which should include that of native language.
4. Nigerian parents should also help to promote and sustain native language before it goes into extinction, by speaking the language to their children at home and also, instill to the children national cultural pride of dressing them in native attire, serving them with local dishes, buying for them books written in their language to be studied at home.
5. Government, Corporate organizations, traditional rulers across ethnic groups should on the other hand assist in sponsoring local language programmes via different media so as to enable the children to be more proficient.

References

[1] Anyaegbunam, N. the Media and Cultural Orientation. In J. B. Yusuff (Ed.), Culture and the Media in Nigeria, National Institute for Cultural Orientation, Abuja. Phalanxs Books publishers, 2019, pp. 17 - 21.

[2] Aluba Bari D. N. and Somieari, I. *Film and Cultural Imperialism in Nigeria*: A Critical Developmental Perspective. (JOTMA) Journal of Theatre and Media Arts, Number 9. 2014, *p.123-138.*.

[3] Asemah, E. Principles and practice of mass communication: Great Future Printing and Business Cente Jos; 2009, p.19

[4] Akpabio, E. (2013). Themes and Content of Nigerian Home Video Movies. Unilag Sociological Review, volume 2, N0.129-143.

[5] Akpabio, E. Attitude of Audience Members to Nollywood Films. (JOAS) Journal of African Studies, 2007. volume 1. N0.7, P. 90-100.

[6] Adbulkareen, Y. M. Role of public libraries electronic information media in the promotion of indigenous languages: Kwara state, Nigeria; 2014, p.76..

[7] Baran, S. J., & Davies, D. K. Mass Communication theory: Foundations, ferment and future, 4th edition. Belmont, C.A.: Wadsworth Thomson Learning. 2006, p.76.

[8] : Danbello, I. A., &Dakogol, B. J.. The Role of Indigenous Films in Preserving Culture in Nigeria: An Appraisal of Nollywood Home Videos. International Conference on Communication, Media, Technology, and Design, 16-18 May, Dubai – United Arab Emirates. 2015, p.37.

[9] Dzurgba, Akpenpuun) Elements of Tiv Culture: Material and Ideological Studies, Ibadan, John Archers publishers; 2003, p.67

[10] J.A Sambe, (2005, p.59). Introduction to mass communication practice in Nigeria. Spectrum books limited. Ibadan Nigeria,

[11] Nwosu & O. Onuzulike, U. 'Nollywood: The Influence of the Nigerian Industry on African Culture, (JPACA) Journal of the Pacific and Asian Communication Association. 2007, p. 231 - 242. Vol. 10. No. 3.

[12] Nwodu, C (2006, p.65).Research in communication and other Behavioural sciences: Principles, Methods and issues. Rhyce Kerex publishers, Enugu,

[13] Nwaozor, O. The importance of mother tongues**: A** speech in commemoration of The International Mother Language Day 2015.

[14] Onuzulike, U. The Influence of the Nigerian Industry on African Culture. (JHC) Journal of Human Communications: 2017. Vol. 10 N0 3, 231-242.

[15] Ozele, M. A. (n.d). Representations of Cultural Resilience and Perceptions of Religiosity in Nigerian Movies and the Crisis of Personal Identity among Nigerian Adolescents.

[16] Opubor A., O. E. Nwuneli and. Oreh O. 'The Status, Role and Future of the Film Industry in Nigeria. Lagos: National Council for Arts and Culture. 1979.

[17] Oyowole, A. A, Youths and Conflict: The Role of the Media. In S. K. O. Idebi& W. M. Madaki (Eds.), An Integrated Approach to Communication Principles and Practice, 2013. pp. 65-71. Abuja: Cobweb Book Publishers.

[18] Waldron, C., & Okoye, I. Video in the Lives of Nigerian Children: Some Socio-Cultural Implications. Africa Media Review, 1993. 7(3), 134. Retrieved from [URL].
[19] Shija T, "Tiv Cultural Heritage and the Idea of Development in Contemporary Nigerian Society. JHSS. 2018, p. 1-8, vol. 23 N0. 0071.
[20] Yaroson, E. (2018). Theories and Models of Mass Communication: Great Feature Printing Jos.
[21] Pattanayak, D.P. (2003). Mother tongues: The problem of definition and the educational challenge. In Ouane, A. (ed.). Towards a multilingual culture of education. Paris: UNESCO Institute for Education, 39
[22] Turner & Terence "Representation, Collaboration and Mediation in Contemporary Ethnographic and Indigenous Media." Visual Anthropology Review 11(2):1, 2005.P. 2-106.
[23] Tanes, Z., & Cemalcilar, Z. *Learning from SimCity:* An empirical study of Turkish adolescents. 33(5), 731-739 2010, P.45.

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp.261-269, November 13-16, 2023

The Imperatives to Absolute Primogeniture Rules under the Bini Customary Law of Succession

Lugard A. Emokpae
{lugardemokpae@yahoo.com}

College of Law, Igbinedion University Okada, 08056184400, 08038554075

Abstract

Under the Bini Customary Law of succession, a female child is not entitle to the right to inherit the 'Igiogbe' of her father, which is the principal house where the deceased lived and died.The 'Igiogbe' is the exclusive right of the deceased eldest survival son. In respective of his age, he must inherit the principal house of his deceased father, provided he has performed the first and second burial ceremony of his late father. The daughters of the deceased are only entitled to reminants. This rule, though has survived for centuries, it is an affront to the rights of the female daughters who through section 42(1) of the 1999 constitution (as amended) has the right to the same position of the male surviving son of the deceased. The discriminatory primogeniture of the Bini Law of succession is a violation of human rights of several international covenants which Nigeria has ratified and domesticated, among which are Convention on the Elimination of all forms of Discrimination Against Women (CEDAW) European charter for equality of women and men in local life, Convention on the political rights of women, African protocol on women's rights etc. Discrimination of female child in her father 'Igiogbe' for the simple reason of being born a female instead of a male is repugnant on social justice and equity. Being born in either gender should not in any way hamper the right of inheriting the principal house of the deceased. Male and female genders should have equal rights to the throne in any Bini Customary rights of inheritance and with no discrimination of any kind. Example of the British monarchial system where sex is irrelevant should be copied where both genders has equal right in succession to the throne. This is the beauty of globalization and transformation of traditional institutions in modern customary system.What is good for the goose is also good for the ganders. The 'Igiogbe must not be sancrosanctly reserved for only the male eldest son rather it should be on the basis of absolute primogeniture, which allows for eldest survival child of whatever sex. Even if being a female she should have the unrestricted rights to her father's "Igiogbe'.

Keywords: Succession, Primogeniture, CEDAW, Igiogbe

1 Introduction

The Binis are one of the ethnic minor tribes in Nigeria, they are concentrated in several local governments of Edo State with a paramount king, (the Oba), residing at the state capital, Benin City. Benin Kingdom formerly known as Igodomigodo', (the city of Blood) is one of the oldest, developed along the coastal hinterland of the Nigeria Niger Delta region. The Oba is the custodian of the people's tradition and custom. The present Oba, Oba Ewuare II is the 40th monarch that has ruled the Kingdom from the inception of the Obaship.The Kingdom is the remainants of the old Ogiso dynasty, in which two of the Ogisos were women. However, it is noted that in 1440 AD Oba Ewuare I (the great) also known as Ogidigan, introduced a lot Of innovations to the Kingdom, he reduced the powers of the Uzama Chiefs to appointing the Oba into the throne, he adopted the primogeniture lineage system[1] which posits that upon the death of the Oba the eldest surviving son shall take over the Kingdom of his father with a condition that he had observed the necessary funeral obsequies.Then the first surviving son would automatically step into the position of his late father. Primogeniture rules ensures that property remain intact and in a familial line.Some of the earliest references to primogeniture are traceable to the ancient Greek, Romans and Egyptians, the practice was introduced to England following the introduction of Feudalism by the Normans in the 11th century. It is the right of every first born to inheritance of a deceased parents and also a right to the throne of a deceased father.

[1] Kevin Shillington, Encyclopedia of African History ed (2005) Vol. 1 ed New York: Taylor & Francis. accessed 10/9/23.

2 Origin of Primogeniture in Benin Kingdom

According to the Benin tradition, the Oba dictates the pattern of succession and inheritance, in the entire Kingdom. The words of the Oba is regarded as law to this day especially on the tradition of the Kingdom. He is the traditional ruler of the people. The Oba of Benin is revered and respected among the people, and his is regarded as the mouth piece of the gods or deities of the people. He is sometimes referred to as the son of 'the sky', and that, he owns the entire universe, and that he has the power to pronounced a blessing or a curse on anyone. Before the emergence of Oba Ewuare I, the Benin law of primogeniture was often challenged, there were occasions between 1000 AD to 1050, the primogeniture system was rejected and the Odionwere rotational system of administration was revived, however, the ruling Odionwere were often performing below expectation before it was reversed to status quo.

The other two period that defiled the primogeniture rule were remarkable between 1200-1235 and 1334-1370.[2]They were the reign of Oba Eweka I and Oba Ohen respectively, but in the reign of Ewuakpe 1700-1712 the rule of primogeniture by which the eldest surviving son inherits the throne was further enhanced.He dethrone the position of Chief 'Iken' of Uselu and introduced his son to the palace of Iken who never returned from the battle field of Owo.

Uselu, a few kilometres from Benin became a training ground and the palace for the 'would-be' Oba, usually the first son of the Oba,who is also called the crown prince. Iken palace became the palace of the Crown Prince of the Benin Kingdom till this day. Iken could have become the King of Benin but for the decree by the Oba, that it is only the Crown Prince that would be prince of Uselu. The Crown Prince of the Benin Kingdom usually leave the palace to become the Oba of Benin[3] and whoever becomes the Edaiken of Uselu (Prince of Uselu also known as the Crown Prince) is entitled to the Kingship of the Kingdom of Benin as the Obawhen the King demises.

In all, no Bini Princess was ever considered to the position of the Crown Prince. No matrilineal primogeniture otherwise known as the eldest survival daughter has ever inherited the bini throne, so, every bini indigene copied from the Oba. The Oba is the role model of every indigenous bini family.Prior to the ascension of Oba Akenzua in 1933, the British had wanted to install Oba Akenzua's elder sister to become the Oba of Benin, but the move was vehemently condemn and resisted by the Benin Chiefs who reminded the colonial masters' of the rule of male primogeniture in the Kingdom, prior to this time, in 1897 when Oba Ovonramwen was captured and deported to Calabar, the British had wanted to Crown the then appointed administrator, Chief Obaseki to be the Oba of Benin, but the rule of primogeniture prevailed, and until the death of Oba Ovonramwen in Calabar in 1914, Obaseki remain a de facto administrator of the Benin people and did not ruled as "Oba of Benin". It was the son of Oba Ovonramwen, Oba Eweka II that was entitled to the throne and he eventually became the Oba at the death of his father.

The Benin Kingdom has been keen in keeping with male primogeniture rules up to the present day. It should be of note that the primogeniture rules is not particular with the Binis alone. It was brought along with the bini from Egypt and a part of Israel where primogeniture rules dominates major Kingdoms, the middle east were renowned for this system, biblically, characters such as Jacob, Abraham, etc practiced this style of succession. Historically account had it that, the Binis migrated from the middle East, some oral account had it that, the Binis were the lost Israelites who decided to

[2] Jacob Eghareoba (A short History of Benin, 1936, reprint Ann Arbor: Michigan State University Press 1991.
[3]Igbafe Philip; Benin under British: The impact of colonial on an African Kingdom 1897-1938 (London Longman) 1979 p.2.

settle down the riverine region of West Africa, owing to the afflictions suffered by King Pharaoh which prompted their exodus to the present-day location.

3 Primogeniture and Inheritance in Benin Kingdom

Under the Bini native law and custom it is the eldest surviving son who had performs his late father's first and final burial rites that has the rights to his fathers' principal estate, (the house which the deceased lived and died), known as 'Igiogbe'. The Supreme Court set a decision in the case of *Arase v. Arase*[4] it was held that the male surviving son of the decease under the rule of primogeniture has an exclusive rights over his late father's estates. In*Agidigbi v. Agidigbi*[5]it was held inta alia:

> Under the Bini native law and custom, the eldest son of a deceased person or testator is entitled to inherit without question the house or houses known as 'Igiogbe' in which the decease/testator lived and died. Thus, a testator cannot validly dispose of the Igiogbe by his will except to his eldest surviving male child. And any devise of the 'Igiogbe' to any other person is void.

In the case of *Idehen v. Idehen*[6]the eldest son must inherit the principal effects of the deceased: what is left is distributed to other children.

Traditionally the 'Igiogbe' of a Bini man is believed to house a shrine through which the living senior son of the deceased communicates with his late father and other deities, through the use of 'Ukhure' which is a wooden staff.The eldest son can always gain access to his late fathers' spirit for inquiry or help whenever the need arises and the senior son must always solicit for his younger ones and other sisters who could either be his senior or junior by age. And with the 'Ukhure' he can also invoke his late father's spirit to punish any of his siblings who disrespected him.

According to Asemwonta[7]

> Under the Bini native law and custom, the system of primogeniture (i.e from father to eldest son) is rapidly adhered to in deciding who succeeds his father, both to the inheritable properties and ascension to the throne. If a man has no male child, distribution of properties is made among the female children according to their ages. If there are no children, the male grand child steps into the shoes of the first male son of the deceased as if he is the first son of the deceased. He has to perform all the rites as the son would have done.[8]

Under the Bini customary law of inheritance, daughters have the right to inherit their father's landed property apart from the 'Igiogbe' whenever the property is distributed[9]. In the share of property, sons are given preference over daughters, daughter are not wholly prevented from their father's property, but the remainants are always reserved for them and sometimes, no property would be given to them (depending on the volume of property available), and before any bini daughter is entitle to any property of his deceased father, she must have perform her fathers' burial rite also.[10] It is customary that a daughter who is the eldest child of the deceased person does not have the right to inherit the

[4](1981) NSCC 101, 114.
[5](1996) 6 NWLR 302-303.
[6](1991) 6 NWLR 387.
[7]Usi Asemwonta: The Customary Law of the Binis (Benin Commercial Press, 2000) 36.
[8]Ibid.
[9]Finine Fekumo Customary Land Law in Nigeria (Port Harcourt F & F Publishers, 2002) 373.
[10]Supra Note 8.

'Igiogbe' under the Bini Law of inheritance. The eldest son of the deceased upon inheriting his father's principal estates and sometimes his father's young wives he has the responsibility to cater for the women who are now his wives and his siblings and other children of his late father, if he does not want to marry any of his late father's younger wives, he could devise a means for their livelihood.

The eldest son inherits both assets and liabilities from his late father. On the condition that he fails to provide or care for his late father's younger ones who are entitled to stay at the 'Igiogbe' until they are strong enough to be independent, there will be acrimony among them, which would attract the elders of the family to intervene and thereby ordering the re-distribution of the property or properties among the children and if the eldest son refuses, the elders' through the family gods 'Edionegbe' would place a curse on the eldest son.

The Benin traditional system also adopted a system called the 'Urho' which mean per stripe or per 'branch'. This is usually done in polygamous setting where the property is distributed per the number of wives. Every 'branch' will have their own share of the deceased father's property and every senior male child of the 'branches' will have their property, but the 'Igiogbe' is left untouched (it belongs to the overall eldest son). At this junction, it is obvious that the pattern of the Benin style of inheritance is discriminatory against the female children, simply for no fault of theirs. This system appear to be unfair and inequitable to the female children, and in some polygamous setting, wives with no male children sometimes loose out of the decease father's property. For the simple reasons of being a female, to be prevented of the rightful place, as a senior, where necessary, is an aberration to the provision of the 1999 Constitution in Nigeria.

A male child is highly regarded in the Bini custom and tradition, a woman could go at any length to secure a male child for a man in the Bini culture for the reasons of inheritance, also a man could go all out for a male child even outside wedlock believing that without a male heir, he has only wasted his entire time on earth, labouring for his in- laws, (men to whom his daughters would be married to) meaning that no one is left on earth after his demise to communicate with his spirit, when he is gone to the great beyond, and when no one communicates with his spirits, there could be no chance for his reincarnation, he was going to rot and lost in hell. This is a 'No' for a Bini man. He would not allow himself for this eternal punishment; therefore, he must seek for a male heir at any cost.

4 The Practices of Primogeniture in other Jurisdiction

4.1 The Igala/Idoma Custom on Inheritance

Under the Igala culture, it is only the male children that can inherit their deceased father's estates; the females are out rightly excluded from this rights[11] and where there is no son, close male relatives will succeed to the deceased man estates. In the events that the son of the deceased inherits the property, the female daughters who are now disfavoured are at the mercy of their brother who could magnanimously provide for them.[12] However, the female daughters can share in the economic trees planted on the family land, but has no right or share over the family land or other properties.

In *Ihiama v. Akogu*[13] the court held:

> A daughter under Igala customary law will not own land in the family but the male could, because the female will be married to another family.

[11]Richard Mordi, An appraisal of the inheritance rights of women in Nigeria http//www.academic.edu 718784/an appraisal.accessed 1/9/23.

[12]Ibid.

[13]Unreported case in suit No MD/26A/78, Okpo Area Court II.

> It would mean that her children will own their fathers' land and the land of their mother's father as well.

Just for the above reasons, women are discriminated from their fathers' property.

4.2 Hausa Custom on Inheritance

The Hausa and Fulani are dominant in Northern Nigeria, Islamic law under the Sharia system is domicile in must customary activities in the region, the indigenous Hausa native law is somewhat replicated by the Islamic laws; prior to Islam, young boys and females were not eligible to inherit from their deceased father's property, this was simply because, young sons and girls cannot go to war and collect booty or treasure (Gamima) they should not be part of beneficiary to inheritance *Mohammadu v. Mohammed*.[14]

Today, in hausa customary law, it is only the male members of the family that has the right of inheritanceand where there are no sons, the brother of the deceased is entitle to succession in the family, but in Islam law, the number of wives of the deceased will determine how properties are shared. It will be shared 8 times, and 1 out of the 8 will be shared among the wives in respect of their numbers. The remaining estates will be mixed together and shared among the children. While the girls will inherit half of what the boys inherits, (properties which are movables).

> In Hausa land we follows Islamic methods of inheritance, which in Islam is done by God. God himself make the division we follows whatever the Koran sys sometimes we do the division by ourselves. If it is complex for instance where a man has upto 4 wives and they are not united, when he dies and there are some misunderstanding in sharing the property, we involves the Sharia Court.[15]

Land can only be inherited by males within the family in customary law system but the Sharia, gave the rights to both men and women to inherit the estates of their deceased parents; Sharia afford women, whether daughter or wives the right to inheritance. This provision makes the Sharia laws, of more value in the realm of inheritance,with emphasis on equality and human rights[16] to the rejection of the core Hausa customary law of succession.

4.3 Itsekiri Custom of Inheritance

The Itsekiri lived within the delta region of Delta State of Nigeria; they are related to the Yorubas and the Binis. In *Thompson Oke and others v. Robinson Oke and others*[17] it was held that the Itsekiri and the Urhobo have similar customary system of inheritance, in the Itsekiri system the eldest son choose first with the exclusion of the eldest daughter; it is a male primogeniture system, the first son inherits the house where the father lived, and other person effects are shared among other children both sex (male and female) can inherits including those born outside wedlock. The property of the deceased is shared by the following method:

a) Sharing equally without any distinction

[14]Ibid

[15] Interviewed with Mr. Hussein Ali Institute of Advance Legal Studies (NAILS) Librarian http:motun 911 Word Press.com. accessed 1/9/23.

[16]Supra note II

[17] 1974 1 ALL NLR (pt. 1) 443.

b) Male children gets larger shares against the female children yet within the same sex, they share equally.

c) Sharing the estate in the order of seniority whereby older ones gets larger shares, that is in descending order.

The above options are open to the children, usually supervised by the family head.

4.4 Absolute Primogeniture and the Customary Right to Inheritance

Absolute primogenitures is a system known as equal or lineal primogeniture which allows succession to be pass to the eldest surviving child regardless of gender. In this system, sex is irrelevant to inheritance. The following countries are known to have adopted this kind of primogeniture, Sweden since 1980, the Netherland since 1983, Norway since 1990, Denmark since 2009, and United Kingdom 2013.

In this method, females are given the same rights to the deceased property, estates or throne like their male counterparts. The above countries no longer regard cognatic primogeniture as fashionable, they believed that the change is needed to get more female hereditary peers into the House of Lords, for fairness and equality of opportunity; sex must be irrelevant, rather it should be the contribution and views that counts.[18]

Absolute primogeniture is a right that recognized the dignity of the human person as a right founded on the rights of women as a human being, a right defined as inalienable[19] rights to which a person is inherently entitled simply because he or she is a human being.[20] Human rights are indivisible and interdependent which are inherent in all human being regardless of sex, and this right is necessary for the survival of individuals to the realization of his or her potentials to the full, therefore, a deprivation of this right from any human beings be a male or female is a distortion of humanhood and tantamount to the destruction of humanity.Human being, (male or female) possesses the rights that are founded on the notion of individual respect, with the assumption that each human is a moral and rational entity who deserves to be treated with dignity. Human rights are in the sense of civil, political economic social and cultural[21], which are essential to meaningful existence.

In the case of Ransome-*Kuti v. AG Federation*[22], Oputa JSC highlighted that human beings must enjoy the rights he or she is endowed, which he described as privileges of equal benefits.

> ".... derived from the premises of man's inalienable right to life liberty and pursuit of happiness and are enshrined and clearly spelt out in the constitution of the federal Republic of Nigeria".

Britain is a good example in the practice of absolute primogeniture and it is in tandem with human right and equitable flavour.

5 Legal Frame work on Gender Equality and Absolute Primogeniture

[18]Martin Docherty-Hughes, Addressing, Parliament in the U.K. on Hereditary titles (female succession) Vol. 655. Debates 5/3/19.accessed 8/9/23.

[19]The United Nations, office of the High Commissioner of Human Rights, 19/8/2014.

[20]Sepulveda Magdalene: Human rights reference Handbook (University for peace) 3rd edition (2004) p.3.

[21]See International Covenant of Economic, Social and Cultural Rights (ICESCR) 1966.

[22](1985) 2 NWLR pt. 6; p. 211.

There have been provisions for gender right protection for the past decades globallyowing to the fact that gender disparity has been a problem in succession related issues to which the international and local legislation has now ruled on. The United Nations Declaration of Human right[23]provides for equality of men and women and also prohibits discrimination on ground of sex.

The European convention, through regional human rights instruments provides also for freedom from discrimination on any grounds.[24] The African Charter on Human and People's Rights also recognized the right of women to the exclusion of all forms of discrimination based on sex.[25] The Convention on the Elimination of all forms of Discrimination Against Women (CEDAW) prohibits any forms of discrimination either in Personal life, Social, Political, Civil or Cultural system by which a woman finds herself, it also stipulates that a woman must have the rights to obtain family benefits.[26]

A woman also should have equal rights with men in a matter of law and business contracts[27] and in other magnification, including the right to absolute primogeniture in any customary setting. Other instruments protecting women rights includes the following:

(a) European charter of equality of women and men in local life.
(b) Convention in the political rights of women.
(c) Declaration on the Elimination of violence against women (DEVAW) 1993.
(d) African protocol on women's rights.
(e) Beijing Declaration and platform for Action 1995.
(f) International Labour Organisation (ILO).
(g) United Nations International Children's Emergency Fund etc (Unicef).

In Nigeria, section 42(1) is very explicit on the right of equality in respective of any circumstances surrounding the birth of individuals.

6 Discussions

It is interesting that Nigeria is a signatory to most of the instruments protecting gender's equality as enumerated above, regrettably the rule of primogeniture in most customary system in the country has been in favour of the male primogeniture which tends to place the female counterparts in an absolute disadvantaged position, just because of the circumstances surrounding their birth:they are born as female, and are also regarded inferior human beings, this ought not to be in primogeniture. The Convention for the Elimination of all forms Discrimination Against Women (CEDAW) specifically point to the elimination of all forms of discriminations against women as a right that all human system must obey, inclusive of the right of women to absolute primogeniture in all modern customary system of succession in Nigeria including the Bini customary system.

The human rights to be enjoyed by women should include the right to absolute primogeniture, given the fact that, women contributes largely to social and economic stability of the society, and a carefully look revealed that nothing differentiates the male and female human beings, rather than their reproductive systemwhich helps in complimentary to one another. In terms of procreation, and warmth they need each other, also in social and political life, they co-exist, and contributes to the human wellbeing, for national goals, and future regenerations. The popular saying that:

[23]UNDHR Article I, II 1948.
[24]European Convention, Article 14, protocol 12.
[25]See Generally, Article 1(f) African Charter on Human and People's Right.
[26]CEDAW Article 13.
[27]CEDAW Article 16.

'What a man can do, a woman could even do better', is not to be joke with it is an incontrovertible fact,therefore there should be no discrimination against human diversity. In human relations and posterity women have been seen to lead several revolutions where men dared not. Queen Idia, the mother of Oba Esigie of Benin Kingdom in the fifteenth century was an army captain who conquered many towns and expanded the Benin Kingdom as far as to the present day Idah in Kogi State. And in the present day Nigeria, women like Olufunmilayo Ransome-Kuti, Ngozi Okonjo-Iweala, Margaret Ekpo, Chimamanda Ngozi Adichie Elizabeth Abimbola Awoliyi, Adetowun Ogunsheye, Grace Alele Williams[28] etc were all known to have done exploit in their different field of endeavours.

The first, woman warrior in modern Nigeria was also a woman, a skillful Hausa woman Amina, the Queen of Zazzau, she commanded a vast battalion of soldiers in the expanding her Kingdom, she was fearless, in her spirit, she was a lioness. she symbolizes the spirit and strength of womanhood. She reigned for 34 years, and she greatly impacted her Kingdom as a Queen and left an exemplary foot marks, and today, many institutions in Nigeria are named after her, among them are Queen Amina College, and Queen Amina hall in Ahmadu Bello University, Zaria[29] etc.

In modern world, the notion that men are bread winners, while women are to continue to play the secondary part of social affairs are over, most homes relied rapidly on the strength of women to navigate the ocean of economic and social crush that the country currently domicile, if women are given the chance of absolute primogeniture in modern traditional institutions in Nigeria, there would be rapid transformation and innovations in the male dominated world.

It is not sufficient to rely solely on cultural practices of conservative social system that posits on male primogeniture system to advance socioeconomic socialization of a particular ethnic groups, against the female counterparts rather in shift to absolute primogeniture would provide social balances and equity to the moribund culture of the people of Nigeria especially the Binis and their Kingdoms. There is nothing that suggest that men possesses a superior intellects or creativity to the women counterparts in social, economic and political premises, neither is there any clause in the various legislation relegating the female folks to the second fiddle. The exuberance that women are for their husband family whenever there are married off, is a clear demonstration of ignorance and weird thought anchored on compulsive selfishness by their male counterparts.

7 Conclusion

Women marginalization in primogeniture in the bini customary law of succession is a reflection of the world's current gender inequality which has had an absolutely negativism on women's lives, this devastation has contributed to the persistence women's inferior standing in the society.This is a breach tothe provision of the United Nations General Assembly and the Universal Declaration of Human Rights of 1948. The declaration categorically laid emphasis on race, colour, sex language and other status on the basis of discrimination. It was positioned that all (human beings) which also applies to women either in the traditional or political setting should not be prejudiced.

The rightful place of absolute primogeniture should be given to women. It is prejudicial of the Benin Kingdom that it is only the survival eldest male child of the deceased that steps into the 'Igiogbe' to claim ownership, instead of the most eldest child: in respective of sex. The 'Igiogbe' should be made to be inherited by any first born of the deceased (whether a male or a female) provided they are legitimate children of the deceased father.

[28]http//www.google.com/m>q=female and legends+ accessed 9/9/23.
[29]http//www.dw.com/en/amina_the_warrior also see Amina https//g.co/kgs/Z 4nF4g accessed 8/9/23.

The absolute primogeniture system globally is in demonstration in many advanced democracies and it is efficacious in usage. Absolute primogeniture would curb unhealthy rivalries and competitions in the human race. The male preference primogeniture is oppressive and also runs against section 42(1) of the 1999 Constitution of the Federal Republic of Nigeria, as well as other international legislations on Human rights all of which forbids gender discrimination.

All sons and daughters are to be treated equally as God is the creator of both sex. The Benin traditional system must adopt absolute primogeniture so as to meet up with the current global system which called for collaborative efforts in achieving goals. The rights of women equality with men must be respected at all levels including the traditional systemsin Benin Kingdom.

References

[1] Shillington, K. (Ed.). (2005). Encyclopedia of African History (Vol. 1). New York: Taylor & Francis. Retrieved on 10/9/23.
[2] Eghareoba, J. (1991). A Short History of Benin (Original work published 1936). Ann Arbor: Michigan State University Press.
[3] Igbafe, P. (1981). Benin under British: The Impact of Colonialism on an African Kingdom 1897-1938. London: Longman.
[4] (1981) NSCC 101, 114.
[5] (1996) 6 NWLR 302-303.
[6] (1991) 6 NWLR 387.
[7] Asemwonta, U. (2000). The Customary Law of the Binis. Benin Commercial Press.
[8] Ibid.
[9] Fekumo, F. (2002). Customary Land Law in Nigeria. Port Harcourt: F & F Publishers.
[10] Supra Note 8.
[11] Mordi, R. (Accessed 1/9/23). An Appraisal of the Inheritance Rights of Women in Nigeria. Retrieved from http://www.academic.edu/718784/an-appraisal.
[12] Ibid.
[13] Unreported case in suit No MD/26A/78, Okpo Area Court II.
[14] Ibid.
[15] Interview with Mr. Hussein Ali, Institute of Advanced Legal Studies (NAILS) Librarian. Retrieved from http://motun911.WordPress.com. Accessed 1/9/23.
[16] Supra Note II.
[17] (1974) 1 ALL NLR (pt. 1) 443.
[18] Docherty-Hughes, M. (2019). Addressing Parliament in the U.K. on Hereditary Titles (Female Succession). Vol. 655 Debates 5/3/19. Retrieved on 8/9/23.
[19] The United Nations, Office of the High Commissioner of Human Rights. (2014). [Include the title of the document or report].
[20] Sepulveda, M. (2004). Human Rights Reference Handbook (3rd ed.). University for Peace.
[21] International Covenant of Economic, Social and Cultural Rights (ICESCR). (1966).
[22] (1985) 2 NWLR pt. 6; p. 211.
[23] UNDHR Articles I and II (1948).
[24] European Convention, Article 14, Protocol 12.
[25] African Charter on Human and People's Rights, Article 1(f).
[26] Convention on the Elimination of All Forms of Discrimination Against Women (CEDAW), Article 13.
[27] CEDAW Article 16.
[28] [Include the title of the webpage]. (Accessed on 9/9/23). Retrieved from http://www.google.com.
[29] Amina the Warrior. (Accessed on 8/9/23). Retrieved from http://www.dw.com/en/amina_the_warrior.

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp.270-282, November 13-16, 2023

Relationship between E-Learning Facilities and Lecturers Job Productivity in Federal Colleges of Education in North Eastern Nigeria

Edoh CLETUS[1], Musa USMAN[2]
{edohcletus@mau.edu.ng[1], Musman902@hotmail.com[2]}

Department of Physical Sciences Education, Faculty of Education, ModibboAdama University, Yola, +2348066412064, +2349019657695[1],Department of Physical Sciences Education, Faculty of Education, ModibboAdama University, Yola, +2348035390088[2]

Abstract
This study examined the **relationship between e-learning facilities and lecturers job productivity in Federal Colleges of Education in North Eastern Nigeria**. Three research questions and three hypotheses guided the study. Correlational research design was adopted for this study. The population of this study is 805. The sample size for this study is 365. Multi-stage sampling procedure was adopted for the study. The instrument to be used for data collection is a self-structured questionnaire titled "E-Learning Facilities Questionnaire (ELFQ)" and Lecturers Job Productivity Questionnaire (LJPQ) with a total of 15-items. The items are structured on a five-point rating scale of VHL=Very High Level (4), HL=High Level (3), ML=Moderate Level (3), LL=Low Level (2) and VLL= Very Low Level. The reliability co-efficient of (ELFQ) and (LJPQ) yielded 0.84 and 0.86 respectively. Descriptive statistics of Mean and Standard Deviation were used in answering the three research questions raised for the study using real limits of numbers. Pearson Product Moment Correlation Co-efficient was used in testing hypotheses 1 and 2, while ANOVA of Multiple Regression Analysis was used in testing hypothesis 3 at 0.05 Alpha level of significance. Based on the analysis of data it was revealed that Multimedia Applications and Internet Facilitiesare significant predictors of **Lecturers Job Productivity in Federal Colleges of Education in North Eastern Nigeria**, $F_{(1, 364)} = 33045.230$, $p < 0.05$. Since the p – value (0.000) is less than 0.05 alpha level, we can conclude that the null hypothesis should be rejected. This means that Multimedia Applications and Internet Facilitiessignificantly predict **Lecturers Job Productivity in Federal Colleges of Education in North Eastern Nigeria.** Based on the findings of the study, it was recommended among others that: Federal Government should ensure adequate provision of quality and up-to-date multimedia applications such as; video (screen-capture, Lecture Capture, talking head videos, animation, glass screen videos), slideshow/presentation and infographic as this could enhance lecturers job productivity in classrooms.

Keywords: E-Learning Facilities, Multimedia Applications, Internet Facilities, Lecturers Job Productivity, and Federal Colleges of Education.

1 Introduction

The introduction of Information Technology tools such as multimedia technologies and the internet in todays classrooms has greatly improved learning situations in tertiary institutions of learning as Information Technology has improved accessibility and quality of instructional delivery among lecturers and students. Thus, e-learning is a new paradigm shift in higher educational sector purposive geared towards advancing the knowledge base of the 21st Century learner. The beginning of 21st Century has heralded the educational technology that has facilitated e-learning among secondary and tertiary institutions in the developing countries. The influence of e-learning is increasingly dominating the current educational style as the influence of technology increases dominating our day to day activities worldwide [12]. As one of the major sectors of technological influence is education it is assumed the vanguard for developmental change of all countries in the contemporary world.

The Information Communication Technology (ICT) integrated learning is therefore highly recommended for facilitating individually constructed knowledge by supporting the lecturers professional development, the students benefit there after promoting organizational learning [12]. [12] revealed that knowledge is natural byproduct of an individual within the environment and context, which is supported by constructivist idea that learning is tends to be holistic. This is taking sense of the world by taking information from the environment. The author explain further that what a student does is more important than what the teacher does. [12] adds that students should depend

on what they perceive, interpret and intend to do. So, the ICT integrated learning creates opportunities to facilitate such interaction of learning. This supports [5] idea that constructive learning environment will be enhanced if reinforced to play more task oriented activities like in the electronic supported learning. Lecturers are among the group of employees classified as knowledge workers whose job productivity uses mental faculty and involves the use of information, creativity and decision making [13].

Lecturer productivity is a measure of how efficiently a given set of resources either improvised by the lecturer or provided by the school authority is utilized judiciously by lecturer to achieve predetermined set of objectives within the school system. Thus, educational productivity is the ratio between the contributions made by education to general development and the cost of education. Job productivity has been described in various ways by different educators. For instance Mohanta (2010) defined productivity as the ability to combine skillfully the right behaviour towards the achievement of organizational goals and objectives. [4] Defined teachers' job productivity as the duties performed by a teacher at a particular period in the school system in achieving set organisational aims, goals and objectives. It is also the ability to combine relevant inputs for the enhancement of teaching and learning processes. Quality in higher education can be achieved through ensuring lecturer's increased productivity by provision of quality and conducive work environment [4]. There are links between educational programs and Information Communication Technology facilities.

Technology can impact on learning through a presentation, the use of information utilising devices, use of educational modules and the use of online reference books and electronic diaries. However, the use of e-learning as a teaching methodology has witnessed massive adoption in developed countries where several institutions see e-learning activities as a means to grow and improve their institutions [6]. Furthermore, the way and manner in which the methods of teaching are changing in the 21st century are alarming. The integration of technologies as a way of life due to the emergence of the internet has also changed how teaching is conducted in HEIs especially in developed economies [8]. Today, the combination of e-Learning strategy and traditional face-to-face learning strategy (blended learning technique) has been embraced. While this technique or method caters specifically for individual needs of the learner compared to the conventional classroom teaching approach because the students may have unique learning styles, this approach is not prominent in Nigeria. Early developments in e-learning focused on computer assisted learning, where part or all of the learning content is delivered digitally. More recently the pedagogical dimension of e-learning has become prominent. E-learning comprises all forms of electronically supported learning and teaching. The information and communication systems, whether networked learning or not, serve as specific media to implement the learning process. E- learning can be viewed as computer assisted learning, and as pedagogy for student-centered and collaborative learning [7].

E-learning as a sub-system within Information and Communication Technology (ICT), is the electronic process which enhances the delivery and administration of learning opportunities and support via computer, networked and web-based technology to help individual performance and development. The basic principle of e-learning is connectivity – the process by which computers are networked to share information which can connect people. This is provided for by what is often called the e-learning landscape or architecture, which refers to the hardware, software and connectivity components required to facilitate learning [5]. E-learning technology has the potential to transform how and when learners learn. Learning will become more integrated with work and will use shorter, more modular, just-in-time delivery systems. E-learning delivers contents through electronic Information and Communications Technologies (ICTs), [5].

E-learning is defined as digitally permitted and technology-facilitated learning devices that use a digital camera, personal computers (PCs), digital videos, tablets, projector; OHP, software, operating systems which aid in the interaction of students and teachers [14;7]. It includes other applications that support learning from a distance or face to face with the help of PC [16]. E-learning has moved from learning from the conventional method to contemporary driven, synergistic, customized and adaptable learning method involving learners', facilitators and instructors [8]. According to the authors, the use of these facilities involves various methods which include systematic feedback system, computer-based operation network, video conferencing and audio conferencing, internet facilities, multimedia applications, worldwide websites and computer assisted instruction. This delivery method increases the possibilities for how, where and when learners can engage in lifelong learning. This study focused only on multimedia applications and Internet Facilities. Multimedia applications support verbal instruction with the use of static and dynamic images in form of visualization technology for better expression and comprehension in classrooms.

Multimedia application is interactive software that combines several types of media at once in order to convey information to its end user (audience) [11]. Different types of media that can be used in today's lecture theatre include; text images (photographs, illustrations), audio (music, sounds), animation, slideshow or presentation, diagrams, infographic, video (screen-capture, Lecture Capture, talking head videos, animation, glass screen videos). Multimedia is utilized in education to create popular reference books like encyclopedias and guidebooks as well as computer-based training courses (often referred to as CBTs). Text, pictures, music, and animation are all used in CBTs. Multimedia is a combination of more than one media type such as text (alphabetic or numeric), symbols, images, pictures, audio, video, and animations usually with the aid of technology for the purpose of enhancing understanding or memorization [10]. Multimedia technology has some characteristics like integration, diversity, and interaction that enable college lecturers to communicate information or ideas with digital and print elements to her target audience (the students). The digital and print elements in this context refer to multimedia-based applications or tools used for the purpose of delivering information to students for better understanding of abstract concepts, thereby making teaching and learning experiences more interesting. [2] revealed that apart from text and images, existing tools were found to have multimedia components such as audio, video, animation and 3-D. [2] revealed that the majority of the multimedia solutions deployed for teaching and learning target the solution to the pedagogical content of the subject of interest and the user audience of the solution while the success of the different multimedia tools that have been used on the various target groups and subjects can be attributed to the availability of internet technologies and components embedded in their development for ease of utilization.

Internet could mean interrelated network of networks. It is useful for academics because it allows colleagues to connect with themselves around the globe and at same time provides access to interactive forum with the aid of some network resources. Internet is defined as means through which users source information across places and keep up-to-date on issues of interest [3]. According to [15], internet is universal communication grid that disseminates information with the aid of computer in wide area networks. [1] also describe the use of internet as a universal experience that allows operators to localize and share massive collection of data required to facilitate their duties. According to [15] the internet is seen as an electronic library that provides and displays large amount of information through various sources. The internet has no doubt, provided the means by which researchers and teachers access useful information that they need for teaching and research. As noted, stable internet connectivity and computer is necessary for electronic learning [3]. Internet reliability could be seen as critical hindrance to integration of e-learning into education system of developing countries, especially in Nigeria who is the 'Giant of Africa'. [15] Revealed that lecturers recognized that the use of e-learning facilities could enhance their job effectiveness. However, the author further

revealed that majority of them does not often use electronic board. Further, result by the author showed that lecturers' use of e-learning facilities significantly influence their job effectiveness. The author suggested that lecturers should use e-learning facilities for increased productivity in carrying out their academic work.

To access/exchange large amount of data such as software, audio clips, video clips, and text files, other documents, etc., lecturers and students need stable internet services. Some of the commonly used internet services within the school system are: Communication Services (to exchange data/information among individuals or organizations via; Internet Relay Chat, VoIP (Voice over Internet Protocol), describes how to make and receive phone calls over the internet, List Server (LISTSERV): delivers a group of email recipients' content-specific emails, E-Mail: Used to send electronic mail via the internet, User Network (USENET): hosts newsgroups and message boards on certain topics, and it is mostly run by volunteers, Telnet: it's used to connect to a remote computer that's connected to the internet, Video Conferencing: Video conferencing systems allow two or more people who are generally in different locations to connect live and visually. Live video conferencing services are necessary for simulating face-to-face talks over the internet. Information Retrieval Services (procedure for gaining access to information/data stored on the Internet through Net surfing or browsing), File Transfer (exchange of data files across computer systems via gopher, FTP (File Transfer Protocol) and Archie), World Wide Web Services, Web Services, Directory Services, Automatic Network Address Configuration, Network Management Services, Time Services, Usenet, News-Group and E-commerce.

The introduction of new multimedia technologies and the Internet in teaching-learning relationship has been seen as a means to improve accessibility, efficiency and quality of learning by facilitating access to information resources and services as well as remote exchanges and collaboration. Nonetheless, by the middle of the 20th century the growth in technology and applications even in the field of education has been unavoidable to be overlooked. It has been found that students in higher educational institutions that engaged in E-Learning, generally performed better than those in face-to-face courses. [9] found that students who participate in online/ E-Learning achieve better grades than students who studied traditional approach. As result of this finding E- learning is growing very fast and become popular and that is why many higher educational institutions are adopting to virtual learning system.

The use of new multimedia technologies and the Internet in learning is seen as a means to improve accessibility, efficiency and quality of learning by facilitating access to resources and services as well as remote exchanges and collaboration. E-learning has become a new paradigm and philosophy in education with a mission to serve as a development platform for present-day society based on knowledge. For example, online instruction has the potential to provide opportunities for reflective and integrating learning outcomes in the 21st century classrooms. This approach provides the students with enhanced speedy adaptive personalized e-learning because it is a general term used to refer to computer-enhanced learning. It may involves the use of mobile technologies such as personal digital assistants and MP3/MP4 player and includes the use of web-based teaching materials and hypermedia in general, as rooms or web-sites, discussion boards, collaborative software, e-mail, blogs, wikis, text chart, computer aided assistant, educational animation, simulation, games, learning management software et cetera.

It is evident that the concept of e-learning is considered to be very attractive as a new learning model whose effect will be a positive one to the development of education in developing countries especially Nigeria, with all its potentialities. Although, not much effort is taken for its implementation, present-day research of e-learning in Nigeria shows that having e-learning on the educational agenda in Nigeria still face a lot of challenges. This study is informed by the deplorable state of educational system in

Nigeria due to the inadequate teaching –learning facilities and infrastructures, especially in public higher institutions as observed by the researchers. Most public colleges in Nigeria have audio-visual learning materials that are hardly utilized as a result of incessant power outages and lecturers computer self-efficacy.

Hence, traditionally, the main learning approach of biro, paper andchard copy files is still predominantly being practiced. A teacher determines what to teach, how to teach and thus, less concern about the students that is are at the receiving end. There are various learning approaches being put in place to compensate for the problems occasioned by this traditional learning paradigm. While e-learning has constantly been adopted and helped in the establishment of virtual universities in most western countries, only a few private colleges of education in Nigeria completely carry out their academic activities through e-learning [7]. Majority of lecturers find it difficult to use e-learning, while to some, it is still a dream because of poor and weak technological infrastructure. Therefore, the survival of tertiary educational institutions, especially public colleges of education in the 21st century will increasingly rely on various forms of electronic delivery system and communication facilities that are available in markets as requirements for educational flexibility. It is against this background that the researchers examined the **relationship between E-learning facilities and lecturers job productivity in Federal Colleges of Education in North Eastern Nigeria.**

1.1 Purpose of the study

This study examined the **relationship between E-learning facilities and lecturers job productivity in Federal Colleges of Education in North Eastern Nigeria**. Specifically, the study sought to;

1. Examine the relationship between Multimedia Applications **and Lecturers Job Productivity in Federal Colleges of Education in North Eastern Nigeria**.
2. Examine the relationship between Internet Facilities **and Lecturers Job Productivity in Federal Colleges of Education in North Eastern Nigeria.**
3. The level of **Lecturers Job Productivity in Federal Colleges of Education in North Eastern Nigeria.**

1.2 Research Question

The following research questions guided the study.

1. What is the level of Multimedia Applications **in Federal Colleges of Education in North Eastern Nigeria**?
2. What is the level of Internet Facilities **in Federal Colleges of Education in North Eastern Nigeria**?
3. What is the level of **Lecturers Job Productivity in Federal Colleges of Education in North Eastern Nigeria**?

1.3 Statement of Hypotheses

The following null hypotheses were formulated to guide the study and were tested at 0.05 Alpha level of significance:

Ho_1: There is no significant relationship between Multimedia Applications **and Lecturers Job Productivity in Federal Colleges of Education in North Eastern Nigeria**.

Ho_2There is no significant relationship between Internet Facilities **and Lecturers Job Productivity in Federal Colleges of Education in North Eastern Nigeria**.

Ho_3: There is no significant relationship between Multimedia Applications, Internet Facilities **and Lecturers Job Productivity in Federal Colleges of Education in North Eastern Nigeria**.

2 Methodology

Correlation research design was adopted for this study. The study area is North-Eastern Nigeria. The population of this study is 805. This comprise of 100 administrators (provost, registrar, dean and HODs) and 705 lecturers in three Federal Colleges of Education in North-Eastern Nigeria. The sample size for this study is 365. This sample size comprises of 45.34% of the entire population which is 805. Similarly, Nwana (1981) suggests that if the population is a few hundreds, a 40% or more samples will suffice. Multi-stage sampling procedure was adopted for the study. This includes purposive sampling, simple random sampling and proportionate stratified random sampling techniques. Purposive and simple random sampling techniques were used in selecting Federal Colleges of Education.

Federal Colleges of Education were purposively sampled to take care of the variable of ownership. At the second stage, purposive sampling technique was used to select administrators: Provost, Registrars, Deans and various Heads of Departments on three Federal College of Education. At third stage, proportionate stratified random sampling technique was used in selecting the lecturers. Lecturers were sampled proportionately in the following order; Federal College of Education, Yola, Adamawa State (130), Federal College of Education (Techical) Potiskum, Yobe State (87) and Federal College of Education (Technical), Gombe, Gombe State (148). The use of proportionate stratified random sampling technique is to avoid sampling bias. At the last stage, simple random sampling technique was used in selecting the three hundred and sixty-five (365) lecturers. Simple random sampling technique was used because it gave the respondents equal opportunity of being included in the study.

The instruments to be used for data collection are a self-structured questionnaire titled "E-Learning Facilities Questionnaire (ELFQ)" and Lecturers Job Productivity Questionnaire (LJPQ) with a total of 15-items. The items are structured on a five-point rating scale of VHL=Very High Level (4), HL=High Level (3), ML=Moderate Level (3), LL=Low Level (2) and VLL= Very Low Level. To ensure the validity of the instruments were submitted to three senior lecturers from the Department of Physical Sciences Education, Faculty of Education, ModibboAdama University, Yola for face and content validation. Data were collated and analyzed for reliability using Cronbach Alpha Statistic. Cronbach Alpha Statistics was used because it helped the researchers to determine the internal consistency of items of the instruments (The reliability co-efficient of (ELFQ) and (LJPQ) yielded 0.84 and 0.86 respectively. This total reliability coefficient of 0.84 and 0.86 was considered high enough and reliable to be used for the study.

Three hundred and sixty-five (365) copies of the instruments were administered to the respondents by the researchers with the aid of six research assistants who are conversant with the study area. The direct delivery approach was to used to enable the researchers and research assistants to thoroughly explain the purpose of the study to the respondents and also, to ensure all completed questionnaire copies are retrieved on the spot. Descriptive statistics of Mean and Standard Deviation were used in answering the three research questions raised for the study using real limits of numbers. Pearson Product Moment Correlation Co-efficient was used in testing hypotheses 1 and 2, while ANOVA of Multiple Regression Analysis was used in testing hypothesis 3 at 0.05 level. The decision rule was that, if the p-value is less than the significance level ($\alpha = 0.05$), the null hypothesis would be rejected and alternative hypothesis accepted.

2.1 Results

Three research questions were raised and answer using descriptive statistics of mean and standard deviation. Three hypotheses were also formulated and tested at 0.05 level of significance using PPMC and ANOVA of Multiple regression.

2.1.1 Research Question one

What is the level of Multimedia Applications **in Federal Colleges of Education in North Eastern Nigeria**?

To answer this research question, responses on the level to which Multimedia Applications are utilized **in Federal Colleges of Education in North Eastern Nigeria** were collected and analyzed as shown in Table 1.

Table 1: Mean and Standard Deviation of Level of Multimedia Applications **in Federal Colleges of Education in North Eastern Nigeria**

S/N	Items	n=365	Mean	S. D	Remark
1	Use of text images (photographs, illustrations)		4.36	0.92	HL
2	Use of audio (music, sounds)		4.38	0.86	HL
3	Use of slideshow/presentation		4.49	0.95	HL
4	Use of video (screen-capture, Lecture Capture, talking head videos, animation, glass screen videos)		4.51	0.96	VHL
5	Use of infographic to improve cognition using graphics to enhance the human visual system's ability to see patterns/trends		4.15	0.93	HL
	Average Mean		**4.38**	**0.92**	**HL**

The average mean and standard deviation of the level of Multimedia Applications **in Federal Colleges of Education in North Eastern Nigeria** are shown in Table 1. In **Federal Colleges of Education in North Eastern Nigeria**, a high level of Multimedia Applications is indicated by an average mean score of 4.38 and standard deviation value of 0.92. This implies that lecturers use of video (screen-capture, Lecture Capture, talking head videos, animation, glass screen videos), slideshow/presentation and infographic to improve cognition using graphics to enhance the human visual system's ability to see patterns/trends to a high level.

2.1.2 Research Question Two

What is the level of Internet Facilities **in Federal Colleges of Education in North Eastern Nigeria**?

To answer this research question, responses on the level to which Internet Facilities are utilized **in Federal Colleges of Education in North Eastern Nigeria** were collected and analyzed as shown in Table 2.

Table 2 Mean and Standard Deviation of level of Internet Facilities **in Federal Colleges of Education in North Eastern Nigeria**

S/N	**Items**	n=365	**Mean**	**S. D**	**Remark**
1	Use of Internet Relay Chat to exchange data/information among lecturers/students		4.52	0.96	VHL
2	Use of VoIP (Voice over Internet Protocol) to make/ receive phone calls over the internet		4.59	0.98	VHL
3	Use of live video conferencing services for simulating face-to-face talks with students over the internet		4.50	0.95	VHL

4	Use of User Network (USENET) to hosts newsgroups on certain topics	4.56	0.97	VHL
5	Use of Retrieval Services to gaining access to information/data stored on the Internet through Net surfing or browsing	4.73	1.03	VHL
	Average Mean	**4.58**	**0.98**	**VHL**

Result of analysis in Table 2 shows the mean and standard deviation of level of Internet Facilities **in Federal Colleges of Education in North Eastern Nigeria**. An average mean of 4.58 and standard deviation of 0.98 shows high level of Internet Facilities usage **in Federal Colleges of Education in North Eastern Nigeria**. This implies that College lecturers use; Retrieval Services to gaining access to information/data stored on the Internet through Net surfing or browsing, VoIP (Voice over Internet Protocol) to make/ receive phone calls over the internet and User Network (USENET) to hosts newsgroups on certain topics to a very high level.

2.1.3 Research Question Three

What is the level of **Lecturers Job Productivity in Federal Colleges of Education in North Eastern Nigeria**?

To answer this research question, responses on the level to which Internet Facilities are utilized **in Federal Colleges of Education in North Eastern Nigeria** were collected and analyzed as shown in Table 3.

Table 3 Mean and Standard Deviation of level of **Lecturers Job Productivity in Federal Colleges of Education in North Eastern Nigeria**

S/N	Items	n=365	Mean	S. D	Remark
1	Lecturers use on-line assessment data for instructional decision making		4.39	0.88	HL
2	Lecturers provide a variety of opportunities that support student's integrated e-learning development		4.50	0.94	VHL
3	Lecturers employs integrated planned instruction to meet the learning needs of all students using multimedia tools		4.61	0.97	VHL
4	Lecturers employs online Internet based instruction to meet the learning needs of all students		4.64	0.98	VHL
5	Lecturers use Value-Added Models to provide a summary score of the contribution of various factor towards growth in students achievement		4.59	0.96	VHL
	Average Mean		**4.55**	**0.95**	**VHL**

The mean and standard deviation of the level of **Lecturers Job Productivity in Federal Colleges of Education in North Eastern Nigeria** are shown in Table 3. A high level of **Lecturers Job Productivity in Federal Colleges of Education in North Eastern Nigeria** is indicated by an average mean score of 4.55 and standard deviation value of 0.95. This implies that to a very high level; Lecturers employs online Internet based instruction to meet the learning needs of all students, Lecturers employs integrated planned instruction to meet the learning needs of all students using multimedia tools and Lecturers use Value-Added Models to provide a summary score of the contribution of various factor towards growth in students achievement.

3 Hypotheses Testing

3.1 H_{01}: There is no significant relationship between Multimedia Applications **and Lecturers Job Productivity in Federal Colleges of Education in North Eastern Nigeria**.

Table 4 Summary of PPMC of relationship between Multimedia Applications **and Lecturers Job Productivity in Federal Colleges of Education in North Eastern Nigeria**

Variable	Mean	S. D	R – value	P - value	Remark
Multimedia Applications	4.38	.92	0.821	0.000	**H_{01} reject**
Lecturers Job Productivity	4.55	.95			

The summary of the results from the PPMC analysis performed to investigate the relationship between Multimedia Applications **and Lecturers Job Productivity in Federal Colleges of Education in North Eastern Nigeria** are presented in Table 4. According to the result, Multimedia Applications **and Lecturers Job Productivity** are strongly, positively and significantly correlated ($r = 0.821$, $p < 0.05$).

3.2 H_{02}: There is no significant relationship between Internet Facilities **and Lecturers Job Productivity in Federal Colleges of Education in North Eastern Nigeria**.

Table 5 Summary of PPMC of relationship between Internet Facilities **and Lecturers Job Productivity in Federal Colleges of Education in North Eastern Nigeria**

Variable	Mean	S. D	R – value	P – value	Remark
Internet Facilities	4.58	.98	0.802	0.000	**H01 reject**
Lecturers Job Productivity	4.55	.95			

The results of the PPMC analysis used to investigate the relationship between Internet Facilities **and Lecturers Job Productivity in Federal Colleges of Education in North Eastern Nigeria** are summarized in Table 5. The outcome shows a significant strong and positive relationship (r - value = 0.802, p 0.05) between Internet Facilities **and Lecturers Job Productivity in Federal Colleges of Education in North Eastern Nigeria**.

3.3 H_{03}: There is no significant relationship between Multimedia Applications, Internet Facilities **and Lecturers Job Productivity in Federal Colleges of Education in North Eastern Nigeria**.

Table 6a Summary of Multiple Regression of relationship between Multimedia Applications, Internet Facilities **and Lecturers Job Productivity in Federal Colleges of Education in North Eastern Nigeria**

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	85.394	1	17.867	33045.230	.000[b]
	Residual	.456	363	.001		
	Total	85.850	364			

a. Dependent Variable: **Lecturers Job Productivity**

b. Predictors: (Constant), **Multimedia Applications**, **Internet Facilities**

Results of Analysis in Table 6a revealed that Multimedia Applications and Internet Facilitiesare significant predictors of **Lecturers Job Productivity in Federal Colleges of Education in North Eastern Nigeria**, $F_{(1, 364)} = 33045.230$, $p < 0.05$. Since the p – value (0.000) is less than 0.05 alpha

level, we can conclude that the null hypothesis should be rejected. This means that Multimedia Applications and Internet Facilitiessignificantly predict **Lecturers Job Productivity in Federal Colleges of Education in North Eastern Nigeria**.

Table 6b Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.994[a]	.992	.893	.02325

a. Predictors: (Constant), **Multimedia Applications**, **Internet Facilities**

The result in Table 6b shows a model summary which shows how the independent variable explains the variance in the dependent variable. The result shows that Multimedia Applications and Internet Facilitiesexplained 89.3% of the variance in **Lecturers Job Productivity in Federal Colleges of Education in North Eastern Nigeria**.

Table 6c Coefficients of Beta

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.016	.012		1.416	.156
	Multimedia Applications	.485	.004	69.2	220.051	.000
	Internet Facilities	.486	.004	68.3	198.742	.000

a. Dependent Variable: **Lecturers Job Productivity**

The analysis in Table 6c shows the coefficients of multiple regression analysis. The regression analysis presented reveals how each variable included in the model contributed in **Lecturers Job Productivity in Federal Colleges of Education in North Eastern Nigeria**. Multimedia Applications has a beta value of .692 which implies that is Multimedia Applications explains 69.2% of the variance in **Lecturers Job Productivity in Federal Colleges of Education in North Eastern Nigeria**, at a p-value of 0.000. Furthermore, Internet Facilities has a beta coefficient of .683 which implies that is Internet Facilities explains 68.3% of the variance in **Lecturers Job Productivity in Federal Colleges of Education in North Eastern Nigeria,** at p – value of 0.000. It can be concluded that Multimedia Applications make the strongest unique contribution to explaining **Lecturers Job Productivity in Federal Colleges of Education in North Eastern Nigeria**, when the variance explained by all other variables in the model are controlled for since it has the largest beta coefficient of .692.

4 Summary of Major Findings

The following are the findings of the study:

1. Multimedia Applications **and Lecturers Job Productivity** are strongly, positively and significantly correlated ($r = 0.821$, $p < 0.05$).
2. The outcome shows a significant strong and positive relationship (r - value = 0.802, p 0.05) between Internet Facilities **and Lecturers Job Productivityin Federal Colleges of Education in North Eastern Nigeria**.
3. The results revealed that Multimedia Applications and Internet Facilitiesare significant predictors of **Lecturers Job Productivity in Federal Colleges of Education in North Eastern Nigeria**, $F_{(1, 364)} = 33045.230$, $p < 0.05$. Since the p – value (0.000) is less than 0.05 alpha level, we can conclude that the null hypothesis should be rejected. This means that

Multimedia Applications and Internet Facilitiessignificantly predict **Lecturers Job Productivity in Federal Colleges of Education in North Eastern Nigeria**.

5 Discussion of Findings

The finding of this study revealed that Multimedia Applications **and Lecturers Job Productivity** are strongly, positively and significantly correlated. The major findings were that; that lecturers use of video (screen-capture, Lecture Capture, talking head videos, animation, glass screen videos), slideshow/presentation and infographic to improve cognition using graphics to enhance the human visual system's ability to see patterns/trends to a high level. Similarly, a test of related hypothesis revealed that Multimedia Applications **and Lecturers Job Productivity** are strongly, positively and significantly correlated ($r = 0.821$, $p < 0.05$). This finding corroborate with that of [10] whose findings revealed that multimedia technology has some characteristics like integration, diversity, and interaction that enable college lecturers to communicate information or ideas with digital and print elements to her target audience (the students). [10] further reveaked that digital and print elements in this context refer to multimedia-based applications or tools used for the purpose of delivering information to students for better understanding of abstract concepts, thereby making teaching and learning experiences more interesting. The finding corroborate with that of [2] revealed that apart from text and images, existing tools were found to have multimedia components such as audio, video, animation and 3-D. [2] concluded that the majority of the multimedia solutions deployed for teaching and learning target the solution to the pedagogical content of the subject of interest and the user audience of the solution while the success of the different multimedia tools that have been used on the various target groups and subjects can be attributed to the availability of internet technologies and components embedded in their development for ease of utilization.

The second findings of the study revealed that there is a significant strong and positive relationship between Internet Facilities **and Lecturers Job Productivityin Federal Colleges of Education in North Eastern Nigeria** (r - value = 0.802, p 0.05). The major findings were that College lecturers use; Retrieval Services to gaining access to information/data stored on the Internet through Net surfing or browsing, VoIP (Voice over Internet Protocol) to make/ receive phone calls over the internet and User Network (USENET) to hosts newsgroups on certain topics to a very high level. Similarly, a test of related hypothesis revealed showed a significant strong and positive relationship between Internet Facilities **and Lecturers Job Productivityin Federal Colleges of Education in North Eastern Nigeria** (r-value = 0.802, p 0.05)**. This finding is in agreement with that of** [15] whose findings revealed that the internet is seen as an electronic library that provides and displays large amount of information through various sources for effective teaching and learning in schools. [15] further revealed that internet has no doubt, provided the means by which researchers and teachers access useful information they need for teaching and research in higher educational institutions. The finding further corroborate with that of [3] whose findings revealed that stable internet connectivity and computer is necessary for electronic learning in schools. [15] further revealed that Internet reliability could be seen as critical hindrance to integration of e-learning into education system of developing countries, especially in Nigeria who is the ‘Giant of Africa’. [15] revealed that lecturers recognized that the use of e-learning facilities could enhance their job effectiveness. [15] further revealed that majority of lecturers do not often use electronic board. Further, result by the [15] showed that lecturers' use of e-learning facilities significantly influence their job effectiveness. [15] suggested that lecturers should use e-learning facilities for increased productivity in carrying out their academic work.

The third finding of the study revealed that Multimedia Applications and Internet Facilitiesare significant predictors of **Lecturers Job Productivity in Federal Colleges of Education in North Eastern Nigeria**, $F_{(1, 364)} = 33045.230$, $p < 0.05$. Since the p – value (0.000) is less than 0.05 alpha

level. This means that Multimedia Applications and Internet Facilitiessignificantly predict **Lecturers Job Productivity in Federal Colleges of Education in North Eastern Nigeria**. The major findings of the study revealed that to a very high level; Lecturers employs online Internet based instruction to meet the learning needs of all students, Lecturers employs integrated planned instruction to meet the learning needs of all students using multimedia tools and Lecturers use Value-Added Models to provide a summary score of the contribution of various factor towards growth in students achievement. Similarly, a test of related hypothesis revealed Multimedia Applications and Internet Facilitiessignificantly predict **Lecturers Job Productivity in Federal Colleges of Education in North Eastern Nigeria. This finding is in line with that of** [15] whose findings revealed that lecturers' use of e-learning facilities (Internet and multimedia tools) significantly influence their job effectiveness. Sunday's finding further corroborate wit the finding of this study because it revealed that lecturers should use e-learning facilities for increased productivity in carrying out their academic work. This finding is consistent with that of [16] whose findings revealed that multimedia technology has some characteristics like integration, diversity, and interaction that enable college lecturers to communicate information or ideas with digital and print elements to her target audience (the students) through stable internet connectivity.

6 Conclusion

Based on the findings of the study, it was concluded by the researchers that the role multimedia applications and internet facilities plays in lecturers job productivity in Federal Colleges of Education cannot be over-emphasized. The researchers envisaged that if lecturers in Federal Colleges of Education utilize the immense benefits of multimedia applications and internet facilities in their daily instructional delivery; their job productivity would be greatly enhanced.

7 Recommendations

Based on the findings of the study, the following recommendations were made:

1. Federal Government should ensure adequate provision of quality and up-to-date multimedia applications such as; video (screen-capture, Lecture Capture, talking head videos, animation, glass screen videos), slideshow/presentation and infographic as this could enhance lecturers job productivity in classrooms.
2. Federal government and other non-governmental organisations should ensure college lecturers are provided with daily free access to stable internet connectivity in order for them to explicitly use retrieval services to gain access to information/data stored on the Internet through Net surfing or browsing, VoIP (Voice over Internet Protocol) to make/ receive phone calls over the internet and also use User Network (USENET) to hosts newsgroups on certain topics as this could enhance lecturers instructional delivery on a daily basis.
3. Lecturers should employ online Internet Based Instruction, Integrated Planned Instruction and Value-Added Models to meet the learning needs of all students in order to improve students' achievement through improved e-instructional delivery.

References

[1] Abdel-Rahman, A. M., & Hamid, M. E. (2012). Influence of some socioeconomic characteristics on the use of information and communication technologies (ICT) by vegetable farmers in the Gezia State, University of Gezira, Wad Medani, Sudan. International Journal of Research in IT, Management and Engineering (IJRIME), 2(12), 1-9. [Link]

[2] Abdulrahaman, M. D., Faruk, N., Oloyede, A. A., Surajudeen-Bakinde, N. T., Olawoyin, L. A., Mejabi, O. V., Imam-Fulani, Y. O., Fahm, A. O., & Azeeze, A. L. (2020). Multimedia tools in the teaching and learning processes: A systematic review, 1-11.

[3] Akpan, C. P. (2014). ICT competence and lecturers' job efficacy in universities in Cross River State, Nigeria. International Journal of Humanities and Social Science, 4(10), 259-266. [Link]
[4] Ankeli, I. A., Dabara, I. D., Omotehinshe, O. J., Adamu, M. K., & Adaranijo, L. O. (2017). Assessment of Housing Condition and Its Effect on Occupiers' Health Condition. The 12th International Conference on Advances in Science, Humanities and Education, 12(4), 57-64. Shongai Centre, Porto Novo, Republic of Benin.
[5] Boma, I. D., & Bariledum, L. P. (2021). Perceived Influence of E-Learning on Business Education Students' Academic Performance in Rivers State Universities. International Journal of Innovative Information Systems & Technology Research, 9(4), 33-40.
[6] Eze, S. C., Chinedu-Eze, C. V. (2018). Examining information and communication technology (ICT) adoption in SMEs: a dynamic capabilities approach. Journal of Enterprise Information Management, 31(2), 338–356.
[7] Eze, S. C., Chinedu-Eze, V., Bello, A. O. (2018). The utilization of e-learning facilities in the educational delivery system of Nigeria: a study of M-University. International Journal of Educational Technology in Higher Education, 15(34), 1–20. [Link]
[8] Falana, F. T. (2015). Prospects and challenges of e-learning in Nigerian university education using the National Open University of Nigeria, Akure study centre, Akoko: Department of science and technical education (computer education unit) Adekunle Ajasin University Akungba Akoko.
[9] Fayomi, O., Ayo, C., Ajayi, L., & Okorie, U. (2015). The impacts of e-learning in facilitating academic performance among private secondary schools and tertiary institutions in Ota, Ogun State, Nigeria. Conference Paper. Ota; Ogun State. Pp. 1-12. [Link]
[10] Guan, N., Song, J., Li, D. (2018). On the advantages of computer multimedia-aided English teaching. Procedia Computer Science, 131, 727–732.
[11] Ilhan, G. O., Oruc, S. (2016). Effect of the use of multimedia on students' performance: a case study of social studies class. Educational Research and Reviews, 11(8), 877–882.
[12] Kassahun, M. T. (2014). The Influence of E-Learning on the Academic Performance of Mathematics Students in Fundamental Concepts of Algebra Course: The Case in Jimma University. Ethiopian Journal of Education and Sciences, 9(2), 41-59.
[13] Mohanta, G. C. (2010). Knowledge Worker Characteristics and Knowledge Worker Productivity Determinants. Nairobi: ACTS Press. Pp. 23-24.
[14] Olojo, O. J., Adewumi, M. G., Ajisola, K. T. (2012). E-learning and its effects on teaching and learning in a global age. International Journal of Academic Research in Business and Social Sciences, 2(1), 203–210.
[15] Sunday, N. O. (2021). Lecturers' Job Effectiveness through the Use of E-Learning Facilities in the University of Ibadan. The African Journal on Behavioral and Scale Development Research (AJB-SDR), 3(1), 22-33.
[16] Sunday, C. E., Chinedu-Eze, V. C. A., Clinton, K. O., & Adenike, O. B. (2020). Factors influencing the use of e-learning facilities by students in a private Higher Education Institution (HEI) in a developing economy. Humanities and Social Sciences Communications, 7(133), 1-15. [Link]

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp.283-296, November 13-16, 2023

Empirical Review of Studies on Risk Management Strategies and Operational Efficiency in Educational Institutions

JINGS Dogara Jingina[1], Muhammad Musa[2]
{jinginajings@gmail.com[1], kallam934@gmail.com[2]}

Department of Education, Brønnum Lutheran Seminary. P.O Box 74 Yola, Adamawa State, Nigeria. +234-8034013959(NG)[1], Department of Educational Foundation, Federal University Kashere, Gombe State, Nigeria.+234-7035981261 (NG)[2]

Abstract
The problems of educational institutions are multifaceted due to rapid competition, fast-paced technological developments, and insecurity, coupled with government, student, and staff-related issues that are difficult even to predict. Educational institutions have not been able to escape from these unpredictable risk components, as they are also exposed to the same amount of uncertainty in the present situation. This paper reviews empirical studies on risk management strategies and the operational efficiency of educational institutions from 2017 to 2023. The review focuses on the operational inefficiency of educational institutions in managing risk. Two objectives guided the review, while the significance of the review was clearly stated based on the problem of the operational inefficiency of educational institutions in managing risk. The methodology used was a systematic review of 15 empirical papers, with 13 focusing on risk management strategies and two on operational efficiency. The studies used various research designs, including correlational, survey, experimental, qualitative, and case study research. Data collection methods included questionnaires and interviews, which were adopted, adapted, or self-structured. Data analysis was mainly descriptive statistics, with some authors focusing on multiple sub-variables. The findings aligned with the study's titles and were well organized. The study found that for educational institutions to be operationally efficient and contribute to national development and innovation, risk identification, assessment, communication, planning, implementation, review, culture and mitigation are necessary.

Key Words: Risk management strategies, educational institutions, operational efficiency.

1 Background of the Study

The transmission of knowledge, the development of skills, and the advancement of society are all intersected by educational institutions such as primary and secondary schools, colleges, polytechnics, seminaries, research institutes, and universities. These institutions face complicated, diverse, and multifaceted challenges in their laudable efforts to ensure sustainable development and nurture the next generation. No wonder Jings (2021) stated that there are many different issues plaguing educational institutions in developing countries, particularly Nigeria. These issues include those pertaining to the government, financial instability, inadequate funding, staff and student issues, and the fact that federal and state government funding for education is not keeping up with the rising cost of education. Additionally, certification is becoming increasingly important, and educational programmes are not being designed to meet the needs of the domestic and international labour markets. Other issues include brain drain within the educational system, packed lecture halls, and a high percentage of half-baked, unemployed school graduates. But Coombe, as cited by Jings (2021: p. 4), gave a soft landing to the problems of educational institutions, especially universities: “Despite the brains that have been drained out of them over the years and the compromises they have been compelled to make with their own standards, universities remain great national storehouses of trained, informed, inquiring, and critical intellects, and the indispensable means of replenishing national talent”. The foresaid pointed out two pivotal elements that play an instrumental role in steering the course of educational institutions in Nigeria and other developing nations towards success since they have no substitute: adopting risk management strategies and ensuring operational efficiency.

Operational efficiency is the cornerstone of an educational institution's ability to function effectively and achieve its educational goals within resource constraints. According to Jorim and Koech (2015), operational efficiency in education refers to the effective and judicious use of resources, processes,

and strategies within educational institutions of learning to achieve their academic and administrative goals while minimising waste and reducing costs. The world of education operates under the constant pressures of time, budget limitations, and the need for resource optimization. Operational efficiency, therefore, becomes an essential strategy for institutions aiming to provide quality education, streamline their processes, and minimise waste. Furthermore, operational efficiency is a critical issue in university administration. It refers to how efficiently various faculties within an institution operate. It is a comparison between the inputs and outputs of an institution (Fabunmi, 2015). The goal of operational efficiency in education is to ensure that educational institutions can fulfill their educational missions, adapt to changing circumstances, and remain sustainable in the long run (Lester, 2014).

On the other hand, risk is an inherent element in the operations of educational institutions. Risk management strategies in educational institutions constitute a strategic and systematic approach to identifying, evaluating, assessing, communicating, reviewing, implementing, culturing, and mitigating potential risks that can disrupt the institution's operations, threaten financial stability, and impact the well-being of students, staff, and stakeholders (Heubach and Heubach, 2012). According to Öznacar and Gülyüz (2021), risks span a wide spectrum, from financial uncertainties, corruption, legal liabilities, and academic integrity concerns to environmental and safety threats. To navigate these risk landscapes effectively, educational institutions must employ rigorous risk management measures, ensuring that they are well-prepared to handle challenges when they arise. Risk management strategies and operational efficiency in educational institutions are crucial and symbiotic to national development and innovation. Operational efficiency is intertwined with elements that create a resilient and thriving educational institution (Ting and Cho 2015). According to Coetzee and De Jager (2019), by identifying, analyzing, communicating, assessing, implementing, culturing, and mitigating risks, institutions can ensure smoother operations, allocate resources wisely, and focus on the continuous improvement of processes and services so that the goals of national development and innovation can be achieved.

In educational institutions, risk management has developed into a crucial part of institutional governance and strategic planning, especially in recent years. This is to achieve their goals and protect their image as they handle more challenging issues and uncertainties. Primary and secondary schools, universities, and colleges must effectively identify risks, plan for them, assess them, review them, communicate them, implement them, culture them, and mitigate them (Brown, de Kock, and Wakelin 2019). The operating environment for educational institutions in Nigeria is one that is always evolving in terms of technology, demographics, money, security, and regulatory frameworks (Ogbuabor, Ikwu, and Nwakoby 2018). The authors also emphasized that increased scrutiny from a range of stakeholders, including students, professors, donors, and governmental agencies, has increased the significance of risk management measures for potential threats. This simply implies that effective risk management techniques support educational institutions' long-term sustainability and performance by reducing unfavourable events and improving operational efficiency.

By using risk management strategies in educational institutions, it means that such institutions are aimed at enhancing their ability to navigate uncertainties and challenges while safeguarding their reputation, financial stability, and overall efficacy in national development. Various elements and tactics are used to direct risk management procedures in education. Risk identification is the initial stage in identifying possible threats that could have an impact on the institution (Brown, de Kock, and Wakelin 2019). Risks can come from a variety of sources, including technical, environmental, reputational, financial, operational, and strategic aspects. This implies that risks undergo an assessment to ascertain their possible degree, effect, and possibility of hazard after being recognized. Based on the importance of the risks to the institution, this assessment aids in prioritizing them (very low, low, moderate, high, and very high) (Oladimeji and Akpan 2022).

Similar to this, research by Ogbuabor, Ikwu, and Nwakoby (2018) emphasized that risk reduction should occur after risk assessment. This only suggests that solutions are established by figuring out how to lessen or manage risks after they have been assessed. For example, diversifying funding sources, enhancing security, creating a cyber-security network, or improving the school's emergency preparedness are all examples of risk mitigation measures that can be planned, put into place, and developed as backup plans (Kanganas and Pettersson, 2020). In a similar vein, it is important to continuously assess the efficiency of the risk mitigation plan once it is implemented and make any required adjustments in order to manage the risk.

Kimani (2017) stated that routine reviews assist in detecting developing risks and evaluating the efficiency of current risk controls in his study on risk management methods and the performance of building projects in public secondary schools in Muranga County, Kenya, while Nnadozie and Ezeh (2019) state that enterprise risk management (ERM), often known as an integrated approach that integrates risk management into an organization's strategic planning and decision-making processes, is another risk management technique. It guarantees that risks are taken into account comprehensively and that risk management is integrated into corporate culture and the process of strategy planning (Oladimeji and Akpan 2022). According to Onuorah, Nwankwo, and Okoye (2022), risk communication is another risk management strategy that is required in educational institutions in Nigeria. According to the authors, it's crucial to communicate clearly about hazards and risk management techniques. The risk profile of the institution, risk mitigation actions, and risk management progress must be communicated to stakeholders.

Raji and Akanbi (2019) said that risk culture is one of the most effective risk management techniques, which serves as more evidence that risk management measures are necessary in our schools. It entails fostering a common knowledge of risks and their repercussions. Risk culture promotes risk awareness, responsibility, and proactive risk management behaviours throughout an organization (Fadun 2018). Educational institutions at all levels may reduce risk by incorporating these risk management techniques into their daily operations and decision-making procedures. Since educational institutions face numerous challenges, including financial constraints, regulatory changes, and operational disruptions, academic integrity can significantly impact their effectiveness and efficiency. These challenges necessitate the development and implementation of robust risk management strategies to ensure smooth operations and sustainable educational excellence for development and innovation. This study aims to review empirical studies on risk management practices and their influence on operational efficiency within educational institutions**.**

1.1 Purpose of the Empirical Review

The goal of this study is to review empirical studies that discuss risk management strategies and the operational efficiency of educational institutions. The study was specifically designed to:

1 Review empirical studies on risk management strategies and operational efficiency in educational institutions.

2 Critique the empirical studies on risk management strategies and operational efficiency in educational institutions.

1.2 Significance of the Empirical Review

Empirical research on risk management tactics in educational institutions has accelerated due to these contextual considerations. Researchers have investigated several facets of risk management strategies at universities, colleges, and secondary and primary schools using surveys, case studies, and quantitative analyses. The results of these empirical studies gave institutional leaders, decision-makers, and risk management specialists important information that helped them create strategies that would successfully help the education sector deal with its difficulties and uncertainties. To ensure the

continuous success and resilience of educational institutions throughout the world as the landscape changes, continual study in this field is crucial.

1.3 Methodology

The researcher searched a wide range of academic databases and respected publications for relevant literature for this review. To make sure that the results are still current and applicable, empirical articles that were published within the last six years were given priority. The chosen studies, which cover various geographic locations and institutional kinds, give various viewpoints and insights into risk management practices and operational efficiency in educational institutions.

2 Review of Empirical Studies on Risk Management Strategies and Operational Efficiency in Educational Institutions (EI)

Aetdinova, Chorosova, and Maslova (2020) examined the risk assessment methods of higher education institutions in Russia. The paper sets out two objectives and research questions to discuss the different methods of assessing risks in relation to universities in Russia. In collecting data, a questionnaire was shared using an expert poll of six experts who were invited (50% men and 50% women; experts' ages: 50% up to 40 years old, the rest older than 40 years old) from six Russian universities (Northern (Arctic) Federal University, Southern Federal University, Astrakhan State University, and Crimean Federal University). Such a large number of experts corresponds to a degree of authenticity in the analysis of up to 90%. The study adopted an explorative survey research design. Method of data analysis is inferential and descriptive statistics where the probability of occurrence and the arithmetic mean of the socio-economic risks characteristic of the universities were under consideration: risks of change in the budgetary policy in the area of education, risks of change in ownership at the university, inability to do jobs under business contracts, restructuring of the educational services market, deterioration of tax burden for the universities, change in the requirements relating to university applicants at the government level, fiercer competition among universities, demographic situation, teachers' low level of salaries which the probability of its occurrence is at a of 2,4,and 6 with the grand arithmetic mean of 4.432 signifying higher level likelihood of their materialization and the level of possible losses to the universities.

The study's problem statements were clear and educational, but the problem was not easily visible to the average reader. The study was limited to the researchers' capabilities and resources, and the objectives were answerable, but only two were stated. The purpose was clearly stated, and the methods used for data collection were explained. However, the population used was inadequate, with only 100 experts from six universities in Russia. The findings were well organized, sectioned, and reported objectively. The tables were well organized, but the statistical tests, especially the use of probability, were difficult for the average reader. The conclusions were not stated. Overall, the study was an interesting and significant contribution to the field of risk management strategies, a sub-variable of risk assessment.

Ahmad, Noor, Nor, and Azhar (2017) investigated risk assessment in infrastructure in educational institutions: A study of Malaysian post-basic schools. This particular study was conducted to assess the hazards of exposure in educational institutions and to highlight the possible risk levels available. Therefore, two specific objectives and two research questions guided the study using a descriptive survey research design. Data collection was collected by walkthrough observation and calculated using the Hazard Identification, Risk Assessment, and Risk Control form, where the risks were ranked using the Spearman correlation coefficient and multiplied by the rate of occurrence. The findings tabulation of the data analyzed shows that there are 5 groups of severity ratings: catastrophic-5, fatal-4, serious-3, minor-2, negligible-1, and likelihood rating: most likely-5, possible-4, conceivable-3, remote-2, and

inconceivable-1. Ranking hazards are represented by numbers. The first ranking (1) indicates that the hazard on the playing field was the highest compared to another area. The office or teacher's room indicates second ranking, which differs by one point from risk on the playing field. The canteen (3), classroom (4), and toilet (5) showed a medium level of risk, followed by the lowest (6) result for drainage. The paper concluded that the exposure hazard among the staff and educators is high, and further action and control are needed.

The authors' study's problem statements, objectives, and research questions align with its title and are significant. However, there is a gap in the objectives, as only two are limited by a proper risk assessment hypothesis. The authors cited clear literature, but the arrangements were skewed. The methods used for data collection were explained, but the authors failed to state whether the risk assessment and risk control forms were adopted, adapted, or developed. The population used was not stated, but the statistical tools were explained. The findings answered the research questions and were easily understandable by an average reader. Overall, the paper is a well-researched and significant contribution to the field of risk management strategies, a sub-variable of risk assessment.

Alsu and Alexander (2019) researched the university risk assessment and management systems of employees and students of the Kazan National Research Technical University, Russia. Educational organizations in modern society are full participants in economic activity; they also face various "threats" that affect the quality of their work. These risks can be located both inside and outside the organization. It is very important to realize that managing risks is possible only when they are known; otherwise, it is simply not feasible. To be competitive in the developing area of education, it is necessary to identify threats timely, assess them directly, and adopt any management decisions. Therefore, three objectives and three research questions guided the study. The study used a descriptive survey research design where an online survey questionnaire was used to gather data from 80 experts and 120 students from Kazan National Research Technical University, Russia. The external and internal risks at Kazan National Research Technical University, Russia, were analyzed using inferential statistics to determine the percentage and probability of risk occurrence and the degree of their influence on the quality of the institution. The result revealed that internal risks exist in not ensuring a high level of quality in educational services. 70% with 4,5 points of degree of occurrence; shortage of prospective students entering university for the first time: 25%, 3, 6; ineffective personnel policy (teacher professional development, teacher exchange programs, recruitment of third-party specialists, etc.) 40% with 2 points; corruption risk 15% with 1,2 points; and high cost of studying 20% with 1,5 degrees of occurrence. External risks result in an economic recession of 52% with a probability of 3,2 degrees of occurrence; rivalries between universities of 60% with 2, 4; reduction of budget funds allocated for education of 25% with 3, 5; reduction of the number of people entering the university of 40% with 4, 7; shortfall of budget funds of 45% with 2, 2; impact of global trends of 51% with 2, 1; reducing the quality of education at the university due to the development of its branches of 60% with 3, 7. Based on the results obtained, the findings conclude that for higher education institutions to provide high-quality education in their academic programs, risk management strategies such as risk identification, risk measurement, risk assessment, and risk planning are necessary to ensure the management systems of employees and students in higher education institutions.

The study's problem, objectives, and research questions were well-stated and measurable, but the absence of a hypothesis limited the interaction between variables. The sample size of 120 from one university in Russia is insufficient for general conclusions. Although the statistical tools are adequate, the lack of a hypothesis to test the relationship between variables and the population sample limits the generalizability of the findings. Overall, the work is a significant contribution to the field of risk identification, assessment, and control.

The study by Amos et al. (2022) on operational efficiency through operational resilience of private universities in Southwest Nigeria during COVID-19 Private universities were established to impact knowledge, enable unhindered learning, and ensure the timely turnout of graduates since their inception in 1999. However, private universities' operational efficiency was challenged and truncated by the outbreak of the COVID-19 pandemic, which motivated the thrust to determine their operational resilience along with their efficiency. Primary data were obtained from academic lecturers in eight selected private universities in Southwest Nigeria. The questionnaire used was adapted, and validity and reliability were established. Findings showed that operational resilience significantly affected the operational efficiency of the universities. β0 was 0.522 when X = 0. The value of 0.522 inferred that statistically holding operational resilience indicators to a constant zero, operational efficiency would be 0.522, implying that without operational resilience indicators, the operational efficiency of private universities in Southwest Nigeria would be 0.522. Operational resilience (mental health, physical work environment, technological work environment, workload, psychological work environment) had a significant positive effect on the operational efficiency of private universities in Southwest Nigeria (adjusted R 2 = 0.455, F (5, 526) = 89.703, p = 0.000). Also, the results for individual effects revealed that mental health (β = 0.087, t = 2.657, p = 0.008), physical work environment (β = 0.178, t = 4.963, p = 0.000), technological work environment (β = 0.301, t = 7.003, p = 0.000), workload (β = 0.111, t = 2.583, p = 0.010), and psychological work environment (β = 0.210, t = 4.719, and p = 0.000) had a positive and statistically significant effect on the operational efficiency of private universities in Southwest Nigeria. Therefore, institutions should leverage technology to enhance response and fast-track learning to drive their operational efficiency in the face of disruptions and pandemics.

The problem statements of the above study agreed with the title, even though they were clearly visible to the average reader, since they required several readings and research knowledge. The authors cited clear review literature; however, the study is limited because of several appropriate references used in the introduction section. The authors' objectives were two research questions that were answerable and two hypotheses that were stated. The purpose was clearly and concisely stated, which agreed with the title. The methods used to gather the data for this paper were clearly explained. The instruments and their development were explained. The findings were well organized and reported objectively based on the results and the findings of the study. There was a definite need for a short review of the literature and to make the statement of the problem visible to the reader, while the hypothesis of the study needed to agree with the objectives. Overall, it was a very in-depth research article with a significant contribution to the field of research in establishing a risk management process and policy in higher education.

Ekpenyong, Ekanem, and Nse (2020) have undertaken a study to assess the causal effects of a task-based approach to learning risk management on effective business decision-making and outcome appraisal at universities in Nigeria. The study used three objectives, three research questions, and a hypothesis to guide the study. The study was a true experimental design study aimed at knowledge and learning management (KALM) in universities for enforcing business accountability. The population included 250 undergraduate final-year students of educational management in public universities in Cross River State, Nigeria, for the 2017–2018 session. The sample consisted of 120 subjects purposefully selected. Research developed a scale titled 'Task-based Learning of Risk Management in University Business Management Scale (TLRMUBMS)'. The scale, comprised of 16 items of self-reported inventory, was used to assess the knowledge of university students after learning risk management in university business administration. Each item had an option A to D ranging from agree to disagree, which respondents indicated on a four-point rating scale. The scale maintained four sub-scales within the range of improvement in risk management, namely: planning, action, observation, and reflection. The instrument was face-validated, and a reliability coefficient of 0.88 was obtained using Cronbach's alpha method. The collected data was analyzed using mean, percentage, and

independent t-test analyses. The results showed that a task-based approach produced an improvement in knowledge after learning about risk management. The demographic results showed that the participants in this study were 63% male and 37% female. The federal university had 61% of the students, while the state university had 39%. The sample revealed 26% males and 34% females from each of the universities. Also, 17.2% of the respondents were aged 18–21 years, 23.7% aged 22–24 years, 30.3% aged 25–27 years, 11.1% aged 28–38 years, and 20.1% above 30 years. 17.4% had 3-5 years' work experience, 12.6% had 1-3 years' experience, and the rest, 69.8%, had no experience. Through the Joint Admission and Matriculation Examination (JAME) (68%), only 6% of the direct entry students were married, while 94% of them were single. 91% of the JAME entry students were single, while only 9% of them were married. The mean rating of task processes in learning risk management in university business administration was 2.89, SD = 1.72, which indicated task processes in learning risk management in university business administration are effective. The mean rating of risk management strategies in university business administration stands at 2.78, SD = 1.69, which indicates that risk management strategies in university business administration are effective, and the Cycle 1 scores were 43.42, 50.38, 56.57, and 60.45. Cycle 1 scores were 43.42, 50.38, 56.57, and 60.45, while cycle 2 scores were 72.38, 71.79, 75.32, and 80.72 percentages, which shows that there was improvement in students' activities as indicated by the 22.32 percentage. The calculated t-value of 0.04 was less than the critical t-value of 0.06. Therefore, the null hypothesis was accepted, indicating that there was no significant difference between male and female university students in learning risk management in university business administration.

The authors presented a study with a single hypothesis to guide the research while having four sub-variables. The experimental design was consistent with the title, and the data treatment and control group were presented in table form. Although the statistical tools used were simple percentages, they were limited in experimental research. The findings were adequate for a general conclusion, and the paper contributed to the field of risk identification, measurement, assessment, and planning.

Kehinde et al. (2020) conceptualized the operational efficiency construct within an institution context, specifically in the Nigerian higher educational institution, the university. The research applied a single case study to Covenant University, Ota, Ogun State, Nigeria. This study used a multi-stage development process based on an online survey. Seven dimensions were identified: teaching, research and publication, recruitment and selection, community service, technology, training and development, and effective communication. The study provides evidence of the scale's reliability and validity. The scale proposes a new approach to measuring and evaluating operational efficiency within higher educational institutions and shows the need to go beyond the traditional approach to efficiency.

Kehinde's et al. article tightened the statements of the problem and was not clearly visible to the average reader, and it required several readings and research knowledge. The authors cited clear review literature; however, the study is limited because of several appropriate references used in the introduction section. The authors' objectives were objectives; research questions and hypotheses were not mentioned, hence its limitations. The purpose was clearly and concisely stated, which agreed with the title. The methods used to gather the data for this paper were clearly explained. The instrument's reliability, validity, and development were explained. The findings were well organized and reported objectively based on the results and the findings of the study. There was a definite need for the problem of the study to be visible to the reader, while the objectives, research questions, and hypothesis of the study needed to be stated, especially in case study work. Overall, it was a very in-depth research article with a significant contribution to the field of research in establishing the dependent variable of this study, operational efficiency.

Kimani (2017) studied risk management strategies and the performance of construction projects in public secondary schools in Muranga County, Kenya. The study aimed to investigate the effects of risk management strategies and the performance of construction projects in public secondary schools in Muranga County, Kenya, with four objectives, four research questions, and two hypotheses that guided the investigation. The study employed a descriptive research design, while judgmental or purposive sampling techniques were used to select 136 respondents, comprising school principals, BOM chairpersons, accountants, SCEOs, and SCQASOs in public secondary schools in Muranga County, to participate in the study. The study used a structured questionnaire. Then the data was summarized and analyzed using descriptive and inferential statistics. The findings of the study were presented in the form of tables, frequencies, percentages, and pie charts to ease interpretation and understanding. Analysis of the data was performed with the help of SPSS software, where regression analysis was performed to determine the relationship between independent and dependent variables. The results indicated a risk avoidance strategy (3.686), a risk reduction strategy (3.628), a risk transfer strategy (2.583), and a risk retention strategy (3.14). The correlation analysis of risk management strategies and performance showed a positive correlation of 0.858 + 0.265 (R.Avd) + 0.228 (R.Rdn) + 0.114 (R.Tsnf) + 0.130 (R.Rtn) +. The findings led to the conclusion that risk management strategies have a significant influence on the performance of construction projects in secondary schools.

The author's problem statements have four objectives, four research questions, and three hypotheses that guided the study. The design of the study agreed with the title, while the population used was adequate and explained. The statistical tools used are adequate, and the sampled population is explained. Overall, this was a well-researched paper that was well-written. The article gap is due to the absence of one hypothesis to test the relationship between the variables. Overall, it was very good work with a significant contribution to the field of research in the sub-variables of risk avoidance, reduction, transfer, and retention strategies.

The study by Mahfod and Talha (2021) examined the perceptions of faculty members at Prince Sattam bin Abdulaziz University on the impact of accreditation standards on quality assurance (QA) and risk management within Saudi Arabia's higher education institutions. Three specific objectives, three research questions, and two hypotheses guided the study. Data collection was conducted with 305 participants who responded to an e-survey questionnaire that was conducted with quality assurance consultants. The study adopted a purposive sampling technique and a descriptive survey research design. The result was analyzed using descriptive statistics of mean and standard deviation to test the research questions, while to compare variances of mean scores, a t-test and Levene's test for equality of variances and an ANOVA with the Scheffe's post hoc test for multiple comparisons were used to test the hypotheses. Findings revealed that faculty members perceive accreditation standards to have a positive impact on Quality Assurance procedures of: (1) program management regarding handbooks, strategic planning, committees, KPIs, and feedback mechanisms stands at F (3, 301) = 17.589, p =.000, 2 =.149, indicating a moderate effect size; (2) missions and goals relating to stakeholders' awareness and mission consistency (303) = -5.201, p =.000, d =.082, representing a moderate effect size; (3) teaching and learning concerning course portfolios, periodic reviews, quality of teaching, outcomes, and coursework plans, F(3, 301) = 2.931, p =.034, 2 =.028, indicating a small effect size. (4) Faculty involvement in quality assurance and research output: F(3, 301) = 2.731, p =.031, 2 =.022, indicating a small effect size. (5) Risk management concerning resources and educational risks: F(3, 301) = 2.631, p =.033, 2 =.028, indicating a small effect size. (6) learning resources, facilities, and adequacy of equipment; and (7) students, with more emphasis on learning, admission policies, and involvement in assessment, F (3, 301) = 18.589, p =.000, 2 =.159, indicating a moderate effect size. Significant differences were found for gender, age, teaching experience, and academic rank since (p.05).

The authors' paper explores faculty members' perceptions of accreditation standards' impact on quality assurance and risk management in Saudi Arabian higher education institutions. The study focuses on a single university in Saudi Arabia, using descriptive survey tools and adequate statistical tools. The paper is well-researched and well-written, but it has gaps in citations, a literature review, and problem statement identification. It contributes significantly to the field of risk management strategies for quality control during university accreditation.

Onuorah, Nwankwo, and Okoye (2022) investigated secondary school principals' application of risk management strategies for secondary school improvement in riverine communities in Otuocha Education Zone in Anambra State, Nigeria. Three objectives and three research questions guided the study. The study adopted a descriptive survey design. The population of the study comprised all 28 public secondary school principals in the Otuocha Education Zone. The instrument for data collection was a structured questionnaire developed by the researcher. The instrument for data collection was validated by three experts in the faculty of education at Nnamdi Azikiwe University, Awka. A pilot test was conducted to test the reliability of the instrument. The test of reliability using the Cronbach's alpha method yielded coefficient values of 0.80, 0.77, and 0.72 for clusters B1 to B3, respectively. The Cronbach's alpha reliability analysis of the obtained data yielded a score of 0.76 for internal consistency. A descriptive statistic of mean and standard deviation was used to answer research questions 1–3. The result indicated that The cluster mean of 2.33 indicates that principals apply risk identification strategies for secondary school improvement in riverine communities in Otuocha Education Zone of Anambra State to a low extent; the cluster mean of 2.13 indicates that principals apply risk analysis strategies for secondary school improvement in riverine communities in Otuocha Education Zone of Anambra State to a low extent; and the cluster mean of 2.16 indicates that principals apply risk monitoring strategies for secondary school improvement in riverine communities in Otuocha Education Zone of Anambra State to a low extent. Findings showed that principals of public secondary schools do not apply risk identification, risk analysis, and risk monitoring strategies for school improvement in riverine communities in the Otuocha Education Zone in Anambra State, Nigeria.

The study adopted a descriptive survey design with three objectives and three research questions. The authors' cited review literature and provided clear citations in the introduction, which is their limitation. The purpose was clearly stated, and the methods used for data collection were explained. The population and instruments were explained, and the statistical tools were adequate. The findings were well organized and reported objectively. The paper was well-written and organized, but it needed to avoid citations and state hypotheses that aligned with the study's objectives. Overall, it made a significant contribution to the field of risk management strategies, including risk identification, analysis, and monitoring for secondary school improvement.

Öznacar and Gülyüz (2021) examined risk management strategies in the development of schools in Northern Cyprus. The article tries to show the risks that are available at schools and identify some strategies to manage the effects of such risks if they are likely to occur. Two objectives, two research questions, and a hypothesis guided the study. Thus, for education given at schools to become better and more effective, schools need good quality planning to avoid any risk that would prevent students from learning and facing treats. Therefore, establishing a risk management policy and conducting a risk analysis before the academic year begins will help to monitor risks and see weaknesses beforehand to maximize quality education. A descriptive survey research design was adopted to find out the opinions of teachers and administrators on risk management strategies and their contribution to the development of schools in Northern Cyprus. The research is done to reveal the opinions of teachers and educational managers and their past experiences in such cases using pre-test and post-test survey questions. The collected data was analyzed using simple percentages for the demographic data; probability was used to test questions 1–4, and ANOVA was used to test the hypothesis with the help

of SPSS. The result revealed that 60% of participants are male and 40% are female. The probability of risk occurring in Northern Cyprus schools is 55% to 40%, while there is a high relationship between the current risk management strategies used at schools and their development. As a result of this, for school quality to be sustained, risk management, risk policies, and risk strategies need to be supported.

The study, based on two specific objectives, research questions, and a single hypothesis, is limited to a single statement. The data collection tools, population, and sampling technique are adequate, and the statistical tools are adequate. The conclusion agrees with the results and findings, but there is an article gap in the introduction, difficulty in identifying the problem statement, and the author's only stated one hypothesis on three sub-variables. Overall, the work is a significant contribution to risk management, risk policies, and risk strategies in Northern Cyprus.

Porras (2021) investigated risk management for higher educational institutions for pedagogical advancement at Sultan Kudarat State University, Philippines. Technology in education allows students to learn more in less time and allows schools to focus on a global learning environment. Therefore, two objectives and three research questions guided the study; however, as change happens, the risk becomes an integral part of it. Thus, this paper promotes an IT risk management scheme for higher educational institutions to explore the different risks that teachers are facing in teaching and learning. A quantitative approach was used, a descriptive survey design was adopted, and fifty-three (53) teachers responded to the structured survey questionnaire on the risks encountered in integrating technology in the classroom. The results were analyzed through inferential and descriptive research methods such as frequency percentage, mean, and rank, and a 3-point Likert scale was used in determining the risk level. Results showed the mean scores and qualitative descriptions of the risk level of the different risks in the pedagogical advancement of HEIs. It shows that virus attack risk was 84.9 and ranked 1st, teachers insufficient skills in ICT were 75,46% and ranked 2nd, lack of technology integration was 67.48% and ranked 3rd, and lack of technical support, poor funding, teachers resistance to change, theft, and natural disasters were ranked 4th, 5th, 6th, 7th, and 8th, respectively. The result for the level of risk indicated that virus attack risk has a mean score of 2.53 and is rated high; teachers with insufficient skills in ICT (2.32) are rated moderate; technology integration is rated high (2.44); lack of technical support (2.56) is rated moderate; poor funding (2.60) is rated high; teachers resistant to change (2.00) is rated moderate; theft (2.17) is rated moderate; and natural disaster risk (1.26) is rated low. Since technology integration in HEI has become an important aspect of successful teaching, it is necessary to adapt the IT risk management scheme, that is, to identify, evaluate, monitor, and mitigate risks.

The author’s introduction is full of citations, while the problem statements, objectives, and research questions were stated properly and are measurable, but the absence of a hypothesis limited the interaction between the variables. The design tools for data collection, population, and sampling techniques of the study agreed with the title. The statistical tools used are adequate. Overall, this was a well-researched paper that was well-written. The article gap is in the absence of a hypothesis to test the relationship between the variables and the over-citations in the introduction.

The paper by Porsanger and Magnussen (2021) aimed to explore and understand teachers’ risk and safety management (RSM) practices in physical education (PE) programs in Norway. The study was guided by four objectives and four research questions. A survey questionnaire and semi-structured interviews were therefore used to generate quantitative data on trends from a larger sample of teachers (n = 698) and rich, in-depth qualitative data concerning teachers’ (n = 17) practices through a multi-stage sampling technique. By providing the teachers’ perspectives, a better understanding of the complexity of RSM in PE may be possible. An explorative survey design was used for this study, and the results were analyzed using descriptive statistics of the mean and standard deviation. The results

from both the survey and interviews suggest that teachers employ multiple strategies, from safety procedures to complying with compulsory risk measures to the use of common sense in their RSM practices, with M = 3.65 and SD = 1.335 indicating compliance with risk management. However, the interview data suggest that teachers do not primarily conceptualize this part of their practice as RSM but as measures of other pedagogical concerns. Combined, the results from both the survey and the interviews may characterize a RSM practice that relies on teaching experience and the use of discretion (M = 5.99, SD = 0.981), supervising students (M = 5.96, SD = 1.054), facilitating activities for the students (M = 5.84, SD = 0.933), and following up on rules (M = 5.74, SD = 1.089). The results in this article emphasize the importance of teachers' risk and safety management practices if physical education (PE) programs are to be sustained.

The authors' problem statements are difficult to identify; it requires high-level reading to deal with them. Two objectives and three research questions guided the study, and the objectives were measurable but limited in the total absence of hypotheses. The design of the study agreed with the title, while the population used was adequate and explained. The statistical tools used are adequate, and the sampled population is explained. The reporting system for the results and findings in tabular form is adequate. Overall, this was a well-researched and well-written work. The article gap is in the absence of one hypothesis to test the relationship between the variables and problem statements, which was difficult to identify. Overall, it was very good work with a significant contribution to the field of research in risk management strategies.

Raji and Akanbi (2019) studied the contributions of emergency risk management factors (risk identification, RI, risk evaluation, RE, risk analysis, RA, and risk mitigation, RM) to the PSSS effectiveness (school leadership, SL, school climate, SC, and teaching effectiveness, TE) in the FCT. The study used three objectives, one research question, and three hypotheses to guide the study using a descriptive survey design. Standards Australia's Risk Management Model provided the framework, while survey research design was adopted. All principals of the 57 PSSS in the six area councils of the FCT were enumerated, while 1,140 teachers (20 per school) were randomly selected. The RI (r =.87), RE (r =.79), RA (r =.88), and RM (r =.86) scales, as well as the School Effectiveness Checklist, were used to collect data. Descriptive statistics, Pearson product moment correlation, and multiple regression were used to analyze the data at the 0.05 level of significance. Fire extinguishers (62.3%) and buckets (56.7%), surveillance equipment (75.6%), and emergency management committees (42.8%) were either inadequate or not available in the PSSS. Risk identification (=0.196), evaluation (=0.317), mitigation (=0.260), and analysis (=-0.242) made significant contributions to SL. Only RE (=0.682) made a significant contribution to TE, while RI (=0.165) and RE (=0.157) contributed to SC. The PSSS authorities should make adequate provisions for emergency risk management devices and be proactive in adopting risk identification, evaluation, and mitigation measures in schools.

The article's objectives include one research question and three hypotheses that guided the study. The study adopted a descriptive survey design. However, the study is limited to only one research question, which does not cover the sub-variables of the study. The authors cited clear review literature; however, his introduction section is full of citations. The purpose was clearly and concisely stated, which agreed with the title. The methods used to gather the data for this article were clearly explained. The population and instruments were explained, and the statistical tools used were adequate. The findings were well organized and reported objectively based on the results. Overall, this was a very in-depth research paper with a proper conclusion. For the most part, it was well written and organized. There was a definite need to avoid citations in the introduction and to state three research questions that agreed with the objectives of the study. Overall, it was very interesting, with a significant contribution to the field of research in risk management strategies of risk identification, evaluation, analysis, and mitigation that can only be guided by effective school leaders and teachers.

Yang, Dong, and Liu (2022) studied the safety risks of primary and secondary schools in China: A systematic analysis using the AHP-EWM method. Owing to the frequent accidents in primary and secondary schools (PSS) in China in the past decades, a systematic analysis of indicators influencing safety risks in PSS is critical to identifying preventive measures. Three objectives were derived from the study, along with three research questions. A two-hierarchy structure of indicators was adopted from the Education System Overall Emergency Response Plan for Public Emergencies and the China Emergency Education and Campus Safety Development Report (2016–2019). In-depth interviews were employed to collect data from 111 respondents, who were randomly selected from the pool of teachers, school presidents, and principals. The results are as follows: Accidental Injury Risks (X4) = 0.1256 were the biggest source of risk with an evaluation value of 3.6377, followed by Public Health Risks (X2) = 0.3104, while Individual Health Risks (X7) = 0.1359 and Natural Disaster Risks (X1) = 0.2548 were the two smallest sources of risk with an evaluation value of 0.6377. In conclusion, several managerial implications are proposed for these stakeholders to reduce safety risks in primary and secondary schools in China.

The authors' problem statements were not clearly visible to the average reader, and it required several readings to establish why the researchers felt this study needed to be done. Three objectives with three research questions raised guided the study, and the objectives were measurable but lacked hypotheses limited in agreement with the three variables of the study. The design of the study agreed with the title, while the population used was adequate and explained. The statistical tools used are adequate, and the sampled population is explained. Overall, this was a well-researched paper that was well-written. The article gap is due to the absence of a hypothesis to test the relationship between the variables and a lack of clarity in the statement of the problem. Overall, it was a very in-depth research project with a significant contribution to the field of research in safety risk management strategies among primary and secondary schools in China.

Zaina and Mohammed (2021) examined establishing a risk management process and policy in higher education: a study of the Oman College of Nursing. One of the recent risks that nursing education is facing in Oman and all around the world is the post-COVID-19 pandemic. The spread of COVID-19 has forced nursing colleges to change their plans. Therefore, the purpose of the paper was to describe the experience of one nursing college in Oman during the COVID-19 pandemic and how it responded to the crisis. In addition, the research work was guided by two objectives, two research questions, and a hypothesis. A descriptive survey research design was adopted for the study. A survey questionnaire was used to collect data from 200 nursing teachers and students from a nursing college in Oman. The result revealed that despite the fact that there were no clear policies or guidelines for a risk management system with 1.267 at a low level, the nursing program in the college was able to develop a contingency plan to deal with the wide spread of COVID-19 at a moderate level of 2.57. The strategy of shifting learning from face-to-face teaching to online teaching was at a high level of 3.723, while postponing clinical practicum had a direct effect on learning at a high level of 4.213. Based on the results obtained, risks are inevitable; therefore, a risk management system should be part of any nursing college to help in the identification, planning, avoiding, transfer, or retention of any risk. Therefore, the Omani nursing curriculum should be flexible for risky changes and upgraded with more learning opportunities to respond to future educational problems during pandemic or non-pandemic crises.

The problem statements of the above study agreed with the title, but the problem was not clearly visible to the average reader, and it required several readings and research knowledge. The authors cited clear review literature; however, the study is limited because of several appropriate references used in the introduction section. The authors' objectives were two, with two research questions that are answerable, but only one hypothesis was stated instead of two to cover the sub-variables of the study, probably because of choice or limitation. The purpose was clearly and concisely stated, which agreed

with the title. The methods used to gather the data for this paper were clearly explained. The instruments and their development were explained. The findings were well organized and reported objectively based on the results and the findings of the study. There was a definite need for a short review of the literature and to make the statement of the problem visible to the reader, while the hypothesis of the study needed to agree with the objectives. Overall, it was a very in-depth research article with a significant contribution to the field of research in establishing a risk management process and policy in higher education.

3 Findings of the empirically reviewed papers

Based on the fifteen empirical papers reviewed, four out of the fifteen are from the continent of Europe (two from Russia, one from Cyprus, and one from Norway). In the same vein, the Asian Tigers of Malaysia, Saudi Arabia, the Philippines, China, and Oman each got papers from these respective countries. The continent of Africa got six papers, with Nigeria having five and Kenya having one, respectively. The findings show a wide spread but a limited number of papers and the absence of Latin America and South America. Therefore, the findings pointed out that for educational institutions to be operationally efficient and contribute to the development and innovation of our societies, there is a need for risk identification, assessment, communication, planning, implementation, monitoring, reviewing, culture, and risk mitigation

.

4 Conclusions

The primary purpose of this research work was to review empirical papers on risk management strategies and operational efficiency in educational institutions. The reviewed paper revealed that risks are potential causes of harm or accidents to employers, employees, students, and visitors; therefore, for educational institutions and organizations to navigate through risks and be operationally efficient, they must manage them by adopting risk management strategies of identification, planning, assessing, communicating, reviewing, implementing, monitoring, and mitigating the risk.

Reference

[1] Aetdinova, R., Chorosova, O., & Maslova, I. (2020). Risk assessment methods of higher education institutions in Russia. *Advances Journal in Economics, Business, and Management Research, 12*(8), 2678-2689.

[2] Ahmad, R. S., Noor, A. H., Nor, K. M., & Azhar, M. D. (2017). Risk assessment in infrastructure in educational institution: A study of Malaysia post-basic schools. *4th International Conference on Mechanical Engineering Research (ICMER), 012056*. doi:10.1088/1757-899X/257/1/012056

[3] Alsu, K., & Alexander, S. (2019). University risk assessment and management system of employees and students of the Kazan National Research Technical University, Russia. *Journal of Quality Management and Reliability of Technical Systems, 3*(6), 23-36.

[4] Amos, N. B. A., Dogo, E. B., Egwakhe, J. A., & Umukoro, J. E. (2022). Operational Resilience and Efficiency of Private Universities in Southwest Nigeria: The COVID-19 Pandemic Experience. *Journal of Business and Entrepreneurship, 10*(1), 1-14.

[5] Brown, M., de Kock, C., & Wakelin, D. (Eds.). (2019). *Risk management in higher education: A handbook for institutional decision-makers*. New York, USA: Springer.

[6] Coetzee, M., & De Jager, J. W. (2019). Risk Management in Higher Education: A Case Study of South African Universities. *Higher Education Research & Development, 38*(5), 1062-1076.

[7] Ekpenyong, E. E., Etor, C. R., & Nse, N. U. (2020). Task-based approach to learning risk management on effective business decision making and outcome appraisal of universities in Nigeria. *International Journal of Educational Studies, 13*(40), 133-144.

[8] Fabunmi, M. (2015). *Perspective in educational planning*. Ibadan, Nigeria: Awemark Industrial Printers.

[9] Fadun, O. S. (2018). Risk factors and risk management strategies as correlates of profitability and survival of selected small and medium enterprises (SMEs) in Nigeria. *Nigerian Journal of Management Studies, 18*(2), 12-26.

[10] Heubach, A., & Heubach, C. (2012). Risk Management in Higher Education: An Australian Case Study. *Journal of Higher Education Policy and Management, 34*(2), 189-199.
[11] Jings, D. J. (2021). Strategic planning effectiveness as a predictor of operational efficiency of universities in Plateau State, Nigeria. *Unpublished Master's Project*. MauYola, Nigeria.
[12] Jorim, E. B., & Koech, L. M. (2015). Factors Affecting the Efficiency of Technical Training Institutes in Kenya: A Case of Rift Valley Technical Training Institute. *International Journal of Education and Research, 3*(11), 75-88.
[13] Kanganas, A., & Pettersson, F. (2020). Risk management in higher education institutions: an exploratory study of challenges and opportunities. *Higher Education, 80*(6), 1193-1211.
[14] Kehinde, B. E., Ogunnaike, O. O., Ibidunni, A. S., Ilogho, S. O., Adedugba, A. T., & Kehinde, S. I. (2020). Operational Efficiency in Higher Education in Nigeria: A Scale Development: A Case Study of Covenant University, Ota, Ogun State, Nigeria. *Proceedings of International Conference on Advances in Education, 6th*.
[15] Kimani, P. M. (2017). Risk management strategies and performance of construction projects in public secondary schools in Muranga County, Kenya. *Journal Educational Management and Research, 3*(5), 234-249.
[16] Lester, J. P. (2014). Balancing efficiency and effectiveness in higher education through organizational design. *Higher Education Policy, 27*(2), 201-215.
[17] Mahfod, A., & Talha, A. S. (2021). Perceptions of faculty members at Prince Sattam Bin Abdulaziz University on the impact of accreditation standards on quality assurance (QA) and risk management within Saudi Arabia Higher Education Institutions. *Journal of Legal, Ethical, and Regulatory Issues, 24*(1), 1-17.
[18] Nnadozie, E. C., & Ezeh, P. C. (2019). Managing risks in higher education institutions in Nigeria: The imperative of enterprise risk management. *Journal of Economics and Sustainable Development, 10*(16), 26-33.
[19] Ogbuabor, J. E., Ikwu, F. C., & Nwakoby, N. C. (2018). Risk management in Nigerian higher education institutions: an empirical investigation. *International Journal of Economics, Commerce, and Management, 6*(5), 194-209.
[20] Oladimeji, J. A., & Akpan, E. S. (2022). Impact of enterprise risk management on the sustainability of financial institutions in Nigeria. *International Journal of Economics, Commerce, and Management*, United Kingdom, 10(7), 157-189.
[21] Onuorah, H. C., Nwankwo, N. B., & Okoye, F. N. (2022). Principals' application of risk management strategies for secondary schools' improvement in riverine communities in Otuocha education zone of Anambra State. *International Journal of Trend in Scientific Research and Development (IJTSRD), 6*(2), 1099-1105.
[22] Öznacar, B., & Gülyüz, D. (2021). Risk management strategies in the development of schools in Northern Cyprus. *National Academy of Managerial Staff of Culture and Arts Herald, 3*(1), 1071-1078.
[23] Porras, E. M. (2021). Risk management for higher educational institution on pedagogical advancement in Sultan Kudarat State University, Philippines. *International Journal of Management & IT, 13*(1), 29-35.
[24] Porsanger, L., & Magnussen, L. I. (2021). Risk and safety management in physical education: A study of teachers' practice perspectives programs in Norway. *Frontiers in Sports and Active Living, 7*(6), 1-13. doi: 10.3389/fspor.2021.663676
[25] Raji, I. A., & Akanbi, A. E. (2019). Emergency risk management factors and effectiveness of public senior secondary schools in the Federal Capital Territory (FCT), Nigeria. *Nigerian Journal of Educational Administration and Planning, 18*(1), 14-33.
[26] Ting, I. W. K., & Cho, V. (2015). Risk management in higher education institutions: An empirical study of the USA. *International Journal of Educational Management, 29*(1), 6-20.
[27] Yang, J., Dong, X., & Liu, S. (2022). Safety risks of primary and secondary schools in China: a systematic analysis using AHP–EWM method. *Journal of Sustainability, 1*(4), 82-98. doi: 10.3390/su14138214
[28] Zaina, M., Harmali, A., & Mohammed, A. (2021). Establishing a risk management process and policy in higher education: A Study of Oman Nursing-Midwifery College. *Journal in Nursing-Midwifery, 3*(3), 99-105.

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp. 297-307, November 13-16, 2023

Power and Authority Anchored on Christ's Leadership Style: It's Impact on Deconstructing Misleading Theologies in Pastoral Ministry in North-Eastern Nigeria

Sekenwa Moses Briska
{sbriska001@luthersem.edu}

Brønnum Lutheran Seminary, Yola. PO Box 74, Yola, Adamawa State, Nigeria. +234-810-035-3320 (NG)

Abstract
This research investigates the impact of power and authority in pastoral ministry in north-eastern Nigeria, focusing on understanding the dynamics of relational leadership in providing care and counselling among Christian communities and beyond. The research aims to lift up genuine pastoral power and authority in accordance with Christ's leadership style, highlighting the spiritual, sociological, and psychological freedom associated with the power and authority of leaders in the church. The study uses a descriptive survey research design, with student pastors and church leadership interviewed as participants. Data collection includes structured questionnaires and oral interviews. The objectives of the study include identifying forms of misuse of power and authority due to misleading theologies, recommending biblically rooted theologies based on the Christ model, and critically examining Jesus' alternative servant leadership style to contribute to bringing sound theologies and mutual leadership to Africa. The study also aims to determine the role of church leadership style in deconstructing misleading theologies among Christian communities, identify abuses of power and authority among church leaders, and use Jesus's leadership style in deconstructing misleading theologies through the hierarchical church leadership structure of pastoral care and counselling, freedom, self-learning, self-determination, and self-confidence of Christians in their collective participation in mutual servant leadership.

Keywords: Power, Authority, Leadership, Model, Servant, Participation

1 Introduction

The traditional exercise of power in leadership is meant to offer service to people and communities, since power comes from the authority bestowed on leaders by the community. Genuine power is not given as authority to control, discriminate, segregate or exploit other people on the basis of race, ethnicity class or religion. Leaders emerged from the communities as representatives to lead with humility. In most ethnic groups in Nigeria, a leader, elder, chief, king, or queen is regarded as a servant. It means a servant leader listens to all his or her people without discrimination. The traditional leadership that is community-based distinguishes the self from the power ego, which is obtained by force, violence, manipulation, and deception. This means one with power and authority takes care of people by settling disputes, listening, intervening, and guiding, helping to free others from the burdens of their challenges. People take their problems to the leader; it indicates that the traditional role of a leader comes with a sense of service to the people who empower the leader. It is stated that "God blesses humanity, and the responsibility of those who play a leadership role within these communities is a great concern for everyone."[30]

Power can be defined as "the ability to act or to be acted upon. A psychologically, socially, philosophically, and morally necessary part of our personal and social experiences, it is also open to great abuse."[31] While authority refers to "a fundamental relationship between persons, behaviours, or organisations and ideas in which one component has or is deemed to have important or legitimate

[30] Frouisou Samuel, "Theological Response to the Ecological Crisis, Wealth and Prosperity" In *Complexities of Theologies of Wealth and Prosperity: Africa in Focus*, Bosela E. Eale and Njoroge J. Nogige Eds. (UK: Woodstock Road, Regnum International, 2022) 87.

[31] C Kedekop, "Power" In *Dictionary of Pastoral Care and Counselling*, ed. Rodney J. Hunter, (Nashville: Abingdon Press, 1990, 2005),931.

power over the other."[32] In other words, authority is referred to as "the power or right to enforce obedience, a doctrine of moral or legal supremacy, the right to command or to make the ultimate decision."[33] This can be interpreted in so many ways, depending on the circumstances, event, and context. To have authority means one has full power or command to discharge duties or functions according to the authority given to the person.

Gradually, traditional leaders holding titles (such as elder, chief, king, emir, or queen) began to be viewed as power and authority as well as prestige and economic advantage, which reinforced control over people. Today, our cultural diversity (which includes traditional cultures, Islam, Christianity, and Western civilization) has had an impact on pastoral leadership by adapting to the form of exclusive racial, clerical, social-class, and ethnic supremacy; this has made them more powerful in enforcing these types of leadership in Nigeria.

Power and authority come from God, as found in the Scripture, which reveals the source of human existence. Power is understood as the capacity to control others for a purpose, while authority is the capacity to execute, carry out, or implement to actualize control and influence over others. Power and authority then have a major impact on human actions. As a result, there is discontinuity and continuity in understanding the dynamics of power and authority as they apply to our Christian faith and ministry.[34] We cannot keep to the old form of understanding of power and authority today as it was centuries ago. God is relational; as a result, power and authority mean participatory self-giving. Paul Fiddes states regarding language of power and authority that "personal language for God remains an analogy, but it has the capacity to be a language of participation, pointing to engagement in God and drawing us into such involvement."[35] This is because God values the human beings he created in his image and likeness for relational encounters, not by imposition.

Falola Toyin, a Nigerian historian, describes traditional political systems that existed among various tribes as "centralised and non-centralised."[36]states. However, outside forces have also influenced the area. For example, Islam introduced the caliphate, which means a territory over which a caliph's rule extends, stemming from the term "leader" in Islam.[37] In northern Nigeria today, these territories are called "emirates," being under the rule of an emir. The term "emir" is commonly understood as a rank or office, but in Islamic countries, the term refers to a commander or governor.[38] Furthermore, hierarchy is also based on various ethnic and regional forms of leadership, both organised and unorganized. Therefore, due to the current political system, economic hardship, and injustice, pastoral leadership is challenging.[39] Such leadership often suppresses the vulnerable and denies them their right to exist with full human dignity.

2 Theological Framework

Interview research questions were used to draw data from participants to understand the suffering, pain, and segregation being experienced by Christians and beyond in Africa due to the misuse of power and authority that exploits and destroys human dignity. With provoking issues raised, the following

[32] R. J. Arnot "Authority" In *Dictionary of Pastoral Care and Counselling,* ed. Rodney J. Hunter, (Nashville: Abingdon Press, 1990, 2005), 59.

[33]Arnot "Authority" 59.

[34]Gorden, D. Fee *God's Empowering Presence: The Holy Spirit in the Letters of Paul* (Massachusetts: Hendrickson Publishers, Inc., 1994), 3.

[35] Paul S. Fiddes, *Participating in God: A Pastoral Doctrine of the Trinity* (Louisville, Kentucky: Westminster John Knox Press, 2000), 33

[36] Falola, *The History of Nigeria,* 21.

[37] C.T R. Hewer, *Understanding Islam: An Introduction* (Minneapolis: Fortress Press, 2006), 37.

[38] Sir Alan Burns, *History of Nigeria* (New York: Harper &Row Publishers, 1972), 52.

[39]Burns, *History of Nigeria*, 48, 49.

questions were used to access the results of the research: What are the places of power and authority anchored in church ministry? What is the effect of power and authority on church leadership? How do power and authority influence the spiritual formation of Christians in northeastern Nigeria? Misleading theologies leads to the wrong use of power and authority and brings suffering. How can power and authority be a source of misleading theologies in pastoral ministry?

2.1 Power and Authority in Public Space

What is happening in various Nigerian communities is unfortunate because there are so-called stronger neighbours dominating the weak, which still persists in a new dimension. Control is apparent in both religious and secular governance and leadership. Major or stronger tribes who control political and religious governance tend to marginalise and exploit the weaker or minority tribes, which leads to continued tension. Burns claims that despite all the opportunities given to people for self-understanding and development, very little has changed because the situation in Nigeria today has taken on a different dimension of inflicting suffering on the people, and "the comparatively few years of ordered administration have not yet outweighed the centuries of chaos that preceded them."[40] Hatred and political, religious, and economic segregation persist due to the ongoing ethnic conflicts in the country. Stronger tribalism dominating the weaker tribe has become the order of the day, which dictates both secular and spiritual matters. With the above analysis, the problem of ethnic segregation and oppression in Nigeria is evident.

Leadership functions in public: power and authority wrongly misrepresented can be violently communicated in manners that defeat the meaning of Christian life, which should be a public expression of genuine love. There are times when power and authority mean confronting evil and wickedness in society in different ways. One of such ways is the long-held conspiracy that Christian leaders are sanctioned by God and can act anyhow because they are citizens of heaven. Christians are citizens of heaven, but they are also citizens of the world God created. Therefore, such an assertion does convey the fullness of the revealed God in Jesus Christ, because "He is the image of the invisible God." (Col. 1:15) who submissively humbled himself. Jesus Christ came into the world and lived among the human community; in his leadership, he used power and authority to pray for his disciples, asking God not to take them out of the world but to protect and secure them in the world (John 17:13–18). This affirms the fact that Christians have power and authority in the affairs of the world. Transforming human society requires just and peaceful co-existence where everyone enjoys freedom and love. This purpose of power and authority of Christ is manifested in the lives of people created in God's image in the world. Christ's power and authority mean love, peace, and justice for all human beings, regardless of their social standing.

2.2 Impact of Power and Authority Anchored in Christ's Pastoral Ministry

A non-hierarchical church leadership structure exemplified by Jesus Christ throughout his earthly ministry empowers the downtrodden and the outcasts in society. Christian life has power and authority that serve as a voice in both public and private (Luke 4:18, 19). Due to Christian inconsistency and voices in our society, people are very sceptical about the power and authority of the sermons preached in churches. This is because what preachers preach does not correspond with their lifestyles. Today, Nigeria is faced with numerous challenges, ranging from poverty, terrorism, violence, kidnapping, displacement of people, and human rights abuses.

Christ's power and authority are countercultural; right from the birth of Jesus, the news of his birth in the world became a threat to the world's human system of leadership. Jesus Christ's power and authority are to restore the glory of God. Jesus' ministry persisted through the gates of hatred, wickedness, and

[40] Burns, *History of Nigeria,* 26.

all forms of evil. Jesus, in his ministry, revealed the will of God; he confronted powers and evil forces with a clear interpretation of the Word of God. Jesus countered human cultures by reinterpreting the scriptures and value systems of human society. Church leaders are supposed to use their power and authority "to unearth and name the oppressive underlying social structures."[41] To actualize such change, leaders with power and authority, full of faith in Christ, need to embody the spirit, courage, and boldness to name evil by identifying every black spot in any system in order to eradicate them and establish a peaceful environment for the freedom of the whole creation.

In recent years, the church has experienced the challenge of empowered laity as they participate in church ministry. There are some who think that the power of the clergy will be reduced. On the other hand, there is this increasing sense of secularisation that takes away the attention of church leaders when providing leadership. Reactions to these challenges have led church leaders to stress their power and authority over their followers.[42] In trying to exert power, authority, and competence by pastors and leaders according to their expertise, they end up not achieving their objectives as desired. God himself came into the world through his Son in human form and lived among human society. This is to enable Christians to display their power and authority to confront evil, persecution, and injustice against humanity. In our individual differences, Christians can experience similar problems; reactions and approaches may appear in different ways. There are leaders who feel defeated even before they begin to think of being confronted by any challenges.[43] The word of God provides Christians with the enabling Holy Spirit power available to make the right choices in managing and exposing injustice, violence, persecution, and human rights abuses. Emmanuel Y. Lartey asserts that "the devastating loss of self-esteem, the hopelessness and rage that fuel intrapersonal and interpersonal violence, the dependency and despair in the suicidal person's eyes, and the survival mentality... require a psychological as well as a political and economic analysis."[44] and courage to respond constructively and assertively to human predicaments.

2.3 Impact of Power and Authority in Pastoral Leadership Ministry

Power and authority can permeate all forms of human structures, and as a result of social status, leaders are inclined towards controlling others instead of providing support. A certain negative effect of power in the traditional worldview impacts the church. What is commonly regarded as excessive power and authority in pastoral leadership is actually misuse of power in ministry. However, it is undoubtedly true that there are positive and negative influences of power in church ministry relationships. Certain attitudes and actions are always indicative of a hierarchy enshrined in power and authority that controls and leads to imbalanced leadership; ignorantly, others consider it to be normal leadership. In the affairs of God, human beings have powers, but one cannot be more powerful than the other. People know that every human being has innate power and authority over certain things, but they need to understand what type of power it is. Many do not seem to distinguish the power they display; it is always assumed that, by virtue of pastoral training, pastors are seen to have more power and authority than their members.

People think that positions come with power and authority entrusted to pastors; therefore, they can operate from a top-down style of leadership. This kind of view of power and authority is dangerous, especially when pastors are not conscious of the negative side of power and authority. They can easily subject those under them to unnecessary suffering. Ordinarily, when members addressed pastors with

[41] Lartey, *In Living Color*, 127.

[42] Arnot "Authority" 60.

[43] Gary M. Simpson, "God, Civil Society, and Congregations as Public Moral Companions, In Luther Seminary, Digital Commons @Luther Seminary, 2009), 67-68.

[44] Emmanuel Y. Lartey, *In Living Colour*: *An Intercultural Approach to Pastoral Care and Counselling*. (London UK. Jessica Kingsley Publishers 2003), 127-28.

their titles, they already assumed positions of power and authority. In this kind of situation, power has already been sanctioned, recognised, and accepted by followers; as a result, typically, people feel powerless to even think that they can themselves be empowered. Pastoral leadership is supposed to enable people to develop the capacity to be strong from the inside and have the skills to understand how other people feel, whether intimidated or not. Leaders need to lift people's confidence from below, and in the process, they also reveal the type of person they are as leaders.

As Christians, all power and authority are related to ministry issues. It can be creative, but it can also be destructive. There is a power differential between the pastor and the parishioner. The pastors are seen as those with more powers. They are considered to have answers to all problems. They may actually not have all the answers to everything, but they assumed to have more experience and power than the parishioners. With all these, we need to understand that power anchored in Christ is centred on serving people and not lording it over others. In terms of misuse of power, a person can misuse power wrongly. But one can also translate it into an empowering, enriching, relational, and mutual agent for people to grow. It is said, "Participatory management and patterns of authority that enhance the empowerment of human beings seem very often to be more effective than those that emphasise control."[45] It means that one has taken the position of a servant rather than a lord who is seeking to be served.

Misuse of power and authority is a misleading theology. African views of power and authority in beliefs and value systems support excessive use of power. The power difference that exists among pastors calls for the church to be sensitive in relationships that respect and value other people. Otherwise, power and authority can be misused by taking advantage of others, rather than being used as a creative, empowering force that liberates people. Evidently, this shows that there is a power differential between pastors and parishioners. Clergies can easily see themselves as lords, not as servants of the Word; they are served rather than serving their members. This shows how pastors are viewed as traditional kings, chiefs, and emperors within communities. People consider power to be greatness and prestige, not a responsibility to serve. Therefore, this view of power and authority in leadership is oppressive in that it humiliates or shames parishioners. Africa, specifically Nigeria, needs models with relevant resources to challenge domineering leadership that tends to exert excessive power. Pastors must acknowledge that they have power and authority, but they also need to be aware of the manner in which they apply it and not use it for their own selfish interests. This will undermine authoritarian forms of leadership in order to offer an alternative approach. Sound theologies create a conducive atmosphere for relationships between pastors and members, where power is not the key but humility, mutuality, and respect.

Describing positive and negative forms of power and authority means they can either be used for freedom or domination. In other words, there are different ways of exercising power and authority, either constructive or destructive, or to help, guide, rebuke, or silence others. This portrays the kind of self-consciousness with which some pastors understand themselves. They are shielded with power, like walls separating them from parishioners; relationships are supposed to flow freely in both directions. Pastors understand that power poorly used in pastoral care relationships scares people away. Pastors are supposed to be leaders that parishioners can confide in for support and guidance.

2.4 Impact of Power and Authority in Identifying Misleading Theologies

The use of power can be complex; it can help, rebuke, and encourage others. African culture teaches that a person is the boss or master; therefore, one can do everything; sound theologies, which are biblically rooted, teach us to respect one another. African culture says you are the boss; you are also a

[45]Arnot "Authority," 60.

servant of the people. With proper management of power, parishioners can be valued and respected by pastors as equal human beings. It is important to understand how to balance leadership that promotes peace, love, and justice. The dynamics of the use of power that has a double-edged sword are at the discretion of pastors to threaten instead or encourage, separate instead of creating unity. Pastors must discern when and how to manage their power appropriately.

Information can be used to transform power and authority. Information as a source of power is a key to any leadership; it is used for moral and ethical transformation that brings development and peaceful coexistence. Conferences like this play a major role in the formation of character and faith for attitudinal change. Leaders are supposed to use such a medium to address issues of injustice, discrimination, and violence against humanity. Doing so can help us provide alternatives for managing challenging conditions that affect human beings. Nigeria should not tread on this path because:
The ethical and moral values of the citizens have declined, giving room for the present moral and ethical decadence being experienced in the nation. Realizing the place of educational institutions in the dissemination of ethical and moral values, the church in Nigeria has gone back to establishing schools. Much as this is commendable, much is still needed to be done.[46]

2.4.1 The Role of Church Leadership in Deconstructing Misleading Theologies

Biblical Esther in the scripture stood for liberty and justice; her Jewish people found themselves facing a calculative attempt to eliminate them. The response of the Jews alongside Esther was a dual approach; it was through prayers, fasting, and the audacity of Esther to go and speak out to the King constructively and affirmatively at the appropriate time in a nonviolent manner (Esther 4:1–17). When we read especially (Esther 4:14), the verse makes it clear that our actions (prayers and fasting) must be accompanied by our public denunciation of the wrong use of power and authority for injustice against people. Considering the situation in Africa, Nigeria in particular, Ayankeye asserts that "the church (leadership) has to rise up and intervene."[47] with mutual use of power and authority for the good purpose of the church in sustaining God's creation. This should be done to mitigate all forms of suffering and various persecutions that people go through, rather than inflicting more suffering.

2.5 Jesus's Leadership Style of Participation

Pastoral leadership as the art of participation, Paul Stanley Fiddes asserts that "participation in this triune God affects both our images of God and our acts. Christ, as the second person of the Trinitarian perichoretic family, bore our burdens and invites us as partners to participate with our various gifts to fulfil one purpose; pastors need to understand the concept of bearing one another's burdens (Gal. 6:1). Yet we should notice that this is no new venture, for the doctrine of the Trinity has been a pastoral theology since its formulation."[48] The triune God indwells in God's self and extends the relationship to all humanity and creation. Each person of the Trinity is acting in relation to the other two persons as equals and without confusion. Yet, the three persons are not the same in their operations. This interactive relationality is the life of Triune, which continues to extend to us this relational encounter. The three persons of the Trinity exist in the greatest possible interdependency, through which God reaches out to the human community. God exists in reciprocal relationality.

---

[46] J. O. Adeloye, "The Role of the Church in Laying a Strong Ethical, Moral and Spiritual Foundation for Prosperous and United Nigeria" 157-168. In *Journal of the West African Association of theological Institutions: Politics and the Church in Africa*. eds, Stephen Oladele Ayankeye et al. (Ghana, Accra: SonLife Press, 2017), 166.

[47] Sunday Oludele Olajide, "Balancing Prayer and Work for Achieving a Prosperous United Developed Africa by 2063: A Case Study of Esther and Mordecai (Esther4:1-3, 5-17)" 123-135. In *Journal of the West African Association of theological Institutions: Politics and the Church in Africa*. eds, Stephen Oladele Ayankeye et al. (Ghana, Accra: SonLife Press, 2017), 128.

[48] Paul S. Fiddes, *Participating in God: A Pastoral Doctrine of the Trinity* (Louisville, Kentucky: Westminster John Knox Press, 2000), 8.

Confronting poverty, persecution, and injustice, as Christians can see from the example of Esther, indicates that it is the responsibility of every believer to be guided by leaders occupying positions of power. Pastors display an ambiguous attitude and approach to issues affecting believers in this context. Adejuwon states that "Christians in Nigeria seem to have become entirely complacent with the system of corruption in the land."[49] The power and authority of leaders should be able to summon the courage to confront the face of evil with boldness and love, instead of oppressing their subjects more. Today, we need to raise Christian leaders with strong conscience, spirit, and resilience, wherever they are. Trained pastors have a better opportunity to speak with confidence to challenge and confront violence and persecuting powers.[50]

Christians must have the boldness and inner courage of Jesus Christ, which are always required as sources of strength. With this, Christian leaders have the responsibility of speaking out according to their faith affiliations to display an authentic lifestyle in public space. However, the kind of approach to this obligation depends on the appropriate use of power and authority in language principles.[51] Faith in Christ's salvific work is the basis of Christianity and enables all believers to stand for justice. Jesus Christ demonstrated strong faith in his Father during trial, which led him to be crucified (Mk. 14:32–42). The church is called to proclaim this mission; however, "the church's responsibility is not only to preach the gospel but also to ensure the enthronement of a just, stable, and orderly society."[52]

3 Abuse of Power and Authority by Church Leaders

Pastors in Nigeria tend to overemphasise their traditional African understanding of leadership to the detriment of pastoral care ministry. In most places, the position of elders or leaders in a traditional community comes with certain powers over those under them, and most of the time, such authority cannot be challenged or critiqued. These leaders demand total obedience from their followers. For example, in Nigeria, "one 'always' belongs to a community that offers security but at the same time imposes some demand on one, depending on the individual.… Rituals are effective weapons in the traditional imagination. Not only do they inspire respect, they inspire fear as well, and individuals very easily obey them."[53] In such leadership situations, pastors tend to require members to honour and respect them as their spiritual leaders who are acting as representatives of God on earth.

3.1 Power and authority to bear one another's burden

Christian leaders who display humility are meant to bear one another's burden in Christ. Christ's humility is an example for guiding our pastoral ministry. God's divine power and protection poured out in Jesus Christ." Kenosis refers to the self-emptying of Christ in the incarnation as well as his conscious acceptance of obedience to the divine will that led him to death by crucifixion.[54] This is manifested in John 1:1ff. We have to understand the deepest relationality of the triune God expressed in Christ as kenosis, which was fulfilled by his death and resurrection. Jesus Christ emptied himself fully for the salvation of humankind, and by his love he entered into the human world and suffered

[49] Ezekiel A. Adejuwon, "Relevance of the Message of the Minor Prophets to Nigerian Context" In International *Council for Higher Education*. ed. Emiola Nihinlola (ICHE West Africa Network, 2017) 243.

[50] Emmanuel Y. Lartey, *In Living Color*: *An Intercultural Approach to Pastoral Care and Counseling*. (London UK. Jessica Kingsley Publishers 2003), 125.

[51] Thomas Oduro, *Christ Holy Church International: The Story of an African Independent Church* (MN: Minneapolis, Encounters in World Christianity, 2007), 211.

[52] J. O. Adeloye, "The Role of the Church in Laying a Strong Ethical, Moral and Spiritual Foundation for Prosperous and United Nigeria" 157-168. In *Journal of the West African Association of theological Institutions: Politics and the Church in Africa*. eds, Stephen Oladele Ayankeye et al. (Ghana, Accra: SonLife Press, 2017), 165.

[53] Ugwu, *Healing in the Nigeria Church*, 28.

[54]Stanley J. Grenz, David Guretzki & Cherith Fee Nordling, *Pocket Dictionary of Theological Terms* (Downers Grove, Ill: InterVarsity Press, 1999), 70.

death on the cross. Saint Paul tells us in Philippians 2:2–7 that Jesus "emptied himself" and became nothing. He did not regard his power and authority to dominate, but to empower, care for, and offer us eternal salvation. The implication of kenosis for the human community is that Christ's outpouring of himself fills our hearts and offers transformative sacrificial leadership. Kenosis in pastoral ministry: Christ's ministry goes beyond tribal, national, or cultural inclination that divides, offering salvation, freedom, respect, dignity, authenticity, and value to all human beings without any boundary. This suggests that "the Triune God turned in on Himself would not fulfil the ideal of communal being since the communion would ultimately be a closed one," but God opens up for humanity to be a part of it.[55]

4 Research Methodology and Research Design

The researcher adopts a descriptive survey research design where qualitative and quantitative methods are applied to draw both primary and secondary data. The population of the study comprises 2600 pastors and student pastors from three theological seminaries in north-eastern Nigeria (Bronnum Lutheran Seminary, Baptist Theological College Demsa, and Ecwa Theological Seminary Billiri). The sample size is 260, which represents 10% of the entire population. The selection was carried out through multi-stage sampling techniques, where 160 respondents were selected from Bronnum Lutheran Seminary, 50 respondents were selected from ECWA Theological Seminary, and Baptist Theological College Demsa, and the data gathered were analysed using simple percentages.
Discussion of Findings

4.1 What is the place of power and authority anchored in church ministry?

The place of power and authority anchored in church ministry was investigated, and a negative response with a cumulative 75% was obtained, which shows that power and authority in the church do not belong to Christian pastors only. The source of power and authority comes from Christ and is shared with no one. It received a negative response, with 57% strongly disagreeing, which indicates that the power and authority come from God and are shared with every faithful believer in Jesus Christ. But pastors claim the power as their personal property. The place of power and authority in the church is for excessive control from top-down for good ministry, which received a positive response with 76% agreeing. This reveals that every power and authority within the church that is anchored on Jesus should be used from top to bottom for the good of Christ ministry here on earth. This is where the problem lies; it is not meant for excessive power but for mutual and relational respect for each other. While 71% strongly agreed that sound theologies can produce mutual use of power and authority, 59% of the respondents agreed that power and authority are within the church or congregation for its purpose.

4.2 What is the effect of power and authority on church leadership?

The effect of power and authority in church leadership on Christians in North Eastern Nigeria was examined. The result shows that 81% strongly agreed that power and authority that is biblical is a means to liberate the church, and 74% of the respondents also agreed that power and authority empower people to live out authentic Christian faith when anchored on Jesus leadership styles. But what is used now does not seem to liberate and empower people to have self-respect. Also, cumulatively, 85% of the respondents strongly agreed that the genuine use of power and authority enables the church to build a community of faithful. But the current situation experiences discrimination and segregation among communities. While 72% cumulatively strongly disagreed that Christians who have power and authority at certain levels, whether in private or government agencies, are using it for the benefit of the church in Nigeria. This simply implies that most Christians in leadership positions use power and authority for their own personal gain. In contrast, 95% of the

[55] Ibdi., 78.

respondents strongly agreed on a positive note that misuse of power and authority brings suffering to believers and non-believers in north-eastern Nigeria. Today, we have more displaced people in north-eastern Nigeria.

4.3 How do power and authority influence the spiritual formation of Christians in north-eastern Nigeria?

In an attempt to investigate how the right use of power and authority influences the spiritual formation of Christians in north-eastern Nigeria, 57% strongly agreed that power and authority influence people into acts of righteousness, and 85% strongly agreed that sound theologies nurture people who are decent in their use of power and authority. Similarly, 77% of the respondents strongly agreed that power and authority, if faithfully used, can empower Christians to be productive in wealth creation and change the fortunes of Nigeria. There is so much poverty because it is not properly used. Participants (86%) strongly agreed that sound use of power and authority can change the church in Nigeria from its terrible condition, as Jesus did during his earthly ministry. While 87% of the respondents agreed that power and authority, if exercised according to God's will, will influence spiritual formation, The result shown above indicates that power and authority should have influenced the spiritual formation of Christians in north-eastern Nigeria, especially when they are anchored in Jesus leadership style. As a result of this empirical research, listen to this patriotic African leader who spoke about the misuse of power and authority for the purpose of liberating the masses. J. J. Rawlings, former President of Ghana

4.4 Misleading theologies leads to the wrong use of power and authority and brings suffering.

The result reveals that wrong use of power and authority can lead to misleading theologies among church leaders, with 88% of respondents strongly supporting this assertion, while 86% were of the opinion that misleading theologies make clergy feel untouchable in the ministry, and 80% of the respondents agreed that the biblical expression "touch not my anointed" makes pastors feel they are specially ordained more than their followers. This was concluded with 72.4% of respondents strongly agreeing that power and authority anchored on Jesus leadership style in the church can be used to eradicate poverty and suffering among Christians. The church needs to emulate Christ's mutual leadership style. But 83% strongly agreed that most pastors in the church use power and authority for their selfish interests and gains. The above result shows that misleading theologies lead to the wrong use of power and authority and bring suffering to Christians in north-eastern Nigeria.

4.5 How can power and authority be a source of misleading theologies in pastoral ministry?

In an attempt to investigate how power and authority are serving as sources of misleading theologies in Nigeria, 89% of respondents strongly agreed that power and authority in the church, when centred on ego, can be a source of misleading theologies. This is why it leads to the misinterpretation of biblical texts to suit one's interests. While 90.4% were of the opinion that power and authority can sway people into a love of material possession and focus on personal prosperity instead of Jesus flocks under their care. This is why there are so many prosperity sermons all over the continent. The opinion of 68% of respondents asserted a negative response, disagreeing with the fact that most Christians view the gospel as a source of prosperity and therefore use personal power and authority to acquire it. While 84% strongly agreed that misleading theologies in pastoral ministry are caused by the wrong application of power and authority in church leadership, a positive response from 90% of respondents strongly agreed that misuse of power and authority can lead to misleading theologies in the church, especially in north-eastern Nigeria. By this assertion, the result indicates that power and authority can be sources of misleading theologies if not properly applied based on sound Biblical interpretations of texts that are anchored in Christ's leadership styles.

5 Conclusion

From the above analysis, it is evident that pastoral leadership uses excessive power to control, oppress, and discriminate against people, not to serve in ministry. This encourages selfishness and false spiritual formation by rejecting sound theologies and equal participation, and it increases poverty among people. Leadership misusing power and authority does not emulate Christ's leadership; therefore, it continues to misinterpret scriptural texts for selfish interest.

Jesus spoke these words to his disciples in Matthew 20:25–26: "You know that the rulers of the gentiles lord it over them, and their great ones are tyrants over them. It will not be so among you; but whoever wishes to be great among you must be your servant. "This research provides a suggestion that the church should function in a more "Christlike" manner. The church has to repent and renew its ministry by embracing mutual participation.

6 Recommendations

1. Power and authority belong to God; leadership participation should not take the place of God but to emulate Christ's obedience and humility in service.
2. Leadership should embrace nonviolent leadership communication principles instead of excessive use of power and authority by dehumanising others for personal gain.
3. The church in Africa should focus power and authority on influencing spiritual formation with a leadership style that empowers others to serve God and humanity with humility.
4. Rather than theologies of prosperity, pastors and church leaders should use power and authority to liberate and alleviate the suffering Christians in Africa.
5. Pastors and church leaders should focus on authentic interpretation of biblical texts anchored on Christ's gospel message.
6. The church in Africa should embrace communal life as true Africans by taking on one another's burden.

References

[1] Adejuwon, E. A. (2017). Relevance of the Message of the Minor Prophets to the Nigerian Context. In E. Nihinlola (Ed.), ICHE West Africa Network. International Council for Higher Education.

[2] Adeloye, J. O. (2017). The Role of the Church in Laying a Strong Ethical, Moral, and Spiritual Foundation for a Prosperous and United Nigeria. In S. O. Ayankeye et al. (Eds.), Journal of the West African Association of Theological Institutions: Politics and the Church in Africa (pp. 157-168). SonLife Press.

[3] Arnot, R. J. (1990, 2005). Authority. In R. J. Hunter (Ed.), Dictionary of Pastoral Care and Counseling. Abingdon Press.

[4] Ayankeye, S. O. (2011). Pastoral Leadership and Holistic Ministry. In E. Nihinlola (Ed.), ICHE West Africa Network. International Council for Higher Education.

[5] Burns, Sir Alan. (1972) *History of Nigeria*. New York: Harper &Row Publishers.

[6] CRUX. (2017). Congo Illustrates the New Look of Christian Martyrdom. Retrieved from Cruxnow.com. Accessed May 18, 2021.

[7] Falola, T. (1999). *The History of Nigeria*. Westport, Connecticut: Greenwood Press.

[8] Fiddes, P. S. (2000). Participating in God: A Pastoral Doctrine of the Trinity. Westminster John Knox Press.

[9] Fee, G. D. (1994). God's Empowering Presence: The Holy Spirit in the Letters of Paul. Hendrickson Publishers, Inc.

[10] Eale, B. E., & Nogige, N. J. (2022). Addressing Contextual Misleading Theologies in Africa Today. Regnum International.

[11] Grenz, Stanley J. (1995). *Women in the Church: A Biblical Theology of Women in Ministry.* Downers Groves, Illinois: InterVarsity Press.

[12] Hewer, C.T. R. (2006) *Understanding Islam: An Introduction*. Minneapolis: Fortress Press.

[13] Lartey, E. Y. (2003). In Living Color: An Intercultural Approach to Pastoral Care and Counseling. Jessica Kingsley Publishers.
[14] Kedekop, C. (1990, 2005). Power. In R. J. Hunter (Ed.), Dictionary of Pastoral Care and Counseling. Abingdon Press.
[15] Luther, M. (1999). Luther's Works, Vol. 51: Sermon I. J. J. Pelikan, H. C. Oswald, & H. T. Lehmann (Eds.). Fortress Press.
[16] Oduro, T. (2007). Christ Holy Church International: The Story of an African Independent Church. Encounters in World Christianity.
[17] Olajide, S. O. (2017). Balancing Prayer and Work for Achieving a Prosperous United Developed Africa by 2063: A Case Study of Esther and Mordecai (Esther 4:1-3, 5-17). In S. O. Ayankeye et al. (Eds.), Journal of the West African Association of Theological Institutions: Politics and the Church in Africa (pp. 123-135). SonLife Press.
[18] Samuel, F. (2022). Theological Response to the Ecological Crisis, Wealth, and Prosperity. In B. E. Eale & N. J. Nogige (Eds.), Complexities of Theologies of Wealth and Prosperity: Africa in Focus. Regnum International.
[19] Simpson, G. M. (2009). Changing the Face of the Enemy: Martin Luther King Jr. and the Beloved Community. Digital Commons @Luther Seminary.
[20] Simpson, G. M. (2009). God, Civil Society, and Congregations as Public Moral Companions. Digital Commons @Luther Seminary.
[21] Turaki, Y. (1993, 2017). The British Colonial Legacy in Northern Nigeria: A Social Ethical Analysis of Colonial and Post-colonial Society and Politics in Nigeria. ECWA Productions Ltd.
[22] Ugwu, Chinonyelu Moses. (1998.). *Healing in the Nigerian Church: A Pastoral-Psychological Exploration.* New York: Peter Lang.

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp. 308–318, November 13-16, 2023

Reclaiming the Role of Philosophy (Reason) in the Christian Faith[1]

Johnson Madi[1], Ibrahim S. Bitrus [2]
{johnsonmadi@yahoo.com[1], bitrus_ibrahim@yahoo.com[2]}

(D.C.R.E (ABU, Zaria), B.Th, (TCNN/UNIJOS), M.A in Ethics and Philosophy (UNIJOS)).
Bronnum Lutheran Seminary, Yola. P.O. Box 74, Adamawa State, Nigeria. Cell: +234 8039625850[1], (NCE (Hong), BDD & M.Th. (TCNN, Bukuru), PhD in Systematic Theology (USA)). Senior Lecturer at Taraba State College of Education, Zing. Cell +23481303336154[2]

Abstract
Theology and philosophy are arguably the two greatest fields of divine and human knowledge that precede and give birth to other disciplines, including natural and social sciences. However, the relationship between these two subjects has always been controversial. Scholars, who perceive theology and philosophy as two separate antagonistic disciplines, deny outright the role of the latter in the former. As a darkness, they contend that philosophy has no light to shed on the Christian faith. On the contrary, those who maintain that the two subjects are mutually related, argue that philosophy is not anti, but pro-faith. As a rational friendly ally, they claim that philosophy is a tool with which theologians explicate the articles of the Christian faith. In this paper, we analytically describe the two conflicting views on the relationship between theology and philosophy. Without denying the tension between them, we contend that philosophy, reason plays an indispensable role in the Christian faith and life precisely because professing the Christian faith without a rational explication of its doctrines reduces it to a fideistic and irrational religion.

Key Words: Philosophy, Theology, Christian, Relationship, Role, Faith and Reason

1 Introduction

Our topic of discussion is one that has generated a lot of debate throughout the history of Christianity. Some of the famous statements concerning the relationship between theology and philosophy came from St. Paul, who said:

> See to it that no one carries you off as spoil or makes you yourselves captive by his so-called philosophy and intellectualism and vain deceit (idle fancies and plain nonsense), following human tradition (men's ideas of the material rather than the spiritual world), just crude notions following the rudimentary and elemental teachings of the universe and disregarding [the teachings of] Christ (the Messiah) (Colossians 2:8 AMP).

And Tertullian, who emphatically asked; "What indeed has Athens got to do with Jerusalem? What concord is there between Academy and the Church?"[56]

Even though theology and philosophy has a lot in common, in the sense that both deal with same subject matter: God, universe, man, truth, and ethics etc. Also, they deal with concept and issues that have direct effect on man and the society. But the debate has always been how these two relate to each other; throughout history it has taken different forms.

This paper analytically explores the suspicion and answer the question by these Christian scholars raised. We shall begin by defining the two terms, then go on to discuss the various position taken by scholars on what the relationship should be, and finally, we will examine the relevance of philosophy for the Christian. In the paper, we will use the term reason to stand for philosophy and the word faith for theology.

2 Conceptual Clarification

2.1 Theology

[56] Tertullian, *de praescriptione haereticorum,* 7; in Sources *chretiennes* vol. 46, ed. R.F. Refoule. Paris: Editions du cerf; 1957. P. 7

The term Theology does not occur anywhere in the Bible. So, the best place to start is the etymological meaning. Theology comes from two Greek words; *Theos* meaning God and *logos* meaning word about or the study of God. So, the term means talking, discussing hard about God.

Grace Theological Seminary opines that; "Theology is the study of God, God's character, God's actions in relation to the *cosmos*, and especially God's relationship to humanity (the character and history of humankind) in its responsive relationship to God within the panorama of the world and history, space and time."[57]

Thielicke and Louth states that; "Theology is the attempt of adherents of a faith to represent their statements of belief consistently, to explicate them out of the basis (or fundamentals) of their faith, and to assign to such statements their specific place within the context of all other worldly relations (e.g., nature and history) and spiritual processes (e.g., reason and logic)."[58] Erickson define Theology as; "that discipline which strives to give a coherent statement of the doctrines of the Christian faith, based primarily upon the scripture, placed in the context of culture general, worded in a contemporary idiom, and related to issues of life."[59] Theology, therefore, concerns itself with knowledge that has been revealed by God, which man must accept by faith.

2.2 Philosophy

The definition of philosophy is not free from controversy. Philosophers define philosophy differently.

> As a matter of fact, philosophers disagree on many issues and subject-matters including the notion of philosophy itself. The only matter on which they seem to have a consensus of opinion is that the term 'philosophy' does not have a universally acceptable definition. So then, is the definition of philosophy impossible? The answer is definitely no. Indeed, there are as many definitions of philosophy as there are philosophers.[60]

So, let begin with the root meaning of the word philosophy: Etymologically the word "philosophy" is derived from two Greek words: "Philos" is meaning, "love" and "Sophia" is meaning "wisdom." Therefore, philosophy means "the love of wisdom." But etymological definitions are by nature vague and superficial…. They come short of stipulating the true nature of philosophy. Most at times, philosophers would suggest that alternative definition be given that will be viable in the discus of philosophy.

Aben defines philosophy "as a critical reasoning or thinking and discursion or interaction on perennial issues confronting us in the world or universe"[61] Also, Omoregbe defines the term philosophy in two ways, that one; "it is a rational investigation with pondering questions in the mind as one wonders about the human experiences, with one singular aim to find out answers to that question. On the other hand, it is a rational inquiry using questions about the ultimate meaning of reality in general with particular focus on the human life, seeking for answers to such basic questions"[62]

---

[57] "Theology" by Grace Theological Seminary. Available at https://seminary.grace.edu. 16th December, 2020. Accessed on 15th April, 2023.

[58] Helmut Thielicke and Andrew Louth. "Theology". Encyclopedia Britannia. Available at https://www.britannica.com/topic/theology. Accessed on 15th April, 2023.

[59] Millard J. Erickson *Christian Theology* 2nd Edition. Grand Rapids: Baker Academic; 1983. P. 21

[60] Isaac E Ukpokolo. *Methodology of Research and Writing in Philosophy: A Guide*. Ibadan: Kairos Publishing; 2015. p 28

[61] Tersur Aben. *The Relevance of Philosophy in the Study of Theology.* T.C.N.N Monday Lecture Series giving on the 19th January, 2009. P. 1

[62] Joseph Omoregbe. *Knowing Philosophy* 2ndedition. Ikeja: Joja Press Limited; 2005. P. 3

Philosophy, at least as defined by Aristotle, is concerned with knowledge that man acquires through sensory experience and the use of the natural light of reason. To sum it up, Plantinga remarks that philosophy, "is just thinking hard about something"[63]

Philosophy is generally a reflective thinking about God, man, and the universe by asking questions and searching for meaning of concepts or words or terms. It is based on the force of arguments, trying to verify through reasoning by seeking to find out rational justifications for any views that are maintained or held.

Philosophy insists on coherency of ideas according to standard order or systematic presentation of ideas. Therefore, verification of ideas or facts is an essential aspect of this discipline. It also demands for proofs; it does not just take anything for granted or at face value but seeks to provide proofs for holding a rational position.

Philosophy engages the kind of reasoning different from the scientist (observation) but values judgment that attempt to establish the truth or falsity of proposition. Philosophy therefore, is simply a logical thinking or analysis of facts with the understanding of reaching a rational conclusion.

3 A Case for Disparity between Theology and Philosophy (Faith and Reason)

Here we have two schools of thought, which are religious pietism or fideism and rationalistic atheism.

3.1 Religious Pietism or Fideism

This constitutes a handful of theologians who rejected any relationship between the two fields or renounced any compatibility between faith and reason. They saw reason as irrelevant, as far as the development and preservation of the Christian faith is concerned. This kind of attitude manifested itself in the following people.

St. Paul, who in one of his epistles to the Church in Colossae warn them against philosophy, saying: "Beware lest anyone cheat you through philosophy and empty deceit, according to the tradition of men (sophistry), according to the basic principles of the world, and not according to Christ (Colossians 2:8 NKJV). What kind of philosophy is Paul talking about?

Tertullian (c. 160-230) is among the early Christian theologians that held this approach of disjoining theology and philosophy. He took a wholesale rejection of every aspect of philosophy for use in the Christian faith. He was trying to defend the divine foolishness of the Christian faith by denouncing philosophy as the demon-inspired mother of heresies. He put forth his comments as follows:

> Philosophy provides the material of worldly wisdom, in boldly asserting itself to be the interpreter of the divine nature and disposition. The heresies themselves receive their weapons from philosophy…. What is there in common between Athens and Jerusalem? What between the Academy and the Church? What between heretics and Christians? Our system of beliefs come from the porch of Solomon, who himself taught that it was necessary to seek God in the simplicity of the heart, So much the worse for those who talk of a "stoic," "platonic" or "dialectic" Christianity.[64]

[63] J.P. Moreland and William Lane Craig. *Philosophical Foundations for a Christian Worldview.* Illinois: InterVarsity Press; 2003. P. 28

[64] Tertullian, *de praescriptione haereticorum,* 7; in Sources *chretiennes* vol. 46, ed. R.F. Refoule. Paris: Editions du cerf; 1957. P. 7

By this Tertullian was implicitly implying that there is nothing in common between faith and reason. For him, Athens represents the philosophy of the Greeks and Jerusalem stands for the Christian faith. He regarded philosophy as antithetical to theology and therefore Christians should not rely on reason in their explicating and explaining Christian theology. He further exclaimed in regard to the death and resurrection of Christ by saying; "I believe because it is absurd; it is certain because it is impossible!"[65]

For him, it is sufficient that God himself has spoken and the only guide and standard for the Christian is the scripture in all matters of faith and doctrine, and there is a need to constantly be alert and guard against those seeking to ensnare the Christian using human reasoning. He concludes that the Christian come to know through revelation all that is needed for life and godliness; anything beyond that is dangerous, it is better to remain even ignorant than to risk being entangled in the evil grip of philosophy[66]

Furthermore, Erickson also has this to say on the comments made by Tertullian: "This approach regards philosophy as having nothing to contribute to Christian theology. In fact, the two have such different goals that the Christian is well advised to avoid contact and dialogue with philosophy completely, belief does not arise because of support from philosophy or other sources, but virtually *in spite of* the contribution of these disciplines."[67]
Finally, Lawhead also gave an interpretation of Tertullian statement about philosophy and theology to mean; "… just as Athens (the intellectual center of philosophy) and Jerusalem (the spiritual home of Christianity) are separated by hundreds of miles geographically, so pagan philosophy and the Christian Gospel are miles apart spiritually and can never meet."[68]

Another Christian thinker by name Pascal (1623-1662), who was an eloquent man spoke for non-rational approach to religious truth, also manifested this kind of attitude saying that: "The heart has its reasons which are unknown to reason . . . It is the heart which is aware of God and not reason. That is what faith is: God perceived intuitively by the heart, not by reason."[69] This implies that the Christian faith is very different from philosophical reasoning, and it is only reasonable when viewed with the eye of faith and not with philosophy – it will look irrational. He believed that there is a decidedly a non-rational aspect to Christian faith, and it is clear that even Pascal appeared to be preoccupied with it in practice. For example, Pascal tried to distinguish the god of the philosophers from the God of Abraham, Isaac, and Jacob.[70]

Furthermore, one of the most spiteful attacks on philosophy, which shows the disparity between theology and philosophy came from Martin Luther, the Medieval Reformer (1483-1546). Luther calls philosophy or reason, "the devil's whore."[71] Again, Luther in his Table-talk says, "Let philosophy remain within her bounds as God has appointed, and let us make use of her as a character in a comedy; but to mix her up with divinity *(faith)* may not be endured."[72] Luther is clearly setting a boundary for reason that does not allow its usage in the Christian theology. It is only to be used where necessary but does not contribute significantly to the development and preservation of Christian faith. Is it the whole

[65] Tertullian,
[66] Ed L. Miller. *God and Reason.* New York: Macmillan Publishing Company; 1972. P. 120
[67] Millard J. Erickson. *Christian Theology* 2nd Edition. Grand Rapids: Baker Academic; 1983. P. 41
[68] Lawhead, William F. *The Voyage of Discovery: A Historical Introduction to Philosophy* 4th Edition. Stamford: Cengage Learning; 2007. P. 124
[69] Blaise Pascal. *Pensees.* Translated by Martin Turnell. N.C: Harvill Press; 1962. P. 163
[70] Ed L. Miller. *God and Reason.* New York: Macmillan Publishing Company; 1972. P. 134
[71] *Luther's Works* (American Edition) vols. 40 and 51. Ed. Helmut Lehmann and Jaroslav Pelikan. St. Louis: Concordia Publishing House and Philadelphia: Fortress; 1955-1986. PP. 175; 374
[72] Martin Luther. *Table Talk.* Updated and revised from a translation by William Hazlitt. Gainesville: Bridge-Logos; 2004. P. 58

of philosophy or a certain kind of philosophy that Luther is talking about? This question will not be answered here.
Finally, on this subject, there is a non-Christian theologian; Averroes (a.k.a Ibn Rushd) (1126-1198). He was an Arabic Islamic philosopher, who developed a rich natural theology with argument for the existence of God. In his thought, he conceives a double concept of truth, thereby declaring that theology and philosophy have the truth, but they are totally distinct and separate issues from one another.[73] This simply intimate that there is no common ground between them, each can stand on its own since their truths are not same. Also, their sources of truth cannot be the same; they are completely incompatible with one another.

3.2 The Rationalistic Atheism

"By rationalism is meant the system or theory which assigns undue authority to reason in matters of religion…"[74]

This constitutes the idea of stressing the importance or superiority of the *mind (Reason)* over the *heart (Faith),* in the knowing process of anything to be true or that which gives the primary place or attention to the use of reason in inquiring about truth. It is the attempt of making every judgment in the light of reason rather than faith. The rationalist believes that reason is not compatible or is antithetical with faith. It seems unnecessary and unthinkable to them for anyone to be rational and still adhere to religious faith. In other to prove their claim and stand, rationalist gives excessive arguments that demonstrate the favorable position of reason above faith and tend to consider anyone who hold to religious faith as someone who is ignorant, lazy in the exercise of his mind to think, and having an intellectually weak-minded fellow in accepting the religious faith claims that are unlikely to true.[75]

Brown acutely reveals the main target of the rationalist: "Bound up with this is the assumption that, when this is done, reason will have completely disposed of the supernatural, and that we are left with nothing but nature and hard facts." That, even though the rationalist differs in the way they develop their systems, one thing is common to all of them, and this is the rationality of the universe and the ability of the power of reason to understand or comprehend it.[76]

4 A Case for Complementarity between Theology and Philosophy (Faith and Reason)

Under this heading we have about three schools of thought namely: The Evangelical/Reformed position, Roman Catholicism, and Deistic or Religious Naturalism.

4.1 The Evangelical/Reformed Position

Some evangelical orthodox Christian scholars or theologians in the Patristic, Medieval and even the Reformation periods saw the need to confirm that, reason is relevant to the Christian faith. They continue to affirm that reason and faith are necessary tools or ways through which we can come to know God. The orthodox Christian theologians believed that God in His infinite wisdom decided to reveal Himself to mankind in two ways: the general revelation and the special revelation. The general revelation consists of all that God created in the universe: all that we can see and all we cannot see; we know God through His creatures via the instrumentality of reason. While the special revelation consists of the scriptures and Jesus Christ, we know God here via faith. For them, faith and reason are essential

[73] Stuart McClintock. "Averroism," in *Encyclopedia of Philosophy* vol. 1, ed. Paul Edwards. New York: Macmillan, 1967. P. 225

[74] Charles Hodge. *Systematic Theology* Abridged Edition. ed. Edward N. Gross. New Jersey: P and R Publishing; 1992. P. 46
[75] Tersur Aben. *The Relevance of Philosophy in the Study of Theology.* T.C.N.N Monday Lecture Series giving on the 19th January, 2009. P. 3
[76] Colin Brown. *Philosophy and the Christian Faith.* Illinois: Inter-Varsity Press;1968. P. 48

medium for knowing God, but reason only complement faith in explicating and explaining the Christian truth. They characterize this relationship between faith and reason with an axiom: "Faith seeking understanding." Meaning that for the Christian, believing comes first before understanding and not the other way around. The Reformed/Evangelical position on the relationship between faith and reason is largely influenced by St. Anselm, St. Augustine, and John Calvin.

For St. Augustine (354-430), faith is not inferior to reason; and correct faith is never in conflict with reason. He put this in a cache phrase '*credo ut intelligam'* meaning; 'I believe in order that I may understand.'[77] Also, the relationship between faith and reason can be compared to the story of the Israelite leaving Egypt; although they left the evil practices of the people behind them, they carried the treasure (silver and gold) of Egypt along with them for proper usage. Likewise, theologians for the service of the Christian faith can appropriate the good aspect of philosophy. Augustine really maintains a good attitude toward philosophy, emphasizing the good aspect of it to be employed and used for the explicating the Christian truth because all truth is God's truth.[78]

He strongly holds that faith comes first before reason; therefore, reason is useful in validating faith. It was not in the power of reason to establish the truthfulness of the Christian doctrine, but contain the power to contribute to the degree of comprehending the doctrines that are believed by faith. Humans can only acquire knowledge when the two are working together in the right manner or order.

Also, St. Anselm (c. 1033-1109) did not differ much from Augustine in the matter of placing faith first before reason. His methodology is generally summarized with an axiom: '*Credo ut intelligam'* meaning; 'I believe so that I may understand' (Proslogion). He did not see any conflict between reason and faith, thereby employed the power of reason in his ontological argument to proof the existence of God. Anselm wrote in the *Proslogion*, saying:

I do not endeavor, O Lord, to penetrate thy sublimity, for in no wise do I compare my understanding with that; but I long to understand in some degree thy truth, which my heart believes and loves, For I do not seek to understand that I may believe, but I believe in order to understand. For this also I believe, that unless I believed, I should not understand" (Anselm 6-7). Furthermore, he began the essay by saying: "And so, Lord, do thou, who dost give understanding to faith, give me, so far as thou knowest it to be profitable, to understand that thou art as we believe; and that thou art which we believe.[79]

And finally, Calvin (1509-1564), in his *Institutes of the Christian Religion,* holds that reason is not anti-faith but rather he sees both as God's gifts to mankind. The human reason functions as faith's enlightener and this faith transcends human reason. He observes that reason is that which human beings use to distinguish between what is good and what is bad, and that which they employ to come to understand and judge is a natural gift of God. Calvin sees reason as an instrument or tool in the hand of Christian for explicating the Christian truth and doctrines. So, philosophical reasoning is not anti-faith but friendly to the Christian faith.

4.2 Roman Catholicism

In the Roman Catholic tradition, faith and reason are given a very prominent place and are regarded with high esteem. This is evident in the integrated training of the Catholic priests, which encompasses both theological and philosophical courses. Most of the Roman Catholic theologians if not all, place reason and faith on equal level.

[77] Augustine. *The City of God* in *Basic Writings of Saint Augustine II*, trans. M. Dods. New York: Random House; 1948. P. 11.2
[78] Alister E. McGrath. *Theology: The Basics.* Oxford: Blackwell Publishing; 2004. P. 8
[79] Anselm Basic Writings, 2nd edition. Translated by S.N. Deane. Illinois: Open Court Publishing Company; 1966. P. 7

> They even rank reason and faith equal in status as instruments for developing and sustaining Christian faith. Thus, seeing faith and reason as equals, St. Thomas Aquinas assigned certain doctrines to the domain of faith and he assigned others to the domain of reason. Aquinas says that Trinity, Creation, Resurrection, and Eternal Life are doctrine that we must believe by faith – which reason can neither teach nor confirm their veracity. But Aquinas says that the oneness of God, the Love of God, and the Laws of God are doctrines that reason too teaches or confirms their veracity.[80]

For Aquinas, there are basically two different kinds of knowledge that humans can gain and these are the natural knowledge available in the field of reason (philosophy), and the supernatural knowledge available by revelation from God and received by faith (theology). Both faith and reason are not in any way logically incompatible with one another, but rather different levels of operations or activities of the human soul within its own allocated zone, sphere or domain. The domain of reason contains knowledge that humans can acquire through experience and reasoning without any help from divine revelation, while the domain of faith deals with knowledge gain upon the ingredient of divine revelation.[81]

The Roman Catholic position is one that governs and controls the entire affairs of the church life and practice all over the globe. From the parish priest to the Pope, all are known for employing these tools (faith and reason) for use in both their religious and public life on daily basis.

Popes John Paul II acutely summarized this Roman Catholic position using the analogy of the bird in an Encyclical Letter "Fides Et Ratio" to the Bishops of the Catholic Church on the Relationship between faith and reason. He said, "Faith and reason are like two wings *(of a bird)* on which the human spirit rises to the contemplation of truth; and God has placed in the human heart a desire to know the truth – in a word, to know himself – so that, by knowing and loving God, men and women may also come to the fullness of the truth about themselves"[82]

Just as the two wings of a bird function to give a bird balance to fly, faith and reason also play the role in the life of a Christian. The two are necessary for correct and balance flight. Without one, the bird cannot fly. So also, is the believer who without one (faith or reason), he cannot acquire complete knowledge of God. This simply means that faith and reason must of necessity be placed at the same equal level or position in other to gain knowledge about God. Faith and reason comprehend correctly; can never be in conflict with each other.

4.3 Deistic or Religious Naturalism

The deist is a school of thought, which holds the idea that there is God, who is responsible for the creation of this world or cosmos but denies the fact that this God is not miraculously or supernaturally active in the running of affairs of humans or creations in the universe. They vary in their religious believe; some believe that God is good and the afterlife of the soul of an individual, others are strong anti-Christian polemics among whom are Voltaire, Francois Marie Arouet (1694-1778) and Thomas Paine (1737-1809). There are however, people like Thomas Jefferson, who seeks to marry deism with the Christian practice.[83]

---

[80] Tersur Aben. *The Relevance of Philosophy in the Study of Theology.* T.C.N.N Monday Lecture Series giving on the 19th January, 2009. PP. 3-4

[81] Ronald H. Nash. *Life's Ultimate Questions: An Introduction to Philosophy.* Grand Rapid: Zondervan; 1999. P. 170

[82] Encyclical Letter Fides Et Ratio of the Supreme Pontiff John Paul II to the Bishops of the Catholic Church on the Relationship between Faith and Reason. Published 14th September, 1998. Available at www.vatican.va Accessed on 15th April, 2023.

[83] *"Deism"* in A Dictionary of Philosophy of Religion. Edited by Charles Taliaferro and Elsa J. Marty. New York: Continuum; 2010. PP. 60-61

Whichcote (1609-1683) of the religious naturalism wrote, "To go against Reason is to go against God; it is the self-same thing, to do that which the Reason of the case doth require; and that which God Himself doth appoint: Reason is the Divine Governor of Man's Life; it is the very voice of God."[84]

On a general note the deist admit that reason is related to faith, but hold that reason come first before faith or reason is above faith or they prioritize reason over faith, in that they push or relegate faith as a tool for the acquiring of only religious knowledge. Insisting that nothing can be rationally believed which is not understood, therefore they maintain that they are not under any compulsion to believe all that is in the scriptures.[85]

In other to demonstrate their position, they engage in discussing ideas or concept without reference to the scripture or and refuse to acknowledge Church claims or teachings. A good example of this is Alighieri (1265-1321), who discusses the idea of hell in his explicit representation of the inferno, but at the same time, does not use scripture to support it.

Another deist by name Jefferson, believes in the existence of God as a religious naturalist and that is all about it. He only relies on the tool of reason to gain his knowledge about God but refuses to accept whatever the teaching of the church regarding God. And in our contemporary society, we have people like Wittgenstein (1889-1951) and some Logical Positivists who advocate and maintain that reason is above faith or that reason is primarily over faith and seek to explain the discussion of religious faith as a Language game, being played by a group of people in the Christian communities around the globe.[86] (Aben 4).

The deists propagate the supremacy of reason over faith, so whatever the claim of the church has about God, truth, and doctrines that cannot be explicated using reason is unacceptable and irrational to them, only that which is rational is the truth to believe. For them God is a rational being and if anybody desires to be a good Christian it is for that person to participate in the rationality of this being called God.

4.4 Role of Philosophy, Reason in the Christian Faith

The role of critical, logical, systematic and skeptical thinking in the life of any human being and the vocation of a theologian cannot be over emphasised. Man is a thinking being, this is what distinguishes him from other animals in the society. So, that one becomes a Christian does not negate his thinking faculty which is a gift from the Creator himself. In fact, Christianity is not a mindless faith but a rational one for that matter. Therefore, philosophy has an enormous relevance for a Christian theologian in a variety of ways. This can be seen throughout the history of Christianity – from the early period to the contemporary times.

> The history of the church reveals that philosophy has always played a crucial role in the nurture of believers and in the proclamation of a Christian world-view in general and the gospel in particular. The first universities in Europe were, of course, Christian, and the study of philosophy was considered of central importance to the health and vitality of the university and the Christian life. This is no less true today. In fact, . . . philosophy is crucial to the texture, curricula and mission of the Christian university and the development of a robust Christian life.[87]

[84] Colin Brown. *Philosophy and the Christian Faith.* Illinois: Inter-Varsity Press;1968. P. 75

[85] Charles Hodge. *Systematic Theology* Abridged Edition. ed. Edward N. Gross. New Jersey: P and R Publishing; 1992. P. 50

[86] Tersur Aben. *The Relevance of Philosophy in the Study of Theology.* T.C.N.N Monday Lecture Series giving on the 19th January, 2009. P. 4

[87] J.P. Moreland and William Lane Craig. *Philosophical Foundations for a Christian Worldview.* Illinois: InterVarsity Press; 2003. P. 34

First, philosophy aids in the task of defending the Christian faith – technically known as Apologetics. Apologetics is derived from a Greek word 'apologia' meaning 'defence.' "This is the task of giving a reasoned defence of Christian theism in light of objections raised against it and of offering positive evidence on its behalf"[88] The task of defending Christian faith against outsiders (unbelievers) and sometimes even from within, from those who embrace dangerous doctrinal error of the truth is a crucial one. But to do that effectively requires the aid of philosophy; for instance, to demonstrate or give evidence for the existence of God or to answer the question "Does God exist?" Also, the issue of the problem of evil – how can one vindicate God in spite of the evidential and existential evil that seem inconsistent with his attribute such as Omnipotent, Omniscience, Omnibenevolence? This cannot be a matter of just believe, one needs to demonstrate by argument – presenting a set of statements, which will serve as premises that lead to a conclusion in other to clarify and defend the theistic view. Doing this involve the use of philosophy. The attacks on Christianity normally and always involve the use of reason to object some of the beliefs like the Trinity, resurrection, angels etc. How shall one defend the faith, without depending on the evidence provided by the light of natural theology (the attempt to say what can be known about God or divine matters apart from any commitment to any claims to special revelation and so on)? The light of revelation is necessary but not sufficient to handle the objections against Christianity.

Christianity can flourish if she adopts the tools of philosophy in the practice of apologetics, it would help her in substantiating the faith against distortion of the truth. The scripture commands believers to not only tell what they believe, but also why they believe. ". . . always being prepared to make a defence to anyone who asks you for a reason for the hope that is in you" (1 Peter 3:15). Gerhard a Lutheran theologian explains that Apologetics are an essential part of the theological task. He outlines three reasons such an enterprise is important: first, to refute sceptics, second, to strengthen the faith of believers, and third, it perfects one's natural knowledge of God.[89]

Second, philosophy aids the church in its task of polemics – this is the task of criticizing and refuting alternative views of the world. There are legions of ideologies in the world, some of which are secularism, modernism, post-modernism etc, which are in direct conflict with Christian world view. A Christian theologian can develop a purely scriptural critique of such ideologies employing the tools of reason.

Third, philosophy is a central expression of the image of God in us as Christians. God himself is a rational being, and humans are made like him in this respect. They demonstrate this in their ability to engage in abstract reasoning, especially in areas having to do with ethical, religious, and philosophical issues. For Christians to deny the use of philosophy in theological enterprise is tantamount to an erroneous conception of the being called God. Frame affirms, "Scripture does teach that God observes the law of logic, not because there are laws "above" him to which he must conform, but because he is by nature a logical person. That God is logical is implied by the scriptural teachings that he is wise, just, faithful, and true – attributes that would be meaningless if God were free to contradict himself."[90]

Fourth, philosophy permeates systematic theology and serves as its handmaid in several ways. Philosophy helps to add clarity to the concepts of systematic theology. Further, it can help to extend biblical teaching into areas where the Bible is not explicit since theology needs to be systematized. Doctrines such as the attributes of God, Trinity, incarnation, human freedom, and Eucharist etc need a

[88] J.P. Moreland and William Lane Craig.
[89] Johann Gerhard. *On the Nature of God and on the Trinity*. Translated by R.J. Dinka. St. Louis: Concordia; 2007. PP. 56-57
[90] John M. Frame. *Apologetics: A Justification of Christian Belief.* New Jersey: P & R Publishing; 2015. P. 163

rational explication. Philosophy can provide the tools and terms that aid to add clarity and to shed more light on these concepts of systematic theology.

Fifth, the discipline or field of philosophy can facilitate the spiritual discipline of study. Study itself is a spiritual discipline, and the very act of study can change the self. Of course, the discipline of study is not unique to philosophy. But philosophy is among the most rigorous of fields and its approach and subject matter are so central to life . . . that the discipline of philosophical study can aid someone in the pursuit of truth in any other area of life or university study. And Christians believe that other areas of discipline are also a vocation from God and philosophy cannot be excluded from such academic pursuit.

Sixth, the field of philosophy is absolutely essential for the task of integration – to integrate means to blend or form into a whole. In this sense, integration occurs when one's theological beliefs, primarily rooted in Scripture, are blended and unified with propositions judged as rational from other sources into a coherent, intellectually adequate Christian worldview. Christians need to relate with other cultures in a way that is thoughtful and faithful to the culture of the scriptures. This requires the clarifications of questions of value, knowledge, and thought forms, and this can only be achieved through the involvement of philosophical victuals.[91]

C.S. Lewis said; "to be ignorant and simple now – not to be able to meet the enemies on their own ground – would be to throw down own weapons, and to betray our uneducated brethren who have, under God, no defence but us against the intellectual attacks of the heathen. Good philosophy must exist, if for no other reason, because bad philosophy needs to be answered"[92]

Eighth, philosophers are in the business of thinking clearly, cogently, and profoundly. So, for anyone to understand and evaluate their material requires an excellent mental exercise. Christian theologians, preachers, and teachers can benefit a great deal from this in the exposition of the subject matter to their audience.

Ninth, some of the difficult challenges that Christianity faces in history and will continue to face is from the discipline of philosophy. Therefore, when Christians study philosophy, they get the privilege of becoming acquainted with the most formidable adversaries of the gospel and this is a great benefit for the gospel witness.[93]

It is one thing to study philosophy; it is another thing to be involve in the art of philosophizing. One must make the choice of what to become.

5 Conclusion

In conclusion, faith and reason are not vicious enemies, but friendly colleagues in search for the truth about God, humanity, and the universe. Faith needs reason to explicate and explain the Christian doctrines for proper understanding. Also, to establish the certainty of what people belief. Therefore, it suffices to say that; all theologians are philosophers by nature, which they can either be simple or sophisticated in their enterprise, directly, or indirectly, but not all philosophers are theologians.

---

[91] J.P. Moreland and William Lane Craig. *Philosophical Foundations for a Christian Worldview.* Illinois: InterVarsity Press; 2003. PP. 14-17

[92] C.S. Lewis. *The Weight of Glory*. Grand Rapids: Eerdmans; 1949. P. 50

[93] John M. Frame. *Apologetics: A Justification of Christian Belief.* New Jersey: P & R Publishing; 2015. PP. 3-4

References

[1] Aben, T. (2009). The Relevance of Philosophy in the Study of Theology. T.C.N.N Monday Lecture Series given on the 19th of January, 2009.
[2] Anselm. (1966). Basic Writings (2nd ed.), translated by S.N. Deane. Illinois: Open Court Publishing Company.
[3] Aristotle. (n.d.). "Protreptikos," quoted in Jacques Maritain, An Introduction to Philosophy, translated by E. I. Watkin. New York. Cf. Clement of Alexandria, Stromata, Book VI, Ch. XVIII.
[4] Augustine. (1948). The City of God in Basic Writings of Saint Augustine II, trans. M. Dods. New York: Random House.
[5] Brown, C. (1968). Philosophy and the Christian Faith. Illinois: Inter-Varsity Press.
[6] "Deism" in A Dictionary of Philosophy of Religion. (2010). Edited by Charles Taliaferro and Elsa J. Marty. New York: Continuum.
[7] John Paul II. (1998). Encyclical Letter Fides Et Ratio to the Bishops of the Catholic Church on the Relationship between Faith and Reason. Published 14th September, 1998. Available at [URL]. Accessed on 15th April, 2023.
[8] Erickson, M. J. (1983). Christian Theology (2nd ed.). Grand Rapids: Baker Academic.
[9] Frame, J. M. (2015). Apologetics: A Justification of Christian Belief. New Jersey: P & R Publishing.
[10] Gerhard, J. (2007). On the Nature of God and on the Trinity, translated by R.J. Dinka. St. Louis: Concordia.
[11] Hodge, C. (1992). Systematic Theology (Abridged Edition), ed. E.N. Gross. New Jersey: P and R Publishing.
[12] Lawhead, W. F. (2007). The Voyage of Discovery: A Historical Introduction to Philosophy (4th ed.). Stamford: Cengage Learning.
[13] Lewis, C. S. (1949). The Weight of Glory. Grand Rapids: Eerdmans.
[14] Luther, M. (2004). Table Talk, updated and revised from a translation by William Hazlitt. Gainesville: Bridge-Logos.
[15] Luther's Works (American Edition) 55 vols. (1955-1986). Ed. Helmut Lehmann and Jaroslav Pelikan. St. Louis: Concordia Publishing House and Philadelphia: Fortress.
[16] McClintock, S. (1967). "Averroism," in Encyclopedia of Philosophy, vol. 1, ed. P. Edwards. New York: Macmillan.
[17] McGrath, A. E. (2004). Theology: The Basics. Oxford: Blackwell Publishing.
[18] Miller, E. L. (1972). God and Reason. New York: Macmillan Publishing Company.
[19] Moreland, J. P., & Craig, W. L. (2003). Philosophical Foundations for a Christian Worldview. Illinois: InterVarsity Press.
[20] Nash, R. H. (1999). Life's Ultimate Questions: An Introduction to Philosophy. Grand Rapids: Zondervan.
[21] Omoregbe, J. (2005). Knowing Philosophy (2nd ed.). Ikeja: Joja Press Limited.
[22] Pascal, B. (1962). Pensées, translated by M. Turnell. Harvill Press.
[23] Tertullian. (1957). De praescriptione haereticorum, 7, in Sources chretiennes, vol. 46, ed. R.F. Refoule. Paris: Editions du cerf.
[24] Thielicke, H., & Louth, A. (n.d.). "Theology" in Encyclopedia Britannica. Available at [URL]. Accessed on 15th April, 2023.
[25] Grace Theological Seminary. (2020). "Theology." Available at [URL]. Published 16th December, 2020. Accessed on 15th April, 2023.
[26] Ukpokolo, I. E. (2015). Methodology of Research and Writing in Philosophy: A Guide. Ibadan: Kairos Publishing.

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp. 319–326, November 13-16, 2023

Engaging Government in ICT Policy Formulation for Girl-Child Participation in Science, Technology, Engineering, Art and Mathematics Education in Nigeria

Ibrahim Umaru Jongur[1], Fatima A. Umar[2,] Dahiru Sintali[3]
{Jongur2@Yahoo.Com[1]}

School of Early Childhood Care and Primary Education 08060702394[1], Federal College of Education, Yola[2], Adamawa State, Nigeria.

Abstract
Globally, since 2000, study after study has made it clear that there is an alarming crisis in relation to students' interest in STEAM education particularly biology. This paper examines the influence of government policy engagement in Information Communication Technology of the girl-child in Science, technology, engineering, art and mathematics (STEAM) in Nigeria.It viewed ICT simply as communication gadgets or equipment that have modernized, improved and eased exchange of ideas and information of various kinds between and among people within or across distant boundaries/frontiers. A gender-responsive ICT policy is one that equally considers and addresses the connectivity challenges and needs for all groups in society, and takes into particular consideration the unique challenges faced by women and girls.
The paper outlined following as strategies that should be employed to ensure the girl child have access and engagement with ICT facilities for STEAM learning: Development of ICT infrastructure; Enabling environment; Government Engagement of Stakeholders; Legal, institutional and regulatory framework; Exploring partnerships; How ICT will facilitate growth and the achievement of development objectives; and using a multi-stakeholder approach is required for the development of ICT policies and strategies. It identified some Factors That Restrict Women's Equal Participation in ICT and STEAM to include among others: Lack of government leadership and direction; Ignorance; Gender issues;Globalization and Technological Changesin addition to cultural, social and religious undertones. It concluded that ICT provides every opportunity to improve the challenges facing the women and girl child education in STEM education, Technology, Engineering, Arts and Mathematics in Adamawa State. Therefore, policy reform is required in bridging the gap in the accessibility, participation and engagement of girls and women in STEAM using ICT educational resources.

Keywords: Government Policy Engagement, Information Communication Technology, Girl-Child, STEAM education, Technology, Engineering, Art and Mathematics

Epigraph

"On a worldwide scale, STEM education... is still a man's business. This situation is no longer acceptable. It is economically unacceptable because of the waste of human resources that it entails; it is humanly unacceptable since it prevents half the population from taking part in building the world; it is intellectually unacceptable as it deprives scientific and technological research of ideas and methods, in a world, of creativity……." (—Federico Mayor (1999), the Director General of UNESCO2019).

1 Introduction

Globally, since 2000, study after study has made it clear that there is an alarming crisis in relation to female students' interest in STEM education and technology particularly biology, either as a possible future career, or as an intrinsic interest that will continue after school (Fensham, 2008). Girl-child education is the process through which the girl child is made functional members of her society. It is a process through which the girl-child acquires knowledge and realizes her potentialities and uses them for self-actualization, to be useful to her and others (Olaniyi, 2021).

UNICEF report in Olaniyi (2021) indicates that some 121 million children are out of school for various reasons and 65 million of them are girls. With the educational rights of 65 million girls unmet, something should be done to ensure that they complete their education. The same report indicates that

Nigeria is one of the 25 developing countries of the world with low enrolment rates for girls, gender gap of more than 10% in primary education and with more than 1 million girls out of school (Olaniyi, 2021).

According to the UNESCO (2020) groundbreaking report on cracking the code: girls' and women's education in STEM reveals that only 35% of STEM students in higher education globally are women and differences are observed within STEM disciplines. For example, only 3% of female students in higher education choose information and communication technologies (ICT) studies. This gender disparity is alarming, especially as STEM careers are often referred to as the jobs of the future, driving innovation, social wellbeing, inclusive growth and sustainable development (UNESCO, 2020).

In Nigeria, an average girl-child faces significant obstacles in accessing proper education because of many circumstances, including socio-cultural norms and economic barriers and practices that inhibit formal education, especially for girls (Olaniyi, 2021). According to the Nigeria National Bureau of Statistics (2020) report, the percentage of males and females in the total population is approximately equivalent: 49.2% and 50.8%, respectively. This model is comparable across rural-urban areas and the states. However, more male children are in school than female children in Nigeria. According to a UNICEF (2015) report, the female adult literacy rate (ages 15 and 9 above) in Nigeria was 49.7% compared to that of males, 69.2%, with a gender difference of 19.5%. In the northeast part of Nigeria, the picture is even bleaker (Olaniyi, 2021).

According to U.S. Bureau of Labor Statistics (2020) globally, women make up only 28% of the workforce in science, technology, engineering and math (STEM), and men vastly outnumber women majoring in most STEM fields in college. The gender gaps are particularly high in some of the fastest-growing and highest-paid jobs of the future, like computer science and engineering. Women in STEM Occupations: Biological Scientists 46% Chemists & Materials Scientists 40.4% Computer & Mathematical Occupations 25.2% Engineers & Architects 16.5% (U.S. Bureau of Labor Statistics, Table 11, 2020).

Therefore, empowering girls and women to enter STEM fields of study and careers, and stay the course, is an imperative (UNESCO, 2020). As Ministers of Education and other stakeholders pointed out during the UNESCO International Symposium and Policy Forum on this topic (Bangkok, 2017), this requires holistic and integrated responses that each across sectors and engage girls and women in identifying solutions to persistent challenges. Therefore, UNESCO's work in this area aims to:

i. Improve the participation, achievement and continuation of girls and women in STEM education and careers to reduce the gender gap in STEM professions
ii. Strengthen the capacity of countries to deliver gender-responsive STEM education, including through teacher training, educational contents and pedagogy
iii. Enhance awareness of the importance of STEM education for girls and women.

The list of countries experiencing declining interest of students in STEM education is on the increase in both developed and developing countries of Africa (Fensham, 2008). One factor which has contributed to low interest in biology by students is the method adopted for teaching and learning STEM education. Fensham (2008) listed four views of students which contribute directly to low interest in STEM education:
(i) STEM education teaching is predominantly transmissive, (ii) The content of STEM subjects has an abstractness that makes it irrelevant, (iii) Learning STEM is relatively difficult, for both successful and unsuccessful students particularly girls, and (iv) Hence, it is not surprising that many students in considering the senior secondary years as waste: Why should I continue studying STEM education

subjects when there are more interactive, interesting and less difficult ones to study? Fensham asked (Fensham, 2008 p. 20-21).

This unhealthy development in the disposition of students towards STEM subjects has sparked the search for and development of alternative methods of STEM teaching and learning which can stimulate students' interest and guarantee an educational system that offers equal opportunities for all sexes (Ekine, 2013). STEM education as a field of study is therefore in dire need of methods with qualities such as lesson clarity, promotion of self-activity, promotion of self-development, stimulation of interest and curiosity and relying on the psychological process of teaching and learning to recommend to biology teachers (Ajaja, 2013). The methods should encourage biology teaching and learning that is better than it is now. Many students today are learning biology in a passive way in classrooms where information is organized and presented to them by their teacher (Moyer, Hackett & Everett, 2007). They noted that "often, the teacher pays little attention to what students already know about STEM education. In this learning model, the information transmitted by the teacher and curriculum materials is assumed to make sense and seem reasonable to the students" (Moyer, et al., 2007 p.4).
Like other countries in the Global South, Nigeria has in recent years sought to ensure equitable access to education for all. In this context, girls' access to education has received attention at the policy level, and progress has been made toward gender parity in enrollments in some regions of the country. However, far less attention has been paid in Nigeria to the quality of children's learning and to girls' participation in different areas of learning, including STEM education and technology
The major dilemma that Nigerian youths particularly the girl-child are faced with is the inability to create jobs and businesses which will enable them not only become self-employed but also become self-reliant capable of creating jobs attributed to low level of STEM education particularly among girl-child (Igwebuike., & Ikponmwosa, 2013). To confirm this, the UNESCO Global Education forAll (EFA) Monitoring Report 2015, indicted that Nigeria has 10.5 million out-of-school children - the highest number in the world. 60 per cent, of them live in the northern part of the country and of this figure over 71 per cent are girls and women as reported by Reed (2019) reporting for UNESCO. Graduates in skill oriented field of study like STEM education, Technology, Engineering, Arts and Mathematics (STEAM) subjects known for their capability of equipping learners with life skills that enhance self-reliance, independence, empowerment and self-employment continue to search for paid employment instead of being job creators (Igwebuike., &Ikponwwosa, 2013). This situation is further compounded by women and girls lack of access to, skills and engagement in ICT and STEAM related fields.

The reality of ICT convergence has not yet been reflected in Nigeria where the institutions that regulate and/or develop the ICT sector still function as distinct actors in the industry, without much coordination (FGN, 2012). Though there have been significant gains over the last decade, especially with regard to mobile telephony, the lack of industry convergence in the Nigerian ICT sector has resulted in fragmentation and inefficient management of resources.

The goal of this National ICT Policy therefore is to provide a framework for streamlining the ICT sector, and enhancing its ability to catalyze and sustain socioeconomic development critical to Nigeria's vision of becoming a top 20 economy by the year 2020. Concurrently, the policy thrusts will facilitate the transformation of Nigeria into a knowledge-based economy and will be used to develop action plans, sub-sectorial policies and specific implementation guidelines as appropriate.

On October 17 2017, the World Wide Web Foundation and Paradigm Initiative hosted a Workshop on Closing the Digital Gender Gap (CDGG) and Mainstreaming ICTs into Women's Rights Policy and Program Frameworks (WRPPF) in Nigeria. The Workshop, suggested for exploring the existing government digital literacy initiatives able to reach rural/urban poor populations: e.g. The Office on

SDGs working on initiatives to connect people in remote areas through various programs in its state offices nationwide (Paradigm, 2017).There should be an effort to map and coordinate existing government and cooperate initiatives around bridging the digital divide in the use of ICT in STEAM in schools, (such as initiatives from NITDA, TETFUND, MTN, e.t.c) with the aim to avoid waste, redundancy and duplication of efforts, and to promote programme effectiveness.

The CDGG Workshop, also touched on the role of government stakeholders in working together to ensure the right mix of regulatory initiatives and intervention not only needed to encourage greater competition among market players but also to encourage deeper penetration and use of ICT services. In this respect, it will be tempting to ask:

1. To what extent has the government implemented concrete policy goals for gender equity in internet access and use?
2. To what extent has the ICT policy supported girls' participation in STEAM?
3. To what extent has ICT increased access to information for the girl child in improving STEAM learning?
4. How can government policy engagement in ICT of the girl-child in STEAM in Nigeria?

The paper will attempt to answer these questions through secondary review of relevant and current literatures.

2 Information Communication Technologies (ICTs)

Information and communication technologies are often synonymously used with New Media or New Communication Technologies. They are simply communication gadgets or equipment that have modernized, improved and eased exchange of ideas and information of various kinds between and among people within or across distant boundaries/frontiers. ICTs extend and change the entire spectrum of technological possibilities for public communication. Tiamiyu (2003) describes ICTs as a generic name used to refer to a number of communication hardware adopted in ensuring instantaneous dissemination of information and social values across the globe. It is also a disparate set of communication technology that shares that digitization made possible and is widely being made available for personal use as communication device. The essential features of the ICTs lie in their interconnectedness, their accessibility to individual users as senders and/or receivers, their interactivity, their multiplicity of use and open-ended character and their ubiquity. These features essentially describe a computer-mediated medium, the internet.

Women's marginalization from ICT stems from the assumption that women benefit less from new educational and employment opportunities. Gender differences also exist with regard to access to information, access to ICTs, developing skills to search for information, and the very use of these technologies in STEAM.

In an entrenched patriarchal society like Nigeria, women and girls were much less likely to use media especially computer based media. This is partly because women lack the necessary skills to make use of the ICTs and had many negative attitudes about these media. Notwithstanding, in recent years there are some changes in women's use of the ICTs whereby they are now developing skills needed to operate this new technology effectively. The potential of the ICTs for the advancement of women is considerable. Networking, research, training, sharing of ideas and information– all these could be infinitely easier through relatively affordable computer-mediated communications such as E-mail, Internet hypertext and hypermedia (Steffen, 1995).

3 What is a gender-responsive policy?

Rufai (2004) stated that for any country to succeed and develop economically and technologically, girl child education should be a focus for policy formulation and implementation as far as democracy in concerned. A gender-responsive ICT policy Rufai argued is one that equally considers and addresses the connectivity challenges and needs for all groups in society, and takes into particular consideration the unique challenges faced by women and girls when it comes to accessing and using the internet. In so doing, it helps to ensure equal outcomes for women and men.

Developing a truly gender-responsive ICT policy starts with the recognition that technology development and use are both subject to existing socio-economic biases and institutional discrimination. From this base, policy makers can begin to identify the specific challenges and barriers that women and girls face in accessing and using broadband, and can develop the appropriate policy responses to reduce the gap.

The right policy environment is critical to the success of internet access and use, and, ultimately, to achieving universal, ICT or broadband policy that clearly outlines targets and strategies for increasing internet penetration tend to have higher rates of broadband adoption (any Policy to Empower Women ICT should be affordable and efforts should be made to increase their access to internet.
These policies identify investment mechanisms to achieve policy goals, are updated regularly to reflect the evolving policy needs of new technologies, and include measurable, time bound targets for improving access and reducing prices.

Closing the digital divide means closing the gender digital divide — a feat that will require policies that include all of the aforementioned characteristics, as well as a gender-responsive approach to the development and implementation of the policy.

Gender-responsive broadband planning is not just about making policy for women; rather, it is policy that ensures that all groups have equal opportunities to access and make use of broadband services. The more people that come online, the more a person is able to connect with friends and family, increase business opportunities, organize, and share knowledge and ideas. Thus, gender-responsive broadband policies will also be successful broadband policies.

4 Factors That Restrict Girl-Childs Equal Participation in ICT and STEAM

The problems militating against the girl child education in Nigeria is an age long factor that hinges on cultural, social and religious undertones where the girl-child is perceived as inferior to the male and hence denied access to education and her roles relegated to that of a home maker, child rearing and house keeper. Others gender issues that hamper the larger participation of girls and women in education in general and ICT training in STEM education in particular include:

a. **Lack of government leadership and direction**: E-governance is for transparency in government operations, improving the quality of government's service delivery, improving efficiency, accountability, financial management, information management, reducing bureaucracy, and delivery of public policy in STEAM. It also affects the enhancement of government ICT infrastructure, supporting an enabling environment as mentioned earlier and providing leadership by making ICT a national priority. Often leadership can make the difference between failure and success. A government that does not appreciate the strategic opportunity provided by ICT cannot provide the required leadership.
b. **Ignorance** is a monster retarding the growth and use of ICT. Policies will deal with ICT diffusion, and ICT literacy, and awareness of the benefits of ICT, the creation of new economic and social opportunities for poverty eradication, job creation and empowerment.
c. **Gender issues:** There is a need for policies to address the issue of equal access of women to ICT. How can the specific developmental needs of women be met? How gender sensitive are the policies?
d. **Globalization and Technological Changes:**Our education system is being challenged in its ability to remain relevant to the needs of students, society and the economy; and in its role to provide the research innovation and creativity that will support the grand challenges facing society that will take us into the 21st Century and beyond.

5 Strategies for enhancing Government ICT policy engagement for Training girls in ICT Skills in STEAM Education
The following are strategies that should be employed to ensure the girl child have access and engagement with ICT facilities for STEAM learning:

1. **Development of ICT infrastructure**: It's not just about provision of infrastructure but also quality, quantity and access issues. Access to infrastructure should lead to access to relevant content and services. Availability and reliability are important, but price is often the most critical factor that affects access.
2. **Enabling environment**: An enabling environment is critical for girls' effective participation in STEAM in the Information Society. Such an environment is supportive and provides support for ICT empowerment while eliminating constraints.
3. **Government Engagement of Stakeholders:** The government should engage stakeholders in ICT and STEAM in working together to ensure the right mix of regulatory initiatives and intervention, resources and facilities needed are provided and made available for use by girls to encourage deeper penetration and use of ICT services teaching and learning of STEAM subjects.
4. **Legal, institutional and regulatory framework**: Legal, institutional and regulatory framework is required to ensure fair competition; to attract investment; to develop ICT infrastructure, solutions and applications; to provide tax and other incentives for ICT industry and investors; to support transfer of technology; to meet the needs, priorities, aspirations of various stakeholders especially for the girl child effective participation in STEM.
5. **Partnerships:** Exploring partnerships around existing government digital literacy policies and initiatives able to reach rural/urban poor populations: e.g. connecting with the Office on SDGs working on initiatives to connect girls in remote areas schools through various programs in its state offices nationwide.
6. **Creating a Good Rapport with the Girl-Child:** Having a regular talk show with the girl-child in the school concerning their academics, career in STEAM and personal problems will create room for the girl-child to express her problems.
7. **Girl-Child Motivation:** Providing incentives for the girl-child such as food, transportation and school fees- The schools visited in this research recognized incentives as a motivator for the girl-child participation in STEAM
8. **Teachers Incentives**: The need for teachers' welfare cannot be overemphasized as the wellbeing of the teacher determines the performances of the teachers and students. STEAM Teachers' salaries should be increased and incentives should be given to them to encourage good output in their career and support for the girl-child..
9. **Parental Involvement:** Educating the parents through PTA meetings – through PTA meetings, the girl-child education can be introduced to parents. The need for girls to acquire functional education, necessary for engendering economic, political and social emancipation should be stressed to the parents.
10. **Availability of the counseling unit to all schools:** Counselors should make guidance services, such as group and individual counseling and information services, available to all in their community. These services will focus on the benefits that are imbedded in the provision of equal rights and opportunities to all irrespective of sex, religion, age and other differences.
11. **Stakeholders Sensitization:** Seminars, symposia, career talks, advertisement through media and pamphlets, skills development programs and workshop could also be organized to sensitize community members and motivate governmental and non-governmental organizations to provide the necessary assistance to help in promoting girl child education in STEAM.

It is already widely accepted that Information and Communications Technologies (ICTs) are an important enabler of growth through the wealth creation, increased productivity and the creation of opportunities. This is particularly important when used in STEAM subjects with the girl child. Therefore, the adaption of the five strategies above will go a long way to ensuring effective participation and engagement of girls in STEAM.

6 Conclusion

In view of the above, it is evident that ICT provides every opportunity to improve the challenges facing the women and girl child education in STEM education, Technology, Engineering, Arts and Mathematics in Adamawa State. Therefore, policy reform is required in bridging the gap in the accessibility, participation and engagement in STEAM using ICT educational resources. It is therefore worthy of note that encouraging women and girls to ICT in STEAM in terms of provision and adaptation in our institutions of learning will go a long way in helping the girl child phase out the challenges that will impede her educational achievement. ICT therefore is a vehicle that can change the STEM education barriers that are pulling the girl child. back.

Recommendations

From the above discussion, the following recommendations have been proffered;

1. ICT should be integrated into the STEAM curriculum mostly in terms of methodologies for instruction through a deliberate policy that will enforce compliance.
2. The provision of ICT facilities to girls at affordable prices in our schools to be supported by training in its use for STEAM learning.
3. The teachers should be made to develop supportive classroom environment that facilitates the adaption of ICT based learning in STEAM by girls to minimize boys/girls disparity in ICT compliance which has been a hindrance to the girl child interest, engagement and participation to ICT and its numerous benefits to learning.
4. More interventions should be encouraged mostly in the areas of private public partnership in the provision of ICT facilities useful in the learning of STEAM subjects by girls in our schools and the training of girls in the usage of ICT in form of seminars, workshops and formal trainings in a safe, secured and friendly environment should be encouraged.

Reference

[1] Abimbola, I. O. (2013). The misunderstood word in STEM education: Towards a technology of perfect understanding for all. Library and Publications Committee, University of Ilorin.

[2] Ajaja, O. P. (2013). Which way do we go in biology teaching? Lecturing, Concept mapping, Cooperative learning or Learning cycle? The Electronic Journal for Research in STEM education & Mathematics Education, 17(1), 1-37.

[3] Ajayi, E. T. (2018). Exploring the Political Skills Required by Women to Become Global Political Leaders (Doctoral dissertation), Colorado Technical University.

[4] Ekine, A. (2013). Enhancing Girls' Participation in Science in Nigeria. Improving Learning Opportunities and Outcomes for Girls in Africa, 41(3), 12-26.

[5] Fensham, P. (2008). STEM education policy-making. Eleven Emerging Issues, 1-47.

[6] Fensham, P. J. (2008). Context or culture: can TIMSS and PISA teach us about what determines educational achievement in STEM education? In Internationalisation and globalisation in mathematics and STEM education (pp. 151-172). Springer, Dordrecht.

[7] Igwebuike, T. B., & Ikponmwosa, I. O. (2013). Influence of school location and achievement level on integrated STEM education students' perception of their classroom environment school of education. Journal of Education and Practice, 4, 22.

[8] Moyer, R. H., Hackett, J. K., & Everett, S. A. (2007). Teaching STEM as investigation: Modeling inquiry through learning cycle lessons. New Jersey: Pearson Merrill: Prentice Hall.

[9] Ogunleye, B. O. (2009). Students' background in STEM education, mathematical ability and practical skills as determinants of performance in senior secondary school chemistry. African Journal of Educational Management, 12(2), 215-226.

[10] Ogunleye, B. O. (2009). Students' background in STEM education, mathematical ability and practical skills as determinants of performance in senior secondary school chemistry. African Journal of Educational Management, 12(2), 215-226.

[11] Olaniyi, O. O. (2021). Best Practices to Encourage Girls' Education in Maiha Local Government Area of Adamawa State in Nigeria. Clinton School of Public Service CSPS 7320.
[12] Paradigm, H. Q. (2017). Closing the Digital Gender Gap and Mainstreaming ICTs into Women's Rights Policy. Retrieved from http://paradigmhq.org/digital-gender-gap/ (Accessed on 17/03/2019).
[13] Reed, M. G. (2019). The contributions of UNESCO Man and Biosphere Programme and biosphere reserves to the practice of sustainability STEM education. Sustainability STEM education, 14(3), 809-821.
[14] Rufai, R. A. (2004). Gender education in Nigeria: Implication for Curriculum Implementation. Journal of Educational Studies, 2(1).
[15] Sanda, H. U., & Kurfi, M. H. (2013). Gender and Information Communication Technologies (ICTS) in Nigeria: Challenges and Prospects. Global Journal of Human Social STEM Education, Sociology, and Culture, 13(6), 50-59.
[16] Timothy, N. E. (2016). Bridging the Barriers: ICT in the Girl-Child Education in Nigeria. Developing Country, 6(10), 44-52.
[17] UNESCO (2020). Girls' and women's education in science, technology, engineering and mathematics (STEM).

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp. 327–336, November 13-16, 2023

Research as a Springboard for National Development: Issues and Challenges

Hussaini Momoh Lawal
{hassan.lawal@aun.edu.ng}
School of Arts and Sciences
American University of Nigeria, Yola, Adamawa State.

Abstract
The role of research in the development of any nation cannot be over-emphasized. Research outcomes arc very important in influencing policy and in determining policy direction towards national development. Many policies have emanated from outcomes of research. Through research, a better understanding of what is actually happening is facilitated and well-informed policy decisions can be taken. In addition to providing data for measuring specific indices of development, a body of research is expected to end up with some far-reaching recommendations that can trigger policy formulation towards making life comfortable for the citizens. This paper x-rayed the relationship between research and national development, with particular reference to Nigeria. The paper relied majorly on available secondary data from literature on the nexus of research and national development. Findings show that, proper environment for research is not yet available in Nigeria, as successive government appears not to appreciate the role of research as a viable tool for national development. For this to happen, many things have to be considered and these include adequate infrastructure, trained manpower, institutional capacity, and adequate financial support. It also involves motivating the entire population to adopt a science culture as a pattern of lifein every human society so as to stimulate nation's goal and development. In order to sustain scientific and technological impetus, it is recommended, among others, that, the authorities and government of Nigeria needs to inject huge amount of funds into initiating and expanding training and research facilities to enhance cutting edge research, so as to encourage indigenous researchers to compete favorably with their peers,elsewhere in the world.

Keywords: Research; National Development; Issues; Challenges.

1 Introduction

Research is the most credible means of understanding the world we live in. It is the vehicle through which the reality of social and natural phenomenon is understood, observed, measured and articulated for the advancement of knowledge and the resolutions of practical needs of mankind vis-à-vis national development. Unfortunately, research is viewed differently across nations in the world and professions. Professionals have this erroneous view that they are trained solely for the practice of their professions. This is the case with most computer analyst, Engineers, Lawyers, Medical Doctors and many others. The succinct truth is that; it is practically impossible to have a successful career in any profession without the component of research. For instance, how does one know what he/she practices is consistently so? How does one know the manner or he/she practices the profession is acceptable by the beneficiaries? How does one know that the policies and programs that are in place are making the required impact? How does one know the opinions of the beneficiaries of these policies and programs? These and many boggling questions cannot be satisfactorily answered without a journey in to the world of research.

All over the world, the objective of achieving national development is the pre-occupation of all national governments. The essence of national development itself is to enhance the well-being of the populace (i.e. citizenry) (Goni & Asaju, 2014). National development is the ability of a country(s) to improve on the well-being of its people by providing social amenities such as; quality education, affordable water, transportation, infrastructure, medical care, security and creating a conducive political atmosphere with the participation of citizenry etc .

Development in human society, at the micro and macro level, is traceable to the advancement in the socio-scientific understandings of the variables enabling production and reproduction of the social and/or material realities. One area that has been implicated in the course of the advancement of society

is research. Broadly speaking, Oyesola (2010), argued that it helps for a more advanced environment. This is achievable through innovative findings and the utilization of scientific knowledge in addressing social problems to improve various social outcomes and human productivity. The above justifies the nexus between socio-scientific findings and various levels of development in the society. Consequently, the place of research in rolling the balls of national development at the public and private levels justifies in the reason why it has a place in the organization of human society.

Adeyeye (2016) observed that, research output is key to development process, thus sources of knowledge are probably less important than the value attached to associated research and the ways in which the research results are utilized. The utilization of research output as data for development varies between the developed and developing countries. In Nigeria, there exist a wide lacuna in the quantum and advancement of research output and its effects on the transformation of the socio-political and economic realities in the country. This may be one of the reasons why the gap between the developed and the developing countries continue to widen uncontrollably. However, prevailing social problems in Nigeria offers a wide opportunity for research. The outcomes of which are presumed towards addressing the developmental issues that have limited the evolvement of the nation (Tinuola & Ogunbor, 2021). The lack of interest or focus in research in addressing and tackling the myriads of problems faced by Nigeria, for example, has not only added to the crisis of development in the country; it has made it look insurmountable for successive governments. The advancement made in industrialized societies are attributed to the investment and priority they place on advancing research and the utilization of its outcome. Therefore, for a country to engender meaningful development with her huge resources' endowment, a focus needs to be placed on proper research to identify areas of national and collective strength for the purpose of initiating a cutting edge research that can stem the tide of various associated problems confronting the country.

Several debates and studies on the connection between research and development to the advancement of plethora of societal issues have affirmed the roles and contributions of research to development. In the 21stcentury, the focus on national development has come to take over the conversations that individuals, policy makers and government engage in. Nigeria, as a nation, has given the issue a place in the national discourse. The conviction on how outcomes are utilized remains a major challenge for the nation in her bid towards development, leaving the subject a re-occurring topic of discussion in several public fora. It is the light of this, that, this paper is conceived to lend credence to this national debate geared towards improving the utilization of research outcomes in national development by taking a cursory look at the issues and challenges. Thus, the paper is structured in to five (5) parts, namely; introduction, conceptual clarifications; understanding the nexus of research and national development; challenges bedeviling research endeavor in Nigeria; as well as conclusion and recommendations.

2 Defining Research

The concept of research has been viewed differently by several scholars using various professional binoculars to present various view of the concept, but pointing to same direction. According to a layman, research simply connotes the idea or act of searching for something. However, in real terms, research means much more than searching for something, but a conscious effort to systematically and objectively measure the existence of a phenomenon (Gyong, 2013). The term research consists of two words, ‘Re’ + ‘Search’. “Re” means again and again and “Search” means to find out something that has already being in existence. Research is step by step scientific research activities carried out by social and natural scientists. The main objective of activities in research is to describe, identify, classify, categorize, explore, investigate, evaluate and understand social life and human activities in relation to his/her existence.

Research is, thus, an original contribution to the existing body of knowledge making for its advancement. It is the pursuit of truth with the help of study, observation, comparison and experiment. In short, the search for knowledge through objective and systematic method of finding solution to a problem is research. The systematic approach concerning generalization and the formulation of a theory is also research. As such the term 'research' refers to the systematic method consisting of enunciating the problem, formulating a hypothesis, collecting the facts or data, analyzing the facts and reaching certain conclusions either in the form of solutions(s) towards the concerned problem. It involves the application of scientific method for understanding and analyzing social life in order to correct and verify the existing knowledge as a system. The main idea behind sociological research is to discover new inter relations, new knowledge, new facts and also to verify and further validate old ones.

Furthermore, Creswell (2008) described research as a process of steps used to collect and analyze information to increase our understanding of a topic or issue. This means that, research is centered on the desire to know, understand and possibly resolve a problem of interest to researchers. For instance, if there is need to to provide borehole to a rural community in order to provide clean water to reduce the problem of water borne disease, if such is eventually provided and the desired result is not being met, a curious researcher could therefore set out to investigate the reasons for such. In this case, the research embarks on a systematic inquiry through the collection of data and analysis of findings to discover the factors responsible and make the necessary recommendations. The three steps include posing a question, collecting data to answer the question, and presenting an answer to the question. Research is an information tool about the behaviour of phenomena in any sector of the economy. In particular, it is the process by which we seek to observe and describe, explain, predict and control the behaviour of phenomena. Policy research therefore is a special type of research that can provide communities and decision-makers with useful recommendations and possible actions for resolving fundamental problems (Adeyeye, 2016). Such research provides policy-makers with pragmatic, action-oriented recommendations for addressing an issue, question, or problem.

The ability to understand and explain, is however, predicated on a sound theoretical and empirical knowledge of the social and natural world (Dejo, 2013). Researchers monitor what is happening at the household and national levels to the historical analysis of phenomenon, and what has happened hundreds of years ago using the combination of art and scientific research methods. This is with a view to ensure that carrying out such an analysis can provide relevant answers to some research questions that are being researched on. Examples of such researchable questions are: why the rising trend of insecurity across the world? Why are some nations more developed than others? Why are some people richer than others? What is mental illness? How can we eradicate mental illness from our society? How can greater equality be brought about in a society? What are the causes/consequences of uneven development across the world? Who benefits and who loses from specific government policies? How can government be made responsive to the governed? The posing of such question pre-supposes that answers exist and can be found through a careful and systematic collection of the evidence available concerning the particular problem (s). It is this systematic collection of evidence that is called research. On the whole therefore, research is designed to answer four questions: What exist? Where does it exist? How does it exist? And why does it exist?

Research therefore gives insight into social occurrence(s) that make researchers understand why, when, where, what and how social life is being constructed and reconstructed daily. Through sociological research, the complex nature of society is being understood because social research provides insight for the sustenance or displacement of preconceived realities. It is a strategic process employed to challenge existing knowledge, based on new findings that supersede prior knowledge on

social reality (Tinuola & Ogunbor, 2021). It uncovers both the latent and manifest aspects of social reality through a systematic process of social enquiry.

Researchers question and analyze why things happen, always considering larger social, political, and economic forces. In Nigeria, research outcomes are expected to have tremendous impact on social life and public policy in order to provide answers to social situations and occurrences within the country.

3 Purposes of Conducting Research

The purpose of conducting all research is to find solution to problems, therefore, research and problems are two sides of the same coin. Without problem, there should be no need for research (Otaha, 2015). Similarly, Isiugo-Abanihe (2002) noted that the purpose of conducting research is to discover answers to questions through the application of scientific procedures. He stressed further that the purpose of conducting research varies, depending on whether the goal is to explore a new topic, to describe a social phenomenon or to explain why something occurs. The main aim of research is to find out the truth which is hidden and which has not been discovered. Though, each research has its own specific purpose, however, the general objective of all research endeavours are exploratory, descriptive, and explanatory. Studies, however, may be multi-purpose, but one purpose is usually dominant.

Exploratory research is necessitated by curiosity and the urge to find out more about an issue on which little empirical documentation is available. This type of social research is valuable for breaking new and novel ground or yielding new insight into new research areas for further investigations. They can also provide useful lead as to the appropriate methods for eliciting valid data on difficult study problems. They are however not good for providing satisfactory answers to questions related to factors, pathways and consequences due to the limited representativeness associated with their unstructured scope, methods and coverage.

To gain familiarity with a phenomenon or to achieve new insights in to it is the goal of exploratory research. Exploratory research is often conducted in new areas of inquiry, where the goals of the research are: (1) to scope out the magnitude or extent of a particular phenomenon, problem, or behaviour, (2) to generate some initial ideas (or "hunches") about that phenomenon, or (3) to test the feasibility of undertaking a more extensive study regarding that phenomenon. Exploratory studies are those which aim at gaining familiarity with a phenomenon or which aim at achieving insights into the phenomenon or studies which deal with formulation of a more precise research problem or developing a hypothesis (Mahesh, 2011). The major emphasis of such studies is on the discovery of ideas and insights. It basically deals with exploring the Ideas and facts which are new. This is the primary and first research done on that particular problem which provides the first hand or new knowledge or discovering something new regarding the study or problem. In general, exploratory research is meaningful in any situation in which the researcher does not have enough understanding to proceed with the research project. This research may not lead to a very accurate understanding of the target problem, but may be worthwhile in scoping out the nature and extent of the problem and serve as a useful precursor to more in-depth research.

Descriptive research is carried out when a study is set out to principally describe some phenomena or a particular subject in terms of its function, attributes, characteristics and frequencies in its current state. Descriptive research is directed at making careful observations and detailed documentation of a phenomenon of interest. These observations must be based on the scientific method (i.e., must be replicable, precise, etc.), and therefore, are more reliable than casual observations by untrained people. Usually this type of research is limited to its subject of focus and does not go beyond it to indicate final definition or generalized conclusions of an exploratory nature.

Explanatory research involves the investigation that seeks to provide answers to questions like what causes what or why is the situation the way it is? Causal explanatory research is very complex but it is the most common academic research available. Explanatory research seeks explanations of observed phenomena, problems, or behaviours. While descriptive research examines the what, where, and when of a phenomenon, explanatory research seeks answers to why and how types of questions (Isiugo-Abanihe, 2002). It attempts to "connect the dots" in research, by identifying causal factors and outcomes of the target phenomenon. Examples include understanding the reasons behind adolescent crime or gang violence, with the goal of prescribing strategies to overcome such societal ailments. Most academic research belongs to the explanation category, though some amount of exploratory and/or descriptive research may also be needed during initial phases of academic research. There are four sub-types of explanatory research namely, historical research, correlational, case study and comparative inquiries.

4 National Development

National Development, which can be seen to include every aspect of life of all individuals. This includes full-growth and expansion of industries, agriculture, social, religious and cultural institutions in a nation. The United Nations defined national development as growth plus changes in social, cultural, economic and political life of a nation.

Development is the transformation of community into socially, economically, politically, educationally and materially desirable conditions, with the aim of improving the quality of life of the people. It is expected to enhance fair distribution of resources, the integration of the people into national economy and socio-economic progress which seeks to bring about a more equitable distribution of resources and income within the society. However, certain distinctions exist between development and other related concepts such as change and growth.

Several indices exist for measuring development; this depends on the lense with which the concept is being viewed. In spite of the magnitude of this concept, Umuru (2002) indicated that development is associated with modernization, material advancement, industrialization scientific and technological progress, and new knowledge about man and the universe. It can be interpreted to mean urbanization, socio-cultural transformation, mass literacy, employment opportunities and the emergence of specialized and independent occupational roles.

Gboyega (2003) described development as an idea that embodies all attempts to improve the conditions of human existence in all ramifications. Developmental goals are tantamount to improvement in material well-being of the citizenry, in a sustainable way such that the present consumption does not endanger the future. It demands through a sustainable approach, that poverty and inequality of access to the basic necessities of life are drastically reduced. This is in addition to improving personal physical security and livelihoods and expansion of life chances. Furthermore, development involves not only economic growth, but also some notion of equitable distribution, provision of health care, education, housing and other essential services all with a view to improving the individual and collective quality of life.

National development brings about sustained improvement in the wellbeing of the individuals and bestows benefits to all for self-reliance and mobilization of domestic resources. This equally involves the transformation of the structure of rural production, the development of small-scale industries and the acquisition of technological and scientific skills. A well-conceived planning, policies and programs are required for the realization of development (Umaru, 1988). This means that development is about self-reliance in every aspect of national life.

By inference, national development therefore can be described as the overall development or a collective social, economic, political, technological as well as scientific advancement of a country. This is best achieved through development planning vis-à-vis the application of results from research that captures burning issues in human society. This process can equally be used as the country's collection of strategies by the government.

5 Nexus of Research and National Development

Globally, the development of every country is tied to the country's research outcomes and the ingenuity of the country's academic prowess. Research has been variously defined by scholars as a systematic process of searching and re-searching to find meaningful and functional solution to society's problem, be it technological, educational, social, economic or political development. Development, on the other hand, according to the Dictionary of Contemporary English is ''the process of gradually becoming bigger, better, stronger or more advanced from a specific stand point'', it is an attempt to improve the condition of human existence in all sphere ranging from the provision of health care, food security, education, physical and social security, housing, transportation, communication, and all other essential services needed for human existence.

The purpose of development is to move a society from an existing state, along the most efficient path, to a more desirable state, within a specified time period. In this sense, development may be viewed as the transition from the existing state towards the desired state. Development depends on the interplay of the matrix of interacting social, economic, political, technological and other variables characterizing the existing state and the human response to these conditions. This human response hinges on three main factors: namely, the possibilities existing in the domestic material environment, the past and/or continuous achievements in other societies; and, the constraints and opportunities desired from the global socio-economic environment (Adeyeye, 2016).

The core thrust of any research is its focus on identifying and proffering solutions to social problems. Ideally, the first step to national development in Nigeria is in identifying issues that impedes the development of the country. Research, in different areas, has always been a key part in highlighting challenges faced by developing and developed countries of the world. Hence, the core impediments to national development in any nation begin with the inadequacy, non-recognition of available research outcomes and the non-use of research data for national development. This thus underscores the relevance of research in national development. Research facilitates the exploration of new knowledge frontiers and how these knowledge aids the advancement of the infrastructural and material realities of the society. Technological, medical, educational and political progressions of society are dependent on the dynamic role and outcomes of research in promoting socio-economic and political life

In relations to national development, research highlights core issues such as education, economic development, agriculture, production among other areas. Research exposes such important areas as it aids the building of society. Consequently, it can be argued that research whether basic, applied and social is relevant in advancing the development trajectory of the Nigerian nation. The issue of national development in Nigeria has evidently generated high volume of literature. Scholars also have researched the linkages (or lack of linkages) between education, one of the primary focus of social research and national development in Nigeria. Specifically, Studies have shown that the major preoccupation of every country's educational institution is for research and development; countries of the world have used the research products of their universities and other research institutes to design policies and develop their economies (Eneji, Bechel, Onnoghen and Okpachui, 2017). To Adeyeye (2016), Singapore and Taiwan are positioning themselves to participate fully in the technology-based economy, other countries, including Ireland and Israel, have clearly established themselves as key

competitors. Ireland, which has succeeded in attracting a large number of multinational information technology and electronics corporations, is now seeking to grow its base of technology companies, with an emphasis on software development. A key strategy is building a strong R&D base in its universities and businesses. China is the second world market today because of their technological development from the product of their academic researches, America, Russia, Israel, the Great Britain, United Arab Emirate (UEA) etc all became developed countries by using the research outcome of their research centers (Eneji, et'al, 2017). Infact, Israel has built on its strong base of defense-related technologies and capitalized on its highly skilled, technical workforce. The country has one of the highest per-capita ratios of scientists and engineers in the world. Like Ireland, Israel has succeeded in attracting corporate investment by providing financial and tax incentives to build the country's industrial base.

Research output is key to the development process, thus sources of knowledge are probably less important than the value attached to associated research and the ways in which the research results are utilized. The ability and willingness to evaluate material from whatever source, to understand its characteristics and its reliability, and to relate it to local circumstances are most important. It is fundamental that knowledge inputs into the planning process that have an impact upon decision-making if such processes are to retain public credibility must be of an understood quality and value (Adeyeye, 2016). Similarly, any processing and presentation of research results for planning purposes must take account both of the inherent qualities of the data and of the reliability and robustness of the methods of analysis used; and this needs to be done in transparent ways.

Research outcomes arc very important in influencing policy and in determining policy direction. Many policies have emanated from outcomes of research. Through research, a better understanding of what is actually happening is facilitated and well-informed policy decisions can be taken. Research in the national planning process is a necessity as variously noted by scholars. However, government in most of the developing countries view research as mere academic exercise that has no place in the policy making process. This constitutes a great impediment to the achievement of national development in countries like Nigeria and has resulted in the quagmire of poor development trajectory.

As noted by Tinuola and Ogunbor (2021), data from research, without any gainsaying, are instrumental in addressing a lot of development deficits in the country. Research as a systematic search for knowledge is an important machinery when applied, for the development of new and improved product and services, technological advancement and industrial growth of any nation. Research has become one of the most enduring and effective means of boosting sustainable economic development and reinforcing competitiveness in the face of rapid growth and development taking place between industries, countries and people of the world.

Since research revolves around issues relating to man and his environment. It is an important tool for uncovering the various socio-cultural issues that in recent years have become an instrument for disrupting the socio-economic wellbeing and the economy of the country. For example, conflicts, one of the subjects of sociological research, viewed by Ayoob (1991), as such vulnerabilities that threaten, or have the potential, to bring down significantly weaken state structures, both territorial and institutional, as well as the regimes that preside over these structures and profess to represent them internationally. Conflict and its outcomes tend to affect the entire structure of a nation which in turn impedes National development, especially in Nigeria. For instance, the North Central region has witnessed violence and conflicts between farmers and herdsmen arising from destruction of farm crops. Not limited to this, the conflicts involved the indigenes of host communities and farmer to farm invasion. Research reveals the reasons for the manifestation of this conflict and how they can be

mitigated and managed in order to facilitate the development of the region and other parts of the country.

Moving further, research can be seen as an indispensable tool for national development because it exposes both national and international values that broaden knowledge, experience, social interaction, skills and output. Such values range from social integration, national unity, religious tolerance to the ideas of nationalism, unity and interdependence among the citizenry. Sociological research helps to expand knowledge on these values as well as suggesting means through which these ideas can be inculcated in the society to bring about qualitative positive contribution to national development (Tinuola & Ogunbor, 2021). These values are what will allow leaders and prospective leaders to possess the spirit of patriotism and make policies that will project national development instead of the current trend of corruption, sectional development, nepotism, intimidation and marginalization, mismanagement of public finance among others.

Furthermore, research enables the researcher to provide answers which can lead to the development of social programmes and public policies for improved welfare, political participation, uphold human rights, reduce inequality, and ensure social justice. Sociological research outcomes in society thus contribute to the sustainability of society, hence its centrality in improvement required by man in his social environment. Research has many uses across the wide array of sub-disciplines in Sociology, the wider social sciences and beyond because it offers different types of knowledge to people. This therefore highlights a need for continue development, practice and promotion of sociological research in Nigeria. More so, gaining access to the body of knowledge on research methods will allow researchers to acquire significant skills to facilitate national development.

6 The challenges confronting Research in Nigeria

Inspite of the laudable benefits of research to national development, there appears to be a neglect in the area of research. In most organizations in Nigeria, research units are poorly funded and thus neglected. Infact, personnel deployed to research unit are either unqualified to man the unit or even deployed to the unit as a punitive to settle scores. In such cases, research activities rarely take place as expected. Even in tertiary institutions where research is supposed to be one of the cardinal component, funds are usually not adequately budgeted for the research unit. This neglect, no doubt, is reflected in the competencies of personnel in the organization.

At this critical point in the history of Nigeria, researchers are faced with the challenges of providing practicable solutions to these plethora of problems besieging Nigeria. Studies have however shown that most research outcomes by both post graduate students and academic staff from most Nigerian universities are either seldom used for any policy formulation or contribute in any way to national development (Anonson, 2008; and Ochuba, 2010). What could be the reasons for the low patronage of research outcome to help in policy formulation or contribute to national development seems to be too numerous. These reasons ranges from the poor quality of graduates from Nigerian universities, the quality of research outcome, the non-availability of functional facilities for carrying out such researches, non-availability of research grants and the most important factor which is the recycling of researches by university staff to meet the compulsory promotion requirement of ‘’publish or perish’’ syndrome (Eneji, et’al, 2017).

As noted by Adeyeye (2016), stakeholders are of the view that one of the major problems militating against scientific research in general and educational research in particular is the complete absence of a clear-cut philosophy of national development, a philosophy which should spell out the direction in which Nigeria wants to channel its development efforts, a philosophy that should not change no matter how frequently political power changes hands. With the frequent changes of political power in Nigeria

and the attendant instability, inconsistency and incoherence in governmental policies and programmes, the practitioner in the education industry, including the researcher, is left confused. Before the researcher concludes an evaluative study of a particular programme or policy, it is either discarded or replaced with a different, sometimes completely divergent policy or programme.

Bamiro, (2012) in his research on the importance of university research to national development found that Nigerian universities research environment are hardly conducive for lecturers, their working condition is one of the worst in the world, and their take home pay leaves more to be desired, hardly do universities have current textbooks in their libraries, not to talk of e-libraries that subscription must be done annually. Research grants are nonexistent, tertiary institution staff hardly get any grant to enable them carry out productive research, if they have to carry out any research, it is to satisfy the dictum of publish or perish because they have to fund such researches with their meager salaries. The learning condition is horrible with over a hundred students taught by one lecturer in a classroom with sitting capacity for only 30 students. Reagents are never seen in the laboratory, machines are not functional, instructional materials are nonexistent. Salaries are just aberration as what is paid to the lecturers cannot take the lectures to the institutions gate talk less of taking them home. Ochuba, (2010) however found out in a research that most university graduates only passed through the university without the university passing through them, most of them just wish to satisfy all righteousness of going to school just to acquire a certificate for the purpose of getting a white collar job, the case is even exacerbated by roles of wealthiest parent who wish their children to study a particular course, just to satisfy the name. The end result is that most students are forced to study courses they are grossly inadequate to study. Considering the university's dictum of ''publish or perish'', they are compelled to publish, and what do you think the quality of their publication will be? It was Fafunwa, (1978) that once said ''the standard of any nation's education cannot rise above the quality of its teachers''.

7 Conclusion and recommendations

The growing evidence on the role and importance of research in the development process of any nation cannot be overemphasized. However, a cursory look at successive government in Nigeria, it appears we are yet to appreciate the role of research as a viable tool for national development. Generally, the knowledge derived from research enable the policy makers to be in advantageous position of formulating policies and programmes. The knowledge would as well put in place adequate regulatory framework that will diversify the Nigerian economy and building strong human capital for overall national development. Nations in the world that have attained a reasonable degree of development and those who aspires to attain similar height are nations that have identified and embraced the tenets of research. The proper environment for research to thrive is not yet available in Nigeria; whereas a conducive environment is needed for growth and utilization of research. For this to happen, many things have to be considered and these includes adequate infrastructure, trained manpower, institutional capacity, and adequate financial support. It also involves motivating the entire population to adopt a science culture as a pattern of life. These and other matters call for the urgent attention of practitioners and policy makers in Nigeria.

There is need to put in place an innovation support fund by government to strengthen the will and capability of innovators, noting that it will also help remove the fears experienced by experimenters of losing their resources should their invention fails.

Government agencies saddled with the responsibilities of overseeing research and other related matters should ensure that research activities are backed up by adequate infrastructure, adequate personnel and adequate funding. Over-reliance on foreign aid would only reduce the relevance of research activities to the peculiarities of Nigeria. In order to sustain scientific and technological impetus, and not with-standing the general depression, the authorities and government of Nigeria needs to inject huge amount

of funds into initiating and expanding training and research facilities to enhance cutting edge research so as to encourage indigenous researchers to compete favorably with their peers anywhere in the world. Integration of indigenous researchers cum scholars in to the international scientific community through output visibility (research findings) and participation at international scientific conferences to create an improved international visibility of the Nigerian scientific publications thus providing a broad access to information resources.

Given the obvious absence of conducive environment needed for qualitative and productive research and scholarship endeavor in Nigeria, as earlier noted, there is no doubt that, this has over time propelled the incidence of brain drain by legions of scholars and researchers to other parts of the world, where the research environment is conducive. Thus, the Nigerian research environment deserves strengthening to encourage brain gain rather than brain drain.

References

[1] Adeyeye, V. (2016). Relevance of Research in Sub-National and National Development. Unpublished paper delivered at the Nigerian Institute of Social and Economic Research (NISER) Ibadan.

[2] Anonson, A. (2008). Exploring the Relationship between Higher Education and Development: A Review and Report.

[3] Ayoobs, M. (1991). The security problematic of the third world. World Politics, 43, 257-283.

[4] Bamiro, B. (2012). The Nigerian university system and the challenges of relevance. Convocation Lecture University of Lagos, Akoka-Lagos, 12 January.

[5] Bhattacharya, I., & Sharma, K. (2007). India in the knowledge economy – an electronic paradigm. International Journal of Educational Management, 21(6), 543-568.

[6] Concise Dictionary. (2013). Oxford University Press.

[7] Creswell, J. W. (2008). Research Design: Qualitative, Quantitative, and Mixed Methods Approaches (Third ed.). Thousand Oaks, California: Sage publication.

[8] Dejo, A. (2013). The Research Process: Nature and Logic. In Dejo, A., Ogundiya, I. S., and Kura, S. Y. B. (Eds.), Research Methodology and Graftsmanship. Ibadan, Foludex Press Limited.

[9] Eneji, C-V.O., Beshel, C. A., Onnoghen, N. U., & Okpachui, A.A. (2017). Academic Research as Nexus for National Development and Global Competitiveness: University of Calabar Experience. The Researcher: A Journal of Contemporary Educational Research, 1(1), 11-30. [URL]

[10] Fafunwa, A. Babs (1978). "The Universities of Nigeria." Commonwealth Universities Yearbook.

[11] Gboyega, A. (2003). Democracy and Development: The Imperative of Local Governance. Inaugural Lecture, University of Ibadan, 6-7.

[12] Goni, I., & Asaju, K. (2014). Local Government as Springboard for National Development in Nigeria: Issues and Challenges. Projournal of Humanities and Social Science (PHSS), 2(1), 12-22. [URL]

[13] Gyong, J. E. (2013). The Imperatives of Research in Nursing and Midwifery Profession. Zaria Journal of Sociological Studies, 5(3), A Publication of the Department of Sociology, Ahmadu Bello University, Zaria-Nigeria.

[14] Isiugo-Abanihe, U. C. (2002). Quantitative Research Techniques. In Isiugo-Abanihe, U. C., Adesina, J., & Isamah, A. (Eds.), Currents and Perspectives in Sociology. Lagos: Malthouse Publishers.

[15] Mahesh, C. S. (2011). Social Research Method: Study Material: University of Calicut School of Distance Education. Unpublished Material.

[16] Ochuba, V. O. (2010). Strategies for improving the quality of education in Nigerian Universities. In N. A. Nwagwu et al (Eds.), Current Issues in Educational Management in Nigeria, A publication of the Nigerian Association for Educational Administration and Planning.

[17] Otaha, J. O. (2015). Research Methodology and Statistics: A step-by-step Approach. Lagos, Malthouse Press Limited.

[18] Oyesola, G. O. (2010). The Contribution of Research to the Development of the National Education System. [URL]

[19] Tinuola, F. R., & Ogunbor, I. J. (2021). Sociological Research and National Development: The Nexus (Humanities Edition). 1(1), 42-48. A Publication of Al-Hikmah University, Ilorin, Nigeria [URL].

[20] Umaru, H. (1988). Science, Technology, and Mathematics Education and Economic Development. In E. N. Okpara (Ed.), Education and National Stability. A Book of Reading by APQEN.

[21] Umuru, G. E. (2002). Re-Focusing Science Technology and Mathematics Education for Rapid National Development. In Refocusing Education in Nigeria: A Book of Readings, 8(75). [URL]

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp. 337–346, November 13-16, 2023

Language, Culture, and National Development

Oladipo Salami, DPhil
{oladipo.salami@aun.edu.ng}

American University, Yola, Adamawa State, Nigeria

Abstract
In today's world, societal development is often conceived as material transformation, economic growth, and industrialization, among others. However, in recent years, development as a concept defined in relation to a nation or a country's socio-economic existence is seen to be much more than material transformation as represented, usually, by the increase in a country's Gross Domestic Product (GDP), the level of external reserves, foreign direct investment (FDI) or the height of a country's industrialization. According to Kinge'i (2000: 26-27), citing Blackler (1983), development involves not just accelerated economic growth but also changes in traditional structures, values, and practices. The twin structures of language and culture are critical players in changing as well as in shaping individual and collective behaviors, values, traditional structures, and practices which are at the root of development. It is the individuals, as citizens or a people, that impact the physical, political, or social environments they find themselves as a collective. We, as individuals or as a collective do, in the different roles that we play, participate in contributing to growing, changing, or transforming our society.
In this paper, I draw, largely, from the studies I had conducted on some language-related social and policy issues of challenge in Nigeria to demonstrate not only the important roles of language and culture to the country's development but also to argue that language is key to the processes of promoting socio-political and economic development in twenty-first century Nigeria.

1 Introduction

I will like to begin this paper from the perspective of the role that I think a linguist could or should play as a citizen who demonstrates concern regarding the challenges confronting Nigeria in its development in the 21st century. As noted by Kinge'i (2000:27), language and culture play a vital part in shaping individual and collective behaviors and values. It is these individuals, as citizens or a people, that impact the physical, geographical, political, or social environments they find themselves as a collective. In other words, we as individuals or as a collective do, in the different roles that we play, participate in contributing to growing, changing, or transforming our society. In this paper, I draw, largely, from the studies I had conducted on some of the language-related social issues that constitute challenges to Nigeria's development and some of the solutions proffered.
In changing our society, we seek growth, transformation or development. In relation to a country or a nation, development is often conceived as material transformation: economic growth, industrialization, the provision of infrastructure, and so on. However, in recent years, development as a concept that has to do with a nation or a country's life is considered to be much more than material transformation such as represented by increase in the Gross Domestic Product (GDP), the level of external reserves or the height of the country's industrialization. According to Kinge'i (ibid, p. 26), citing Blackler (1983), the process of development involves not just accelerated economic growth but also changes in traditional structures, values, and practices. Today, the United Nations' set of criteria of development (referred to as the development index) includes, among other things, such concerns as democracy, women's rights and empowerment, child's rights, long-life literacy, environmental protection, the eradication of diseases as well as the reduction of both poverty and hunger.
In this paper, I like to demonstrate that language and culture are not only critical to the promotion of change or the socio-political and economic transformation of Nigeria but that the Nigerian linguist has

an important role to play in making the country's developmental endeavors in the 21st century achievable. Therefore, in order to be able to play this role, our languages, and cultures need to be repositioned in terms of their practical application to policy formulation and utilization. It does not need to be restated that the challenges of this century are nothing but the challenges of sustainable development as encapsulated by the United Nations' Millennium Development Goals or the 17 Sustainable Development Goals (SDGs). Development, in this sense, is a holistic phenomenon. Thus, a country would be described as developed not just by its high GDP or increase in per capita income but if it has also done well in all the indicators that form the United Nations' human development index (HDI). The components of the HDI are, largely, economic, social, cultural, and political. The HDI aggregates the measurements of growth, transformation, or change in these components or factors which may include the level of growth in literacy, healthcare, governance, human rights, gender rights, standards of living, food security, sanitation, life expectancy, and so on in order to arrive at the composite or general level of development of a given country. Therefore, for Nigeria to see itself, in this century, as developed or developing, it must not just strive to increase its GDP or per capita income, it must also work to improve on governance, education, literacy, healthcare, sanitation, transparency, gender and child's rights, and so on. In playing our roles as linguists and researchers to foster the SDGs, my take is that we must show some social commitments in our research practice, policy formulation, and intervention in language and culture-related policies.

2 The Place of Language and Culture

Language is often described as a means of communication while culture is seen as constituted by those things that a person learns to become a full member of a society or that of their community, including its language (Salami 2014:19). In other words, language and culture are related in that while language is part of what one learns in one's culture, it is also the transmitter and repository of that culture. Culture is both material and non-material and these are represented, projected, and conveyed by language. Kakonge (2017: 1), citing Zimmermann (2015), describes culture as "the characteristics and knowledge of a particular group of people, defined by everything from language, religion, cuisine, social habitats, music, and arts". It is clear from the foregoing definition of culture that everything that makes a society or a people is contained in their culture. These may range from the system of governance, agricultural and economic practices, ethics, values, regulations, or laws to, for example, how women and children are treated. Thus, the growth of a society in several spheres of its life cannot be entirely independent of its cultural practices. It is also possible that a change in a society through foreign or external influences, for example, can impact on its culture while also a change in a particular aspect of the culture of the society may also have a systemic impact on the larger society. This is to say that development, as growth or change, have some roots in culture. Therefore, for the linguist, as a researcher, policy formulator or adviser and a socially conscious citizen, it is important that they must not only demonstrate the awareness of the place and significance of language and culture in a polity, they must strive to show some commitment to their society or community in their research and the application of research results. According to Bodomo (1996:34);

[L]anguage is a granary, a repository of the world-view of its speakers, it is this particular language that best contains and expresses the indigenous belief systems – socio-cultural, political, economic, and technological – of any society. It is in these senses that we notice that the most intelligible and intelligent reactions by speakers to new ideas and technologies are registered through their language.

Following the quote above, I will like to proceed to examining a few areas of language and culture concerns in Nigeria's national development in the 21st century. As noted earlier, I will take as a paradigm of development the United Nations' sustainable development goals or the SDGs.

3 Governance and Democracy in Nigeria

The development of a country involves progress in nation-building, especially in a culturally and linguistically diverse polity like Nigeria. It is a country that has evolved under British colonialism and imperialism to an independent country in about 63 years or so now. Following the departure of the British, Nigeria has been contending, however, with the challenges of self-rule and the practice of democracy and democratic governance to the extent that it had not only witnessed coups and counter-coups and military dictatorships, but it had also failed in the practice of Westminster form of government inherited from the British and has been experimenting with the American presidential system, not with great success. Some of the challenges facing the country have been attributed, largely, to the absence of a sense of nationhood. This lack is, often, linked to Nigeria's linguistic and ethnic diversity or pluralism. Nationhood is usually assumed to engender a sense of belonging and patriotism. Although it is argued by some scholars that the nation is imagined or an imagined entity (Billing, 1995), some societies are considered successful and developed because they have attained nationhood. It has also been held that the success of such nations has been based on their being monolingual or mono-cultural. However, it is not true that those nations are developed only because they are monolingual and mono-ethnic or mono-cultural. According to Batibo (2005: 58), cited by Ndhlovu (2008), there is no direct relationship between multilingualism and economic under-development or a direct relationship between economic prosperity and monolingualism. In other words, it would be too far-fetched to say that there is a one-to-one correspondence between successful polities and monolingualism and monoculturalism. The United Kingdom and USA, for example, are officially monolingual but they are multilingual and multicultural in composition. In these countries, there is the presence of many other linguistic and cultural groups but this has not impeded greatly their socioeconomic development. This might be due, perhaps, to democracy and good governance in which the way they manage their linguistic resources provides every citizen the opportunity to participate. Thus, in these two countries, the sense of nationhood and nationalist feeling are often demonstrated and shared by all citizens, even though they may not share common racial and ethnic backgrounds. Many post-colonial African countries, including Nigeria, face the challenge of nationhood and nationalism which tends to impact often negatively on their development. This is one reason why Bodomo (1996: 31), citing Prah (1993), is of the view that linguistic and other cultural resources are important in finding the solutions to the developmental challenges of Africa.

In a study of "Other Tongue Policy and Ethnic Nationalism in Nigeria", I tried to investigate, among the Yoruba, the prospect of a Yoruba child learning a major Nigerian language (Hausa, or Igbo), in addition to their Yoruba mother tongue, as stipulated in the national language policy. The study was motivated by the political crisis that arose from the collapse of the democratic experiment of June 12, 1993, and the consequent rise in ethnic nationalism in the country (Salami, 2004). My interest in that study was to find out what Nigerians, the target of the policy of an additional tongue, thought about it. It is perhaps pertinent to mention that underlying this policy are two seeming goals: the first is to promote and grow a national language while the second, resulting from the first is to engender Nigerian nationalism in its citizens. In that study, I assumed that the investigation of attitudes to the policy should be able to show us the level of emotional attachment to a Nigerian 'national cause': that is, the desire to have one national indigenous language. The results of that study showed that the Yoruba people interviewed for the study had contrasting attitudes towards the Hausa and Igbo ethnic groups and their languages which are more pragmatic than nationalistic. They claimed that they would learn Igbo or Hausa language to communicate mainly for business purposes as long as neither of the languages would become a national language.

From this study, a number of questions can be asked: how did the formulators of this policy of learning a second indigenous language come about it? Did the government carry out any prior research on the

attitudes of Nigerians to an indigenous national language? What informed their audacity to put Hausa, Igbo and Yoruba forward for promotion? With years of experimentation on this policy, has the government gone back to find out if it is working or not and what are its prospects and challenges? It is our place and role as socially committed linguists and citizens to obtain feedback on such a policy in order not only to be able to make amends where necessary but also to be able to make informed projections, proposals and guides on language policy formulation in relation to development in 21st century Nigeria. I share King'ei's (2000: 26) view that social science research in Africa tends often to indulge in top-down planning approach which neglects the critical position of bottom-up inputs and participation from local and cultural communities. It is, perhaps, true that the historical foundation of Nigeria and the consequent sociopolitical evolutionary pressures on the country make it difficult for Nigerians to see themselves as citizens belonging to 'one nation' in the sense that, for example, a British, an American or French would see themselves in relation to their countries. But will the promotion of the three majority Nigerian languages lead to a Nigerian nation or engender Nigerian nationalism? It has been argued by a number of scholars that the use of indigenous languages may assist to facilitate citizens' participation in governance and democracy (for example, Oyelaran, 1988). However, for me, the promotion of the three major or majority Nigerian languages is, in a way, a marginalization of a large population of the citizenry. In reality, the formulators of that policy were promoting, inadvertently, the tyranny or hegemony of the country's 'big three' ethno-linguistic groups. Its unquestioning acceptance will be an acceptance of linguistic imperialism as well as social inequality which do not augur well for the development of the country as enshrined in SDG 16:

Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.

But then, what should we as linguists do? How is it possible that we make all the country's languages mediate sociopolitical participation by citizens? The answers to these questions will be provided, perhaps, by the involvement of some expert management of the country's linguistic and cultural resources such that we are able to apply equity to their deployment and utilization. For me, the problem with language and development is not with the presence of linguistic or cultural diversity but how we deploy these diversities in our efforts at building a sustainable nation. For example, Nigerian languages are often categorized according to those used at local, regional, national contexts and that which is for international communication purposes. By implication, those categorized as 'local' languages are, status-wise, not 'national' languages and they and their speakers may be excluded from having access to and benefiting from national resources or privileges. This, in essence, can be construed as a violation of their linguistic human rights.

The rise of Egbesu nationalism among the ethnic Izon 'minor' language group beginning early in the fourth republic tells us, for instance, first, that we cannot take away the rights of people to social justice and inclusivity. Secondly, the rise of Izon nationalism shows that planning without the so-called minor or minority language groups in the equation of whatever goal that linguists or language policy advocates set for them in Nigeria may be unachievable. It is clear that the Izon ethnic group may not have political power conferred on them by population but they have discovered that they possess some economic power derivable from the oil resources the Nigerian state obtains from their soil and, therefore, are able to challenge state power.

What is also obvious is that Nigerian linguists have tried to promote corpus planning of many hitherto undocumented languages but many of these languages seem not to have been accorded national recognition. Therefore, the speakers of these languages are disadvantaged in a number of contexts, including education, workplace, and political participation. It is a challenge to their identities as 'Nigerians' and as such, a test of their Nigerian nationalism. This trend would need to be reversed

based on our research and language planning efforts toward enhancing social justice and democratic participation for sustainable development.

What we have discussed, so far, borders on the place of Nigerian languages in governance, especially as it concerns the status assignment of languages and how it has impacted negatively or positively on their speakers in relation to the way they are treated in the polity. It can be observed that speakers of languages that are considered major languages, for example, tend to have greater socio-political visibility than those that are described as minor, minority, or local languages. It is, however, important that we look, also, at the use of Nigerian languages in governance as tools for promoting inclusivity and participation. Here, we are talking about the use of our languages in communication and in the dissemination of information such as in legislative debates and in civil and judicial administration. The allocation of functions to languages in the country shows, largely, a picture of diglossia where the English language is used mostly in formal contexts such as in government business; in educational instruction from upper primary school level, in legislative matters; in most courts, except the shariah and customary courts, and in formal public gatherings. What this means is that millions of Nigerians who have no competence in the English language are excluded from participating actively in public life and governance. Furthermore, this language situation does not only disempower many citizens, but it can also contribute to the heightening of the social or class division in the polity.

Although the impact of the role or place of the English language on the country's development is not likely to reflect directly on its GDP, it will manifest in the lack of inclusion of a high percentage of its population in governance and political participation as they might have no access to much information at the grassroots. So far, the practice is that some of the challenges to citizens' democratic participation resulting from communication and information gaps are handled, often, through the use of *ad hoc* measures such as idiosyncratic interpretations or translations from English into indigenous languages. It behooves Nigerian linguists, therefore, to promote corpus planning, especially terminology planning, in the indigenous languages across the country in order to enhance the capacity of the citizens to be able to participate actively in public affairs. For example, it should be possible for us to make the indigenous language/mother-tongue speakers at the grassroots know and understand 21st-century development terminologies and their purposes or goals, including democracy, governance, fundamental human rights, sustainable development, and also such terms as transparency, accountability, livelihood strategies, social safety net and so on. Some familiarity with these terms in local languages can go a long way to engender inclusivity and mass participation.

4 Language, Culture, and Education

Human capital development is a key factor in the overall development of a country. This involves the education and training of its population and work workforce. However, education is not important only in Nigeria's training of its workforce for global competitiveness in the 21st century, but it also forms the bedrock of so many other efforts at achieving sustainable development in the country. Thus, the United Nation's SDG 4 states the need for countries to "ensure inclusive and equitable education and promote life-long learning opportunities" as inclusive and equitable education will help in promoting, among other things, social justice and democracy; healthy living and eradication of diseases, the reduction of poverty, gender equality and the empowerment of women and girls.

From the foregoing, it is clear that for Nigeria to make progress in the 21st century, it must invest in education at all levels; from early childhood to tertiary level of education as well as literacy or life-long learning to a large number of its citizens who are not part of the formal school systems. Nigeria has, today, over ten million out-of-school children. This is not only bad but it is also very likely that some of these children have become the cannon fodder for current security crisis, especially in the northern parts of the country and they may continue to be incubating for future social upheavals if the

country does not invest in their education today. Therefore, an education that is inclusive of this set of Nigerian children must consider language and culture as having significant roles to play at all educational levels and, particularly at the foundational level where the children need to learn the norms and sustainable values of the society in which they live. A people's norms and values are encoded in their language and may be deployed in idioms, proverbs, wise sayings, oral poetry, and folklore. The norms and values underline the conceptions of their world, including social, economic, and political relations and activities. These norms and values can only be imparted effectively in no other language than the language or languages that the children know and speak most of the time among themselves. The norms and values are expected to guide the children early as well as throughout their life.

Studies have shown that children develop their cognitive and affective capabilities better when they are taught in their mother tongues or home languages (Afolayan, 1982, Freeman, 1998 Tucker, 1999). The Ife 6-Year Primary experiment on mother tongue education has demonstrated that the mother tongue may be superior to the second or foreign language in the development of a child's cognitive skills. In other words, literacy in a mother tongue is likely to achieve more than in a second or foreign language. In using Nigerian languages for school instruction, as applied linguists, we need to ensure that what is to be imparted must also include cultural and creative skills. For example, the Yoruba people are observed to be, generally, very much embracing of diverse religious belief systems to the extent that within a nuclear family, one could find a father who is a Muslim, a mother who is a Christian of Catholic denomination and the children belonging to Pentecostal groups or different Christian denominations. Many such households exist in Yorubaland and this practice has not, to a large extent, bred disharmony or religious conflict among the people. For the Yoruba;

(1) *orun ni o mo eni ti o maa la*
'It is the heaven that knows who would be saved'

As noted in my paper, 'Creating God in our Image…', I have shown that the Yoruba are very pragmatic about religion to the extent that they can switch from one faith or one denomination of a Church to another at will, depending on what is on 'offer' (See Salami, 2006). It is not unlikely that if such cultural 'embracing skills' are imparted early in school that Yoruba children would grow up to see that there is no need for extremism in the practice of their faith or religious belief systems. Here, the stance of the Yoruba language on faith is able to shape and may continue to shape Yoruba's attitude to religion and religious practices which can help to promote harmony in the polity. The 21st-century crisis of global terrorism fueled by religious intolerance and extremism is wreaking havoc in Nigeria and impacting negatively its development in terms of insecurity, political instability, violation of a person's religious freedom and rights as well as violation of women's and children's rights, and so on. I do not wish to discountenance the underlying instigation of the crisis by global capitalism but the positive aspects of language and culture can be called forth for use to promote peace and religious harmony.

There is a report on TED Talk about a research report on Alaba Market in Lagos which has been described as the largest business incubation platform in the world. That report points to the Igbo "apprenticeship principle" which the presenter says promotes locally generated venture capital based on *sharing principle*. I am told, however, that the principle is a re-work of the old Igbo slavery system that now has a human/positive face (Uwasomba, personal communication). I am sure that the apprenticeship-sharing principle, today, has guiding cultural ethics and norms that are being used to drive business and to achieve development. Interestingly, as the world economy is transiting to a variety of forms, including circular, collaborative, sharing, linear, and bio-based economic models, the Igbo apprenticeship-start-up model might be where to go in growing SMEs in some parts of our continent. As linguists, cultural researchers, and citizens with a commitment to the development of Nigeria, it is important that we take on the challenge of not only documenting but also showing how to position such cultural principles and norms within the country's education system for the purpose of promoting its development.

Apart from positioning our languages and cultures to enhance early childhood development in order to build a better society, we must also begin to reappraise the language policies we propose and propagate, especially in the face of 21st-century global multiculturalism and multilingualism. In the paper 'It is still "Double Take": Mother Tongue Education and Bilingual Classroom Practice in Nigeria', I tried to investigate language practices in Nigerian primary school classrooms against the backdrop of the policy of mother tongue education (see Salami, 2008). In that study, I found out that rather than implement the country's mother tongue policy at the lower primary school level, classroom teachers resorted to a varied use of bilingual instruction which involved some systematic code-switching. The study threw up a number of issues. First, it showed that there is a need for the training of teachers in the specialized use of the mother tongue for instruction at the lower primary school level in Nigeria. This is because the assumption that a teacher who speaks the mother tongue would be able to use it as a medium of education is faulty. In this case, the linguist, especially the applied linguist, has a role to play in assisting curriculum planners and teachers to mitigate the challenges to mother tongue instruction (MoI). Secondly, since many languages would have been brought into the MoI framework because of the policy of using the language of the child's immediate environment, there is a need to do more work on terminology planning (corpus planning) in many languages that had not been covered in order to facilitate effective teaching as well as making education equitable.

5 Literacy, Health, and Population Control

I have noted earlier that SDG 4 mentions the need to ensure education, literacy, and life-long learning for every citizen as one of the goals of sustainable development. This goal, just like the other SDGs, is tied to all other components of human development, including health, population control, use of resources, poverty, and so on. SDG 3 expects that nations or countries must "ensure healthy lives and promote well-being for all ages." Healthy lives include also reproductive health, birth control, infant mortality, and immunization. These are challenging areas of development in Nigeria, especially as many citizens' cultural and religious perceptions of birth control and immunization have been observed to constitute obstacles to healthy living. Apart from the need for nations to put up infrastructural facilities like hospitals and health clinics and provide medical equipment and materials to promote healthy living, they are expected to endeavor to train staff as well as do sensitization and health literacy. Community health literacy and sensitization involve the use of linguistic and cultural resources which can be found in the indigenous knowledge systems. Therefore, the linguist and cultural researcher would need to carry out investigations or studies into the indigenous knowledge systems, understand them and adopt or adapt them to meet the realities of Nigeria in the 21st century. Among the Yoruba, there is a saying, for example, that:

(2) *Olorun lo n wo omo*
"It is God that looks after children"

It is not for us, as linguists, to question the world view of the Yoruba as encapsulated in the above saying but the Yorua belief can form the fulcrum on which we can develop proposals for the 21st-century healthcare system based on programs of structured health literacy and sensitization. This is also applicable to the two sayings in (3) and (4) below:

(3) *A kii ka omo fun olomo*
"We do not count the number of children that someone has begotten."
(4) *Omo beere, osi beere*

"The more children, the greater the poverty"
It simply means, the larger the number of children a father has, the greater his poverty.
The Yoruba saying in (3) above seems to support the idea of not putting a ceiling to the number of children parents can have or bear. This is, however, countered by the reality of population-induced

poverty as expressed in (4). As noted by Tony Attah (The Nation, October 25, 2018), the world is changing faster in several areas than we can imagine because;
[T]he world population will grow from the current seven billion to nine billion people in just about 20 years by 2040. Just imagine adding one China and one India to the world or adding about 10 more Nigeria to the world. Two billion is a lot of people indeed. With this population growth, the world will need much more energy to support global development and growth. ...the world now wants energy that is clean to help counter the effects of climate change, rising global temperature with a 2-degree celsus limit, and of course assurance of a cleaner environment for the next generation.
Tony Attah's statement on population growth touches on its negative consequences such as pollution, energy shortage, and environmental degradation. The Yoruba language and culture, as shown in (4) above seem also to be able to apprehend the challenge of population growth outstripping available resources which can, ultimately, lead to poverty. This shows that as one of the sustainable development goals, poverty reduction (SDG 1) can be tackled by understanding the people's worldviews as expressed in their language and cultural practices. For me, here, it will be the work of the applied sociolinguist to assist in developing mitigation strategies where necessary and applicable.

6 The Internet and Communication Technology

The breakthrough in communication with the development of the internet and communication technology in the twilight of the twentieth century has shortened both temporal and spatial spaces of interaction globally. This innovation, which has continued to grow, is constantly impacting the sociocultural, economic, and political life of members of society. SDG 9 expects nations to "build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovations" as part of the ingredients of development in this century. Over the last twenty-five years or so, Nigeria has enjoyed an improvement in communication with the introduction of computer communication and mobile telephony. The improvement has made a significant impact in all sectors, including the commercial, social, and educational sectors. Furthermore, it has resulted in increased usage of internet technology, the growth of cybercafés, e-learning, e-business, e-banking, and so on. It is important to note, however, that the spread or acceptance of innovations can either be enhanced or impeded by factors such as lack of information, cultural perception, worldview, resistance to change, and so on. Thus, in introducing innovations or formulating policies on innovation, there is the need to find out or obtain information on what matters to society. This is, perhaps, one reason Kinge'I (2004:1) is of the view that Africa's development in this century must be research-driven. Therefore, we need to only carry out but strengthen, among other things, social and cultural investigations in order to be able to obtain vital data that can be used to arrive at well-informed judgments and policies governing development in all the facets of the life of our society.

In a study of the Yoruba people's perception of science and technology titled 'Language and Culture in Science and Technology' (Salami, 2008), I tried to explore the relationship among language, culture, and the reception of S & T by Yoruba people. It was assumed that a study of language use and language as a carrier and promoter of attitudes and perceptions of the Yoruba people would assist us in unraveling two things. First, it will show us the linkage between the culture of the people and the way they see development in S & T. Secondly, such a study will show how the Yoruba worldview informs their acceptance of global scientific and technological innovations. The overall goal of the study was to be able to show if the propagation or promotion of these innovations would be impacted by culture and how. The findings showed that even though the interviewees for the study acknowledged the widespread use and acceptance of computer and internet technology, there was still a high level of teleological thinking among a large number of the people interviewed, especially those with little education and rural dwellers. Those with formal education, however, were more rational about the explanation of nature and technological innovations. The study thus seems to point to the need to

consider a factor of culture in any attempt at propagating technology among the people. It can be recalled, for example, the challenge Osun and Ekiti state governments had with secondary school pupils buying into the idea of using laptops and tablets as educational resources. There were stories of how laptops and tablets that were provided by the governments of the two states to pupils for educational purposes were either sold by some parents to augment their incomes or turned into devices for watching home videos.

Mobile telephones, digital cameras, internet video, and so on, have revolutionized communication and interaction between and among the populace. Many research reports on media discourses show that the internet communication technology has become a veritable source of research data that give us glimpses into some of the challenges of development in Nigeria. These challenges include, among others, Nigerians' different understanding and definition of nationhood, nationalism, democratic governance, participatory democracy, transparency, accountability, corruption etc. Media discourses show different stances of participants which are underlined by various ideologies, including ethnic, religious and class ideologies. Thus, it is incumbent on the linguist, especially the discourse analyst, to show some interest in these discourses not just for analytical or theory-building purposes but also to be able to use them to make informed judgments concerning Nigeria's development so as to make critical interventions in any way that they can. In other words, I am suggesting the need for research work on various kinds of media discourses, including social, political, religious, with the goal of identifying areas of challenges to building a 21st century Nigeria. Furthermore, the identification of these challenges should propel us to finding solutions from our languages and cultures to build a nation and promote the good of the country and its peoples.

7 Conclusion and Way Forward

In concluding this paper, I will like to say that what I have done, so far, has been to make a selection from several areas in which the Nigerian linguist can contribute to repositioning the country's languages and cultures through research and intervention efforts for the sake of Nigeria's development in the 21st century. I have looked at governance and democracy, education, literacy, healthcare and population growth among other concerns. In all this, I have been able to show that the Nigerian linguist and cultural researcher have important roles to play by not only understanding the values of our linguistic and cultural resources but also by being able to use them to solve some of the developmental problems confronting the country. Thus, they must try to do a number of things that I like to itemize below.

First, they must constantly demonstrate some commitment to protecting and promoting Nigerian languages, cultural values and norms. Secondly, apart from doing theoretical works, our research should also focus on problem solving and interventions. Thirdly, such of our research works should feed into areas of critical concerns in development. Finally, in engaging with these critical concerns, Nigerian linguists and cultural researchers should also find ways of engaging, as well, our languages and cultures in the discourses of development. As Marana (2010) points out, this would involve some focus on such concerns as cultural and language rights; linguistic diversity; creative industries and so on, because, as earlier noted in this talk, development is not just economic growth but also a "process to boost a people's capacities and broaden their options" (pg.4).

Reference

[1] Afolayan, A. (Ed.) (1982). *Yoruba Language and Literature*. Ife & Ibadan: University of Ife Press and University Press.
[2] Billig, M. (1995). *Banal Nationalism*. London: Sage Publications.
[3] Blackler, F. (Ed.) *Social Psychology and Developing Countries*. New York: John Wiley.

[4] Bodomo, A. (1996). On Language and Development in Africa: The Case of Ghana. *Nordic Journal of African Studies, 5*(2), 31-51.
[5] Freeman, R. D. (1998). *Bilingual Education and Social Change*. Clevedon, England: Multilingual Matters.
[6] Kakonge, J. O. (2017). The Role of Culture in Africa's Development. https://gga.org/the-role-of-culture--in-africas--development/
[7] King'ei, K. (2000). Language in Development in 21st Century Africa. *African Studies Quarterly, 3*(3), 25-29. http://www.africa.ufl.edu/asq/v3/v3i3a3.pdf
[8] Marana, M. (2010). *Culture and Development: Evolution and Prospects*. UNESCO Etxea Working Papers, No. 1.
[9] Ndhlovu, F. (2008). Language and African Development: Theoretical Reflections on the Place of Languages in African Studies. *Nordic Journal of African Studies, 17*(2), 137-151.
[10] Obiegbu, I. (2016). Language and Culture: Nigerian Perspective. *African Research Review: An International Multidisciplinary Journal, Ethiopia, 10*(4), 43: 69-82.
[11] Oyelaran, O. (1988). Language, Marginalization, and National Development in Nigeria. *Ife Studies in English, 2*(1), 1-13.
[12] Salami, L. Oladipo (2006). Creating God in Our Image: The Attributes of God in the Yoruba Socio-Cultural Environment. In Tope Omoniyi and Joshua A. Fishman (Eds.), *Explorations in the Sociology of Language and Religion*. Amsterdam/Philadelphia: John Benjamins.
[13] Salami, L. Oladipo (2008a). It is Still "Double Take": Mother Tongue Education and Bilingual Classroom Practice in Nigeria. *Journal of Language, Identity and Education, 7*(2), 91-112.
[14] Salami, L. Oladipo (2008). It is Still "Double Take": Mother Tongue Education and Bilingual Classroom Practice in Nigeria. *Journal of Language, Identity and Education, 7*(2), 91-112.
[15] Salami, L. Oladipo (2008b). Language and Culture in Science and Technology Development: A Study of the Perceptions of Yoruba People of Global Development in Science and Technology. Unpublished Seminar Paper, Wesley University of Science Technology, Ondo.
[16] Salami, L. Oladipo (2014). *Sociolinguistics*. Ibadan: NPS Educational Publishers.
[17] Tucker, G. R. (1999). *A Global Perspective on Bilingualism and Bilingual Education*. Washington, DC: ERIC Clearing House on Languages and Linguistics. (ERIC Document Reproduction Service, No.: ED435168)
[18] Zimmermann, K. A. (2015). Definition of Culture. http://www.unesco.org/new/en/social-and-human-sciences/themes/internatio...

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp. 347–353, November 13-16, 2023

Effects of Addition of Silicon Oxide Nano Particles on the Rheology of Jatropha Biodiesel (Physic Nut)

A.Y. Fagge[1], H.U. Jamo[2]
{ayfagge@fugusau.edu.ng[1], jamouhfce@gmail.com[2]}

Department of Physics, Federal University Gusau, Zamfara State, Nigeria, 0808 649 0565[1], Department of Physics, Kano University of Science and Technology, Kano State, Nigeria[2]

Subject Classification: Pure and Natural Sciences (Material Science/ Renewable Energy)

Abstract
Due to gradual depletion of world petroleum reserves and the impact of environmental pollution of increasing exhaust emissions of Carbon and Hydrogen with small proportion of Sulphur and Nitrogen, there is an urgent need for suitable alternative fuels for use in diesel engines. In view of this, vegetable oil is a promising alternative because it is renewable and environment friendly. The recent trend is attempted to develop biodiesel from Jatropha oil and investigates the effects of SiO_2 nanoparticles on the rheological properties of Jatropha Biodiesel. The crude Jatropha oil was purified, trans-esterified and nanoparticles were dispersed in the trans-esterified oil with concentration ranging from 0.25% to 1.0% in 0.25% interval. Fourier Transform Infrared spectra (FTIR) was used to examine the structures of the samples, the Viscosity, Pour point, Boiling point and the Flash point were studied. It was found out among other things that small amount of (0.25% SiO_2) nanoparticles in the trans-esterified oil could improve the rheological properties of the fluid. The Nano-fluid with 0.25% concentration of SiO_2 appears to have optimum rheological property.

Key words: Biodiesel, Jatropha, Nano Particles, Rheology, SiO_2

1 Introduction

Vegetable oils are obtained from oil containing seeds, fruits, or nuts by different pressing methods or solvent extraction [3]. Crude oils obtained are subjected to a number of refining processes, both physical and chemical [4]. Biodiesel is produced from various sources of edible and non-edible oils such as Jatropha oil, Castor oil, Olive oil, Soybean oil, and Palm oil throughout the world [5]. Other advantages that encourage the use of vegetable oils include their relatively low viscosity-temperature variation; that is their high viscosity indices, which are about twice those of mineral oils [8]. Additionally, they have low volatilities as manifested by their high flash points [9]. Significantly, they are environmentally friendly: renewable, non toxic and biodegradable [7]. With the concern on the fire safety and environmental issues, alternative fluids are currently being considered [1]. In a comparison of jatropha oil and mineral based lubricants, jatropha oil based lubricants were found to be more effective in reducing the hydrocarbon and carbon monoxide emission levels, among other things. Hence, the present study wishes to investigate the effects of Addition of Silicon Oxide Nano Particles on the Rheology of Jatropha Biodiesel (Physic Nut) for the purpose of using it as transformer lubricating oil.

2 Materials and Methods

2.1 Materials

2.1.1 Chemicals

The materials and reagents used in carrying out the research are as follows: crude jatropha oil, 8 % sodium hydroxide (NaOH), 64 % citric acid ($C_6H_8O_7$, purity: 99.7 %), silicon (SiO_2) reagent, activated carbon and distilled water (H_2O).

2.1.2 Equipment

The equipment used in carrying out this study are: magnetic stirrer with thermostatically controlled rotary hot plate (IKA C-MAG HS10), Brookfield Digital viscometer {Brookfield,RVDV-I},

thermometer, measuring cylinder, Digital weight balance (Model GT2000 EC), beaker, 24 cm filter paper, funnel, Digital stop watch, sampling bottles, spatula.

3 Methodology

3.1 Sample Purification

The Jatropha oil was purified through the following procedure; 200ml of jatropha oil was measured using measuring cylinder; the oil was pre-heated to 70^{o}C using hot magnet stirrer with thermometer. Then 1.5ml citric acid was measured and added to the heated oil sample and continuously heated and stirred for 15minutes at 70^{o}C.4 ml of 8% NaOH (by dissolving 8 g NaOH in 100ml of distilled water) was then be added to the oil and continuously heated and stirred for 15minutes at 70^{o}C. The mixture was then transferred to the vacuum oven where it was heated at 85^{o}C for 30minutes. Then the mixture was taken back to hot magnetic stirrer and heated to 70^{o}C after which a 2g 0f silicone reagent was added while it was being heated and stirred for 30minutes. Then the temperature was increased to 85^{o}C and 4g of activated carbon was added to each 100ml of the oil sample, heated and stirred for 30minutes. Then the mixture was separated using filter paper.

3.2Trans-esterification

60g of the purified jatropha oil was measured in 250ml of conical flask and was heated and stirred to a temperature of 60-65℃ on a hot magnetic stirrer plate, 0.6g of NaOH was measured using the electronic weight machine and allowed to dissolve in 21ml of methanol and then allowed to heat for 60minutes with the stirrer on the hot magnetic plate. After 60minute of uniform stirring and heating on the hot magnetic plate maintaining a temperature of 65℃, it was then poured into the separating funnel through a glass funnel. The mixture was allowed to cool for about 40minute. Afterwards, it was observed that it separated into two liquid layers. The upper layer is the biodiesel and the lower layer is triglycrol fatty acid. The biodiesel was then separated from it is by product using separating funnel.

3.3 Nano-fluids Preparation

The SiO_2 Nano-particles powder was purchased from SkySpring Nano-materials, Inc., U. S. A, the size of the Nano-particles is 10-20nm and the surface was modified with Epoxy Group and it is dispersible as mentioned by the company. Nano-fluids are prepared by two step process. The volume concentration of 0.25%, 0.5%, 0.75% and 1% of powdered Nano-particles and purified palm oil was made respectively. To make the Nano-particles more stable and remain more dispersed, each sample was stirred for 3-4 hours using magnetic stirrer, then the samples were taken for analysis.

3.4Samples Measurement

3.4.1 Viscosity

Viscosity was measured using Brookfield viscometer in a speed range of 50 rpm with spindle size of 2 since a small quantity of the sample is to be measured. The following are the detailed procedure for viscosity measurement; the sample was poured into a beaker, the spindle was fixed and the machine was started, the angular speed was selected on the viscometer and the viscosity was read and recorded the same procedure was repeated for the purified jatropha oil.

3.4.2Pour Point

Using an improvised method, the experimental procedures of pour point measurement for both crude and purified oil are enumerated below; the cylindrical test tube was filled with the crude palm oil to a specific level mark (5ml). The test tube was clamped with a wooden clamp carrying the thermometer then placed in a bath of crushed ice (ice bath) and allowed to cool at a specified rate interval of 3^{o}C for flow characteristics the lowest temperature at which the movement of the oil is observed within 5

s is taken as pour point on the thermometer. ASTM 1999, D 97.The same procedure was repeated for the purified jatropha oil.

3.4.3Flash Point

The flash point for both crude and purified jatropha oil was also measured; A 100ml conical flask was filled to a specific mark level (10ml) with jatropha oil and heated at 14 t0 17ºC / min (25 to 30ºF/min) on the hot plate until the temperature is 56ºC (100ºF) below the expected flash point, the rate of temperature changes was then reduce to 5 to 6 ºC /min (9 to 11ºF/min) and the test flame was applied for every 2ºC (5ºF) until the oil burn for at least 5s. The flash point was taken at the lowest temperature when an application of the flame test caused the vapor above the sample to ignite. ASTM 1999, D 92. Thesame procedure was repeated for the purified and trans-esterified jatropha oil.

4 Results and Discussions

Good heat transfer and fluid flow are characteristics of insulating fluid, as a result of low viscosity which necessitated the additional study of this physical property. Figure 1 shows the graph of the crude, purified and trans-esterified jatropha oil. It could be seen from the Figure that the trans-esterified biodiesel has lower viscosity followed by purified and the crude has the highest viscosity. The viscosity for all the three oils decreases with increase in temperature until when the temperature reaches 100^{O}C. When the temperature increases, the energy level of the liquid molecules increases and the distance between the molecules increases. It causes a decrease in intermolecular attraction between them, which reduce the viscosity. Simultaneously increase in temperature of liquid increase the molecular interchanging between fluid layers interactions increases viscosity [2].

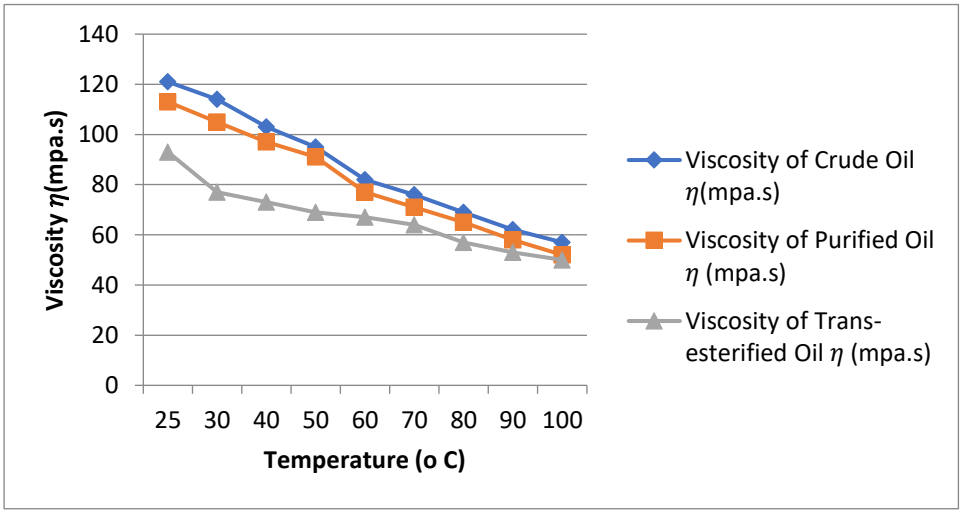


Figure 1: Graph of Viscosity η (mpa.s) versus Temperature (^{o}C) of Jatropha oil.

Cooling equipment in industries is mainly governed by convection, so it is necessary to have low viscosity for that application. The lower the viscosity, the better the cooling and friction reduction. Figure 1; shows that the viscosity of Trans-esterified Jatropha oil at 70ºC is 62mpa.s which is lower than the specified value 65mpa.s of standard motor oil given by Society for Automotive Engineers (SAE) at 70ºC.

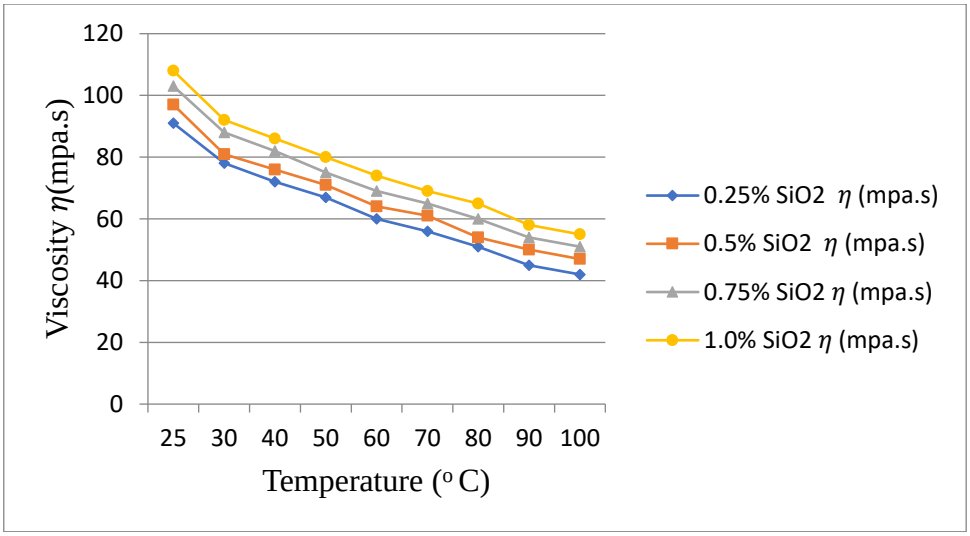


Figure 2. Graph of Viscosity η (mpa.s) versus Temperature (^{o}C) SiO_2 Nano -Jatropha Fluid

Addition of Nano-particles resulted in additional decrease in viscosity of the fluid. Similarly, the percentage concentration shows a significant effect in the enhancement of the viscosity of the fluid. From ever day experience, it should be common knowledge that viscosity varies with temperature. In general, viscosity of sample liquid decreases with increase in temperature and the amount of time they spend in "contact" with their nearest neighbours' decreases. Thus, as temperature increases, the average intermolecular forces decreases.

2.2.1

2.2.2 4.1 Temperature Effect

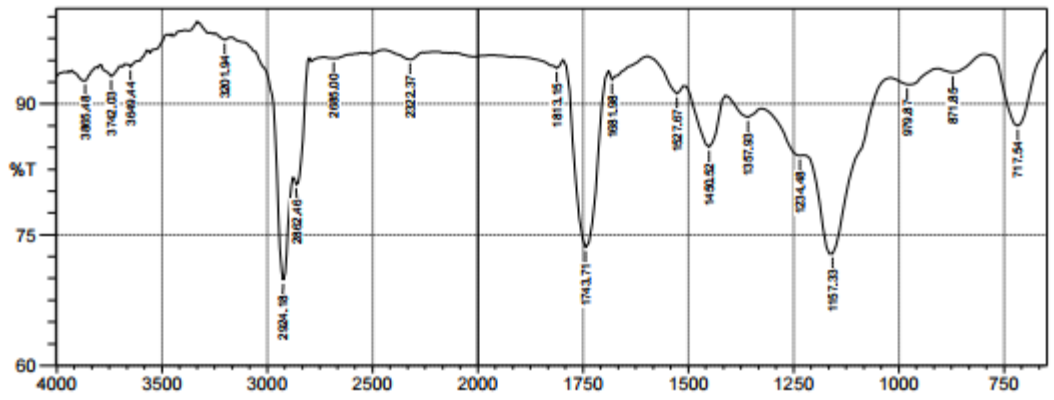
It is necessary to investigate the temperature dependence of the fluid in order to act as lubricants/coolants. They take heat out of the system as a result, it is necessary to know heating effect of the fluid. The effects of temperature on a.c conductivity of the samples were studied from temperature of about 30^{o}C to 70^{o}C at interval of 10^{o}C. Both crude, purified, trans-esterified and nano-jatropha fluid were found to increase with increase in temperature [6]. All samples appeared to have the same response to heat within the temperature range studied.

Table 1. Pour Point, Flash Point and Fire Point Result

S/No.	Sample	Pour point (^{o}C)	Flash point (^{o}C)	Fire Point (^{o}C)
1	Crude Jatropha Oil	10	128	133
2	Purified Jatropha Oil	7	130	140
3	Trans – esterified	4	135	146
4	Trans - esterified (0.25w% SiO_2)	**2**	**142**	**158**
5	Trans - esterified (0.5w% SiO_2)	3	138	140
6	Biodiesel standard (ASTM)	-15 to 10	100 to 170	>130
7	Diesel standard (ASTM)	-15 to 5	60 to 80	60 to 80

Table 1. present the result of Pour point, Flash point and Fire point of Crude, Purified, Trans-esterified and Nano-jatropha fluids. It was observed that 0.25w% SiO_2 Nano-Jatropha fluid have good result with Pour point of 2^{o}C, Flash point of 142^{o}C and Pire point of 158^{o}Cwhich are all within ASTM standard. High flash point of Jatropha Biodiesel has certain advantages compared to petroleum based fluid for greater safety during storage, handling and transport [10].

The FTIR analysis is employed in order to identify the presence of SiO_2 Nano-particles in the based trans-esterified jatropha oil, the FTIR spectra of all the samples were obtained using SHIMADZU FTIR-8400S Spectrophotometer at National Research Institute for Chemical Technology (NARICT) Zaria. It is an established fact that the fundamental vibrations of solids particle (fingerprint) are localized in the low frequency region (<1200 cm^{-1}) of the midrange (400-4000cm^{-1}) of the infrared spectrum. So the FTIR spectra of purified Jatropha and Nano-fluid are presented below.



n in

Figure 3: FT-IR Spectra of Crude Jatropha Oil

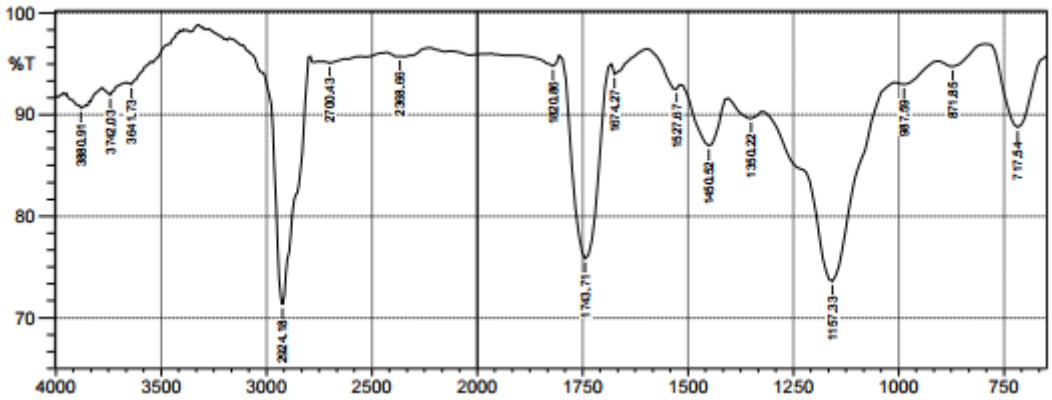


Figure 4. FT-IR Spectra of Purified Jatropha Oil

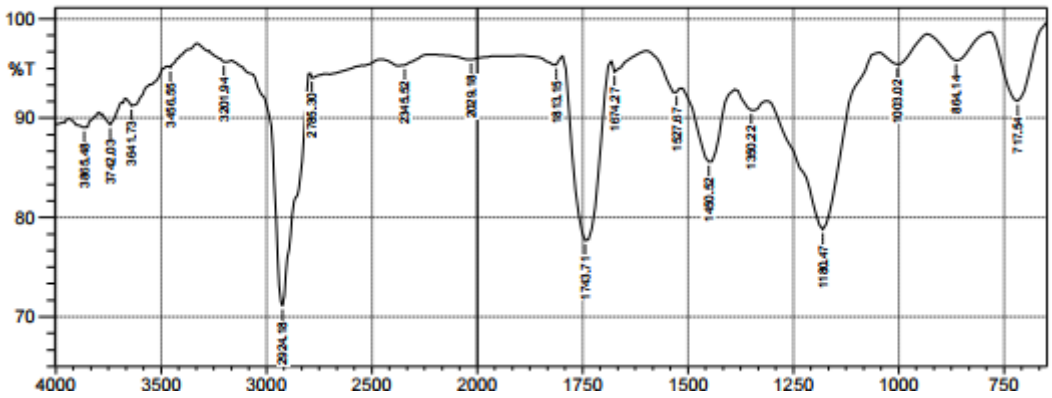


Figure 5.FT-IR Spectra of Trans-esterified Jatropha Oil

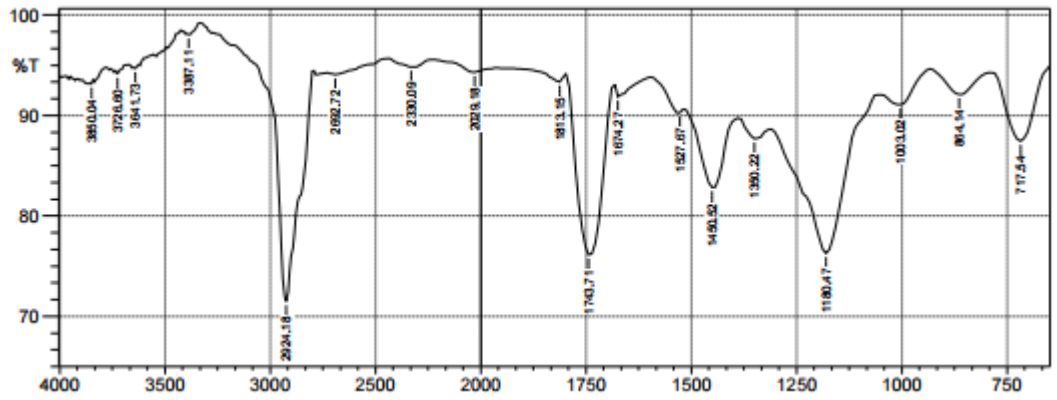


Figure 6: FT-IR Spectra of 0.25% nanoparticles concentration in jatropha oil

The FTIR spectra shown in Figures 3- 6, displayed the typical bands that exist in natural esters. The band with a peak at 2924 cm^{-1} describes C-H stretching. The bands with peaks at 1674 cm^{-1} and 1003 cm^{-1} are vibration of C=O and C-O. These are typical bands that describe esters. The bands with peaks at 1450 cm^{-1} is due to methylene scissoring and rocking.

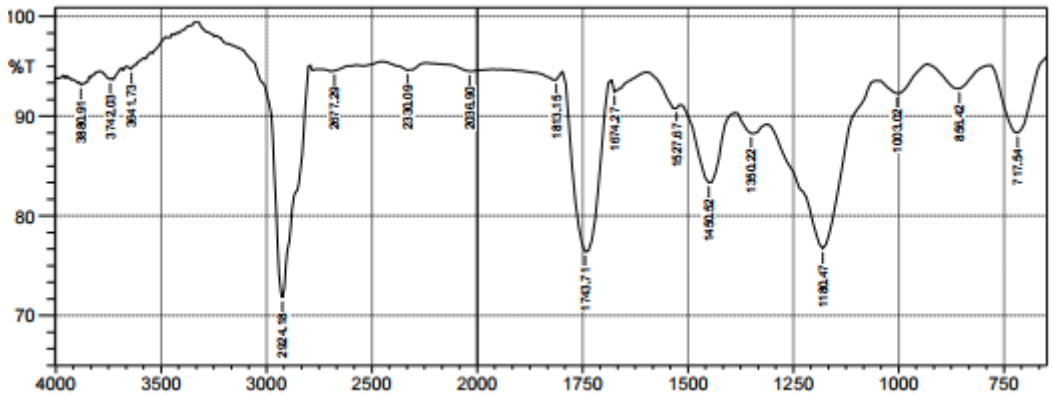


Figure 7.FT-IR Spectra of 0.5% nanoparticles concentration in jatropha oil

The addition of SiO_2 Nano-particles is expected to change the FTIR spectra of the fluid. Meanwhile no visible change was observed when the concentration of the Nano-particle in the fluid was 0.25% and 0.5%, a band was observed around 856 cm^{-1} and 864 $cm^{-1}$is believed to be shrouded ester C-O band.

5 Conclusion

The experimental results show that the sample has viscosity lower than conventional insulating fluid. Just like most insulating fluids, the dynamics viscosity decrease with increase in temperature. The addition of nanoparticles (0.25w% SiO_2) resulted in decrease in viscosity. The viscosity change may have contributed to the observed increase in with temperature. The Trans - esterified Nano-fluid with (0.25w% SiO_2) appears to be more suitable for insulation as the sample was observed to have lowest pour point of 2℃ and higher flash point of 142℃. This is due to the removal of gums in form of phospholipids from the crude oil. Hence, therefore, the result of the study shows that the trans-esterified Nano-fluid Jatropha oil with 0.25% oil is potential candidate for the production of lubricating fluid.

Reference

[1] Azhari, M. A., Suffian, Q. N., & Nuri, N. R. M. (2014). The Effect of Zinc Dialkyldithiophosphate Addition to Corn Oil in Suppression of Oxidation as Enhancement for Bio Lubricants: A Review. Journal of Engineering and Applied Sciences, 9(9), 1447-1449.

[2] Demirbas, A. (2005). Biodiesel Impacts on Compression Ignition Engine (CIE): Analysis of Air Pollution Issues Relating to Exhaust Emissions. Energy Sources, 27(6), 549-558.

[3] Ferreira, I. J., Alexandre, E. M., Saraiva, J. A., & Pintado, M. (2022). Green Emerging Extraction Technologies to Obtain High-Quality Vegetable Oils from Nuts: A Review. Innovative Food Science & Emerging Technologies, 76, 102931.

[4] Gharby, S. (2022). Refining Vegetable Oils: Chemical and Physical Refining. The Scientific World Journal, 2022.

[5] Gui, M. M., Lee, K. T., & Bhatia, S. (2008). Feasibility of Edible Oil vs. Non-Edible Oil vs. Waste Edible Oil as Biodiesel Feedstock. Energy, 33(11), 1646-1653.

[6] Ifijen, I., & Nkwor, A. (2020). Selected Under-Exploited Plant Oils in Nigeria: A Correlative Study of Their Properties. Tanzania Journal of Science, 46(3), 817-827.

[7] Rafiq, M., Shafique, M., Azam, A., Ateeq, M., Khan, I. A., & Hussain, A. (2020). Sustainable, Renewable, and Environmental-Friendly Insulation Systems for High Voltages Applications. Molecules, 25(17), 3901.

[8] Sajeeb, A., & Rajendrakumar, P. K. (2019). Comparative Evaluation of Lubricant Properties of Biodegradable Blend of Coconut and Mustard Oil. Journal of Cleaner Production, 240, 118255.

[9] Salih, N., & Salimon, J. (2021). A Review on Eco-Friendly Green Biolubricants from Renewable and Sustainable Plant Oil Sources. Biointerface Res. Appl. Chem, 11(5), 13303-13327.

[10] Singh, S. P., & Singh, D. (2010). Biodiesel Production through the Use of Different Sources and Characterization of Oils and Their Esters as the Substitute of Diesel: A Review. Renewable and Sustainable Energy Reviews, 14(1), 200-216.

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp. 354–368, November 13-16, 2023

Subclass of Janowski Starlike Functions Associated with Rabotnov Function and Opoola Differential Operator

Ezekiel Abiodun Oyekan[1*]
{ea.oyekan@oaustech.edu.ng}

Department of Mathematical Sciences, Olusegun Agagu University of Science and Technology, P.M.B.353, Okitipupa, Nigeria

Abstract
Hitherto, investigations and studies on divers fascinating subclasses of analytic functions including symmetrical points and other famous regions have been explored by many researchers. In most cases, these numerous subclasses of analytic functions have been considerably enhanced and employed for evaluating the first initial bounds, Fekete-Szego functional and Hankel determinants. The motive of this present study is to employ combination of certain Janowski functions, Rabotnov function and Opooola differential operator to introduce a new subclass of holomorphic functions which is symmetric under rotation. With the aid of this subclass, we derive some characterization properties like coefficient inequalities, radius problems and results related to partial sums. By varying the parameters in the definition of the subclasses, it turns out that the investigated subclasses yields certain corollaries.

Keywords: Analytic function, starlike function, Rabotnov Function, Opoola differential operator, coefficient inequality, integral-preserving property, radii problems, subordination

2020 *Mathematics Subject Classification.* Primary 30C45; Secondary 30C55.

1 Introduction

This investigation is on a set of normalized analytic functions herein denoted by $\mathcal{A}$ and defined in the unit disk: $|z| < 1$. Further, let S be a subclass of $\mathcal{A}$ which consists of analytic and univalent functions defined such that *f* is expressed in series form

$$f(z) = z + \sum_{k=2}^{\infty} a_k z^k \qquad (|z| < 1) \tag{1}$$

and normalized such that $f(0) = f'(0) - 1 = 0$. Recall that the Hadamard product of

$$f \text{ in } (1.1) and\ F(z) = z + \sum_{k=2}^{\infty} c_k z^k \tag{2}$$

is defined by

$$(f \star F)(z) = \sum_{k=2}^{\infty} (a_k \times c_k) z^k = (F * f)(z) \qquad (|z| < 1)$$

Likewise, *f* is subordinate to *F*, regularly symbolized as $f \prec F$ if $f = F\ o\ s = F\big(s(z)\big)$ for the analytic function

$$s(z) = s_1 z + s_2 z_2 + s_3 z_3 + \cdots (s(0) = 0\ and\ |s(z)| < 1)$$

If by peradventure *F* is univalent for $|z| < 1$, then

$f \prec F$ if and only if $f(0) = F(0)$ and $f(|z| < 1) \subset F(|z| < 1)$.

An astounding application of subordination in Geometric Function Theory (GFT) is the peculiar way it is use to define some subsets of S. For instance, the set $S^{\star}$ of starlike functions consist of functions that fulfill the condition

$$zf'/f \prec \wp_0(z) = \frac{1+z}{1-z}$$

where $\wp_0(z)$is the well-known Mobius function and serves as the extremal function for all function-type

$$y(z) = 1 + y_1 z + y_2 z^2 + \cdots \in Y(\Re y(z) > 0, |z| < 1).$$

In 1973, Janowski [12] generalized functions in Y where the author introduced the sets

$$Y(A,B) = \left\{ y \in Y : Y(z) \prec \frac{1+A_z}{1+B_z} \; and \; -1 \le B < A \le 1 \right\}$$

and

$$S^{\star}(A,B) = \left\{ f \in S : \frac{zf'(z)}{f(z)} \prec \frac{1+A_z}{1+B_z} \; and \; -1 \le B < A \le 1 \right\}$$

1.1 Certain Operators and Series. Rabotnov [1] created a unique viscoelasticityrelated function in 1948. The following equation describes this function, Let

$$\mathcal{M}_{\beta,\gamma}(z) = z^{\beta} \sum_{k=1}^{\infty} \frac{(\gamma)^k z^{k(1+\beta)}}{\Gamma(k+1)(1+\beta)}, \qquad (\beta, \gamma, z \in \mathbb{C}). \tag{3}$$

often known as the Rabotnov fractional exponential function or simply the Rabotnov function:

$$\mathcal{M}_{\beta,\gamma}(z) = z^{\beta} \mathcal{E}_{1+\beta,1+\beta}\left(\gamma z^{1+\beta}\right),$$

where $\mathcal{E}$ is Mittag-Leffler and it expresses the relation betweeen Rabotnov Mittag-Leffler [2]. ([3],[4],[5],[6]) lists a number of characteristics of the generalized Mittag-Leffler function and the Rabotnov function is a special example of the well-known Mittag-Leffler, which is frequently employed in the solution of fractional order differential equations or integral equations.
It is obvious that $\mathcal{A}$ does not contain the Rabotnov function $M_{\beta,\gamma}(z)$. As a result, it makes sense to think about how the Rabotnov function can be defined in such a way that it will belongs to the usual class $\mathcal{A}$ of analytic functions, This according to Eker and Ece in [21] is defined by

$$\mathcal{R}_{\beta,\gamma}(z) = z^{1+\beta}\Gamma(1+\beta)\mathcal{R}_{\beta,\gamma}\left(z^{1+\beta}\right)$$

$$z + \sum_{k=2}^{\infty} \frac{(\gamma)^{k-1}\Gamma(1+\beta)}{\Gamma\left(k(1+\beta)\right)} z^k, \qquad z \in \mathbb{C} \tag{4}$$

normalized form of the Rabotnov function. Also, let

$$\mathcal{D}_{\tau,\sigma}^{m,\mu} f(z) = z + \sum_{k=2}^{\infty} [1 + (k + \mu - \sigma - 1)\tau]^m a_k z^k \tag{5}$$

$$(\tau, \sigma \geqq 0;\ 0 \leqq \mu \leqq \sigma, m \in \mathbb{N} \cup \{0\} := N_0, and\ |z| < 1) \tag{6}$$

be the Opoola differential operator introduced in [19]. This differential operator is well-known to generalize the Sˇalˇagean [33] and Al-Oboudi [7] differential operators, see [13, 14, 22, 23, 24, 27, 29, 34, 35] for more information.

Definition 1.1. The use of the definition of the Hadamard product or (convolution) of two analytic functions mentioned above, it is possible to introduce a new linear operator $E_{\sigma,\mu,t}^{m,\alpha,\beta}\ \mathcal{A} \longrightarrow \mathcal{A}$ as follows.

$$\mathcal{N}_{\beta,\mu,\sigma}^{m,\gamma,\tau} f(z) = \mathcal{R}_{\beta,\gamma}(z) \star \mathcal{D}_{\tau,\sigma}^{m,\mu} f(z)$$
$$= z + \sum_{k=2}^{\infty} \frac{(\gamma)^{k-1}\Gamma(1+\beta)}{\Gamma\big(k(1+\beta)\big)} [1 + (k + \mu - \sigma - 1)\tau]^m a_k z^k \tag{7}$$

or for brevity we may write

$$\mathcal{N}_{\beta,\mu,\sigma}^{m,\gamma,\tau} f(z) = z + \sum_{k=2}^{\infty} \rho(k, \gamma, \beta, \sigma, \tau, \mu) a_k z^k \tag{8}$$

where

$$\rho(k, \gamma, \beta, \sigma, \tau, \mu) = \frac{(\gamma)^{k-1}\Gamma(1+\beta)}{\Gamma\big(k(1+\beta)\big)} [1 + (k + \mu - \sigma - 1)\tau]^m$$

2 MAIN RESULTS

Definition 2.1. From now on, let $\sigma \geqq 0, 0 \leqq \mu \leqq \sigma, m \in N_0, r > 0, -1 \leqq B < A \leqq 1$, and γ, β are as earlier defined, then a function *f* of the form (1.1) is an element of the class $T_{\beta,\mu,\sigma}^{m,\gamma,\tau}(A, B)$ if it fulfills the condition

$$\frac{z\left(\mathcal{N}_{\beta,\mu,\sigma}^{m,\gamma,\tau} f(z)\right)'}{\mathcal{N}_{\beta,\mu,\sigma}^{m,\gamma,\tau} f(z)} \prec \frac{1 + Az}{1 + Bz} \qquad (|z| < 1) \tag{9}$$

for $\mathcal{N}_{\beta,\mu,\sigma}^{m,\gamma,\tau} f(z)$ defined in (7).
Suppose $m = 0$, then set $T_{\beta,\mu,\sigma}^{m,\gamma,\tau}(A, B) = T_r(A, B)$, where $T_r(A, B)$ is the set studied by Liu et al. [17].
Geometric function theorists have studied several geometric properties of many subsets of analytic functions defined by devise number of operators, for instance see [15, 14]. In this investigation, many geometric properties of functions that fulfill condition (9) are presented. Some of the properties are the coefficient inequality, radii problems and subordinating factor sequence. Others are distortion, growth, covering, closure, inclusion and some integral operators that are preserved in the new class. Some contextual work relevant to these properties are cited in [20, 19, 26, 24, 25, 28]

Theorem 2.2. A function $f \in A$ belongs to the set $\mathcal{T}_{\beta,\mu,\sigma}^{m,\gamma,\tau}(A, B)$ if it fulfills the inequality

$$\sum_{k=2}^{\infty} \rho(k,\gamma,\beta,\sigma,\tau,\mu)|a| \leqq A - B \qquad (10)$$

Where

$$\rho(k,\gamma,\beta,\sigma,\tau,\mu) = \frac{(\gamma)^k \Gamma(1+\beta)}{\Gamma\big(n(1+\beta)\big)}[1+(k+\mu-\sigma-1)\tau]^m[k-1+|Bk-A|]$$

Proof. Assume condition (10) is fulfilled, then by subordination technique, (9) can be written as

$$\frac{z\left(\mathcal{N}_{\beta,\mu,\sigma}^{m,\gamma,\tau} f(z)\right)'}{\mathcal{N}_{\beta,\mu,\sigma}^{m,\gamma,\tau} f(z)} = \frac{1+As(z)}{1+Bs(z)}$$

which by equivalence yields

$$\left|\frac{z\left(\mathcal{N}_{\beta,\mu,\sigma}^{m,\gamma,\tau} f(z)\right)' - \mathcal{N}_{\beta,\mu,\sigma}^{m,\gamma,\tau} f(z)}{A\mathcal{N}_{\beta,\mu,\sigma}^{m,\gamma,\tau} f(z) - zB\left(\mathcal{N}_{\beta,\mu,\sigma}^{m,\gamma,\tau} f(z)\right)'}\right| = s(z) < 1$$

such that $|s(z)| < 1$ and $s(0) = 0$. The application of (7) and further simplification yield

$$\left|\frac{\sum_{k=2}^{\infty} \frac{(\gamma)^{k-1}\Gamma(1+\beta)}{\Gamma\big(k(1+\beta)\big)}[1+(k+\mu-\sigma-1)\tau]^m(k-1)a_k z^{k-1}}{(A-B) - \sum_{k=2}^{\infty} \frac{(\gamma)^{k-1}\Gamma(1+\beta)}{\Gamma\big(k(1+\beta)\big)}[1+(k+\mu-\sigma-1)\tau]^m(Bk-A)a_k z^{k-1}}\right|$$

$$= \frac{\sum_{k=2}^{\infty} \frac{(\gamma)^{k-1}\Gamma(1+\beta)}{\Gamma\big(k(1+\beta)\big)}[1+(k+\mu-\sigma-1)\tau]^m(k-1)|a_k|}{(A-B) - \sum_{k=2}^{\infty} \frac{(\gamma)^{k-1}\Gamma(1+\beta)}{\Gamma\big(k(1+\beta)\big)}[1+(k+\mu-\sigma-1)\tau]^m|Bk-A||a_k|}$$

Clearly, the LHS is bounded above by 1 if

$$\sum_{k=2}^{\infty} \frac{(\gamma)^{k-1}\Gamma(1+\beta)}{\Gamma\big(k(1+\beta)\big)}[1+(k+\mu-\sigma-1)\tau]^m(k-1)|a_k|$$
$$\leqq (A-B) - \sum_{k=2}^{\infty} \frac{(\gamma)^{k-1}\Gamma(1+\beta)}{\Gamma\big(k(1+\beta)\big)}[1+(k+\mu-\sigma-1)\tau]^m(Bk-A)|a_k|$$

while some rearrangement and simplification yield (10).

Corollary 2.3. Let $f \in T_{\beta,\mu,\sigma}^{m,\gamma,\tau}(A,B)$. Then

$$|a_k| \leqq \frac{A-B}{\rho(k,\gamma,\beta,\sigma,\tau,\mu)} z^k \qquad (k = 2,3,4,\ldots, |z| < 1)$$

and inequality (10) is sharp for the function

$$f_k(z) = z + \frac{A-B}{\rho(k,\gamma,\beta,\sigma,\tau,\mu)} z^k \qquad (k = 2,3,4,\ldots, |z| < 1). \tag{11}$$

2.1.Growth Theorem.

Theorem 2.4. Let $f \in \mathcal{T}^{m,\gamma,\tau}_{\beta,\mu,\sigma}(A,B)$. Then

$$|z| - \frac{|z|^2 \rho(2,\alpha,\beta,\sigma,\tau,\mu,)(A-B)}{\rho(2,\gamma,\beta,\sigma,\tau,\mu,)} \leqq \left|\mathcal{N}^{m,\gamma,\tau}_{\beta,\mu,\sigma} f(z)\right|$$
$$\leqq |z| + \frac{|z|^2 \rho(2,\alpha,\beta,\sigma,\tau,\mu,)(A-B)}{\rho(2,\gamma,\beta,\sigma,\tau,\mu,)} \tag{12}$$

The result is sharp for the function

$$f_2(z) = z + \frac{A-B}{\rho(2,\gamma,\beta,\sigma,\tau,\mu)} z^2 \qquad (|z| < 1). \tag{13}$$

Proof. From (10) we get

$$\rho(2,\gamma,\beta,\sigma,\tau,\mu) \sum_{k=2}^{\infty} |ak| \leqq \sum_{k=2}^{\infty} \rho(k,\gamma,\beta,\sigma,\tau,\mu)|ak| \leqq A - B$$

so

$$\sum_{k=2}^{\infty} |a_k|$$
$$\leqq \frac{A-B}{\rho(2,\gamma,\beta,\sigma,\tau,\mu)}. \tag{14}$$

Clearly, $|z|^k < |z| < 1$ so that from (8) we get

$$\left|\mathcal{N}^{m,\gamma,\tau}_{\beta,\mu,\sigma,} f(z)\right| = \left| z + \sum_{k=2}^{\infty} \rho(k,\gamma,\beta,\sigma,\tau,\mu) a_k z^k \right|$$
$$\leqq |z| + |z|^2 \rho(k,\gamma,\beta,\sigma,\tau,\mu) \sum_{k=2}^{\infty} |ak| \tag{15}$$

and putting (14) into (15) yields

$$\left|\mathcal{N}^{m,\gamma,\tau}_{\beta,\mu,\sigma,} f(z)\right| \leqq |z| - \frac{|z|^2 \rho(2,\gamma,\beta,\sigma,\tau,\mu,)(A-B)}{\rho(2,\gamma,\beta,\sigma,\tau,\mu,)}$$

Equally,

$$\left|\mathcal{N}_{\beta,\mu,\sigma,}^{m,\gamma,\tau} f(z)\right| \geqq |z| - \frac{|z|^2 \rho(2,\gamma,\beta,\sigma,\tau,\mu,)(A-B)}{\rho(2,\gamma,\beta,\sigma,\tau,\mu,)}$$

which completes the proof.

2.2.Distortion Theorem.

Theorem 2.5. Let $f \in T_{\beta,\mu,\sigma}^{m,\gamma,\tau}(A,B)$. Then

$$1 - \frac{2|z|\rho(2,\gamma,\beta,\sigma,\tau,\mu,)(A-B)}{\rho(2,\gamma,\beta,\sigma,\tau,\mu,)} \leqq \left|\mathcal{N}_{\beta,\mu,\sigma}^{m,\gamma,\tau} f(z)'\right| \leqq 1 + \frac{2|z|\rho(2,\gamma,\beta,\sigma,\tau,\mu,)(A-B)}{\rho(2,\gamma,\beta,\sigma,\tau,\mu,)}$$

The inequality is sharp for the extremal function in (13).

Proof. Clearly, $|z|^k < |z| < 1$ so that from (8) we have

$$\left|\mathcal{N}_{\beta,\mu,\sigma,}^{m,\gamma,\tau} f(z)'\right| = \left|1 + \sum_{k=2}^{\infty} \rho(k,\gamma,\beta,\sigma,\tau,\mu) a_k z^{k-1}\right|$$

$$\leqq 1 + 2|z|\rho(k,\gamma,\beta,\sigma,\tau,\mu) \sum_{k=2}^{\infty} |a_k| \qquad (16)$$

and putting (14) into (16) gives

$$\left|\mathcal{N}_{\beta,\mu,\sigma,}^{m,\gamma,\tau} f(z)'\right| \leqq 1 - \frac{2|z|\rho(2,\gamma,\beta,\sigma,\tau,\mu,)(A-B)}{\rho(2,\gamma,\beta,\sigma,\tau,\mu,)}$$

Equally,

$$\left|\mathcal{N}_{\beta,\mu,\sigma,}^{m,\gamma,\tau} f(z)'\right| \geq 1 - \frac{2|z|\rho(2,\gamma,\beta,\sigma,\tau,\mu,)(A-B)}{\rho(2,\gamma,\beta,\sigma,\tau,\mu,)}$$

which completes the proof.

2.3.Covering Theorem.

Theorem 2.6. Let $f \in \mathcal{T}_{\beta,\mu,\sigma}^{m,\gamma,\tau}(A,B)$. Then $\mathcal{N}_{\beta,\mu,\sigma,}^{m,\gamma,\tau} f(z)$ maps $|z| < 1$ onto a domain that contains the disk

$$\left|\mathcal{N}_{\beta,\mu,\sigma,}^{m,\gamma,\tau} f(z)\right| \leq 1 - \frac{\rho(2,\gamma,\beta,\sigma,\tau,\mu,)(A-B)}{\rho(2,\gamma,\beta,\sigma,\tau,\mu,)}$$

The inequality is sharp for the extremal function in (13).

Proof. Letting $|z| \longrightarrow 1^-$ in (12) completes the proof.

2.4.Radii Problems

Theorem 2.7. *Let $f \in \mathcal{T}_{\beta,\mu,\sigma}^{m,\gamma,\tau}(A,B)$. Then f is close-to-convex of order λ $(0 \leqq \lambda < 1)$ in the disk*

$$|z| \inf_{k \geqq 2} \left\{\frac{\rho(k,\gamma,\beta,\sigma,\tau,\mu,)(1-\lambda)}{k(A-B)}\right\}^{\frac{1}{k-1}}.$$

The inequality is sharp for the function in (11).

Proof. It is sufficient to show that

$$|f' - 1| < 1 - \lambda.$$

Using (1) yields

$$\sum_{k=2}^{\infty} \left(\frac{k}{1-\lambda}\right) |a_k| |z|^{k-1} < 1 \qquad (17)$$

Evidently, inequalities (10) and (17) is only valid if

$$\frac{k}{1-\lambda}|z|^{k-1} < \frac{\rho(k,\gamma,\beta,\sigma,\tau,\mu,)}{(A-B)}$$

while isolating $|z|^{k-1}$ completes the proof.

Theorem 2.8. Let $f \in T^{m,\gamma,\tau}_{(\beta,\mu,\sigma)}(A,B)$. Then f is starlike of order λ $(0 \leqq \lambda < 1)$ in the disk

$$|z| \inf_{k\geqq 2}\left\{\frac{\rho(k,\gamma,\beta,\sigma,\tau,\mu,)(1-\lambda)}{(k-\lambda)(A-B)}\right\}^{\frac{1}{k-1}}$$

The inequality is sharp for the extremal function in (11).

Proof. It is sufficient to show that

$$\left|\frac{zf'(z)-f(z)}{zf'(z)+(1-2\lambda)f(z)}\right| < 1$$

Using (1) yields

$$\sum_{k=2}^{\infty}\left(\frac{k-\lambda}{1-\lambda}\right)|a_k||z|^{k-1} < 1. \qquad (18)$$

Evidently, inequalities (10) and (18) is only valid if

$$\frac{k-\lambda}{1-\lambda}|z|^{k-1} < \frac{\rho(k,\gamma,\beta,\sigma,\tau,\mu,)}{A-B}$$

and isolating $|z|^{k-1}$ completes the proof.

Theorem 2.9. *Let* $f \in \mathcal{T}^{m,\gamma,\tau}_{\beta,\mu,\sigma}(A,B)$. Then f is convex of order λ $(0 \leqq \lambda < 1)$ in the disk

$$|z| \inf_{k\geqq 2}\left\{\frac{\rho(k,\gamma,\beta,\sigma,\tau,\mu,)(1-\lambda)}{k(k-\lambda)(A-B)}\right\}^{\frac{1}{k-1}}$$

The inequality is sharp for the extremal function in (11).

Proof. It is sufficient to show that

$$\left|\frac{zf''(z)}{f'(z)}\right| < 1-\lambda.$$

Using (1) gives

$$\sum_{k=2}^{\infty}\left(\frac{k(k-\lambda)}{1-\lambda}\right)|a_k||z|^{k-1} < 1. \qquad (19)$$

Evidently, inequalities (10) and (19) is only valid if

$$\frac{k(k-\lambda)}{1-\lambda}|z|^{k-1} < \frac{\rho(k,\gamma,\beta,\sigma,\tau,\mu,)}{A-B}$$

and isolating $|z|^{k-1}$ completes the proof.

2.5.Integral Preserving Theorem.

Definition 2.10 ([10])**.** Let $f \in$ A. Then $\mathcal{T}_x : \mathcal{A} \longrightarrow A(x > -1)$ defined by

$$\mathcal{T}_x f(z) = \frac{1+x}{z^x}\int_0^z \zeta^{\kappa-1}f(\zeta)d\zeta = z + \sum_{k=2}^{\infty}\frac{1+x}{k+x}a_k z^k \qquad (|z|<1). \qquad (20)$$

is the well-known Bernardi integral operator.

Theorem 2.11. Let $f \in \mathcal{T}^{m,\gamma,\tau}_{\beta,\mu,\sigma}(A,B)$. Then $\mathcal{I}_x f(z) \in \mathcal{T}^{m,\gamma,\tau}_{\beta,\mu,\sigma}(A,B)$.

Proof. Let $f \in \mathcal{T}^{m,\gamma,\tau}_{\beta,\mu,\sigma}(A,B)$ and note that clearly, from (2.12),

$$|d_k| = \frac{1+x}{k+x}|a_k| < |a_k| \qquad (\forall\, k = \{2,3,4,\dots\}$$

so that from (10) we get

$$\sum_{k=2}^{\infty}\frac{\rho(k,\gamma,\beta,\sigma,\tau,\mu)}{A-B}\frac{1+x}{k+x}|a_k| < \sum_{k=2}^{\infty}\frac{\rho(k,\gamma,\beta,\sigma,\tau,\mu)}{A-B}|a_k| \leqq 1$$

which completes the proof. □

Definition 2.12 ([8])**.** Let $f \in \mathcal{A}$. Then $\mathcal{I}_q^n: \mathcal{A} \longrightarrow \mathcal{A}$ defined by

$$\mathcal{I}_q^0 f(z) = f(z)$$

$$\mathcal{I}_q^1 f(z) = \frac{1}{qz(q^{-1}-1)}\int_0^z \zeta^{q^{-1}-1} f(\zeta)d\zeta = I_q f(z) \qquad (q>0)$$

which in general yields

$$\mathcal{I}_q^n f(z) = I_q(\mathcal{I}_q^{n-1} f(z))$$

and in particular

$$\mathcal{I}_q^n f(z) = z + \sum_{k=2}^{\infty}\frac{1}{(1+(k-1)q)^n}a_k z^k \qquad (q \geqq 0, n = 0,1,2,\ldots, |z| < 1) \qquad (21)$$

is the Al-Oboudi-Al-Qahtani integral operator.

Theorem 2.13. Let $f \in \mathcal{T}_{\beta,\mu,\sigma}^{m,\gamma,\tau}(A,B)$. Then $\mathcal{I}_q^n f(z) \in \mathcal{T}_{\beta,\mu,\sigma}^{m,\gamma,\tau}(A,B)$.

Proof. Let $f \in \mathcal{T}_{\beta,\mu,\sigma}^{m,\gamma,\tau}(A,B)$, then the application of Theorem 2.11 completes the proof. □

Since the Al-Oboudi-Al-Qahtani integral operator $\mathcal{I}_q^n$ (see [8]) generalized the well-known Sˇalˇagean integral operator I^n (see [33]), then the following Corollary holds.

Corollary 2.14. *Let* $f \in T_{\beta,\mu,\sigma}^{m,\gamma,\tau}(A,B)$. *Then* $I^n f(z) \in \mathcal{T}_{\beta,\mu,\sigma}^{m,\gamma,\tau}(A,B)$.

Lemma 2.15 ([16])**.** *Let* $f, F \in \mathcal{A}$ *with* $f \prec F$. *Then*

$$\int_0^{2\pi}|f(z)|^y d\vartheta \leq \int_0^{2\pi}|F(z)|^y d\vartheta$$

for $z = re^{i\vartheta}, \vartheta > 0$ *and* $0 < r < 1$.

Theorem 2.16. *Let* $f \in \mathcal{T}_{\beta,\mu,\sigma}^{m,\gamma,\tau}(A,B)$ *and*

$$F(z) = z + \frac{(A-B)}{\rho(2,\gamma,\beta,\sigma,\tau,\mu,)} \qquad (k = 2,3,\ldots)$$

from (2.3). *Then for* $\vartheta > 0$ *and* $z = re^{i\vartheta}, 0 < r < 1$,

$$\int_0^{2\pi}|f(z)|^y d\vartheta \leqq \int_0^{2\pi}|F(z)|^y d\vartheta. \qquad (22)$$

Proof. Let $f \in \mathcal{T}_{\beta,\mu,\sigma}^{m,\gamma,\tau}(A,B)$. Then by Lemma 2.15, we get from (2.14) that

$$\int_0^{2\pi}\left|1+\sum_{k=2}^{\infty}a_k z^{k-1}\right|^y d\vartheta \leqq \int_0^{2\pi}\left|1+\frac{(A-B)}{\rho(k,\gamma,\beta,\sigma,\tau,\mu,)}z^{k-1}\right|^y d\vartheta$$

so it suffices by Lemma 2.15 to proof that

$$1+\sum_{k=2}^{\infty}a_k z^{k-1} \prec 1+\frac{(A-B)}{\rho(k,\gamma,\beta,\sigma,\tau,\mu,)}z^{k-1}$$

which by implication means that

$$1+\sum_{k=2}^{\infty} a_k z^{k-1} = 1+\frac{(A-B)}{\rho(k,\gamma,\beta,\sigma,\tau,\mu,)}[s(z)]^{k-1}$$

where $|s(z)| < 1$ and $s(0) = 0$ so that

$$[s(z)]^{k-1} = \sum_{k=2}^{\infty} \frac{\rho(k,\gamma,\beta,\sigma,\tau,\mu,)}{(1-\beta)} a_k z^{k-1}$$

Further,

$$[s(z)]^{k-1} = \sum_{k=2}^{\infty} \frac{\rho(k,\gamma,\beta,\sigma,\tau,\mu,)}{(A-B)} a_k z^{k-1} \leqq \sum_{k=2}^{\infty} \frac{\rho(k,\gamma,\beta,\sigma,\tau,\mu,)}{(A-B)} |a_k| \leq |z| < 1$$

which completes the proof.

2.6.Closure Properties.

Theorem 2.17. *From* (1.2), *let* $f, F \in \mathcal{T}_{\beta,\mu,\sigma}^{m,\gamma,\tau}(A,B)$. *Then*

$$G_n(z) = (1-n)f(z) + nF(z) = z + \sum_{k=2}^{\infty} \{(1-n)a_k + nc_k\} z^k \in \mathcal{T}_{\beta,\mu,\sigma}^{m,\gamma,\tau}(A,B). \tag{23}$$

for $n \in [0,1]$.

Proof. Let $f, F \in \mathcal{T}_{\beta,\mu,\sigma}^{m,\gamma,\tau}(A,B)$, then putting (23) in (10) yields

$$\sum_{k=2}^{\infty} \rho(k,\gamma,\beta,\sigma,\tau,\mu)|\{(1-n)a_k + nc_k\}|$$

$$\leqq \sum_{k=2}^{\infty} \rho(k,\gamma,\beta,\sigma,\tau,\mu)\{(1-n)a_k + n|c_k|\}$$

$$= (1-n)\sum_{k=2}^{\infty} \rho(k,\gamma,\beta,\sigma,\tau,\mu)|a_k|$$

$$+ n\sum_{k=2}^{\infty} \rho(k,\gamma,\beta,\sigma,\tau,\mu)|c_k| = (1-n)\{(A-B)\} + n\{(A-B)\} = (A-B).$$

Hence $G_n \in \mathcal{T}_{\beta,\mu,\sigma}^{m,\gamma,\tau}(A,B)$. □

Theorem 2.18. Let $n = 1,2,3,\ldots,x$ and

$$f_n(z) = z + \sum_{k=2}^{\infty} a_{k,n} z^k \in \mathcal{T}_{\beta,\mu,\sigma}^{m,\gamma,\tau}(A,B). \tag{24}$$

then for

$$\sum_{n=1}^{x} \eta_n = 1,$$

the function

$$g(z) = \sum_{n=1}^{x} \eta_n f_n(z) \in \mathcal{T}_{\beta,\mu,\sigma}^{m,\gamma,\tau}(A,B) \quad (|z| < 1) \tag{25}$$

Proof. Note that for function $f_n(z)$ in (24)

$$\sum_{k=2}^{\infty} \frac{\rho(k,\gamma,\beta,\sigma,\tau,\mu,)}{(A-B)} \left|a_{k,n}\right| \leqq 1 \qquad (25)$$

and (2.17) can be written as

$$g(z) = \sum_{n=1}^{x} \eta_n \left(z + \sum_{k=2}^{\infty} a_{k,n} z^k \right) = z + \sum_{n=1}^{x} \sum_{k=2}^{\infty} \eta_n a_{k,n} z^k = z + \sum_{n=1}^{x} \left(\sum_{k=2}^{\infty} \eta_n a_{k,n} z^k \right) z^k. \qquad (26)$$

Putting (2.19) into (2.18) yields

$$\sum_{k=2}^{\infty} \frac{\rho(k,\gamma,\beta,\sigma,\tau,\mu,)}{A-B} \left| \sum_{n=1}^{X} \eta_n a_{k,n} \right| = \sum_{k=2}^{\infty} \frac{\rho(k,\gamma,\beta,\sigma,\tau,\mu,)}{A-B} \left|a_{k,n}\right| \leqq 1$$

Hence, $g \in \mathcal{T}_{\beta,\mu,\sigma}^{m,\gamma,\tau}(A,B)$.

Theorem 2.19. Let $n = 1,2,3,\ldots,x$ for the functions

$$f_n(z) = z + \sum_{k=2}^{\infty} a_{k,n} z^k \in \mathcal{T}_{\beta,\mu,\sigma}^{m,\gamma,\tau}(A,B),$$

then the arithmetic mean $m(z)$ of functions $f_n(z)$ defined by

$$m(z) = \frac{1}{x} \sum_{n=1}^{x} f_n(z) \qquad (|z| < 1) \qquad (27)$$

Proof. From (2.20) we get

$$m(z) = \frac{1}{x} \sum_{n=1}^{x} \left(z + \sum_{k=2}^{\infty} a_{k,n} z^k \right) = z + \sum_{k=2}^{\infty} \left(\frac{1}{x} \sum_{n=1}^{x} a_{k,n} \right) z^k \qquad (28)$$

Since $f_n \in \mathcal{T}_{\beta,\mu,\sigma}^{m,\gamma,\tau}(A,B)$ for all $n = 1,2,3,\ldots,x$, then putting (28) into (10) yields

$$\sum_{k=2}^{k} \frac{\rho(k,\gamma,\beta,\sigma,\tau,\mu,)}{A-B} \left| \frac{1}{x} \sum_{n=1}^{x} a_{k,n} \right| = \frac{1}{x} \sum_{n=1}^{x} \left\{ \sum_{k=2}^{\infty} \frac{\rho(k,\gamma,\beta,\sigma,\tau,\mu,)}{A-B} \left|a_{k,n}\right| \right\} \leqq \frac{1}{x} \sum_{n=1}^{x} (1) = 1$$

implies that $m \in \mathcal{T}_{\beta,\mu,\sigma}^{m,\gamma,\tau}(A,B)$.

Theorem 2.20. *From* (2), let $f, F \in \mathcal{T}_{\beta,\mu,\sigma}^{m,\gamma,\tau}(A,B)$. Then the weighted mean w_n of functions f and F defined by

$$w_n(z) = \frac{(1-n)f(z) + (1+n)F(z)}{2} \qquad (n = 1,2,\ldots, \ |z| < 1) \qquad (29)$$

is also in $\mathcal{T}_{\beta,\mu,\sigma}^{m,\gamma,\tau}(A,B)$

Proof. Using (2) in (29) yields

$$w_n(z) = z + \sum_{k=2}^{\infty} \frac{(1-n)a_k + (1+n)c_k}{2} z^k \qquad (30)$$

To show that $w_n \; is \; in \; \mathcal{T}_{\beta,\mu,\sigma}^{m,\gamma,\tau}(A,B)$ is to show that

$$\sum_{k=2}^{\infty} \frac{\rho(k,\gamma,\beta,\sigma,\tau,\mu,)}{A-B} \left| \frac{(1-n)a_k + (1+n)c_k}{2} \right| \leqq 1$$

This follows by using (10) to give

$$\sum_{k=2}^{\infty}\frac{\rho(k,\gamma,\beta,\sigma,\tau,\mu,)}{A-B}\left\{\frac{(1-n)a_k+(1+n)c_k}{2}\right\}=\frac{(1-n)}{2}\sum_{k=2}^{k}\frac{\rho(k,\gamma,\beta,\sigma,\tau,\mu,)}{A-B}|a_k|$$
$$+\frac{(1+n)}{2}\sum_{k=2}^{k}\frac{\rho(k,\gamma,\beta,\sigma,\tau,\mu,)}{A-B}|c_k|\leqq\frac{(1-n)}{2}+\frac{(1+n)}{2}=1$$

So $w_n \in \mathcal{T}_{\beta,\mu,\sigma}^{m,\gamma,\tau}(A,B)$

2.7.Inclusion Property.

Definition 2.21. The δ-neighbourhood of $f \in \mathcal{A}$ is defined by the set

$$N_\delta(f)=\left\{F:F(z)=z+\sum_{k=2}^{\infty}c_kz^k\in\mathcal{A}\ and\ \sum_{k=2}^{\infty}k|a_k-c_k|\leqq\delta,\delta\geqq0\right\} \tag{31}$$

and for the function $h(z) = z \in A$, the δ-neighbourhood is defined by the set

$$N_\delta(f)=\left\{F:F(z)=z+\sum_{k=2}^{\infty}c_kz^k\in\mathcal{A}\ and\ \sum_{k=2}^{\infty}k|a_k-c_k|\leqq\delta,\delta\geqq0\right\} \tag{32}$$

The concept of neighbourhood of analytic functions was initiated by Goodman [11] where it was proved that $N_1(h) \subset \mathcal{T}^\star$. In 1981, Ruscheweyh [32] presented the sets in (2.24) and (2.25) which was an extension of Goodman's idea.

Definition 2.22. Let $f \in \mathcal{T}_{\beta,\mu,\sigma}^{m,\gamma,\tau}(A,B)$. Then there is a function

$$F \in \mathcal{T}_{\beta,\mu,\sigma}^{m,\gamma,\tau}(U,V) \quad (-1 \leqq V < U \leqq 1)$$

such that

$$\left|\frac{f(z)}{F(z)}-1\right|\leqq1-\gamma \qquad (|z|<1, 0\leqq\gamma<1)$$

Theorem 2.23. Let

$$F(z)=z+\sum_{k=2}^{\infty}c_kz^k\in\mathcal{T}_{\beta,\mu,\sigma}^{m,\gamma,\tau}(U,V) \quad (-1 \leqq V < U \leqq 1,\ |z|<1)$$

and

$$\gamma:=1-\frac{\delta\rho(2,\gamma,\beta,\sigma,\tau,\mu)}{2[\rho(2,\gamma,\beta,\sigma,\tau,\mu)-(U-V)]},$$

Then $\mathcal{N}_\delta(f) \subset \mathcal{T}_{\beta,\mu,\sigma}^{m,\gamma,\tau}(U,V)$

Proof. Suppose $f \in N_\delta(f)$, then from (2.24),

$$\sum_{k=2}^{\infty}k|a_k-c_k|\leqq\delta\Longrightarrow\sum_{k=2}^{\infty}|a_k-c_k|\leqq\frac{\delta}{2} \tag{33}$$

Also, since

$F(z) = z + \sum_{k=2}^{\infty} c_k z^k \in \mathcal{T}_{\beta,\mu,\sigma}^{m,\gamma,\tau}(U,V)$,

then from (10)

$$\sum_{k=2}^{\infty}|c_k|\leqq\frac{(U-V)}{\rho(2,\gamma,\beta,\sigma,\tau,\mu)} \qquad (-1\leq V<U\leqq1 \tag{34}$$

Definition 2.22 implies that

$$\left|\frac{f(z)}{F(z)}-1\right|=\left|\frac{\sum_{k=2}^{\infty}(a_k-c_k)z^{k-1}}{1+\sum_{k=2}^{\infty}c_kz^{k-1}}\right|\leqq\frac{\sum_{k=2}^{\infty}|a_k-c_k|z^{k-1}}{1-\sum_{k=2}^{\infty}|c_k|} \tag{35}$$

Putting (33) and (34) into (35) yields

$$\left|\frac{f(z)}{F(z)}-1\right| \leqq \frac{\delta\rho(2,\gamma,\beta,\sigma,\tau,\mu)}{2[\rho(2,\gamma,\beta,\sigma,\tau,\mu)-(U-V)]} = 1-\gamma$$

2.8.Subordinating Factor Sequence.

Definition 2.24 ([36])**.** The sequence $\{c_k\}_{k=1}^{\infty}$ of complex numbers is called a *subordinating factor sequence* if whenever

$$g(z) = \sum_{k=1}^{\infty} b_k z^k \qquad (b_1 = 1,\ |z| < 1)$$

is analytic and univalently convex in

$$|z| \prec 1, \sum_{k=1}^{\infty} c_k b_k \prec g(z).$$

Lemma 2.25 ([36])**.** The sequence $\{c_k\}_{k=1}^{\infty}$ is called *a subordinating factor sequence* if and only if

$$\Re\left(1+2\sum_{k=1}^{\infty} c_k z^k\right) > 0 \qquad (|z|<1).$$

Theorem 2.26. Let $f \in \mathcal{T}_{\beta,\mu,\sigma}^{m,\gamma,\tau}(A,B)$ *and* $g(z)$ be *a convex function*, then

$$\frac{\rho(2,\gamma,\beta,\sigma,\tau,\mu)}{2[(A-B)+\rho(2,\gamma,\beta,\sigma,\tau,\mu)]}(f\star g)(z) \prec g(z) \tag{36}$$

for

$$\Re f > -\frac{(A-B)+\rho(2,\gamma,\beta,\sigma,\tau,\mu)}{\rho(2,\gamma,\beta,\sigma,\tau,\mu)}. \tag{37}$$

Note that the constant factor

$$\frac{\rho(2,\gamma,\beta,\sigma,\tau,\mu)}{2[(A-B)+\rho(2,\gamma,\beta,\sigma,\tau,\mu)]} \tag{38}$$

cannot be replaced by a bigger value.

Proof. Let $f \in \mathcal{T}_{\beta,\mu,\sigma}^{m,\gamma,\tau}(A,B)$ and suppose $g(z) = z + \sum_{k=2}^{\infty} b_k z^k$ is a convex function, then from (36),

$$\frac{\rho(2,\gamma,\beta,\sigma,\tau,\mu)}{2[(A-B)+\rho(2,\gamma,\beta,\sigma,\tau,\mu)]}(f\star g)(z) = \frac{\rho(2,\gamma,\beta,\sigma,\tau,\mu)}{2[(A-B)+\rho(2,\gamma,\beta,\sigma,\tau,\mu)]}\left(z+\sum_{k=1}^{\infty} a_k b_k z^k\right)$$

$$= \sum_{k=1}^{\infty} \frac{\rho(2,\gamma,\beta,\sigma,\tau,\mu)}{2[(A-B)+\rho(2,\gamma,\beta,\sigma,\tau,\mu)]} a_k b_k z^k$$

Clearly by Definition 2.24, the subordination result (2.29) holds if

$$\left\{\frac{\rho(2,\gamma,\beta,\sigma,\tau,\mu)}{2[(A-B)+\rho(2,\gamma,\beta,\sigma,\tau,\mu)]} a_k\right\}_{k=1}^{\infty}$$

is a *subordinating factor sequence* for $a_1 = 1$. Application of Lemma 2.25 yields an equivalence inequality

$$\Re\left(1+\sum_{k=1}^{\infty} \frac{\rho(2,\gamma,\beta,\sigma,\tau,\mu)}{(A-B)+\rho(2,\gamma,\beta,\sigma,\tau,\mu)} a_k z^k\right) > 0 \tag{39}$$

Observe that $\rho(k,\gamma,\beta,\sigma,\tau,\mu)$ is an increasing function for $k \geqq 2$, so

$$\rho(2,\gamma,\beta,\sigma,\tau,\mu) \leqq \rho(k,\gamma,\beta,\sigma,\tau,\mu) \forall k \geqq 2$$

hence, it follows by $|z| = r < 1$, triangle inequality and inequality (10) that

$$\Re\left(1+\sum_{k=1}^{\infty}\frac{\rho(2,\gamma,\beta,\sigma,\tau,\mu)}{(A-B)+\rho(2,\gamma,\beta,\sigma,\tau,\mu)}a_k z^k\right)=\Re\left(1+\sum_{k=1}^{\infty}\frac{\rho(2,\gamma,\beta,\sigma,\tau,\mu)}{(A-B)+\rho(2,\gamma,\beta,\sigma,\tau,\mu)}\sum_{k=1}^{\infty}a_k z^k\right)$$

$$\geqq 1-\frac{\rho(2,\gamma,\beta,\sigma,\tau,\mu)}{(A-B)(1-\lambda)+\rho(2,\gamma,\beta,\sigma,\tau,\mu)}r-\frac{\sum_{k=2}^{\infty}\rho(2,\gamma,\beta,\sigma,\tau,\mu)|a_k|}{(A-B)(1-\lambda)+\rho(2,\gamma,\beta,\sigma,\tau,\mu)}r^k$$

$$> 1-\frac{\rho(2,\gamma,\beta,\sigma,\tau,\mu)}{(A-B)(1-\lambda)+\rho(2,\gamma,\beta,\sigma,\tau,\mu)}r-\frac{(A-B)(1-\lambda)}{(A-B)(1-\lambda)+\rho(2,\gamma,\beta,\sigma,\tau,\mu)}r$$

$$= 1-r>0$$

This evidently proves the inequality (39) and as well as the subordination result (36). Also, the inequality (37) follows from (36) by taking the convex function

$$g_0(z)=\frac{z}{1-z}=z+\sum_{k=2}^{\infty}z^k$$

To prove the sharpness of the constant (38), consider the function

$$f_2(z)=z+\frac{(A-B)}{\rho(2,\gamma,\beta,\sigma,\tau,\mu)}z^2\in\mathcal{T}_{\beta,\mu,\sigma}^{m,\gamma,\tau}(A,B)$$

so that by using (36) we get

$$\frac{\rho(2,\gamma,\beta,\sigma,\tau,\mu)}{2[(A-B)+\rho(2,\gamma,\beta,\sigma,\tau,\mu)]}f_2(z)\prec g_0(z)=\frac{z}{1-z}. \tag{40}$$

It can *easily* be verified for $f_2(z)$ that

$$\min_{|Z|\leqq r}\left\{\Re\left(\frac{\rho(2,\gamma,\beta,\sigma,\tau,\mu)}{2[(A-B)+\rho(2,\gamma,\beta,\sigma,\tau,\mu)]}f_2(z)\right)\right\}=-\frac{1}{2}\qquad(|z|<1)$$

which shows that the constant $\frac{\rho(2,\gamma,\beta,\sigma,\tau,\mu)}{2[(A-B)+\rho(2,\gamma,\beta,\sigma,\tau,\mu)]}$ cannot be replaced by any bigger value.

Acknowledgments. The Tertiary Education Trust Fund (TETFund) of Nigeria is hereby appreciated for sponsoring the presentation of this paper at the Conference through the 2023 Conference TETFund sponsorship.

References

[1] Y. Rabotnov, Equilibrium of an Elastic Medium with After-Effect. Prikl. Mat. Mekhanika1948(12), 53–62. (in Russian); Reprinted in Fract. Calc. Appl. Anal 2014(17), 2014, 684–696.
[2] G.M. Mittag-Leffler, Sur la nouvelle fonction E(x). C. R. Acad. Sci. Paris 1903, 137, 554–558.
[3] D. Bansal, J.K. Prajapat, Certain geometric properties of the Mittag-Leffler functions. Complex Var. Elliptic Equ. 2016(61), 338–350.
[4] A.A. Attiya, Some applications of Mittag-Leffler function in the unit disk. Filomat 2016(30),2075–2081.
[5] M. Ahmad, B. Frasin, G. Murugusundaramoorthy, A. Alkhazaleh, An application of MittagLeffler-type poisson distribution on certain subclasses of analytic functions associated with conic domains Heliyon 2021, 7, e08109.
[6] M. Garg, P. Manohar, S.L. Kalla, A Mittag-Leffler-type function of two variables. IntegralTransforms Spec. Funct. 2013(24), 934–944.
[7] F.M. Al-Oboudi, On univalent functions defined by a generalised Saˇlˇagean operator, Intern.
J. Math. Math. Sci. 2004(27) (2004). 1429–1436.
[8] F.M. Al-Oboudi, Z.M. Al-Qahtani, Application of differential subordinations to some properties of linear operators, Intern. J. Open Probl. Compl. Anal. 2(3) (2010), 189–202.
[9] D. Bansal, J. Sok´ol, Geometric properties of Mathieu–type power series inside unit disk, J.Math. Ineq. 13 (2019), 911–918.
[10] S.D. Bernardi, Convex and starlike univalent functions, Trans. Amer. Math. Soc., 135(51) (1969), 429–446.
[11] A.W. Goodman, Univalent functions and nonanalytic curves, Proc. Amer. Math. Soc. 8 (1957),598–601.
[12] W. Janowski, Some extremal problems for certain families of analytic functions I, Annal.Polon. Math. 28(3) (1973), 297–326.
[13] A.O. Lasode, A.O. Ajiboye, R.O. Ayinla, Some coefficient problems of a class of close-to-starfunctions of type α defined by means of a generalized differential operator, Intern. J. Nonlinear Anal. Appl. 14(1) (2023), 519–526.
[14] A.O. Lasode, T.O. Opoola, Some properties of a family of univalent functions defined by ageneralized Opoola differential operator, General Math. 30(1) (2022), 3–13.
[15] A.O. Lasode, T.O. Opoola, Coefficient problems of a class of *q*-starlike functions associated with *q*-analogue of Al-Oboudi-Al-Qahtani integral operator and nephroid domain, J. Class. Anal. 20(1) (2022), 35–47.
[16] J.E. Littlewood, On inequalities in the theory of functions, Proc. Lond. Math. Soc. 23(1) (1925), 481–519.
[17] D. Liu, S. Araci, B. Khan, A Subclass of Janowski Starlike Functions Involving Mathieu-TypeSeries, Symmetry 14(2), (2022) pp. 13.
[18] E.L. Mathieu, Trait´e de physique math´ematique, VI-VII: Th´eory de l'Elasticit´e des Corps´ Solides (Part 2), Gauthier-Villars: Paris, France, (1890).
[19] T.O. Opoola, On a subclass of univalent functions defined by a generalised differential operator, Intern. J. Math. Anal. 11(18) (2017), 869–876.
[20] E.A. Oyekan, Some results associated with convolution involving certain classes of uniformlystarlike and convex functions with negative coefficients, Asian J. Math. Comput. Research, 14(1) (2016), 73–82.
[21] E.A. Oyekan, Some properties for a subclass of univalent functions, Asian J. Math. Comput.Research, 20(1) (2017), 32–37.
[22] E.A. Oyekan, Some Properties of certain new classes of analytic functions defined by a generalized differential operator, Trans. Nigerian Math. Phy. 5 (2017), 11–20.
[23] E.A. Oyekan, B.F. Adedara, An extension of a certain subclass of starlike functions withnegative coefficients, J. Sustainable Technol. 8(2) (2017), 73–79.
[24] E.A. Oyekan, O.P. Adelodun, P.T. Ajai, Characterizations for new classes of Analytic Functions defined by Using Sˇal{a}gean operator, IOSR J. Math. 10(2) (2014), 37–42.
[25] E.A. Oyekan, O. Adetunji, L. Adedolapo, On some Analytic Functions with Negative coefficients, Math. Theory Modeling 3(1) (2013), 102–107.
[26] E.A. Oyekan, S.O. Ayinde, Coefficient estimates and subordination results for certain classesof analytic functions, J. Math. Sci. 24(2) (2013), 75–86.
[27] E.A. Oyekan, T.O. Opoola, On subclasses of bi-univalent functions defined by generalizedSˇalaˇgean operator related to shell-like curves connected with Fibonacci numbers, Libertas Math. (new series) 41 (2021), 1-–20.
[28] E.A. Oyekan, T.O. Opoola, A.T. Ademola, On Some Subclasses of Analytic Functions withnegative Coefficients Using a Convolution Approach, General Math. Notes, 24(1) (2014), 109– 126.

[29] E.A. Oyekan, S.R. Swamy, P.O. Adepoju, T.A. Olatunji, Quasi-convolution properties of anew family of close-to-convex functions involving a *q*−*p*-Opoola differential operator, Intern. J. Math. Trends Technol. 69(5) (2023), 70–77.
[30] E.A. Oyekan, S.R. Swamy, T.O. Opoola, Ruscheweyh derivative and a new generalized operator involving convolution, Intern. J. Math. Trends Techno. 67(1) (2021), 88–100.
[31] S. Ruscheweyh, New criteria for univalent functions, Proc. Amer. Math. Soc. 49 (1975), 109–115.
[32] S. Ruscheweyh, Neighborhoods of univalent functions, Proc. Amer. Math. Soc. 81(4) (1981),521–527.
[33] G.S. Saˇlˇagean, Subclasses of univalent functions, Lect. Notes Math. 1013 (1983), 362–372.
[34] T.G. Shaba, A.A. Ibrahim, L.O. Ahmed, On a comprehensive class of *p*-valent functions defined by generalized Al-Oboudi differential operator, Adv. Math. Sci. J. 12 (202 0), 10633– 10638.
[35] T.G. Shaba, A.A. Ibrahim, M.F. Oyedotun, A new subclass of analytic functions defined byOpoola differential operator, Adv. Math. Sci. J. 9(7) (2020), 4829–4841.
[36] H.S. Wilf, Subordinating factor sequences for convex maps of the unit circle. Proc. Amer.Math. Soc. 12 (1961), 689–693.

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp. 369–376, November 13-16, 2023

Prediction of Covid-19 Pandemic in Nigeria using Time SeriesModels Approach

Aderonke J. Ikuomola
{aj.ikuomola@oaustech.edu.ng}

Department of Computer Science, Olusegun Agagu University of Science and Technology, Okitipupa, Ondo State, Nigeria.

Abstract
The problems that arises during pandemic outbreak includes: loss of track of trends by the health practitioners, lack of resources to contain the pandemic, poor decision-making, and inability to track the effect of pandemic on the society. As COVID-19 is a threat to human lives, it is important to study the trends and see into the future on damages and ways to either prevent or contain it. In this work, auto-regression integrated moving average (ARIMA) and seasonal auto-regression integrated moving average (SARIMA) Time series techniques were used to predict the future trend of COVID-19pandemic. The model was implemented using Python programming language. The ARIMA (2,2,0) and (0,2,0) models were finally selected based on the parameter test. It was also used to predict the spread of Covid-19 pandemic for seven-days and the results shows a step upward trend of the spread of COVID-19 in Nigeria within the selected time frame.

Keywords: ARIMA, Covid-19, SARIMA, Pandemic, Prediction

1 Introduction

Forecasting is the process of predicting future events or occurrences based on previous or present experiences [1]. Alternatively, forecasting uses historical data as the primary input to determine the direction of future trends [2]. Pandemic is "an epidemic occurring globally, or over a very wide area, crossing international boundaries, and typically affecting a large number of people; examples include Ebola, Lassa fever, cholera, swine flu, Coronavirus disease of 2019 (COVID-19), and the like." Among all known ribonucleic acid (RNA) viruses, coronaviruses have the biggest genomes, which provides the virus more flexibility in accepting and changing genes.

The World Health Organization declared COVID-19 a Public Health Emergency of International Concern (PHEIC) in January 2020, highlighting the urgent need for immediate community-level prevention and containment efforts. The first confirmed case in Nigeria occurred on March 9, 2020.Issues during the pandemic include loss of track of trends by the health practitioners, lack of resources to contain the pandemic, poor decision-making, and inability to track the effect of pandemic on the society.

This pandemic's spread was predicted via forecasting, which gathered data on previous impacts on the economy, population, and government to provide a prospective perspective on what is expected to occur both during and after the pandemic. In this way, forecasting aids in pandemic containment by assisting with planning, providing insight into impending issues, assisting medical professionals in being appropriately ready for additional infection cases, and assisting in the search for a cure or vaccine.

Forecasting COVID-19 infections, hospitalizations, and deaths is crucial for public health decisions.This forecasts can help hospitals to make use of these projections to prepare for surge in resource demand, and governments and agencies can use them to allocate scarce resources to high-risk locations (Lomte, 2023). One forecasting method that is based on an investigation of the past and its tendencies is the quantitative technique.This method forecasts future events using statistical analysis and other mathematical models.

The technique proposed for this study is based on auto-regression integrated moving average (ARIMA) and seasonal auto-regression integrated moving average (SARIMA) Time series models. The models were used to predict the future trend of COVID-19pandemicin Nigeria. Time series technique is one of the types of quantitative technique used for forecasting. The accuracy of the method was verified by comparing the two models visà-vis actual covid-19 pandemic figures. The work is organized as follows: A brief overview of literature is given in section 2. Section 3 provides a methodology for predicting covid-19 pandemic. The implementation and results are given in section 4. Section 5 concludes the research work.

2 Literature Review

Adesina et al. (2020) used the autoregressive fractionally integrated moving average (AFRIMA) model to predict daily new cases and compared the trend of COVID-19 in Nigeria during the stringent lockdown with when it was loosened. The proposed ARFIMA model was compared with ARIMA (1, 0, 0), and ARIMA (1, 0,1) and was found to outperform the classical ARIMA models.The susceptible, infected, recovered (SIR) model was one of many mathematical models used to simulate epidemic instances.The data set used was the Nigeria Center for Disease Control's (NCDC) daily fresh COVID-19 cases.The suggested ARFIMA model outperformed the traditional ARIMA models when compared to ARIMA (1, 0, 0) and ARIMA (1, 0, 1). The outcome of the forecast indicates that if the lockdown is maintained, the rate of COVID-19 infection would have been much lower. The model's flaw is that there is variation in performance of ARFIMA (p,d,q) resulting from different data set.

Hawas (2020) developed long-term time-series predictions for Brazil's virus daily infections using limited raw data. Training 4200 recurrent neural networks on Johns Hopkins University's online repository ensured reliable extended long-term predictions. The exponential growth pattern fits true data for three-month validation periods, but not extended long-term predictions. The exponential growth pattern can fit true data on a long-term basis when the validation period is about three months, but it becomes not reliable when it comes to extended long-term predictions.

Jamdade & Jamdade (2020) analyze 30 days of COVID-19 cases and deaths using the VARMAX time series method, comparing projections with actual data and assessing societal growth using the median growth rate.The prediction was used to arrive at some preventive measures and the study provide useful information for real-time preparation. This VARMAX model can be very complex

Kanagarathinamet al. (2020) used the earlyR epidemic model and ARIMA model to forecast COVID-19 cases in India. The earlyR model used serial interval data and projections to estimate R0. The ARIMA model used auto.arima function and forecast package to predict new cases. The model showed better accuracy, but uncertainties may arise due to unidentified infections in daily data.

Li et al. (2020) studied COVID-19 transmission in China using official data modeling. They developed a model for forward prediction and backward inference, analyzing Hubei epidemic data. They used Gaussian distribution for simulation, predicting virus transmission trends and determining the impact of controls. The standard deviation of Gaussian distribution has little influence on simulation.

Ogundokunet et al. (2020) used a linear regression model to evaluate the impact of travel history and contacts on COVID-19 confirmed cases in Nigeria. They found that travel history and contacts increased the chances of infection by 85% and 88%, respectively. The model fit well and was free of violation, but there is a possibility of multicollinearity issues.

Satrioet al. (2020) compared performance and accuracy of Facebook's Prophet Forecasting Model and ARIMA Forecasting Model on a 30-day dataset of confirmed COVID-19 deaths and recovered numbers in Indonesia. Both models showed high accuracy initially, but as time progressed, differences increased, creating a visible gap. Both models had positive biases, as indicated by Mean Forecast Error (MFE).

Wang et al. (2020) developed a COVID-19 forecasting model using deep learning and rolling update mechanism, based on Johns Hopkins University epidemic data. The model uses long short-term memory (LSTM) and daily confirmed cases training to predict the epidemic's decline or end. The study modeled trends for Russia, Peru, and Iran, three continents, and analyzed the spread using the Diffusion Index (DI). The study covers both prediction and behavioral responses to the pandemic, but does not consider imported cases or spatial influence between countries.

3 Methodology

3.1 Autoregressive Integrated Moving Average (ARIMA)

ARIMA from ARMA is defined as follows:
Differences of order *d* are defined as

$$\nabla^d = (1 - B)^d \quad (1)$$

where $(1 - B)^d$ can be expanded algebraically for higher integer values of d.
A process X_t is said to be ARIMA(p,d,q) if

$$\nabla^d X_t = (1 - B)^d X_t \quad (2)$$

is ARMA(p,q).
In general, ARIMA(p,d,q) model can be written as:

$$\phi(B)(1 - B)^d X_t = \theta(B) W_t \ . \quad (3)$$

ARIMA forecasting equation
Let *Y* denote the original series
Let *y* denote the differenced (stationarized) series
No difference (d=0): $y_t = Y_t$ (4)
First difference
(d=1): $y_t = Y_t - Y_{t-1}$. (5)
Second difference (d=2):

$$y_t = (Y_t - Y_{t-1}) - (Y_{t-1} - Y_{t-2}) \quad (6)$$

$$= Y_t - 2Y_{t-1} + Y_{t-2} \ . \quad (7)$$

Forecasting equation for y

$$y_t = \mu + \phi_1 y_{t-1} + \cdots + \phi_p y_{t-p} \quad (8)$$

(constant) (AR terms (lagged values of y))

$$-\theta_1 e_{t-1} \ldots - \theta_q e_{t-q}$$

MA terms (lagged errors)

On deafferenting g the forecast
The differencing (if any) must be reversed to obtain a forecast for the original series:
If $d = 0$: $\hat{Y}_t = \hat{y}_t$ (9)
If $d = 1$: $\hat{Y}_t = \hat{y}_t + Y_{t-1}$. (10)
If $d = 2$: $\hat{Y}_t = \hat{y}_t + 2Y_{t-1} - Y_{t-2}$. (11)

3.2 Seasonal Autoregressive Integrated Moving Average (SARIMA)

A seasonal ARIMA model is formed by including additional seasonal terms in the ARIMA models, denoted as ARIMA (p,d,q) (P,D,Q)m,
P represents seasonal autoregressive terms
D represents seasonal differences
Q represents seasonal moving-average terms
m represents the number of observations per year.
i.e

$$\phi(B^m)\,\phi(B)(1-B^m)^D(1-B)^d\,X_t = \theta(B^m)\,\theta(B)w_t \quad (12)$$

The seasonal part of the model consists of terms that are similar to the non-seasonal components, but involve backshifts of the seasonal period.
Seasonal Differences
If *d*=0, D=1:

$$y_t = Y_{t-s} \quad . \quad (13)$$

If *d*=1, D=1:

$$y_t = (Y_t - Y_{t-1}) - (Y_{t-s} - Y_{t-s-1}) \quad . \quad (14)$$

$$= Y_t - Y_{t-1} - Y_{t-s} + Y_{t-s-1} \quad . \quad (15)$$

s is the seasonal period.

3.3 Data description

The data set used in this study is the daily new positive cases of COVID-19 taken from Nigeria Center for Disease control, and can equally be found on the following link: https://ourworldindata.org/coronavirus/country/nigeria?country=~NGA. The data contains Date, Cumulative cases, recovered cases, total death, Patient under treatment, New case per Day, Recovered cases per Day, Death cases per Day and Treatment cases per Day.

4 Implementation

Python library extensions and the Python programming language were used to implement the ARIMA and SARIMA models. The data set used for the development was compiled and officially released by NCDC, and it includes the date, cumulative cases, recovered cases, total death, patient under treatment, new case per day, recovered case per day, death cases per day, and treatment cases per day. To predict the new Covid-19 cases for the period of September 09 to September 152021, the data records for Covid-19 in Nigeria from August 22, 2021 to September 8, 2021 were trained using the ARIMA and SARIMA models. Figures 1, 2, and 3 display the trend of the data set utilized for prediction.

```
In [124]: #Plot the variables to observes the trends present in them
          sns.lineplot(df.index,df['New cases'],color='gold')
          plt.xlabel('Date')
          plt.xticks(rotation=35);
```

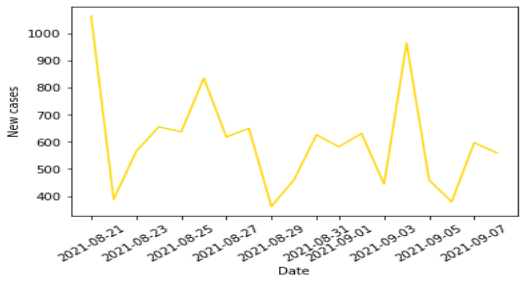


Fig.1. The trend of new cases of Covid-19

```
In [125]: sns.lineplot(df.index,df['New deaths'],color='r')
          plt.xlabel('Date')
          plt.xticks(rotation=35);
```

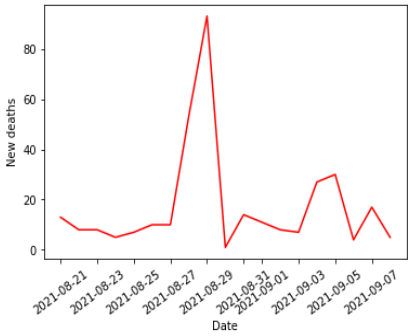
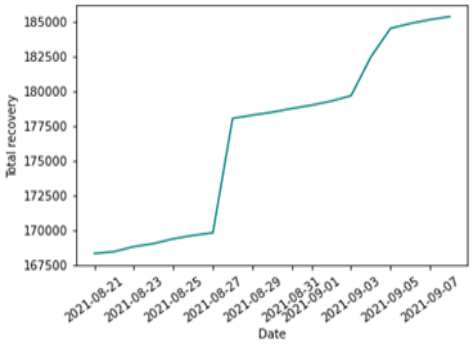


Fig. 2. The trend of new death cases of Covid-19

```
In [126]: sns.lineplot(df.index,df['Total recovery'],color='teal')
          plt.xlabel('Date')
          plt.xticks(rotation=35);
```



Type *Markdown* and LaTeX: α^2

Fig. 3. The trend of recovery of Covid-19

5 Results and Discussion

Below are the new predicted variables for Covid-19 new cases, death cases and recovery cases from September 09th to15th 2021 using ARIMA and SARIMA. After the test had been done to get the best model with the lowest AIC, ARIMA (2, 2, 0) (0,0, 0), ARIMA (1, 2, 0) and ARIMA (0, 2, 0) (0,0, 0) resulted to be the best model to predict the new cases, new death cases, and recovery cases respectively.

Figure 4, 5 and 6 shows the diagnostic plot for the new cases, new death cases and new recovery cases when conducted with ARIMA models. While figures7, 8 and 9 shows the trends of the SARIMA predicted new cases, new death cases and new recovery cases.

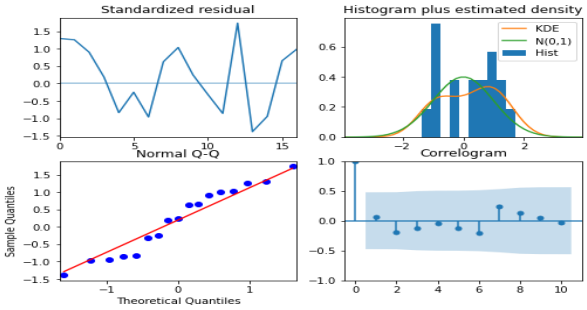


Fig. 4. ARIMA predicted new cases trend

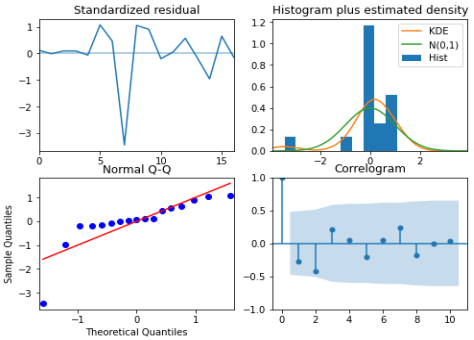


Fig. 5. ARIMA predicted new death cases trend

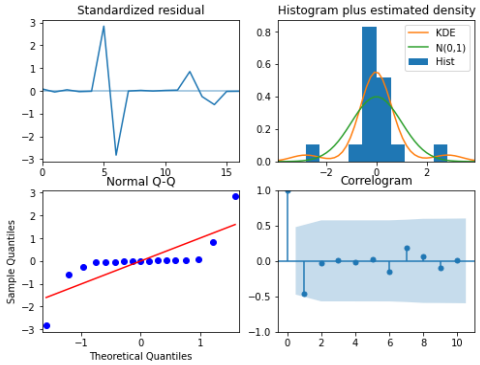


Fig. 6. ARIMA predicted new recovery cases trend

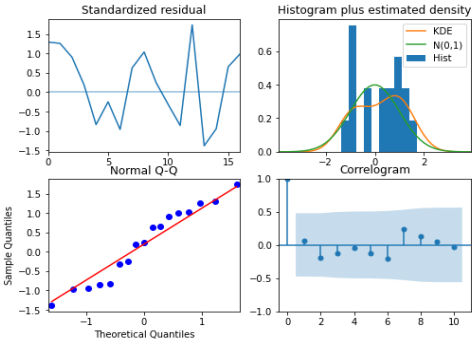


Fig. 7 SARIMA predicted new cases trend

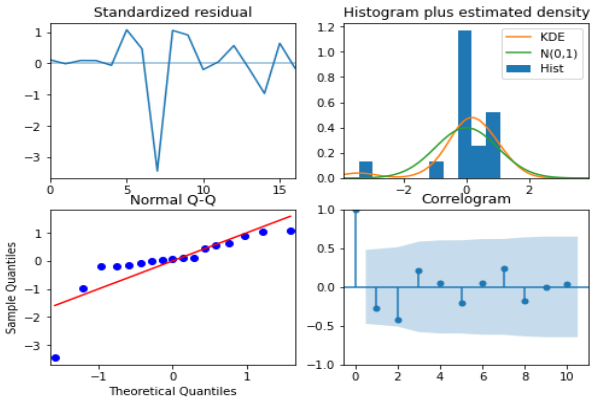


Fig. 8. SARIMA predicted new death cases trend

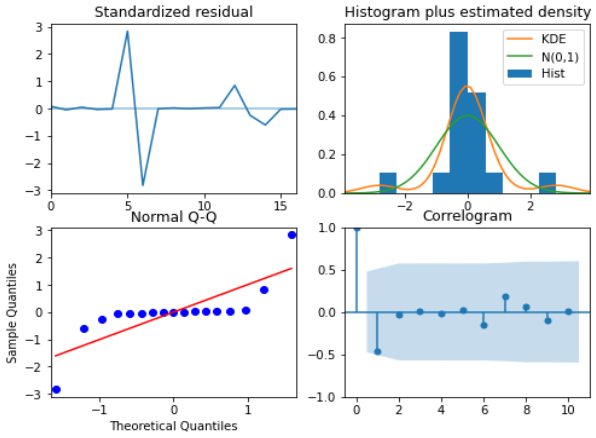


Fig. 9. SARIMA predicted new recovery cases trend

Tables 1 and 2 shows ARIMA and SARIMApredicted records of Covid-19 new cases, death cases and recovery cases from September 09th to 15th2021 with the actual values.

Table 1.ARIMApredicted cases vs actual cases

Date	New cases		New death cases		Recovery	
	Predicted	Actual	Predicted	Actual	Predicted	Actual
09-09-2021	630	72210-09-2021		5	7	185,559185,597
725	466			1	3	185,819185,780
11-09-2021	735	466	3	3		186,039186,168
12-09-2021	822	365	8	8		186,259186,418
13-09-2021	874	387	11	21		186,479188,427
14-09-2021	921	519	15	18		186,699188,719
15-09-2021	992	299	19	3		186,919188,917

Table 2: SARIMA predicted cases vs actual cases

Date	New cases		New death cases		Recovery	
	Predicted	Actual	Predicted	Actual	Predicted	Actual
09-09-2021	630	722	7	7	185,559185,597	
10-09-2021725466			7	3	185,819185,780	
11-09-2021735466			16	3	186,039186,168	
12-09-2021822365			25	8	186,259186,418	
13-09-2021874387			29	21	186,479188,427	
14-09-2021921519			37	18	186,699188,719	
15-09-2021992299			44	3	186,919188,917	

6 Conclusion

Forecasting and studying of Covid-19 is very essential as the disease prove to be life threatening and had claimed so many lives worldwide.A forecasting system was developed using ARIMA and SARIMA model to predict new cases, new deathcases and recovery of Covid-19 in Nigeria for a week, September 09th to 15th 2021. ARIMA model turned out to be effective for the forecastwith minimum difference when compared with the actual value.

The forecasted trend can be used by the Federal Government of Nigeria, through the presidential task group, to make more informed judgments on the further steps that need to be taken to stop the virus's spread. The model's use can also help with research on how well the lockdown stopped the spread of COVID-19 in Nigeria.

In future, it might also be necessary to forecast and study the new variants such as omicron, in order identified it early and prepare timely response to it.

Acknowledgments
The authors sincerely appreciate the referees' insightful comments and suggestions, which had improved the quality of this work.

Funding
The Tertiary Education Trust Fund (TetFund) provided funding for this work.

References

[1] Ikuomola, A. J. and Adebiyi, A. A. (2011). A comparison of fuzzy time series and least-square method in forecasting students' enrollment. Journal of Natural Sciences, Engineering and Technology, 10(1), 19-30.
[2] Indeed Career Guide. (2021). Q&A: What is forecasting? Definition, methods and examples. Retrieved from https://www.indeed.com/career-advice/career-development/what-is-forecasting
[3] Lomte, T. S. (2023). Researchers model possible COVID-19 trajectories for 2023. Retrieved March 14, 2020, from https://www.news-medical.net/news/20230314/Researchers-model-possible-COVID-19-trajectories-for-2023.aspx
[4] Adesina, S. O., Onanaye, A. S., Okewole, D., & Egere, C. A. (2020). Forecasting of new cases of COVID-19 in Nigeria using autoregressive fractionally integrated moving average models. Asian Research Journal of Mathematics, 16(9), 135-146. doi:10.9734/arjom/2020/v16i93022
[5] Hawas, M. (2020). Generated time-series prediction data of COVID-19's daily infections in Brazil by using recurrent neural networks. Data Brief, 32, 106-175. doi:10.1016/j.dib.2020.106175
[6] Jamdade, G. P., & Jamdade, G. S. (2021). Modeling and prediction of COVID-19 spread in the Philippines by October 13, 2020, by using the VARMAX time series method with preventive measures. Results in Physics, 20, 103694. doi:10.1016/j.rinp.2020.103694
[7] Kanagarathinam, K., Algehyne, A. E., & Sekar, K. (2020). Analysis of 'earlyR' epidemic model and time series model for prediction of COVID-19 registered cases. Materials Today Proceedings, Oct 14, 2214-7853. doi:10.1016/j.matpr.2020.10.086
[8] Li, L., Yang, Z., Dang, Z., Meng, C., Huang, J., Meng, H., ... Shao, Y. (2020). Propagation analysis and prediction of COVID-19. Infectious Disease Modelling, March, 282-292. doi:10.1016/j.idm.2020.03.002
[9] Ogundokun, O. R., Lukman, F. A., Kibria, M. B. G., Awotunde, B. J., & Aladeitan, B. B. (2020). Predictive modeling of COVID-19 confirmed cases in Nigeria. Infectious Disease Modelling, Aug. 15, 5, 543-548. doi:10.1016/j.idm.2020.08.003
[10] Satrio, A. B. C., Darmawan, W., Nadia, U. B., & Hanafiah, N. (2021). Time series analysis and forecasting of coronavirus disease in Indonesia using ARIMA model and Prophet. Procedia Computer Science, 179(12), 524–532. doi:10.1016/j.procs.2021.01.036
[11] Wang, P., Zheng, X., Ai, G., Liu, D., & Zhu, B. (2020). Time series prediction for the epidemic trends of COVID-19 using the improved LSTM deep learning method: Case studies in Russia, Peru, and Iran. Chaos, Solitons & Fractals, Nov, 140, 110214. doi:10.1016/j.chaos.2020.110214

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp. 377–383, November 13-16, 2023

Assessment of Radon ^{222}RN Gas in Groundwater of Selected Boreholes and Wells in Sabongida Environment, Bungudu Local Government Zamfara State Nigeria

Yusuf U[1], A. B. Isah[2], Josshua K.[3]
{ yusufusman@fugusau.edu.ng[1]}

Department of Physics, Federal University Gusau, Zamfara State, Nigeria, 07068603407[1]

Abstract
^{222}Rn is a naturally occurring radioactive gas that is generated from the spontaneous decay of naturally existing radium in soil, rock, and water. Many studies were reported in various locations, however, none has been reported in SabonGida Environment and hence this work will focus on determining its concentration to address the concerned community.Radon activity concentration in water samples from SabonGidaEnvironment Zamfara State and their possible health risk was assessed. The Liquid Scintillation Counter was used for the measurement of radon concentration. The radon activity concentration ranged from 0.34 to 27.41Bq/L and 0.20 to 40.10Bq/L with the average mean of 14 and 13Bq/L for wells and boreholes respectively. The result was above the USEPA (1991) and WHO (1996) action levels of11.1Bq/L and10.0Bq/L respectively. The estimated annual effective dose by ingestion ranged from 14. 6 to 512µSv/yr with an average mean ofaverage Annual Effective Dose for Adults, Children and Infants 101µSv/yr, 123µSv/yr, 151µSv/yr, 231µSv/yr, 176µSv/yr, 191µSv/yr respectively. Therefore these water sources pose a threat to the health of the inhabitants of SabonGida EnvironmentBungudu Local Government Area Zamfara State, if continually ingested without proper treatment the likelihood of this threat to health (which is lung cancer) is more to children and infants than Adults.

Keywords: Gross-Alpha Sabon Gida, Effective Dose Bungudu ZamfaraStateNigeria.

1 Introduction

^{222}Rn (radon) is a naturally occurring radioactive gas which is generated from the spontaneous decay of naturally existing Radium (a decay product of Uranium) in soil, rock, water, and building materials all over the earth. It is a tasteless, odourless, and colourless radioactive gas that can be inhaled by humans (Nisha*et al*, 2016). It is the most hazardous radionuclide among all the Radon isotopes (Harb, 2016).

Natural sources contribute significant quantities of radiation toward the total radiation exposure that humans receive. The Natural radiation account for the majority of human exposure to radiation with radon decay products being the largest contributor in spite of the increased use of manmade radiation in industries, medical centres, and scientific research establishments (Tso& Li, 1987). The earth's crust contains a trace amount of ^{238}U and ^{232}Th which decay to ^{222}Rn (radon) and ^{220}Rn (thoron gas), respectively (Tso& Li.,1987). Most of the radon to which people are exposed emanates from soil and rock. The other sources of significance are building materials, portable water, and natural gas (UNSCEAR, 1993).

This research is aimed at the assessment of ^{222}Rn gas in groundwater of the selected boreholes and wells in the Sabon Gida Environment, using Liquid Scintillation Counter, and it is linked with the following objectives. To find out the risk level of ^{222}Rn concentration concerning the standard defined by WHO among others, To measure the activity concentration of ^{222}Rn in boreholes and wells samples collected from Sabon Gida Environment, Bugundu Local Government Area, Zamfara State and to estimate the effective dose due to intake of ^{222}Rn from the measured boreholes and wells samples for Adults, Children, and Infants.

2 Material and Method

2.1 Description of Study Area

The SabonGida village were lie between latitudes 12°03'S, 12°20'N and longitudes 6°70'W, 7°90'E. The population of the inhabitants of Zamfara State is 9.279 million people and consists of fourteen (14) Local Government Areas, and SabonGida is under the Bungudu Local Government Area

2.2 Liquid Scintillation Counting

A scintillating liquid, referred to as the "cocktail," serves as the detector. The cocktail (perhaps 10 ml) is inside a plastic or glass vial that is transparent to the light emitted by the cocktail. Ideally; the sample (e.g., 1ml) is dissolved in the cocktail. Failing that, the sample might be suspended as an emulsion or suspended in a gel. In some cases, a large solid sample (e.g., a smear) is simply placed into the cocktail with no attempt at dissolving it.

2.3 Sample Collection

Two different categories of water samples from boreholes and hand-dug wells were collected in different locations of Sabon Gida and analyzed for ^{222}Rn concentration. A total of ten samples that is 5 well samples and 5 boreholes samples were collected with the aid of bailers, but the stagnant water in the wells was first purged by drawing it out and allowing the wells to refill. Several well volume purges were done to assure fresh samples were obtained while boreholes were operated for at least three minutes before sample collection. The samples were collected in pre-cleaned plastic sample bottles and analyzed as soon as possible after collection, this was done to achieve maximum accuracy because the composition of the sample may change if allowed to stay longer than 3 days before carrying out the analysis.

2.4 Sample Preparation

10ml of each sample was added into a vial containing 10ml of toluene-based cocktail (scintillator) using a hypodermic syringe. The vials were tightly capped and shaken vigorously for three (3) minutes to extract radon222 in the water phase into the organic scintillator. Similarly, a blank sample for the background was prepared using distilled water that has been kept in a glass bottle for at least 3 days. The prepared samples were allowed to stand undisturbed for at least three (2) hours each for ^{222}Rn and its alpha decay products attain equilibrium before counting.

2.5 Materials Used.

- A plastic sample bottle (600 ml) was used for sample collection.
- Disposable hypodermic syringe (20, 10, and 2 ml capacity) with 38 mm (1in) hypodermic needle.
- Surgical globe.
- Water for injection and distilled water.
- Scintillation vial (20 ml capacity) with polyethylene inner seal cap liners.
- Scintillation Cocktail.
- Indelible ink and masking tape.
- Global Processing System (GPS)
- Liquid Scintillation Counter (Packard Tri-Carb LSA 1000TR).

2.6 Sample Analysis

The prepared samples and the blank were each analyzed using the Liquid Scintillation Counter (Tri-Card LSA 1000) at the Centre for Energy Research and Training (CERT), Ahmadu Bello University Zaria, Kaduna, Nigeria. Radiation emitted from the samples transferred energy to the organic scintillator which in turn emits light photons. This way each emission result is a pulse of light in the form of a digit.The liquid scintillation counter was calibrated before the analysis using IAEA ^{226}Ra standard solution. For the calibration, the ^{222}Rn standard samples were counted for 60 minutes. Background count measurements were also made for the same period (60 min).

2.7 ^{222}Rn Activity Concentration and Effective Dose

The ^{222}Rn activity concentration was calculated using the following equation

$$R_n\left(\frac{Bq}{L}\right) = \frac{100(NS - NB)e^{\lambda t}}{60 \times 5 \times 0.964} \qquad 2.1$$

Where,

$$Rn = radon\ level\ in\ BqL^{-1};$$

NS = sample count rate (count min^{-1})
NB = background count rate (Count min^{-1})
K = calibration value;
T = elapsed time from sampling to testing given in minutes (Garba*et al.*, 2008)

2. 8 Calculation of Effective Dose

Determination of annual effective doses of radon The Annual effective doses for inhalation and ingestion were determined using the formula in below respectively.

$C_{ing}^{Rn} = C_w^{Rn} \times I_a \times Df$ 3.2

Where $C_{ing}^{Rn} = Annual\ Effective\ Dose\ and\ C_W^{Rn} = Radon\ Concentration\ of\ each\ sample Df =$ The Ingestion dose (Aruwa*et al.*, 2017)

Given $I_a\ for\ adults = 730, I_a\ for\ children = 547.5$

$$I_a\ for\ infant = 182.5$$

$Df = 10 - 8\ SvBq^{-1}\ for\ adults, Df = 2x10^{-8}\ SvBq^{-1}\ for\ children$

$$\text{Df} = 7\text{x}10^{-8}\ \text{SvBq}^{-1}\ \text{for infants}$$

3 Results and Discussion

Two water samples from boreholes and hand-dug wells were collected and analysed. A total of ten samples that is 5 well samples and 5 boreholes samples were analysed using the Liquid Scintillation Counter respectively. Table 3.1 shows the various coordinates, Radon ^{222}Rn Concentration, and the annual Effective Dose for Adults, Children and Infants (Garba*et al.*, 2008).

Table 3. Radon ^{222}Rn activity concentration and the annual effective dose

S/N	Time Count	Sample ID	Sample Location	Latitude (º0)N'S	Longitude (º0)W'E	^{222}Rn Conc. Bq/L	Annual Effective Dose (µSv/yr)		
							Adults	Children	Infants
1	60 Minutes	SW1	SabonGida 1	12.03	6.70	20.17	147	220	257
2	60 Minutes	SW2	SabonGida 2	12.40	6.30	23.00	167	251	293

3	60 Minutes	SW3	SabonGida 3	12.30	6.50	1.05	76.7	11.4	13.4
4	60 Minutes	SW4	SabonGida 4	12.02	6.20	0.34	24.8	372	43.4
5	60 Minutes	SW5	SabonGida 5	12.80	6.10	27.41	200	300	350
6	60 Minutes	SB1	SabonGida 01	12.43	6.60	40.10	292	439	512
7	60 Minutes	SB2	SabonGida 02	12.22	6.25	0.20	14.6	21.9	25.5
8	60 Minutes	SB3	SabonGida 03	12.13	6.12	7.92	57.8	86.7	101
9	60 Minutes	SB4	SabonGida 04	12.15	6.15	17.18	125	188	219
10	60 Minutes	SB5	SabonGida 05	12.20	6.90	1.82	13.2	19.9	23.2
Average Radon ^{222}Rn Activity Concentration in Bq/L^{-1}= 14 Bq/L^{-1} **Average Annual Effective Dose for Adults, Children and Infants = 101 – 123µSv/yr, 151 – 231µSv/yr, 176 - 191µSv/yr**									

3.1 Risk Level of ^{222}Rn(radon)

In SabonGidaEnvironment, Zamfara State radon concentration in the borehole and well water was determined and the results obtained showed that the concentration of radon is higher than the maximum contaminant level (MCL) value suggested by USEPA (1991)

The risk of lung cancer observed in underground miners due to exposure on radon, was the main reason to investigate similar risk for the general population, due to radon exposure in houses, working places, and buildings (WHO, 2009)

Results from this study show that the mean ^{222}Rn concentration in both wells and boreholes were slightly higher than the maximum concentration limit of 11.1Bq/L and the world average value of 10Bq/L for drinking water, and this may be attributed to the fact that radon readily dissolves in water under pressure which lead to the radon accumulation in groundwater.

3.2 ^{222}Rn Activity Concentration

The ^{222}Rn activity concentrations found ranged from 0.34 to 27.41BqL^{-1} B0.20 to 40.10 BqL^{-1} and, with the average mean of and14 and13 BqL^{-1} for wells and boreholes respectively. This clearly shows that the ^{222}Rn is slightly higher than the Maximum Contaminant Level (MCL) for both WHO and USEPA which is 10 BqL^{-1} and 11.1 BqL^{-1}respectively. The risk of lung cancer observed in underground miners due to exposure on radon, was the main reason to investigate similar risk for the general population, due to radon exposure in houses, working places, and buildings (WHO, 2009)**.**

The ^{222}Rn activity concentration were shown in Figure 3.1, shows that sample well 1, sample well 2, and sample well 5 (SW1, SW2 & SW5) are of high ^{222}Rn concentration that is 20.17BqL^{-1}, 23 BqL^{-1}, and 27.41BqL^{-1} and which is above the Maximum Contaminant Level (MCL) of 11.1Bq/L for USEPA and 10Bq/L for WHO respectively. Also, sample well 3 and sample well 4 (SW3 & SW4) are of low ^{222}Rn concentration is 0.34Bq/L and 1.05Bq/L which is below the Maximum Contaminant Level (MCL) of 11.1Bq/L and 10Bq/L for USEPA and WHO respectively.

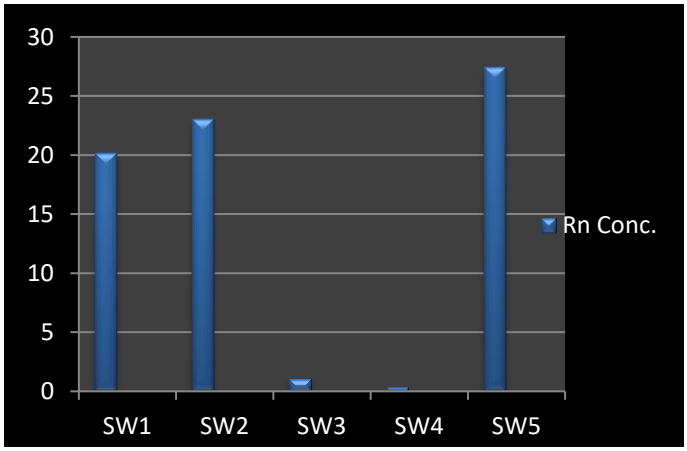


Figure 3.1 Bar Chart of Radon Concentration for Hand dug well water samples

The ^{222}Rn activity concentration is shown in Figure 4.2, which shows that sample borehole 1 SB1 is of a very high ^{222}Rn concentration that is 40.10Bq/L and which is above the Maximum Contaminant Level (MCL) of 11.1Bq/L for USEPA and 10Bq/L for WHO respectively. Also, sample well 2 and sample well 5 (SB2& SB5) are of low ^{222}Rn concentration is 0.2Bq/L and 1.82Bq/L which is below the Maximum Contaminant Level (MCL) of 11.1Bq/L and 10Bq/L for USEPA and WHO respectively. Comparing the samples that are well and borehole, it shows that sample well 5 (SW5) and sample borehole 1 (SB1) are extremely higher than the maximum contaminant level (MCL) of USEPA and WHO.

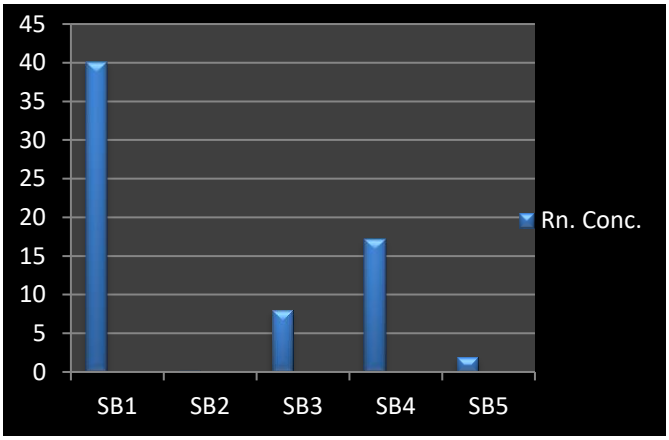


Figure 3.2 Bar Chart of Radon Concentration for Borehole water samples

^{222}Rn concentration in water depends much on the source of radon emanation which may likely be as a result of natural processes or industrial activities and other human activities in the area where the wells and boreholes are located (Garba*et al.*, 2008).

3.3 Annual Effective Dose (AED)

The estimated annual effective dose by ingestion of our study ranged from 14. 6 to 512µSv/yr with an average mean of 101µSv/yr, 151µSv/yr, and 176µSv/yr, for adults, children, and infants respectively. And compared with the study of other researchers ranged from 8.69 to 90.9µSv/yr with an average mean of 85µSv/yr, 100µSv/yr, and 95µSv/yr, for adults children, and infants respectively (Kuttio*et al.*, 2006). This shows that the annual effective doses of SabonGida Environment are higher than the standard level of 100µSv/yrWhereas the estimated annual effective dose by ingestion ranged from 11.4 – 350µSv/yr with a mean of 123µSv/yr, 231µSv/yr and 191µSv/yr for adults, children and infants respectively.

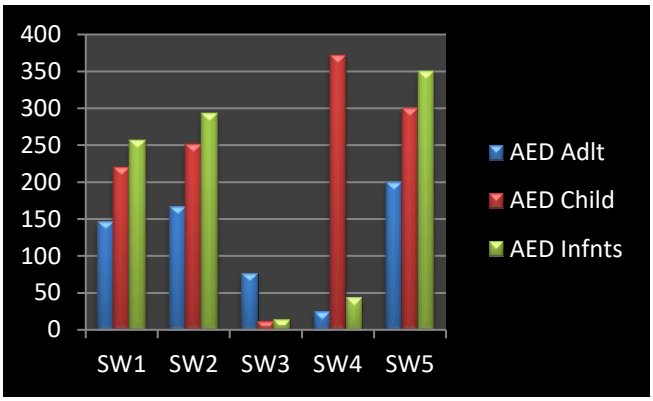


Figure 3.3 Bar Chart of Annual Effective Dose for Well water samples of Adults, Children, and Infants.

The Annual Effective Doses are shown in Figure 4.3 the chart representing well water samples and their Annual Effective Doses show that the highest Annual Effective Doses are sample 5, sample 4, also sample 5, (SW5, SW4, SW5) are of high annual effective dose that is 200µSv/yr, 372µSv/yr and 350µSv/yr for adults, children, and infants respectively. And the lowest Annual Effective Doses are sample well 4 (SW4) sample well 3 (SW3)also sample well 3 (SW3) with 24.8µSv/yr, 11.45µSv/yr also 13.7µSv/yr for adults, children and infants respectively. From these results, it's shown that the Annual Effective Dose is higher than the standard Annual Effective Dose level but the lowest Annual Effective Doses tends to be lower than the standard Annual Effective Dose of 100µSv/yr.

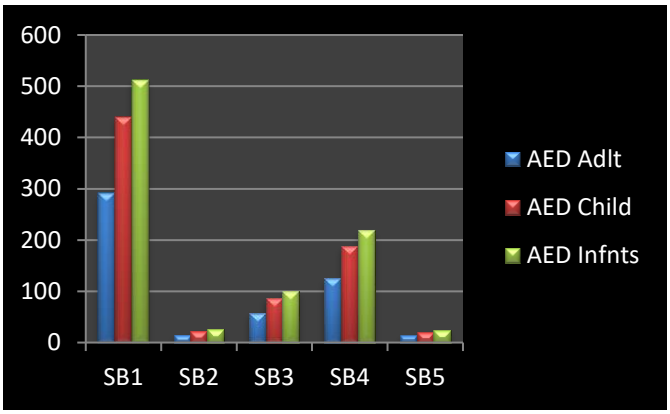


Figure 3.4 Bar Chart of Annual Effective Dose for Borehole water samples of Adults, Children, and Infants.

The Annual Effective Doses are shown in Figure 4.4 the chart representing borehole water samples and their Annual Effective Doses shows that the highest Annual Effective Doses are sample borehole1, (SB1) is of high annual effective dose that is 292µSv/yr, 439µSv/yr and 512µSv/yr for adults, children and infants respectively. And the lowest Annual Effective Doses is sample borehole 5 (SB5) with 13.2µSv/yr, 19.9µSv/yr also 23.2µSv/yr, for adults, children and infants respectively. From these results, it's shown that the Annual Effective Dose is higher than the standard Annual Effective Dose level but the lowest Annual Effective Doses tends to be lower than the standard Annual Effective Dose of 100µSv/yr.

4 Conclusion

^{222}Rn concentrations in groundwater sources from SabonGida Bungudu Local Government area of Zamfara State Northern Nigeria have been determined. Data obtained from the study found 14.00 and

13.00Bq/L as the mean ^{222}Rn concentrations for both wells and boreholes respectively which was slightly higher than the maximum concentration limit of 11.1 Bq/L set by USEPA (1991) and the world average value of 10Bq/L set by World Health Organization (WHO, 1996). The estimated annual effective dose found in our study ranged from 14. 6 to 512µSv/yr with an average mean ofaverage Annual Effective Dose for Adults, Children, and Infants 101µSv/yr, 123µSv/yr, 151µSv/yr, 231µSv/yr, 176µSv/yr, 191µSv/yr respectively. Therefore these water sources pose a threat to the health of the inhabitants of SabonGidaEnvironment, Bungudu Local Government Area Zamfara State, if continually ingested without proper treatment the likelihood of this threat to health (which is lung cancer) is more on children and infants than Adults.

5 Recommendation

After carrying out this research for the assessment of Radon ^{222}Rn gas in the Groundwater of some selected Boreholes and Wells in the SabonGidaEnvironment. I recommend that we:

1. Carry out a national program for estimating radon levels and effective doses to persons in the indoor environments in SabonGida and Zamfara at large and regrouping all efforts dealing with it and turn to a collective work
2. Use educational programs to inform health officials and the public about the health threat from radon and associated risk factors, such as smoking.
3. Apply the Geographical Information System (GIS) technology in the analysis of radon data and the creation of an indoor radon map ofSabonGida, Zamfara
4. Promote scientific research dealing with radon applications in earth sciences and radiation safety at nuclear and industrial facilities.
5. More samples should be carried out in different locations in Bungudu Local Government Area and Zamfara at large.

References

[1] Garba, N.N., Rabi'u N., Yusuf A.M., Isma'ila A. (2008). Radon: Its consequences and measurement in our living Environment. J. Res. Phys. Sci, 4(4), 23–25.

[2] Harb, S., Ahmed N.K., & Sahar E. (2016). Effect of Grain Size on the Radon Exhalation Rate and Emanation Coefficient of Soil, Phosphate and Building Material Samples. Journal of Nuclear and Particle Physics, 6(4), 80-87. DOI: 10.5923/j.jnpp.20160604.02

[3] Kurttio, P., Salonen, L., Taina, I., Pekkanen, J., Pukkala, E., & Auvinen, A. (2006). Well water radioactivity and risk of cancer of the urinary organ. Environmental Research, 102, 333–338.

[4] Nisha S., Jaspal S., Esakk S.C., Tripathi R.M. (2016). A study of the natural radioactivity and radon exhalation rate in some cements used in India and its radiological significance. Journal of Radiation Research and Applied Sciences, 9, 47-56.

[5] Tso M.W., Li C. (1987). Indoor and Outdoor 222Rn daughters in Hongkong. Health Phys, 53(2), 175-180.

[6] UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation). (1993). Sources and Effects of Ionizing Radiation, UNSCEAR report to the General Assembly with scientific annexes. United Nations, New York.

[7] USEPA (United States Environmental Protection Agency). (1996). Drinking Water Contaminants. United States Environmental Protection Agency, 15.

[8] USEPA (United States Environmental Protection Agency). (1991). Prescribed Procedures for Measurement of Radioactivity in Drinking Water. Environmental Monitoring and Support Laboratory. EPA 600/4-80-032.

[9] WHO (World Health Organization). (1993). Guidelines for Drinking Water Quality (3rd ed.). World Health Organization, Geneva, Switzerland.

[10] WHO (World Health Organization). (2016). Radon and Health. Retrieved from http://www.who.int/mediacentre/factsheets/fs291/en/

[11] WHO (World Health Organization). (2009). WHO Handbook on Indoor Radon: A Public Health Perspective. Geneva: WHO Press, World Health Organization, 6-7.

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp. 384–389, November 13-16, 2023

Legendary-Based Innovative Cryptography for Enhanced Security and Efficiency

E.O. Adeyafa[1], A. A James, O.D. Agbolade[2], B.M. Ogunleye
{adeoluman@yahoo.com[1], adewale.james@aun.edu.ng[2], agboladeferanmi06@gmail.com[3], ogunleyebolanle500@gmail.com[4]}

Department of Mathematics, Faculty of Science, Federal University Oye-Ekiti, Ekiti State, Nigeria[1,3], , Department of Mathematics and Statistics, American University of Nigeria, Yola, Nigeria[2], *Department of Physical and Mathematical Sciences, CrownHill University, Ilorin, Kwara State, Nigeria[1], Department of Mathematics, 303 Lockett Hall, Louisiana State University, Baton Rouge, LA 70803-4913, USA*[3]

Abstract
In today's interconnected world, marked by the global reach of the internet and remarkable technological strides, geographical boundaries have diminished, fostering seamless communication across vast distances via diverse mediums. However, this digital landscape introduces vulnerabilities, wherein intercepted information jeopardizes privacy. Recognizing this, platforms such as WhatsApp, Facebook, and Quora prioritize robust information security to instill user trust and sustain engagement. Cryptography stands as the cornerstone in this endeavor, fortifying data transmission against unauthorized access through intricate algorithms and methods. This paper introduces an original cryptographic paradigm, harnessing the potency of Chebyshev Polynomials and the Laplace Transform for encryption. By leveraging mathematical intricacies, this scheme promises heightened security and efficiency in safeguarding sensitive information. As technology races forward, innovations like these underscore the ongoing commitment to fortify digital realms, ensuring confidentiality and bolstering user confidence in an ever-evolving digital era.

Keywords: Chebyshev Polynomials, Cryptography, Decryption, Encryption

1 Introduction

In our contemporary world, marked by the pervasive utilization of computer networks and the internet, cryptography has emerged as a cornerstone of our technologically driven lives. This reliance stems from the imperative need to shield information against unauthorized access. With roots in ancient times, cryptography has evolved into an indispensable security tool, safeguarding data from hackers and theft, with notable prominence during the World Wars.

In today's landscape of expansive computer network usage, the relevance of ensuring network and computer data security is indisputable. The escalating dependence on these systems demands the safeguarding of data against unauthorized entry, constituting a critical concern. Cryptography emerges as a primary solution to address these security challenges, serving as one of the most prevalent avenues for ensuring data security.

Mathematics forms the bedrock of cryptography, as encryption and decryption algorithms fundamentally rest upon mathematical principles. Notably, various authors such asHiwarekar (2013), Balogun et al. (2017) and Mittal and Gupta (2019) have explored distinct polynomial-based encryption methods.
In the scope of this work, the focus is directed towards the application of Legendre polynomials. These polynomials, complete and orthogonal, boast a multitude of mathematical properties and versatile applications. Originating from the Legendre equation, the primary iteration is referred to as the Legendre polynomial.

The Legendre recurrence polynomial is shown below.

$$P_{n+1} = \left(\frac{2n+1}{n+1}\right) xP_n(x) - \left(\frac{n}{n+1}\right) P_{n-1}(x)$$

where Pn(x) is known to have satisfied the Legendre differential equation.

This paper aims to generate the first two terms of the Legendre polynomial using Rodrigues' formula and use the recurrence formula to generate the nth term of the remaining sequences and the chebyshev polynomial.

2 The Cryptographic Scheme Algorithm

In this section, we encrypt some plain texts to demonstrate the applicability of the Legendry polynomials and Laplace transform. The components of these are considered hereunder.

2.1 The Laplace Transform

The Laplace transform, a powerful integral transform, simplifies dynamic system analysis by converting integrals into polynomials. After problem-solving, the inverse transform restores the original domain. Widely applicable in mathematics, physics, and engineering, the Laplace transform offers a broad perspective across diverse fields.

TheLaplace transform of $\boldsymbol{f(x)}$, denoted by $\boldsymbol{L(f(x))}$, is defined as:

$$\mathbf{L(f(x))} = \int_0^\infty \boldsymbol{e^{-sx} f(x) dx},$$

provided the integral exist.

Consider a function $f(t)$ defined for all positive value of t (i.e. $t \geq 0$), then the Laplace transform of $f(t)$ denoted by L{f(t)} is defined by the expression

$$L\{F(t)\} = F(s) = \int_0^\infty e^{-st} F(t)\, dt \qquad (1)$$

where s is a real or complex parameter, assuming the integral converges. The inverse Laplace transform of F(s) is given by

$$L^{-1}\{F(s)\} = L^{-1}\left\{\int_0^\infty e^{-st} F(t)\, dt\right\} = f(t) \qquad (2)$$

These equations shall be employed in the encryption and decryption processes.

2.2 The Encryption Algorithm

In this phase, we would consider the algorithm used for the creation of the new cryptographic scheme using the known Legendre Polynomial. We would also consider a series of examples and make use of a series of steps to consider the algorithm.

Step 1: Choose $M = [M_0, M_1, M_2, \ldots, M_n]$ be plain text and convert it to ASCII code and n be the length of the message. **Step 2**: The plain text to be encrypted is **FEDERAL UNIVERSITY OYE.** Here $n = 21$. Based on the step 1 above;ASCII code for plain text becomes $\mathrm{F} = 70, \mathrm{E} = 69, \mathrm{D} = 68, \mathrm{R} = 82, \mathrm{A} = 65, \mathrm{L} = 76, \mathrm{U} = 85, \mathrm{N} = 78, \mathrm{I} = 73, \mathrm{V} = 86, \mathrm{S} = 83, \mathrm{T} = 84, \mathrm{Y} = 89,\ \mathrm{O} = 79,\ \text{space} = 32$. Therefore the finite sequence for the plain text are:

$$\blacksquare(\&M\_0 = 70, M\_1 = 69, M\_2 = 68, M\_3 = 69, M\_4 = 82, M\_5 = 65, M\_6 = 76, M\_7 = 32, M\_8 = 85, M\_9 = 78, M\_10 = 73@\&M\_11 = 86, M\_12 = 69, M\_13 = 82, M\_14 = 83, M\_15 = 73, M\_16 = 84, M\_17 = 89, M\_18 = 32, M\_19 = 79, M\_20 = 89@\&M\_21 = 69)$$

Step 3: Introduce the Legendre polynomial where the numbers above will be written as its coefficient. The Legendre polynomial can be given as thus.

$$P_{n+1} = \left(\frac{2n+1}{n+1}\right) xP_n(x) - \left(\frac{n}{n+1}\right) P_{n-1}(x)$$

where $P_n(x)$ is known to have satisfied the Legendre differential equation. **Step 4:** We would introduce $P_n(x)$ where $n \leqslant 21$.Hence, we would have $P_0, P_1, \ldots, P_{21}$. The followings are the $P_n(x)$:

$P_0(\mathrm{x}) = 1$

$P_1(\mathrm{x}) = \mathrm{x}$

$P_2(\mathrm{x}) = \frac{3}{2}x^2 - \frac{1}{2}$

$P_3(\mathrm{x}) = \frac{5}{2}x^3 - \frac{3}{2}x$

$P_4(\mathrm{x}) = \frac{35}{8}x^4 - \frac{15}{4}x^2 + \frac{3}{8}$

$P_5(\mathrm{x}) = \frac{63}{8}x^5 - \frac{35}{4}x^3 + \frac{15}{8}x$

$P_6(\mathrm{x}) = \frac{231}{16}x^6 - \frac{315}{16}x^4 + \frac{105}{16}x^2 - \frac{5}{16}$

$P_7(\mathrm{x}) = \frac{12155}{128}x^9 - \frac{6435}{32}x^7 + \frac{9009}{64}x^5 - \frac{1155}{32}x^3 + \frac{315}{128}x$

$P_8(\mathrm{x}) = \frac{6435}{128}x^8 - \frac{3003}{32}x^6 + \frac{3465}{64}x^4 - \frac{315}{32}x^2 + \frac{35}{128}$

$P_9(\mathrm{x}) = \frac{12155}{128}x^9 - \frac{6435}{32}x^7 + \frac{9009}{64}x^5 - \frac{1155}{32}x^3 + \frac{315}{128}x$

$P_{10}(\mathrm{x}) = \frac{46189}{256}x^{10} - \frac{109395}{256}x^8 + \frac{45045}{128}x^6 - \frac{15015}{128}x^4 + \frac{3465}{256}x^2 - \frac{63}{256}$

$P_{11}(\mathrm{x}) = \frac{88179}{256}x^{11} - \frac{230955}{256}x^9 + \frac{109395}{128}x^7 - \frac{45045}{128}x^5 + \frac{15015}{256}x^3 - \frac{693}{256}x$

$P_{12}(\mathrm{x}) = \frac{676039}{1024}x^{12} - \frac{969969}{512}x^{10} + \frac{2078505}{1024}x^8 - \frac{255255}{256}x^6 + \frac{225225}{1024}x^4 - \frac{9009}{512}x^2 + \frac{231}{1024}$

$P_{13}(\mathrm{x}) = \frac{1300075}{1024}x^{13} - \frac{2028117}{512}x^{11} + \frac{4849845}{1024}x^9 - \frac{692835}{256}x^7 + \frac{765765}{1024}x^5 - \frac{45045}{512}x^3 + \frac{3003}{1024}x$

$P_{14}(\mathrm{x}) = \frac{5014575}{2048}x^{14} - \frac{16900975}{2048}x^{12} + \frac{22309287}{2048}x^{10} - \frac{14549535}{2048}x^8 + \frac{4849845}{2048}x^6 - \frac{765765}{2048}x^4 + \frac{45045}{2048}x^2 - \frac{429}{2048}$

$P_{15}(\mathrm{x}) = \frac{9694845}{2048}x^{15} - \frac{35102025}{2048}x^{13} + \frac{50702925}{2048}x^{11} - \frac{37182145}{2048}x^9 + \frac{14549535}{2048}x^7 - \frac{2909907}{2048}x^5 + \frac{255255}{2048}x^3 - \frac{6435}{2048}x$

$P_{16}(\mathrm{x}) = \frac{300540195}{32768}x^{16} - \frac{145422675}{4096}x^{14} + \frac{456326325}{8192}x^{12} - \frac{185910725}{4096}x^{10} + \frac{334639305}{16384}x^8 - \frac{20369349}{4096}x^6 + \frac{4849845}{8192}x^4 - \frac{109395}{4096}x^2 + \frac{6435}{32768}$

$P_{17}(\mathrm{x}) = \frac{583401555}{32768}x^{17} - \frac{300540195}{4096}x^{15} + \frac{1017958725}{8192}x^{13} - \frac{456326325}{4096}x^{11} + \frac{929553625}{16384}x^9 - \frac{669278661}{4096}x^7 + \frac{20369349}{8192}x^5 - \frac{692835}{4096}x^3 + \frac{109395}{32768}x$

$P_{18}(\mathrm{x}) = \frac{2268783825}{65536}x^{18} - \frac{9917826435}{65536}x^{16} + \frac{4508102925}{16384}x^{14} - \frac{4411154475}{16384}x^{12} + \frac{5019589575}{32768}x^{10} - \frac{1673196525}{32768}x^8 + \frac{156165009}{16384}x^6 - \frac{14549535}{16384}x^4 + \frac{2078505}{65536}x^2 - \frac{12155}{65536}$

$$P_{19}(x) = \frac{4418157975}{65536}x^{19} - \frac{2019055425}{65536}x^{17} + \frac{9917826435}{16384}x^{15} - \frac{10518906825}{16384}x^{13} + \frac{13233463425}{32768}x^{11} - \frac{5019589575}{32768}x^{9} + \frac{557732175}{16384}x^{7} - \frac{66927861}{16384}x^{5} + \frac{14549535}{65536}x^{3} - \frac{230945}{65536}x$$

$$P_{20}(x) = \frac{34461632205}{262144}x^{20} - \frac{83945001525}{131072}x^{18} + \frac{347123925225}{262144}x^{16} - \frac{49589132175}{32768}x^{14} + \frac{136745788725}{131072}x^{12} - \frac{29113619535}{65536}x^{10} + \frac{15058768725}{131072}x^{8} - \frac{557732175}{32768}x^{6} + \frac{334639305}{262144}x^{4} - \frac{4849845}{131072}x^{2} + \frac{46189}{262144}$$

$$P_{21}(x) = \frac{67282234305}{262144}x^{21} - \frac{172308161025}{131072}x^{19} + \frac{755505013725}{262144}x^{17} - \frac{115707975075}{32768}x^{15} + \frac{347123925225}{131072}x^{13} - \frac{82047473235}{65536}x^{11} + \frac{48522699225}{131072}x^{9} - \frac{2151252675}{32768}x^{7} + \frac{1673196525}{262144}x^{5} - \frac{37182145}{131072}x^{3} + \frac{969969}{262144}x$$

Introducing the constant M_n which includes values of the text **FEDERAL UNIVERSITY OYE** above, we have the following:

$$M_n(x) = M_0P_0 + M_1P_1 + M_2P_2 + M_3P_3 + M_4P_4 + M_5P_5 + M_6P_6 + M_7P_7 + M_8P_8 + M_9P_9 + M_{10}P_{10} + M_{11}P_{11} + M_{12}P_{12} + M_{13}P_{13} + M_{14}P_{14} + M_{15}P_{15} + M_{16}P_{16} + M_{17}P_{17} + M_{18}P_{18} + M_{19}P_{19} + M_{20}P_{20} + M_{21}P_{21}.$$

Therefore,

$$M_n(x) = \frac{19057605}{262144} + \frac{68594577}{262144}x - \frac{454247277}{131072}x^{2} + \frac{1670198915}{131072}x^{3} + \frac{29876189665}{262144}x^{4} + \frac{72465852753}{262144}x^{5} - \frac{48529248999}{32768}x^{6} - \frac{96322948293}{32768}x^{7} + \frac{1288480455405}{131072}x^{8} + \frac{2291708987425}{131072}x^{9} - \frac{2468172540119}{65536}x^{10} - \frac{4121100853233}{65536}x^{11} + \frac{11570615028973}{131072}x^{12} + \frac{18602823877925}{131072}x^{13} - \frac{4215978858375}{32768}x^{14} - \frac{6619494743325}{32768}x^{15} + \frac{29826510572385}{262144}x^{16} + \frac{46092806655885}{262144}x^{17} - \frac{7325902970925}{131072}x^{18} - \frac{11191194150675}{131072}x^{19} + \frac{3067085266245}{262144}x^{20} + \frac{4642474167045}{262144}x^{21}$$

Multiply the arrangement above by 262144 and we have the following result:

$$M_n(x) = 4642474167045x^{21} + 3067085266245x^{20} - 22382388301350x^{19} - 14651805941850x^{18} + 46092806655885x^{17} + 29826510572385x^{16} - 52955957946600x^{15} - 33727830867000x^{14} + 37205647755850x^{13} + 23141230057946x^{12} - 16484403412932x^{11} - 9872690160476x^{10} + 4583417974850x^{9} + 2576960910810x^{8} - 770583586344x^{7} - 388233991992x^{6} + 72465852753x^{5} + 29876189665x^{4} - 3340397830x^{3} - 908494554x^{2} + 68594577x + 19057605$$

Rearrange the result above in ascending order of the power

$$M_n(x) = 19057605 + 68594577x - 908494554x^{2} - 3340397830x^{3} + 29876189665x^{4} + 72465852753x^{5} - 388233991992x^{6} - 770583586344x^{7} + 2576960910810x^{8} + 4583417974850x^{9} - 9872690160476x^{10} - 16484403412932x^{11} + 23141230057946x^{12} + 37205647755850x^{13} - 33727830867000x^{14} - 52955957946600x^{15} + 29826510572385x^{16} + 46092806655885x^{17} - 14651805941850x^{18} - 22382388301350x^{19} + 3067085266245x^{20} + 4642474167045x^{21}$$

Step 5: Next is to take the Laplace transform of the polynomial $L(t^n) = \frac{n!}{S^{n+1}}$ when $n = 0,1,2,3, \ldots$

Here

$$L[f(t)] = L(M_n(x)) = L[19057605 + 68594577x - 908494554x^{2} - 3340397830x^{3} + 29876189665x^{4} + 72465852753x^{5} - 388233991992x^{6} - 770583586344x^{7} + 2576960910810x^{8} + 4583417974850x^{9} - 9872690160476x^{10} - 16484403412932x^{11} + 23141230057946x^{12} + 37205647755850x^{13} - 33727830867000x^{14} - 52955957946600x^{15} + 29826510572385x^{16} + 46092806655885x^{17} - 14651805941850x^{18} - 22382388301350x^{19} + 3067085266245x^{20} + 4642474167045x^{21}]$$

$$= \frac{19057605}{S} + \frac{68594577}{S^2} - \frac{1816989108}{S^3} - \frac{20042386980}{S^4} + \frac{717028551960}{S^5} + \frac{8695902330360}{S^6} - \frac{279528474234240}{S^7} - \frac{3883741275173760}{S^8} + \frac{103903063923859200}{S^9} + \frac{1663230714713568000}{S^{10}} - \frac{35826018054335308800}{S^{11}} - \frac{658004634153324057600}{S^{12}} + \frac{1108468622372135270400}{S^{13}} + \frac{2316803424531512716800}{S^{14}} - \frac{2940334660867674470400000}{S^{15}} + \frac{6924914883965473274880000}{S^{16}} + \frac{62405381379822197004288000}{S^{17}} - \frac{272270787230718745901752320000}{S^{20}} + \frac{7461917903496445061389516800000}{S^{21}} + \frac{2371883792021510458277634048000000}{S^{22}}$$

Step 6: Next find r_i such that $r_i = M_i + N_i \text{mod} 101$ where $i = 0,1,2,3,\dots,n$ and $N_i = 372270787230718745901752320000$

$r_0 = 372270787230718745901754225760 5, \mathbf{mod}\ 101 = 68$
$r_1 = 372270787230718745901759179457 7, \mathbf{mod}\ 101 = 75$
$r_2 = 372270787230718745901570621089 2, \mathbf{mod}\ 101 = 35$
$r_3 = 372270787230718745899748081302 0, \mathbf{mod}\ 101 = 47$
$r_4 = 372270787230718745973455175196 0, \mathbf{mod}\ 101 = 18$
$r_5 = 372270787230718746771342553036 0, \mathbf{mod}\ 101 = 37$
$r_6 = 372270787230718717948904896576 0, \mathbf{mod}\ 101 = 97$
$r_7 = 372270787230718357527624802624 0, \mathbf{mod}\ 101 = 3$
$r_8 = 372270787230729136208144705920 0, \mathbf{mod}\ 101 = 29$
$r_9 = 372270787230885068973223676800 0, \mathbf{mod}\ 101 = 54$
$r_{10} = 372270787227136144096318789120 0, \mathbf{mod}\ 101 = 1$
$r_{11} = 372270787164918282486419914240 0, \mathbf{mod}\ 101 = 92$
$r_{12} = 372270787341565608138965847040 0, \mathbf{mod}\ 101 = 9$
$r_{13} = 372270789547522170433265036800 0, \mathbf{mod}\ 101 = 49$
$r_{14} = 372270493197252659134305280000 0, \mathbf{mod}\ 101 = 2$
$r_{15} = 372263862315834780428477440000 0, \mathbf{mod}\ 101 = 38$
$r_{16} = 372333192612098568098756608000 0, \mathbf{mod}\ 101 = 57$
$r_{17} = 373910250416034538517026816000 0, \mathbf{mod}\ 101 = 12$
$r_{18} = 362890153520365774523760640000 0, \mathbf{mod}\ 101 = 87$
$r_{19} = 100000000000000000000000000000 0, \mathbf{mod}\ 101 = 100$
$r_{20} = 111846257758036325204070400000 00, \mathbf{mod}\ 101 = 12$
$r_{21} = 240911087074458233286780928000000, \mathbf{mod}\ 101 = 89$

The ASCII value of the above will be the cipher text. Hence the message **FEDERAL UNIVERSITY OYE** is encrypted as DK/↓ %a◯ ↔ $6S_{O_H} \setminus ◯1S_{O_T}$&**9**$F_F$**Wd**$F_F$**Y**

Step 7: Next find K_i such that $K_i = \frac{Q_i - r_i}{101}$ where $i = 0,1,2,\dots,n.$ while $Q_i = M_i + N_i$ Hence, the key K_i is obtained as thus:

$K_0 = 368584937852196778120548738 37$
$K_1 = 368584937852196778120553643 02$
$K_2 = 368584937852196778120366951 57$
$K_3 = 368584937852196778118562456 73$
$K_4 = 368584937852196778191539777 42$
$K_5 = 368584937852196778981527280 23$
$K_6 = 368584937852196750444460293 63$
$K_7 = 368584937852196393591707725 37$
$K_8 = 368584937852207065552618520 71$
$K_9 = 368584937852361454428934333 46$
$K_{10} = 368584937848649647620117612 99$
$K_{11} = 368584937787047804441999915 08$
$K_{12} = 368584937961946146672243412 91$
$K_{14} = 368584646729953127855747801 98$
$K_{15} = 368578081500826515275720237 62$
$K_{16} = 368646725358513433761145156 43$
$K_{17} = 370208168728747067838640411 88$
$K_{18} = 359297181703332450023525386 13$
$K_{19} = 990099009900990099009900990 0$
$K_{20} = 110738869067362698221851881 188$
$K_{21} = 238525828786592310184931611 8811$

Therefore the encrypted message is $\mathbf{DK}\sharp/\downarrow$ %$\mathbf{a}\bigcirc \leftrightarrow \mathbf{6}S_{O_H} \setminus \bigcirc 1S_{O_T}\&\mathbf{9}F_F\mathbf{Wd}F_F\mathbf{Y}$ while the above is the key.

The extension of this work to the decryption algorithm shall be considered.

References

[1] Hiwarekar, A. P. (2013). Application of Laplace transform for cryptographic scheme. In Proceedings of World Congress on Engineering (Vol. 1, pp. 95-100).

[2] Balogun, A. O., Sadiku, P. O., Mojeed, H. A., & Rafiu, H. A. (2017). Multiple Caesar cipher encryption algorithm. 44(2), 250-258.

[3] Mittal, A., & Gupta, R. (2019). Kamal transformation based cryptographic technique in network security involving ASCII value. International Journal of Innovative Technology and Exploring Engineering, 8(12), 3448-3450.

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp. 390–403, November 13-16, 2023

Contribution of Mathematical Modelling in Agriculture to the Development of African Region: A Review of Literatures

Ezra Daniel Dzarma[1], TheophileComlan Dagba[2], Guy Degla[3], James Dzarma Daniel[4], Emmanuel Torsen[5], DanfulaniBitrus Usman[6]

University d'Abomey-Calavi, Benin Republic[1], University d'Abomey-Calavi, Benin Republic[2], University d'Abomey-Calavi, Benin Republic[3], Universiti Putra, Malaysia[4], ModibboAdama University,Yola, Nigeria[5], ModibboAdama University,Yola, Nigeria[6]
https://orcid.org/0000-0002-6517-9668

Abstract
Agricultural modelling has played a significant role in the development of Africa by providing valuable insights, informing decision-making, and supporting sustainable agricultural practices. This research was focused towards analysing the contribution of mathematical modelling in agriculture through systematics and bibliometric literature review. A systematic literature review was carried out on the following areas, mathematical modelling, application of mathematical modelling in crop planning, mathematical modelling in crop breeding, modelling agricultural marketing and risk modelling in agriculture. The results of the review revealed that mathematical models are powerful tool for addressing agricultural problems which in turns improve the standard of living of Africans. While bibliometric data extracted from web of science which was analysed with web-based software called biblioshiny revealed that there were 6326 articles published in the field between the period of 2012 and 19/08/2023 available from 266 articles sources, published by 15527 authors, the annual growth rate in the field was 3.48%, average citation per document was 17.52 and total references of 217306. Furthermore, the study also established that USA who had 4272 articles was the most productive nation in the field globally while South Africa who had 613 articles were the most productive African country. The study also identified five research gaps

Keywords: Agriculture, crop breeding, risk, Bibliometric, modelling and marketing

1 Introduction

Agricultural modelling has played a significant role in the development of Africa by providing valuable insights, informing decision-making, and supporting sustainable agricultural practices. These models simulate various aspects of agricultural systems, such as crop growth, yield prediction, pest and disease management, soil health, and climate impacts. Here are some key contributions of agricultural modelling to the development of Africa, along with references to relevant sources:
Improved Crop Management: Agricultural models help farmers make informed decisions about planting, irrigation, fertilization, and pest management. By considering various factors like weather, soil conditions, and crop characteristics, these models optimize resource use and increase agricultural productivity (Thornton, et al., 2006).

Climate Change Adaptation: African agriculture is highly vulnerable to climate change. Modelling helps assess the potential impacts of changing climate patterns on crops, livestock, and water availability. It also aids in designing adaptation strategies to mitigate risks (Nelson, et al, 2010). Nutrition and Food Security: Agricultural models can assess the nutritional implications of different agricultural interventions and policy decisions. This helps policymakers design strategies that ensure food security and improved nutrition for vulnerable populations (Fan & Pandya-Lorch, 2012).

Natural Resource Management: Models enable the assessment of soil health, water availability, and land-use practices. This information guides sustainable resource management, preventing overexploitation and land degradation (Palm, 2012). Policy Formulation: Decision support tools based on agricultural models assist policymakers in designing effective agricultural policies that promote economic growth, poverty reduction, and sustainable development (Jayne, et al., 2014).

Capacity Building: Agricultural modelling contributes to building local capacity by training researchers, extension workers, and farmers in using and interpreting model outputs for better decision-making (Thornton & Herrero 2015).

2 Mathematical Modelling

Mathematical modelling is a powerful approach used to describe, analyse, and predict real-world phenomena using mathematical equations and relationships. It bridges the gap between theoretical concepts and practical applications, allowing scientists, engineers, economists, and various other professionals to gain insights into complex systems and make informed decisions. Mathematical models are used in a wide range of fields, including Agriculture physics, biology, engineering, economics, and social sciences (Banks, et al., 2005 and Bender &Orszag, 1999).

Mathematical modelling comes in various forms, depending on the nature of the problem and the techniques used: Deterministic Models: These models are based on precise mathematical equations and provide exact predictions. They are suitable for systems where the relationships are well-defined and stable. Stochastic Models: Stochastic models incorporate randomness and uncertainty into the equations. These are used when there's inherent variability in the system, such as in financial markets or biological systems. Continuous Models: Continuous models describe systems that change smoothly over time, often using differential equations. They are suitable for phenomena like fluid flow or population dynamics. Discrete Models: Discrete models represent systems that change in distinct steps, often using difference equations. These include population growth in discrete generations or the spread of information in a network. Agent-Based Models: These models simulate individual agents in a system and model their interactions to understand emergent behaviours. They're used in social sciences, ecology, and economics. Optimization Models: Optimization models aim to find the best possible solution given certain constraints. They're used in operations research, engineering design, and resource allocation (Winston, 2003, Gilbert &Troitzsch 2005).

The process of mathematical modelling typically involves the following steps:

Step 1:Problem Formulation- Clearly define the problem and the specific aspects you want to study. Identify the relevant variables and parameters that play a role in the phenomenon of interest.
Step 2:Assumptions-Make simplifications and assumptions to create a tractable model. While these assumptions might not capture all the intricacies of reality, they help create manageable equations and insights.
Step 3:Equations and Relationships- Formulate mathematical equations that describe how the variables interact with each other. These equations can be differential equations, algebraic equations, or other mathematical expressions.
Step 4:Model Analysis- Analyse the equations to understand their behaviour. This could involve finding solutions, studying stability, identifying critical points, and determining key properties of the model.
Step 5: Data and Calibration- If available, use data to calibrate the model and validate its predictions. Adjust parameters to match real-world observations and improve the model's accuracy.
Step 6: Prediction and Simulation-Use the model to make predictions about the behaviour of the system under various conditions. Simulation and numerical methods are often employed to solve complex models.
Step 7: Validation and Refinement-Compare the model's predictions with real-world observations. If the model doesn't match the data well, refine the model by adjusting equations, incorporating additional factors, or modifying assumptions.

Step 8: Communication-Present the model and its results to stakeholders, decision-makers, or the scientific community. Clearly explain the model's assumptions, limitations, and implications(Hestenes, 1987; Gershenfeld, 1999).

3 Application of Mathematical Modelling in Crop Planning

Mathematical modeling has been applied in different fields of human endeavor, especially in healthcare system, environmental sciences, humanity and agricultural sciences. Mathematical modeling, a novel model time for modeling a real-life scenario has played a vital role in the field of sciences and is still playing its role. For instance, Nicolae-valentin*et al* (2022) applied mathematical model to the threshing and separation from the threshing machine with an axial flow of a thresher. Where their input parameters were: "material flow, rotor speed, distance between rotor and counter rotor, mean density of processed material, feed speed, length of thresher and separating surface". The output parameters they considered were the "distribution function of separated seeds, distribution density function of separated seeds and distribution function of free seeds in the threshing space". Others were the distribution function of unthreshed seeds, together with the value of evacuation losses. The two parameters (input and output) were the ones used to control the modeling process. Their results showed that mathematical models in the field of agriculture improve crops yields, reduced over dependent on human labor and among all minimized pest and diseases on the crops (Ruslana, *et al, 2019).*

Crop planning refers to the farmers deciding on the crop to be cultivated on a farm land in a particular planning season. In this case the decision makers (farmers) must take into account two major aspects of decisions on either the crop rotation or the constraints arising from the government or the non-governmental organizations decision (Chibis&Kutyshev, 2019). In fact, in agricultural science, crop rotation refers to the succession of different crops on the same piece of land over a consecutive seeding period. We know that monoculture where the same crop is assigned on the whole farm land often led to the loss of crop yield and fertility. It further gives rise to increase of pest and diseases that can be mitigated applying suitable crop rotation. Mathematical modeling has always played vital roles in crop rotation. For instance, in assigning crop to a piece of land model can be formulated as:

Assign on each plot an amount of or first year crop to odd plot Y_e. Deciding when to assign or not assign crop to each empty plot on the second year $t\varepsilon Y_e$ such that $_{t-1}$.

$\lambda = (\alpha, \alpha_2, ..., \alpha_n)$. Whose length the number of crops depend on how even distribution are used. Let $Max^t{}_\alpha andMin^t{}_\alpha$ represent the maximum and the minimum land surface that can be assign to $y\varepsilon Y$ all for Y

A sample table for the crop rotation can be seen as follows:

Table 1. Best practice rotation

Land/crop	**Year 1**	**Year2**	**Year3**
1	Corn	Wheat	Soya been

Table 2. Not follow best practice rotation

Land/crop	**Year 1**	**Year2**	**Year3**
1	Corn	Wheat	corn

Source:
Table 1 and 2 shows the best practice and the one that does not follow the best practice crop rotation.

4 Mathematical Modelling in Crop Breeding

The field of mathematical modelling have very wide range of applications, ranging from human endeavors, in biology, ecology, agriculture, industry, and many more. Mathematical modeling is the process of creating a mathematical representation of some phenomenon in order to gain a better understanding of that phenomenon.
Plant (crop) breeding which dates back during the time of Gregor Mendel in the mid-1800s, it generally deals with the creation, selection, and fixation (intentional manipulation) of superior phenotypes for the development of improved lines or cultivars (having desirable features) to fulfil the demands of farmers, consumers, and industries both locally and globally (Are, *et al*, 2019). This is a very good area of mathematical modelling.

Mikhailenko & Dragavtsev (2013) presented the formalized theory for identification of genotypes on phenotypes in modern breeding technologies. As a base, the authors proposed the mathematical models of "genotype-environment" interaction, for which they solve an inverse informational problem during the estimation of sizes of no observed action of seven genetic-physiological systems on selected quantitative traits to be improved.

Weih *et al* (2022) studied and developed intercropping systems by using empirical methods within a localize context. This enhanced the development of good intercropping systems, the individual species that are part of an intercrop can be subjected to breeding. Breeding for intercropping aims at resource foraging traits of the admixed species to maximize niche complementarity, niche facilitation, and intercrop performance. The breeding process can be facilitated by modeling tools that simulate the outcome of the combination of different species' (or genotypes') traits for growth and yield development, reducing the need of extensive field testing. There work suggested that crop growth models can assist breeding for intercropping, if they incorporate the relevant plant characteristics and mechanisms driving interspecific plant, are based on model parameters that are closely linked to the traits that breeders would select, and model calibration and validation is done with field data measured in intercrops.

Other authors also worked on mathematical crop growth models that integrate plant characteristics and environmental conditions (Tilman *et al.*, 1997; Klimek-Kopyra *et al.*, 2013; Evers *et al.*, 2019) as reported by Weih *et al* (2022)

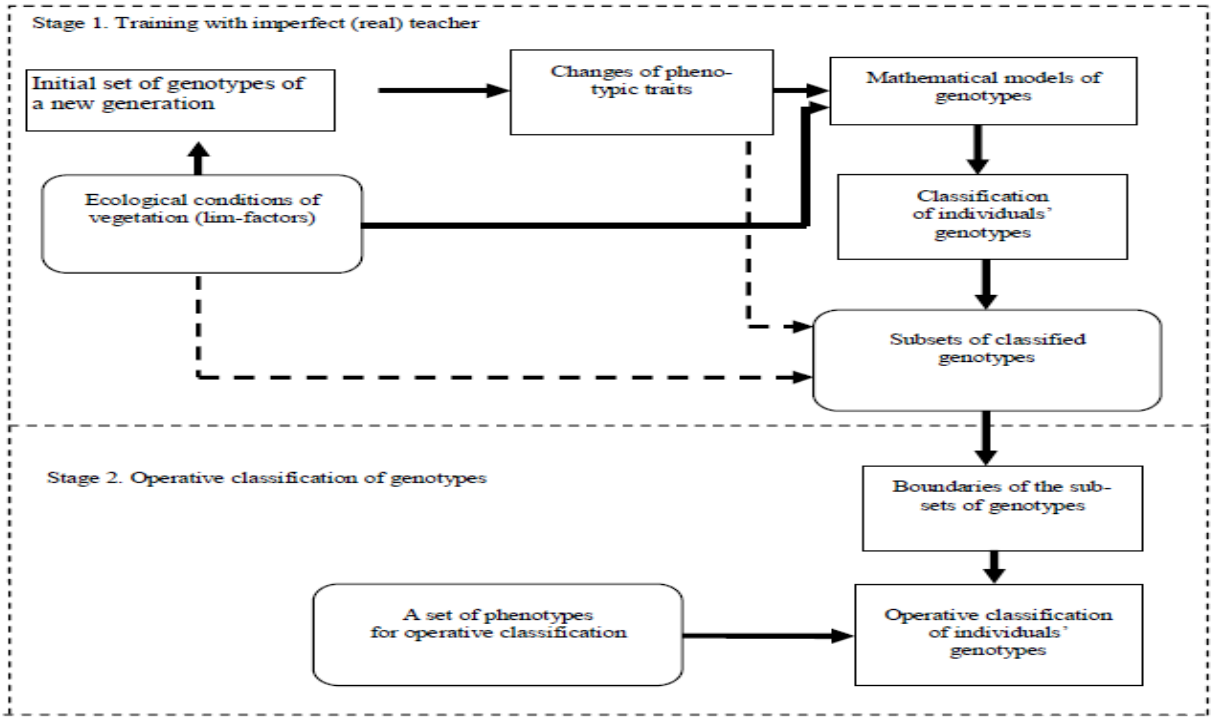


Figure1: The algorithm of classification of genotypes on phenotypes (Source: Mikhailenko & Dragavtsev, 2013)

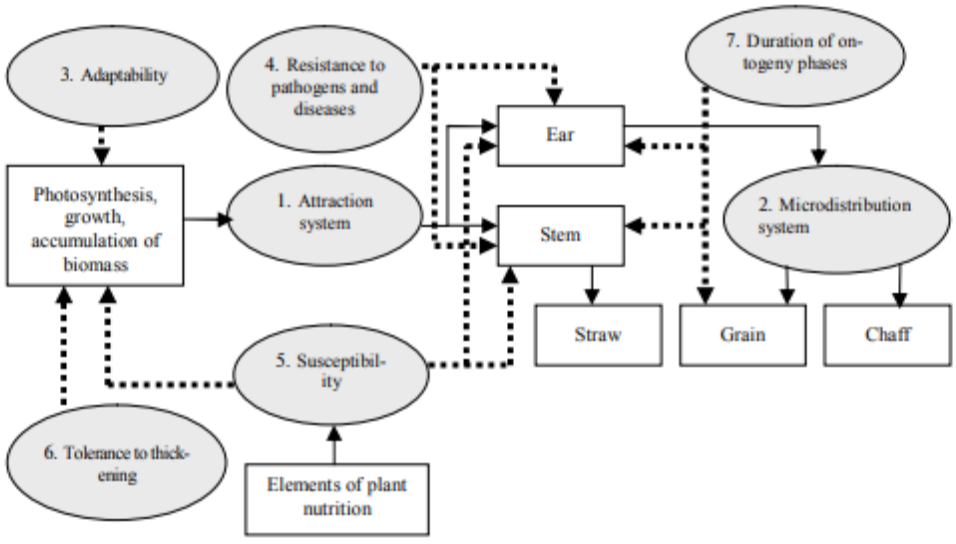


Figure 2. The scheme of "genotype-environment" model for cereal crops (Source: Mikhailenko & Dragavtsev, 2013)

5 Modelling Agricultural Marketing

The role of mathematical modelling in agricultural marketing has proven to be essential and remarkable for the development in the agricultural industry. This is particularly in the area of determining optimal pricing strategies for agricultural products which involves analysing market demand, supply, production costs, and competitor pricing to set prices that maximize profitability while remaining competitive and at the same time for casting future prices for policy implication. This

serves as guide in the allocation of scarce resources among competing ends for optimum output and efficient marketing. Efficient marketing system which increases producers share in consumer price improves rural incomes and revenue generation for both producers and marketers and importantly contribute to sustainable agricultural development (Enibe et al.; 2008; Kumar, 2014; Ruttoh et al 2018). Thus, models help to drive policy actions by studying existing systems and evaluating alternatives situations for selecting acceptable policy strategies. This has been made possible through various application of models.

Abdullahi et al (2021), used a dynamic model for Nigeria's rice market for future policy employed four structural equations, used autoregressive distributed lag (ARDL) cointegration approach. The estimates which showed that paddy area harvested and yield was price inelastic and also area harvested responded favourably to technological innovations. The econometric estimate technique was essential for providing the elasticities, which are very useful to policymakers and analysts since they are utilised to predict the potential effects of policy changes in the agri-food sector. Agricultural commodity market models are useful for analysing structural links, analysing policy impacts, and anticipating future market prices and quantities (Shamsudin, 2008). Relationships between major market factors can be quantified by describing a set of equations using this market modelling methodology (Christ, 1994; Hallam, 1990; Labys & Pollak, 1984). Econometric modelling is one method of measuring these linkages and has so found widespread application in agriculture.

One advantage is that the methodology is less influenced by assumptions about model parameters and behavioural effects; rather, the effects are calculated based on observable market agent behaviour. Additionally, the estimated model may be statistically checked and validated to confirm its adequacy, which is a crucial feature for policy assessments. The agri-food sector's econometric modelling technique might be of two types (Egwuma et al., 2016; Sembiring & Sembiring, 2016; Yazdanshenas et al., 2011). This includes every demand Components of supply, price, and stock component of the market or a single/multiple components of a market (Chandio et al., 2018; Paul et al., 2018; Yusuf et al., 2020).

6 Risk Modelling in Agriculture

Agricultural risk modelling plays a crucial role in understanding and managing the uncertainties and vulnerabilities associated with agricultural production. This type of modelling involves assessing various factors that can impact agricultural outcomes, such as weather patterns, market conditions, pests, diseases, and other external factors. By quantifying and analysing these risks, farmers, policymakers, and stakeholders can make more informed decisions to mitigate potential losses and enhance overall agricultural resilience (Zilberman & Hochman, 2019).

6.1 Benefits of Agricultural Risk Modelling:

a) Risk Identification and Assessment: Agricultural risk modelling helps identify potential risks and vulnerabilities that could affect crop yields, livestock production, and overall farm profitability. By understanding these risks, farmers can take proactive measures to minimize their impact (Antle *et al.*, 2018).
b) Informed Decision-Making: Farmers can make more informed decisions by using risk models to assess the potential outcomes of different scenarios. For instance, they can evaluate the impact of planting different crops, using specific planting techniques, or adopting different pest management strategies.
c) Resource Allocation: Risk modelling aids in the efficient allocation of resources such as labour, fertilizers, and irrigation. Farmers can adjust their resource allocation strategies based on the likelihood and severity of different risks, optimizing their inputs to achieve better outcomes.

d) Financial Planning: Agricultural risk models allow farmers to plan for potential losses and uncertainties in advance. This enables better financial planning, including budgeting for crop insurance, emergency funds, or diversification strategies.
e) Insurance and Risk Management: Agricultural risk modelling is essential for insurance companies that offer crop insurance products. By accurately assessing risk, insurers can provide fair premiums that reflect the actual exposure to potential losses for farmers (Miranda & Glauber, 1997).
f) Policy Development: Policymakers can use agricultural risk models to design policies that promote sustainable agriculture and support farmers in managing risks. These policies can include subsidies, incentives for adopting climate-resilient practices, and disaster response plans (Nelson et al 2010).
g) Climate Adaptation: Climate change poses significant risks to agriculture, including shifts in weather patterns, increased frequency of extreme events, and changes in pest and disease dynamics. Agricultural risk models can help farmers adapt to these changes by identifying strategies to mitigate climate-related risks.
h) Supply Chain Management: Agricultural risk models can benefit stakeholders along the entire supply chain, including processors, distributors, and retailers. By anticipating potential disruptions in supply due to factors like weather or disease outbreaks, these stakeholders can better manage inventory and pricing.
i) Research and Development: Researchers can use agricultural risk models to study the potential impacts of new technologies, crop varieties, and farming practices. This aids in the development of innovative solutions that enhance agricultural productivity and resilience (Diffenbaugh & Giorgi, 2012).

7 Bibliometric Analysis on Modelling in Agriculture

In order to determine the level of research development on the area of the contribution of mathematical modelling in agriculture to the development of sub-Saharan Africa, a bibliometric data was extracted from a world reputable articles data base known as Web of Science. The data related to subject matter for a time frame of 2012 to 19/08/2023 was extracted andanalysed using a bibliometric web-based software called biblioshiny. Some basic information about the data downloaded are as follows: There were 6326 publications available from 266 sources, published by 15527 authors, the annual growth rate in the field was 3.48%, average citation per document was 17.52 and total references of 217306.

i) Articles Production Sources

Article production sources are the organization responsible for scrutinizing manuscripts and authors as well as coordinating and publishing articles. Table 1a presents the ranking of the top 10 publication sources. Agriculture system having the total of 397 articles is rank first, next to it was Computers and Electronics in Agriculture with 397 rank second and Agricultural Water Management with 304 documents is ranked third while others followed as shown in the tablle1. The pictorial presentation of the results is shown in figure 1. Furthermore, Table 1b presents the 10 most productive authors. Which revealed that Wang J who had a total of 46 articles most productive, while Liu Y and Zang J who had total articles of 34 each are the least productive among the top ten authors.

Table. 1a. Article production sources ranking

SOURCES	ARTICLES	RANK

AGRICULTURAL SYSTEMS	397	1
COMPUTERS AND ELECTRONICS IN AGRICULTURE	327	2
AGRICULTURAL WATER MANAGEMENT	304	3
AGRONOMY-BASEL	301	4
AGRICULTURE-BASEL	300	5
AGRICULTURE ECOSYSTEMS \& ENVIRONMENT	269	6
PRECISION AGRICULTURE	136	7
AGRICULTURAL AND FOREST METEOROLOGY	132	8
FIELD CROPS RESEARCH	130	9
GEODERMA	130	10

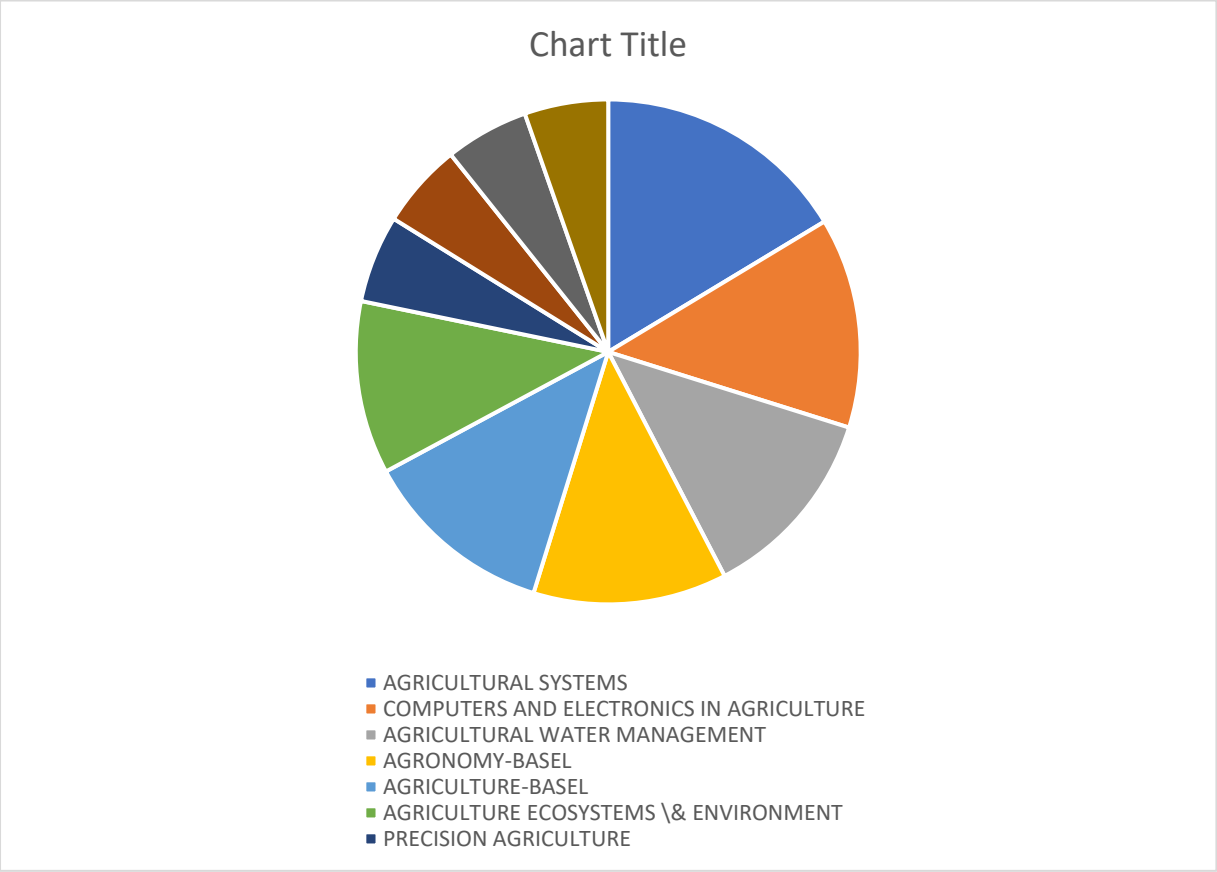


Figure 1. Pie chart of top 10 articles sources

Table 1b: The 10 most productive authors

Authors	Wang J	Li Y	Wang Y	Wang X	Thierfelder C	Zhang Y	Li S	LI Z	LIU Y	ZHANG J
Articles	46	42	42	41	38	37	35	35	34	34
Rank	1	2	3	4	5	6	7	8	9	10

ii) Words Frequency

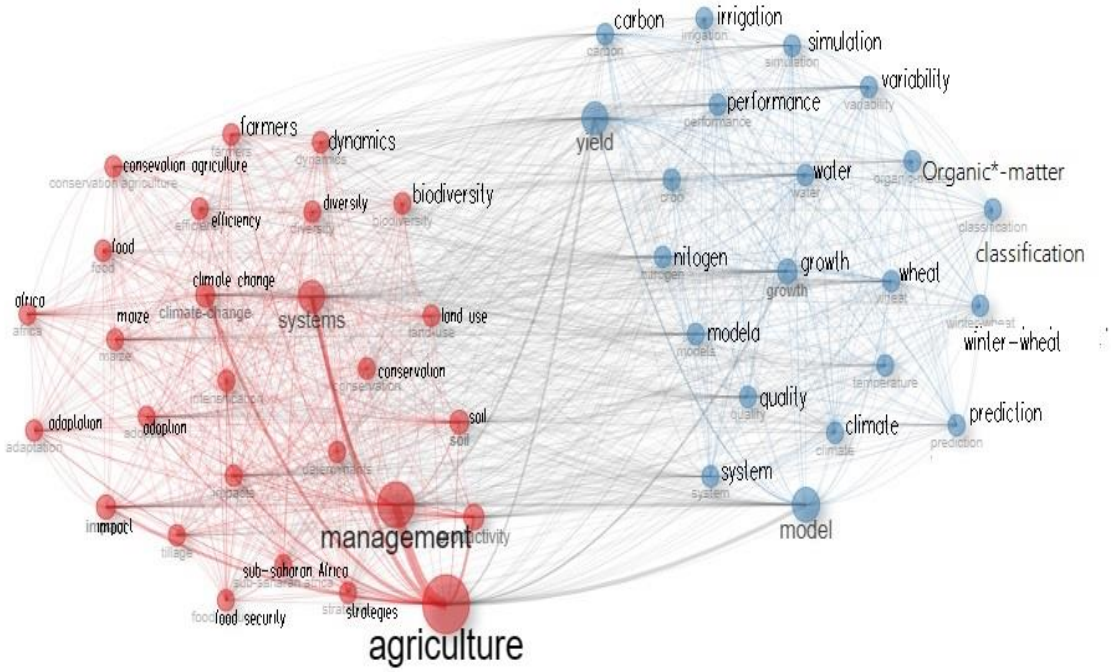
Frequent words in journal publications refer to words that appear often and repeatedly in academic articles, particularly those within a specific field of study. These words are crucial for conveying the core ideas, concepts, methodologies, and findings of the research. They help establish common language and terminology within a particular discipline, making it easier for researchers and scholars

to communicate effectively. Frequent words can include both general academic terms and specialized terminology unique to the field of study (PubMed).

Table 2 present the most frequent ten words used in the field of study on the basis of their hierarchies. Agriculture which appeared 1155 was the most frequent words used, followed by management which was used 803 times and model which appeared 674 is next, while others followed as shown in table 2. The network of the usage of both more frequent and less frequent is as shown in Figure 2.

Table 2. The most frequent 10 words

Words	agriculture	management	model	systems	yield	growth	impact	productivity	soil	climate-change
Occurrences	1155	803	674	513	511	409	384	368	361	358
Rank	1	2	3	4	5	6	7	8	9	10



iii) Country's Productivity

Journal publications of a nation refer to the academic and research articles published in various scientific, technical, medical, social science, and other scholarly journals by researchers, scholars, and academics from that nation. These publications contribute to the dissemination of knowledge, advancements in various fields, and the overall scientific progress of the country (PubMed).

Table 3: Presents the 10 most productive countries in hierarchical order. USA who was having 4272 articles is ranked one, China having 3450 is second while Brazil having 1407 is rank third, and others as presented in the table. Furthermore, Figure 3 presents the information in bar-chart, and the details of various publication by different African Countries are as shown in Table 4.

Table 3. The most relevant 10 productive countries

Region	USA	China	Brazil	Germany	France	Australia	Italy	Uk	Spain	Netherlands
Freq	4272	3450	1407	1306	1278	1061	1009	828	799	781
Rank	1	2	3	4	5	6	7	8	9	10

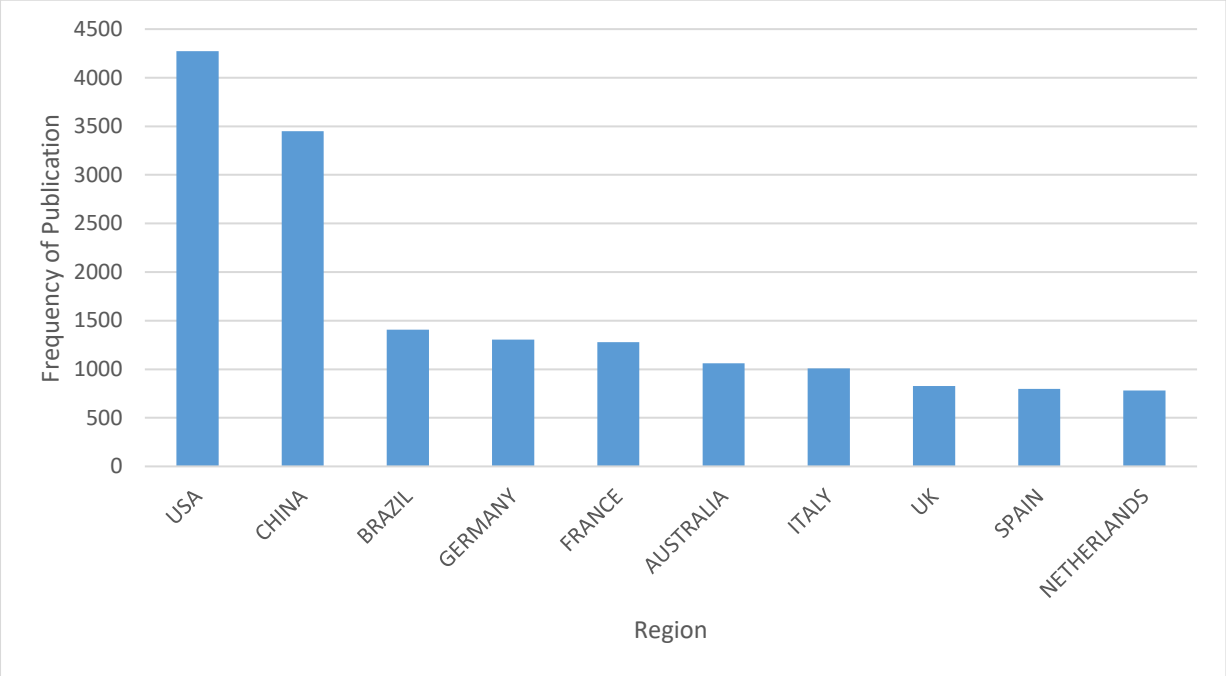


Figure 3. The bar chart of the most relevant 10 productive countries

Table 4. Productivity Ranking of African Country

Country	Articles	Country	Articles	Country	Articles
SOUTH AFRICA	613	MALAWI	86	MOZAMBIQUE	22
KENYA	448	MOROCCO	84	ALGERIA	21
ZIMBABWE	265	UGANDA	83	NIGER	15
ETHIOPIA	237	BENIN	72	SUDAN	14
GHANA	151	ZAMBIA	69	BURUNDI	8
NIGERIA	125	SENEGAL	64	TOGO	7
BURKINA FASO	97	MALI	51	NAMIBIA	4
TANZANIA	91	CAMEROON	47	GABON	2
EGYPT	87	RWANDA	30	GUINEA	2
TUNISIA	87	MADAGASCAR	28	MAURITIUS	2

iv) Global Citation

"Global citation" typically refers to the frequency with which a particular document, publication, or work is cited across a wide range of sources and geographic regions. It indicates the impact and influence of that work on various fields, disciplines, and cultures around the world. Documents that are globally cited often have a significant and lasting impact on academia, policy-making, culture, and society. One notable example of a globally cited document is the scientific paper titled "The Strength of Weak Ties" by sociologist Mark Granovetter, published in the American Journal of Sociology in 1973. Figure 4 presents the 10 most cited global documents on the area of study with the range of 334 and 610 citations.

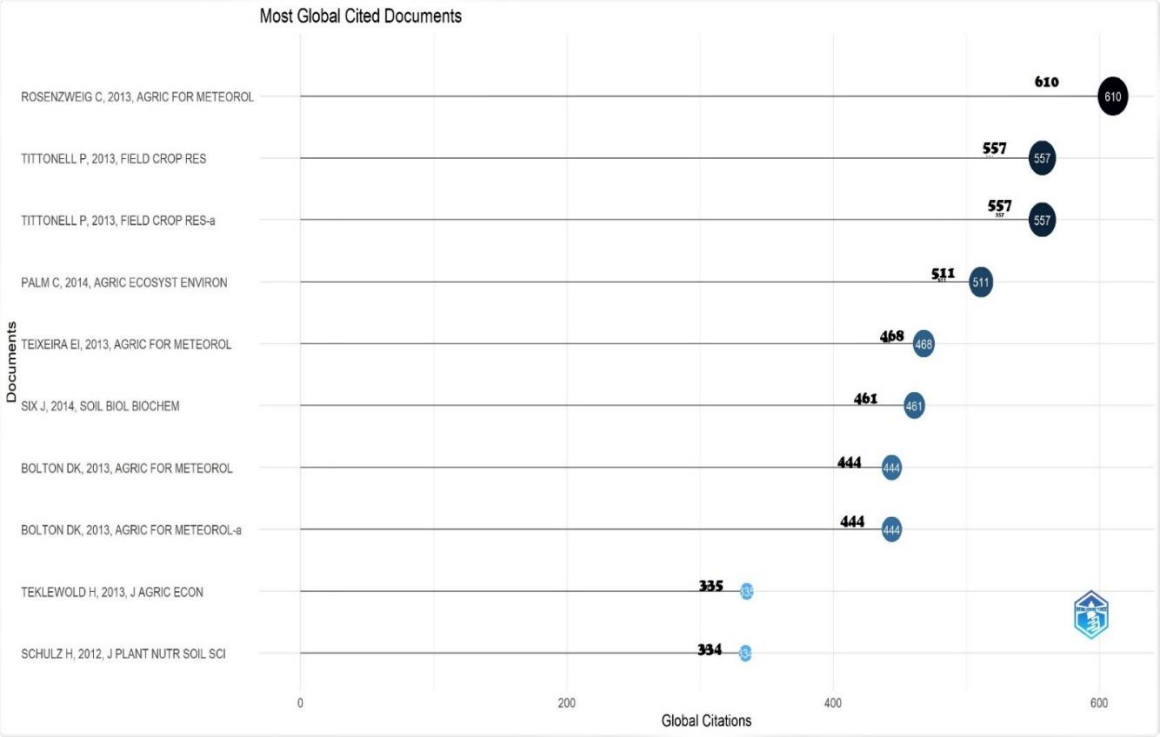


Figure 4. Most globally cited documents

7.1 International collaboration

International collaboration in journal publication and references refers to the practice of researchers and scholars from different countries and institutions working together on research projects, studies, and publications. This collaboration can take various forms, including co-authorship on research papers, sharing of data and resources, joint funding, and collaborative discussions.

The top 14 most collaborated countries are as shown in table 5. USA-China having 186 frequencies of collaboration are the most collaborated nation, followed by USA-United Kingdom having frequency of 67, while China-Australia with frequency of 46 are the least among the top 10. In addition to this figure fives the pictorial representation international collaboration across the globe.

Table 5. International collaboration ranking

From	To	Frequency	Rank
USA	CHINA	186	1
USA	UNITED KINGDOM	67	2

USA	GERMANY	65	3
USA	AUSTRALIA	63	4
USA	FRANCE	56	5
USA	ITALY	55	6
USA	CANADA	54	7
USA	BRAZIL	52	8
GERMANY	NETHERLANDS	51	9
USA	NETHERLANDS	51	10
NETHERLANDS	KENYA	48	11
CHINA	GERMANY	47	12
FRANCE	NETHERLANDS	47	13
CHINA	AUSTRALIA	46	14

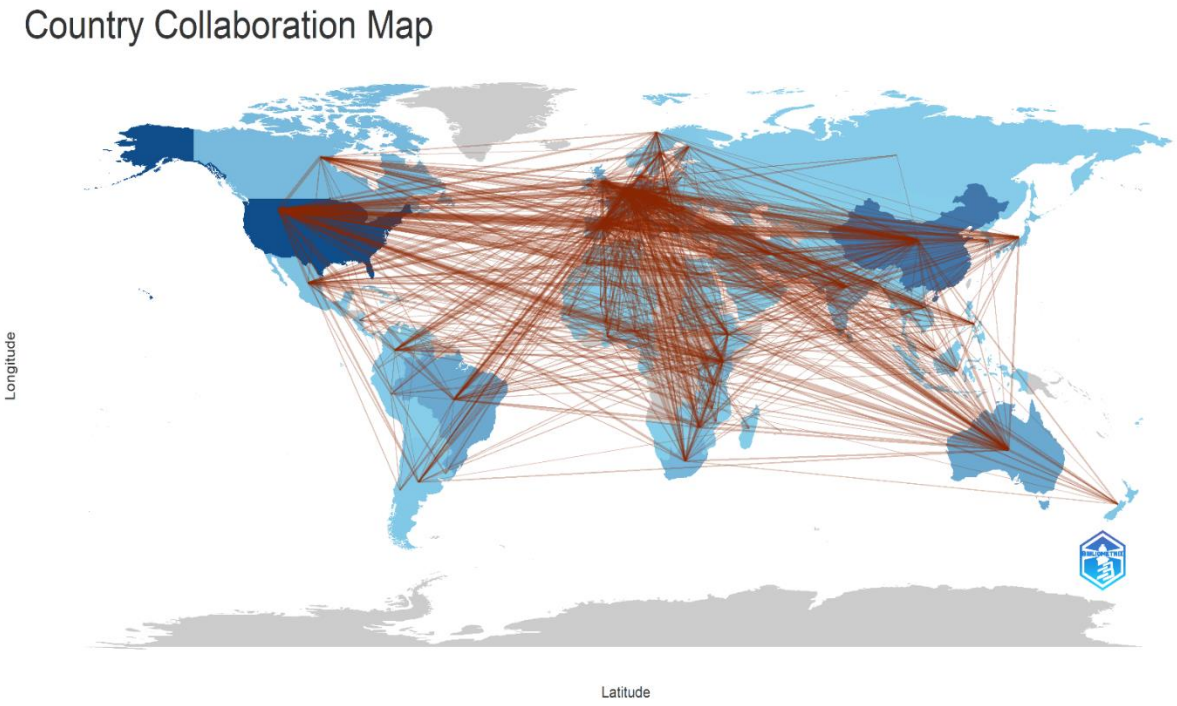


Figure 6. International collaboration network

8 Research Gap

Considering the annual growth of the field 3.48% is a clear indication that there are a lot to be done to enhance it research growth and innovation. It was observed that some areas of the research are less patronized as illustrated in Figure 5. Some these areas with less networks include: climate, prediction, classification, simulation and variability. In view of this recommend the following topics for further research.

i. Epidemiological Models for Crop Diseases
ii. Precision Agriculture Simulation
iii. Carbon Sequestration Prediction
iv. Crop Yield Prediction
v. Analysis of the impact of climatic change on crop yields.

9 Conclusion

This study used systematic and bibliometric literature reviews to examine the effects of mathematical modeling in agriculture. It had been proven that crop breeding, risk management, marketing, and planning are very important aspects of improving food security and development in Africa. There were 6326 articles published in the field between 2012 and 19th August, 2023, available from 266 article sources, published by 15527 authors, with an average citation per document of 17.52 and a total of 217306 references, according to bibliometric data extracted from Web of Science and analyzed with web-based software called biblioshiny. The annual growth rate in the field was 3.48%.

Additionally, the study found that agricultural systems with 397 articles was the most productive article source in the field while Wang J who had 46 articles was the most globally productive author. The study recommended five research areas which are Epidemiological Models for Crop Diseases, Precision Agriculture Simulation Carbon Sequestration Prediction, Crop Yield Prediction, and Analysis of the impact of climatic change on crop yields.

Acknowledgement

We want to appreciate Partnership for skill in Applied Sciences, Engineering and Technology (PASET)/Regional Scholarship and Innovation Fund (RSIF) for sponsoring this research work as well as University d'Abomey-Calavi, Benin Republic; Universiti Putra, Malaysia, and ModibboAdama University, Yola, Nigeria for providing enable environment to carry out this research.

References

[1] Abdulsalam, R. Y., Shamsudin, M. N., Mohamed, Z., Latif, I. S., Wong, K. K. S., & Buda, M. (2021). An econometric Model for Nigeria's Rice Market. Journal of Social Science and Humanities, 29(2), 1171-1191.
[2] Antle, J. M., Stoorvogel, J. J., & Valdivia, R. O. (2018). Crop modeling for integrated assessment of risk to food production from climate change. Environmental Modelling & Assessment, 23(6), 601-615.
[3] Are, A. K., Srivastava, R. K., Mahalingam, G., Gorthy, S., Gaddameedi, A., Kunapareddy, A., Kotla, A., & Jaganathan, J. (2019). Application of plant breeding and genomics for improved sorghum and pearl millet grain nutritional quality. In Sorghum and Millets (pp. 51-68). AACC International Press.
[4] Banks, J., Carson, J. S., Nelson, B. L., & Nicol, D. M. (2005). Discrete-Event System Simulation. Prentice Hall.
[5] Chandio, A. A., Jiang, Y., Joyo, M. A., & Pickson, R. B. (2018). Research on factors influencing grain production in Pakistan: An ARDL approach. European Online Journal of Natural and Social Sciences, 7(3), 538-553.
[6] Chibis, V., & Kutyshev, I. (2019). Optimization of acreages as an element of sustainable development of natural landscapes: IOP Conference series Earth Environmental Science, 395(012005), 1-6.
[7] Christ, C. F. (1994). The Cowles commission's contributions to econometrics at Chicago, 1939-1955. Journal of Economic Literature, 32(1), 30-59.
[8] Diffenbaugh, N. S., & Giorgi, F. (2012). Climate change hotspots in the CMIP5 global climate model ensemble. Climatic Change, 114(4), 813-822.
[9] Egwuma, H., Shamsudin, M. N., Mohamed, Z., Kamarulzaman, N. H., & Wong, K. K. S. (2016). A model for the palm oil market in Nigeria: An econometrics approach. International Journal of Food and Agricultural Economics, 4(2), 69-85. http://dx.doi.org/10.22004/ag.econ.234911
[10] Enibe, D. O., Chidebelu, S. A. N. D., Onwubuya, E. A., Agbo, C., & Mbah, A. A. (2008). Policy issues in the structure, conduct, and performance of Banana Market in Anambra State, Nigeria. Journal of Agricultural Extension, 12(2), 32-40.
[11] Evers, J. B., Van Der Werf, W., Stomph, T. J., Bastiaans, L., & Anten, N. P. (2019). Understanding and optimizing species mixtures using functional–structural plant modeling. Journal of Experimental Botany, 70(9), 2381-2388.
[12] Fan, S., & Pandya-Lorch, R. (2012). Reshaping agriculture for nutrition and health. Food and Agriculture Organization of the United Nations (FAO).
[13] Gershenfeld, N. A. (1999). The Nature of Mathematical Modeling. Cambridge University Press.
[14] Granovetter, M. S. (1973). The Strength of Weak Ties. American Journal of Sociology, 78(6), 1360-1380.
[15] Gilbert, N., & Troitzsch, K. G. (2005). Simulation for the Social Scientist. Open University Press.
[16] Hallam, D. (1990). Econometric Modelling of Agricultural Commodity Markets. Routledge.

[17] Hestenes, D. (1987). Toward a Modeling Theory of Physics Instruction. American Journal of Physics, 55(5), 440-454.
[18] Jayne, T. S., Chamberlin, J., & Headey, D. D. (2014). Land pressures, the evolution of farming systems, and development strategies in Africa: A synthesis. Food Policy, 48, 1-17.
[19] Klimek-Kopyra, A., Zaja, T., & Re, K. (2013). A mathematical model for the evaluation of cooperation and competition effects in intercrops. European Journal of Agronomy, 51, 9-17.
[20] Kumar, S. (2014). Marketing efficiency analysis: A case of broiler marketing in Anand district of Gujarat. International Journal of Comm. & Bus. Manage, 7(1), 186-190.
[21] Mikhailenko, I. M., & Dragavtsev, V. A. (2013). Mathematical modelling in plant breeding. I. Theoretical basis of genotypes identification on their phenotypes during selection in segregating generations. *Сельскохозяйственная биология, (1 (eng)), 26-34.
[22] Miranda, M. J., & Glauber, J. W. (1997). Systemic risk, reinsurance, and the failure of crop insurance markets. American Journal of Agricultural Economics, 79(1), 206-215.
[23] Labys, W. C., & Pollak P. K. (1984). Commodity models for forecasting and policy analysis. Nichols Publishing Co.
[24] Nicolae-Valentin V., Sorin-S¸tefan B., Petru C., Iuliana G., Dan C., Nicoleta U., Lorena-Diana P., Lucian P., Gheorghe M., and Gabriel-Ciprian T. (2022). Contributions to the Mathematical Modeling of the Threshing and Separation Process in an Axial Flow Combine. Retrieved on 17th August, 2023 from https://doi.org/10.3390/agriculture12101520.
[25] Nelson, G. C., Rosegrant, M. W., Palazzo, A., Gray, I., Ingersoll, C., Robertson, R., ... & Tokgoz, S. (2010). Food security, farming, and climate change to 2050: Scenarios, results, policy options. International Food Policy Research Institute (IFPRI).
[26] Nelson, G., Rosegrant, M. W., Palazzo, A., Gray, I., Ingersoll, C., Robertson, R., ... & Sulser, T. B. (2010). Food security, farming, and climate change to 2050: Scenarios, results, policy options. International Food Policy Research Institute (IFPRI).
[27] Paul, M., Molua, E. L., Nzie, J. R. M., & Fuh, G. L. (2020). Production and supply of tomato in Cameroon: Examination of the comparative effect of price and non-price factors. Scientific African, 10(e00574), 1-13. https://doi.org/10.1016/j.sciaf.2020.e00574.
[28] Palm, C. A., Blanco-Canqui, H., & DeClerck, F. (2012). Conservation agriculture and ecosystem services: An overview. Agriculture, Ecosystems & Environment, 187, 87-105.
[29] PubMed (for biomedical and life sciences literature): https://pubmed.ncbi.nlm.nih.gov/
[30] Ruttoh, J. K., Bett, E. K., and Nyairo, N. (2018). Empirical analysis of structure and conduct of tomato marketing in Loitoktok, Kajiado County, Kenya. International Journal of Agricultural Extension and Rural Development, 6(4), 628-638.
[31] Sembiring, S. A., & Hutauruk, J. (2018). Econometric model of rice policy based on presidential instruction. In IOP Conference Series: Materials Science and Engineering, 300. IOP Publishing Ltd. https://iopscience.iop.org/article/10.1088/1757-899X/300/1/012028/meta.
[32] Shamsudin, M. N. (2008). Econometric modeling for agricultural policy analysis and forecasting: Between theory and reality. Journal of Quantitative Methods, 4(2), 1-18. http://myagric.upm.edu.my/id/eprint/6812.
[33] Spielman, D. J., & Pandya-Lorch, R. (2009). Millions fed: Proven successes in agricultural development. International Food Policy Research Institute (IFPRI).
[34] Taratula R., Kovalyshyn O., Ryzhok Z., Malakhova S., (2019). Application of Mathematical Modeling for Optimization of Land-Use Management. Real Estate Management and Valuation, 27(3), 59-68.
[35] Tilman, D., Lehman, C. L., & Thomson, K. T. (1997). Plant diversity and ecosystem productivity: theoretical considerations. Proceedings of the National Academy of Sciences, 94(5), 1857-1861.
[36] Thornton, P. K., & Herrero, M. (2015). Climate change adaptation in mixed crop–livestock systems in developing countries. Global Food Security, 7, 1-10.
[37] Thornton, P. K., Jones, P. G., Owiyo, T., Kruska, R. L., Herrero, M., & Orindi, V. (2006). Mapping Climate Vulnerability and Poverty in Africa. International Livestock Research Institute (ILRI).
[38] Weih, M., Adam, E., Vico, G., & Rubiales, D. (2022). Application of crop growth models to assist breeding for intercropping: Opportunities and challenges. Frontiers in Plant Science, 13, 720486.
[39] Winston, W. L. (2003). Operations Research: Applications and Algorithms. Cengage Learning.
[40] Yazdanshenas, L., Moghadasi, R., & Yazdani, S. (2011). A model for the wheat market in Iran. International Journal of Agricultural Science and Research, 2(2), 49-55.
[41] Yusuf, W. A., Yusuf, S. A., Adesope, A. A. A., & Adebayo, O. Z. (2020). Determinants of rice import demand in Nigeria. Journal of Applied Sciences and Environmental Management, 24(5), 923-931. https://doi.org/10.4314/jasem.v24i5.30.
[42] Zilberman, D., & Hochman, G. (2019). Agricultural risk and uncertainty: Introduction. Applied Economic Perspectives and Policy, 41(4), 581-585.

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp. 404–410, November 13-16, 2023

Impacts of Joule Heating and Suction on Rotating Concentric Cylinders

Badejo O. M[1], Usman M. A[2]
{badeomi@yahoo.com[1], usmanma@yahoo.com2}

Department of Mathematical Sciences, Olusegun Agagu University of Science and Technology, Okitipupa[1],
Department of Mathematical Sciences, Olabisi Onabanjo University, Ago Iwoye, Ogun State, Nigeria[2].

Abstract
Joule heating over rotating concentric cylinders with suction parameter is very important in a wide number of applications. Applications of concentric cylinders were produced for the smooth usage but the contrary is derived once they are used on uneven road. The impact of joule heating along with suction parameter has been the major problems in rotating concentric cylinders. Therefore this study examined the impact of joule heating along with suction parameterin rotating concentric cylinderingwith Hartmann number (Ha), Pressure gradients (G) and suction parameters (V_0) .The governing equations of Joule heating on rotating concentric cylinders which include, continuity, momentum and energy were modelled and adopted with Ha, Gand V_0. The G and V_0were at interval of 0.50 from 0.00 to 2.00 andHa were considered at interval of 5.00 from 0.00 to 20.00. The semi-implicit finite difference scheme with MAPLE 18 software were used for the interpretation.The higher the G the more the fluid flow within the rotating concentric cylinder, suggesting a high fluid viscosity. The temperature of Ha on V_0reduces as the G and V_0 increases suggesting thatsuction with direct joule heating can damage rotating concentric cylinder especially with wrong viscosity. In conclusion, as the G increases, the temperature also increases signifying the usage of rotating concentric cylinder on uneven roads and overloading of moving vehicles and machines; while as Ha increases the temperature decreases implying usage and applications of bearings on smooth road.

Keywords: Concentric cylinder, Joule heating, Magnetic force, Pressure gradient and Suction parameter

1 Introduction

The problem relating to rotating concentric cylinders with fluid has attracted the attention of many researchers for its applications in industry such as manufacturing, crystal growth processes, rotating viscometer, rotating machines, productions and usage of rotating automobile components. The analysis of the hydro-magnetic Nanofluid boundary layer flow over a rotating disk in a porous medium with a constant velocity in the presence of hall current and thermal radiation, *velocity profiles and temperature profiles of the boundary layer are plotted and investigated in details*.Abdel-Waheda*et al.*, *(2016).* Edrogan (1997) has analyzed the unsteady fluid flow by non-coaxial rotations of a disk and a fluid at infinity. Darbhashayanam*et al*., (2019), analyzes the Joule heating effect on the viscous fluid flow over a porous sheet stretching exponentially by employing convective boundary condition and it was observed from the investigation that the rate of heat transfer reduces with Joule heating and enhances with increasing Biot number.Darbhasayanam*et al*., (2017)studied the laminar mixed convective flow of an incompressible chemically reacting nanofluid in an annulus between two concentric cylinders is investigated by considering the Joule heating effect. The maximum values of Bejan number *Be* are observed at the center of the annulus due to more contribution of heat transfer irreversibility on entropy generation and minimum value is near the cylinders, due to more contribution of fluid friction irreversibility on entropy generation with an increase in parameters. Dulal *et al*. (2011) studied the interaction of convection and thermal radiation on an unsteadyhydromagnetic heat and mass transfer for a viscous fluid past a semi-infinite verticalmoving plate embedded in a porous media in the presence of heat absorption and firstorderchemical reaction of the species. The results are presented graphically and in tabulated forms to study theeffects of various physical parameters.Aminfar*et al.* (2014) who experimentally studied the effects of using magnetic nanofluid and applying an external magnetic field on the critical heat flux of subcooled flow boiling in vertica annulus external factors were the major causes. Sometimes ago attention has been paid by

Ashorynejad*et al.* (2013) to the effect of magnetic field convection on natural convection heat transfer in a horizontal cylindrical annulus enclosed filled with nanofluid using the lattice Boltzmann method. The computed results are in good agreement withthe earlier published results. Sharma *et al*. (2017) investigated effects of viscous dissipation and Joule heating on unsteadyMHD flow over a stretching sheet saturated in porous medium are analyzed. The effect ofthese parameters on fluid velocity, fluid temperature, skin-friction coefficient and Nusseltnumber are presented through figures and discussed numerically.

Ali (2014) estimated concentric annular flows of Newtonian fluids in vertical and horizontal arrangements based on CFD simulations, but did not quantify the effects of internal shaft rotation. A Mathematical model is presented for the steady, axisymmetric, magnetohydrodynamic (MHD) flow of a viscous, Newtonian, incompressible, electrically-conducting liquid in a highly porous regime intercalated between two concentric rotating cylinders in the presence of a radial magnetic field. The porous medium is modeled using a Darcy-Forchheimer drag force approach to simulate the impedance effects of the porous medium fibers at both low velocities and also at higher velocities, was studied by Beg *et al.* (2012).

2 Materials and Methods

This section considered the impact of suction parameter on momentum equation of rotating concentric cylinder and direct joule heating on the energy equation with reactive term flow in between concentric cylinders rotating simultaneously, unsteady state, laminar, and fully developed flow of fluids for which the density and the viscosity are constant. The governing partial differential equations presented below will be solve and interpreted with semi-implicit finite difference scheme code with MAPLE 18 software.

Continuity equation:

$$\frac{\partial}{\partial r}(ur) = 0 \tag{1}$$

Momentum Equation with Suction Parameter:

$$v_0 + \frac{\partial u}{\partial t} = \nu\left[\frac{\partial^2 u}{\partial r^2} + \frac{\partial}{\partial r}\left(\frac{u}{r}\right)\right] - \frac{1}{\rho}\frac{\partial P}{\partial r} - \frac{\sigma u {B_0}^2}{\rho} - \frac{\nu u}{K} - \frac{\Gamma u^2}{K} \tag{2}$$

Energy Equation with Joule heating parameter:

$$\frac{\partial T}{\partial t} = \frac{u}{r}\frac{\partial}{\partial r}\left(r\frac{\partial T}{\partial r}\right)K + \mu\left(\frac{\partial u}{\partial r} - \frac{u}{r}\right)^2 + \frac{\sigma u {B_0}^2}{\rho} + QC_0A \tag{3}$$

Equations (1), (2) and (3) are Continuity, Momentum and Energy equations respectively. Therefore, u is the velocity, V is the fluid kinematic viscosity, r is the radius, $\frac{u}{r}$ is the rotating, $\frac{\sigma u {B_0}^2}{\rho}$is the joule heating parameter andv_0 is the Suction parameter in the governing partial differential equations.

The Boundary Conditions are:

$$r = r_1, \quad u = r_1\omega\,, \qquad r = r_2, \quad u = r_2\omega \tag{4}$$

Dimensionless Form

Dimensionless Parameters:

$$U = \frac{u}{\omega b}, R = \frac{r}{b}, T = \frac{t}{t_0}, \theta = \frac{T}{T_0}, V_0 = \frac{\omega}{b}, V = \frac{\mu}{\rho} \tag{5}$$

These can also be written in these forms

$$u = U\omega b \qquad r = Rb \qquad t = Tt_0 \qquad T = \theta T_0 \quad \omega = \quad V_0 b \quad \mu = V\rho \tag{6}$$

Substituting equations (6) into (2) yields

$$V_0 + \frac{\partial U}{\partial T} = \frac{\partial^2 U}{\partial R^2} - \frac{1}{Re}\frac{U}{R} - \left[\frac{Ha^2}{Re} + \frac{1}{Da}\right]U - \frac{FsRe}{Da}U^2 + \frac{G}{Re} \tag{7}$$

Substituting equations (6) into (3) also yields

$$\frac{\partial\theta}{\partial T} = \frac{V_0}{Pr}\left(\frac{U}{R}\right)\left[R\frac{\partial^2\theta}{\partial R^2} + \frac{\partial\theta}{\partial R}\right] + Ec\left(\frac{\partial U}{\partial R}\right)^2 - 2Ec\frac{U}{R}\left(\frac{\partial U}{\partial R}\right) + Ec\left(\frac{U}{R}\right)^2 + \gamma e^{\left(\frac{1}{\varepsilon}\right)} + HaU^2 \quad (8)$$

Therefore:

$$Re = \frac{\omega_2 b^2}{\nu}\nu \;;\quad Fs = \frac{\Gamma}{b} \;;\quad Da = \frac{r}{b^2} \;;\quad Ha^2 = \frac{\sigma B_0^2 b^2}{\mu} \;;\; \gamma = \frac{QC_0 t_0}{T_0 b^2}$$

$$Pr = \frac{b^2}{Kt_0} \;;\quad Ec = \frac{\mu\omega_2^2 t_0}{T_0 b^2} \;;\quad V_0 = \frac{\omega_2}{b} \;;\quad G = -\frac{\partial P}{\partial R};\quad \varepsilon = \frac{RT_0}{E}$$

The Boundary Conditions also give

$$R = \frac{r_1}{b} \qquad U = \frac{r_1\omega}{\omega_2 b} \quad (9)$$

Definition of Symbols

$\boldsymbol{B_0}$: Magnetic Field
$\boldsymbol{\sigma}$: Fluid Electrical Conductivity
$\boldsymbol{\nu}$: Fluid Kinematic Viscosity
$\boldsymbol{k}$: Porus Medium Permeability
Γ: Forchheimer Geometric Inertial drag parameter
$\boldsymbol{V_0}$: Suction Parameter
$\boldsymbol{\rho}$: Fluid Density
$\boldsymbol{G}$: Pressure Gradient
Q: Heat Reaction
A: Rate Constant
E: Activation Energy
R: Universal Gas Constant
$\boldsymbol{C_0}$:Initial Concentrating of the Reacting Species
$\boldsymbol{\gamma}$:Frank-Kamenetskii Parameter
Re: Reynolds Number
Ha: Hartmann Number
Da: Darcy Number
Pr: Prandtl Number
Ec: Eckert Numbe
r

3 Results and Discussion

The results of the reactive flow of rotating concentric cylinder (annulus) system with joule heating are presented below.

Fig.1, Fig. 2, Fig. 3 and Fig. 4 show the temperature profiles of pressure gradient (G) on hartmann number (Ha). It was observed that as the hartmann value increases the temperature increases though Fig.1 did not follow the trend perfectly due to the level of pressure gradient (G=0) it was subjected to. It was also observed that as the pressure gradient increases on hartmann number (Ha) the level of temperature of all values of hartmann number are far from one another, which indicates free flow with low temperature. It also revealed that Fig.1: (0.8 degC), Fig. 2: (0.87 degC), Fig. 3: (0.91 degC) and Fig. 4: (0.97) maximum temperature are higher than Fig. 1B: (0.35 degC) and Fig. 2B: (0.33 degC) maximum temperature due to addition of joule heating in the system. Therefore, as the pressure gradient increases on hartmann number the temperature also increases.

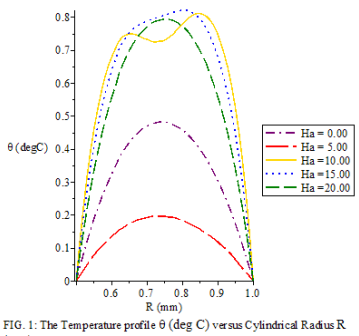


FIG. 1: The Temperature profile θ (deg C) versus Cylindrical Radius R (mm) for values of Hartmann number (Ha) with reactive term and joule heating , when Ec=1, Re=1, Da=1, G=0 and Pr=1

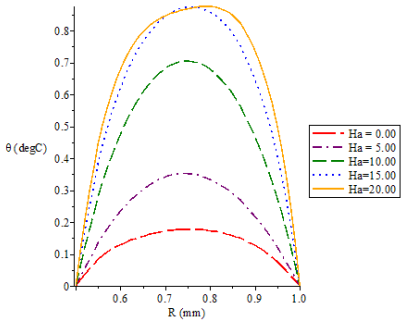


FIG. 2: The Temperature profile θ (deg C) versus Cylindrical Radius R (mm) for values of Hartmann number (Ha) with reactive term and joule heating , when Ec=1, Re=1, Da=1, G=10 and Pr=1

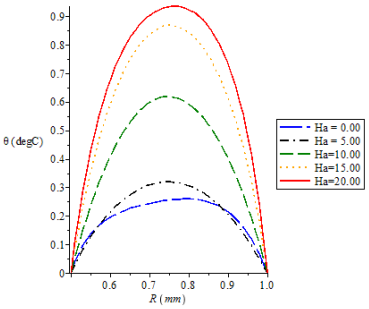


FIG. 3: The Temperature profile θ (deg C) versus Cylindrical Radius R (mm) for values of Hartmann number (Ha) with reactive term and joule heating , when Ec=1, Re=1, Da=1, G=20 and Pr=1

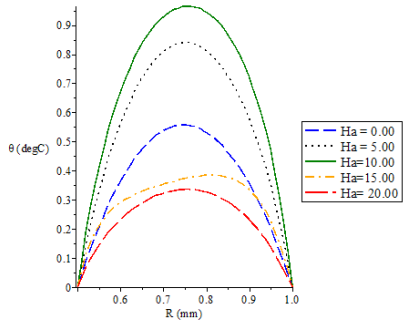


FIG. 4: The Temperature profile θ (deg C) versus Cylindrical Radius R (mm) for values of Hartmann number (Ha) with reactive term and joule heating , when Ec=1, Re=1, Da=1, G=30 and Pr=1

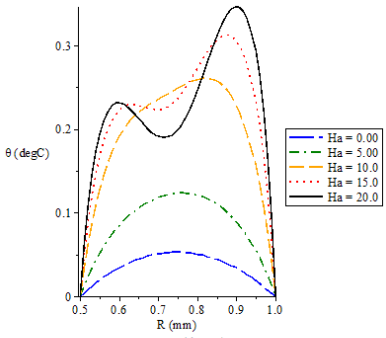


Fig.1B: The Temperature profile θ (deg C) versus Cylindrical Radius R (mm) for values of Hartmann number (Ha) with reactive term, when $Ec = 1$, $\Re = 1$, $Da = 1$, $G = 0$, $Fs = 0.5$, $V_0 = 1$ & $Pr = 1$

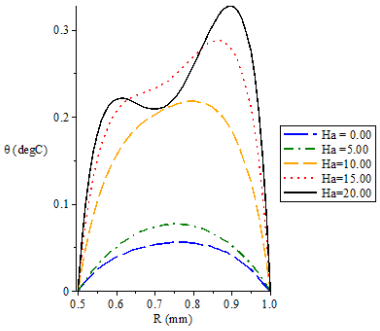


Fig. 2B: The Temperature profile θ (deg C) versus Cylindrical Radius R (mm) for values of Hartmann number (Ha) with reactive term, when $Ec = 1$, $\Re = 1$, $Da = 1$, $G = 5$, $Fs = 0.5$, $V_0 = 1$ & $Pr = 1$

Fig. 5, Fig. 6, Fig. 7 and Fig. 8 present the temperature profile for values of hartmann number (Ha=0.00, 4.00, 6.00 and 10.00) on pressure gradient (G). It was observed that as the pressure gradient (G) increases the temperature decreases but the temperature increases as the hartmann number (Ha) increases on the pressure gradient (G). As the hartmann number (Ha) increases on the pressure gradient (G) the temperature of the pressure gradient get closer towards each value maximum temperature. It also revealed that Fig. 5 (0.18℃), Fig. 6 (0.41℃), Fig. 7 (0.57℃) and Fig. 8 (0.76℃) maximum temperature are higher than Fig. 5B: (0.05℃), Fig.6B: (0.06℃) Fig.7B: (0.09℃) maximum temperature due to addition of joule heating in the system.

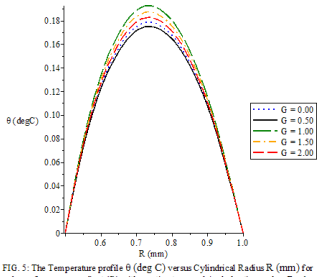


FIG. 5: The Temperature profile θ (deg C) versus Cylindrical Radius R (mm) for values of pressure gradient (G) with reactive term and joule heating , when Ec=1, Re=1, Da=1, Ha=0 and Pr=1

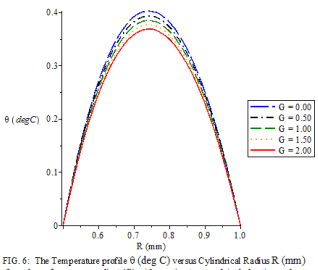


FIG. 6: The Temperature profile θ (deg C) versus Cylindrical Radius R (mm) for values of pressure gradient (G) with reactive term and joule heating , when Ec=1, Re=1, Da=1, Ha=4 and Pr=1

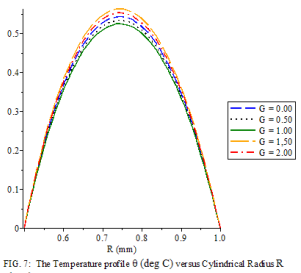


FIG. 7: The Temperature profile θ (deg C) versus Cylindrical Radius R (mm) for values of pressure gradient (G) with reactive term and joule heating , when Ec=1, Re=1, Da=1, Ha=6 and Pr=1

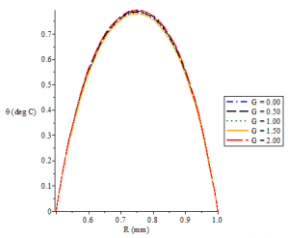


FIG. 8: The Temperature profile θ (deg C) versus Cylindrical Radius R (mm) for values of pressure gradient (G) with reactive term and joule heating , when Ec=1, Re=1, Da=1, Ha=10 and Pr=1

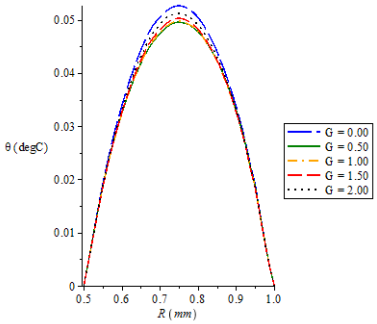


Fig. 5B: The Temperature profile θ (deg C) versus Cylindrical Radius R (mm) for values of Pressure Gradient (G) with reactive term, when $Ec = 1$, $\Re = 1$, $Da = 1$, $Ha = 0$, $Fs = 0.5$, $V_0 = 1$ & $Pr = 1$

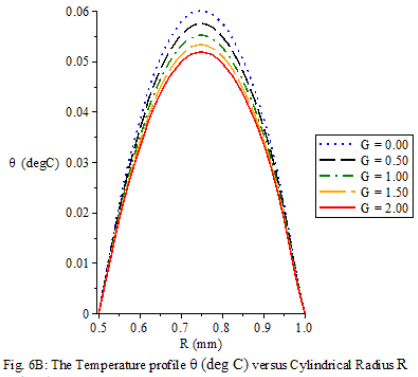


Fig. 6B: The Temperature profile θ (deg C) versus Cylindrical Radius R (mm) for values of Pressure Gradient (G) with reactive term, when $Ec = 1$, $\Re = 1$, $Da = 1$, $Ha = 2$, $Fs = 0.5$, $V_0 = 1$ & $Pr = 1$

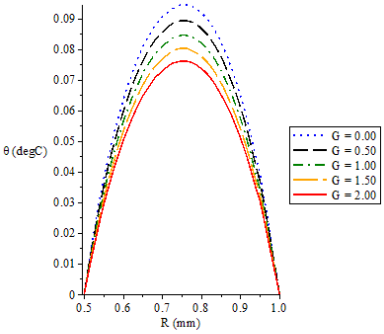


Fig.7B: The Temperature profile θ (deg C) versus Cylindrical Radius R (mm) for values of Pressure Gradient (G) with reactive term, when $Ec = 1$, $\Re = 1$, $Da = 1$, $Ha = 4$, $Fs = 0.5$, $V_0 = 1$ & $Pr = 1$

Fig. 9, Fig. 10 and Fig. 11 present the temperature profile for values of hartmann number (Ha=0.00, 1.00 and 2.00) on suction parameter(V_0). As the suction values increases, the temperature of each graph also increases likewise the temperature of each profile increases as hartmann number increases except the when ($V_0 = 0.00$) which indicates no permeability in the system.

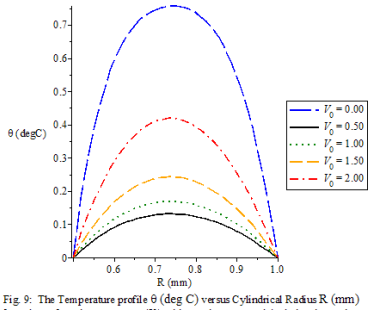


Fig. 9: The Temperature profile θ (deg C) versus Cylindrical Radius R (mm) for values of suction parameter (V_0) with reactive term and joule heating, when Ec=1, Re=1, Da=1, Ha=1, G=0 and Pr=1

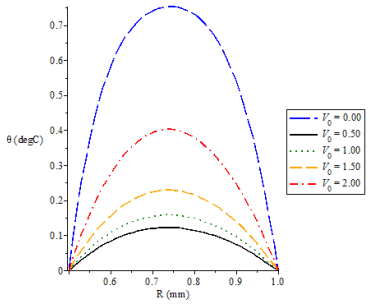


Fig. 10: The Temperature profile θ (deg C) versus Cylindrical Radius R (mm) for values of suction parameter (V_0) with reactive term and joule heating, when Ec=1, Re=1, Da=1, Ha=1, G=1 and Pr=1

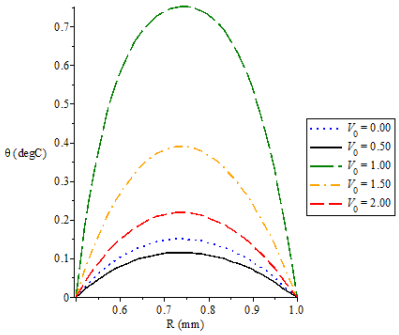


Fig. 11: The Temperature profile θ (deg C) versus Cylindrical Radius R (mm) for values of suction parameter (V_0) with reactive term and joule heating, when Ec=1, Re=1, Da=1, Ha=1, G=2 and Pr=1

Fig. 9B, Fig. 10B and Fig. 11B present the velocity profile for values of hartmann number (Ha=0.00, 1.00 and 2.00) on suction parameter(V_0). As the suction values increases, the velocity of each graph does not follow a particular pattern except from 1.00 and above and as the hartmann number increases there shows a smooth curve like an elbow which allows free flow of fluids within the proximity.

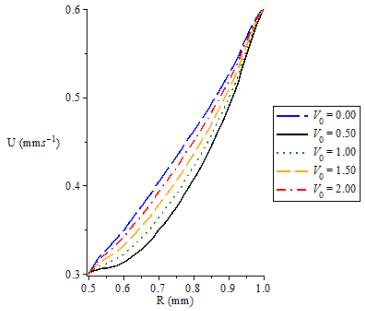


Fig. 9B: The Velocity profile U (mms^{-1}) versus Cylindrical Radius R (mm) for values of suction parameter (V_0) with reactive term and joule heating, when Re=1, Da=1, Ha=1 and G=0

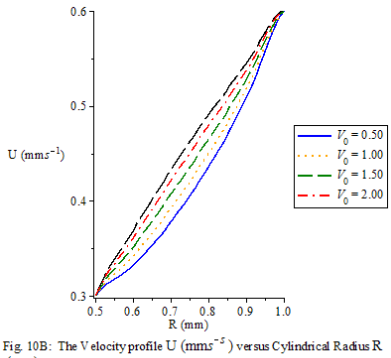


Fig. 10B: The Velocity profile U (mms^{-1}) versus Cylindrical Radius R (mm) for values of suction parameter (V_0) with reactive term and joule heating, when Re=1, Da=1, Ha=1 and G=1

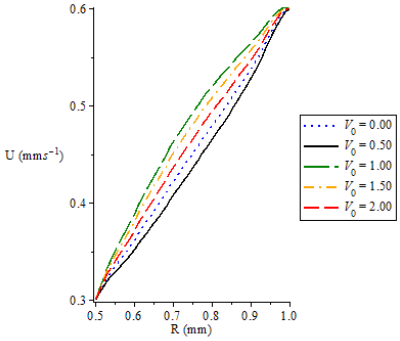


Fig. 11B: The Velocity profile U (mms^{-1}) versus Cylindrical Radius R (mm) values of suction parameter (V_0) with reactive term and joule heating, when Re=1, Da=1, Ha=1 and G=2

Fig. 12, Fig. 13 and Fig. 14 present the temperature profile for values of pressure gradient (G=0.00, 1.00 and 2.00) on suction parameter(V_0). As the suction values increases, the temperature of each graph also increases likewise the temperature of each profile increases as pressure gradient (G) increases except when ($V_0 = 0.00$) which indicates no permeability in the system.

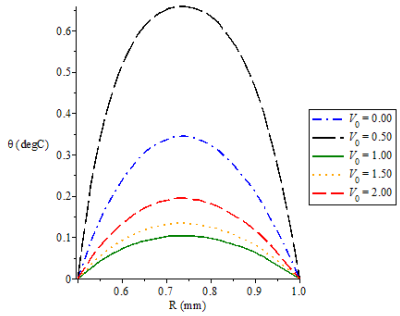


Fig. 12: The Temperature profile θ (deg C) versus Cylindrical Radius R (mm) for values of suction parameter (V_0) with reactive term and joule heating, when Ec=1, Re=1, Da=1, Ha=0, G=1 and Pr=1

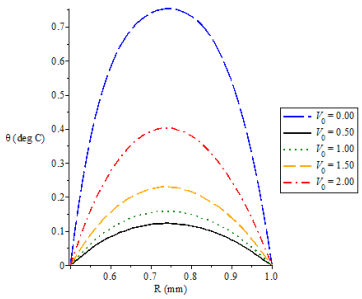


Fig. 13: The Temperature profile θ (deg C) versus Cylindrical Radius R (mm) for values of suction parameter (V_0) with reactive term and joule heating, when Ec=1, Re=1, Da=1, Ha=1, G=1 and Pr=1

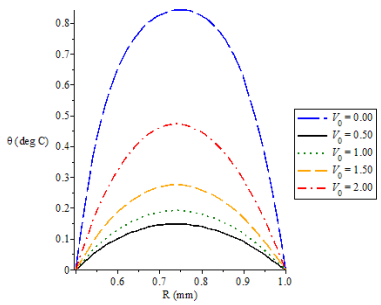


Fig. 14: The Temperature profile θ (deg C) versus Cylindrical Radius R (mm) for values of suction parameter (V_0) with reactive term and joule heating, when Ec=1, Re=1, Da=1, Ha=2, G=1 and Pr=1

Fig.12B, Fig.13B and Fig.14B present the velocity profile for values of pressure gradient (G=0.00, 1.00 and 2.00) on suction parameter (V_0). As the suction values increases, the velocity of each graph does not follow a particular pattern except from 1.00 and above and as the pressure gradient increases there shows a lost in smooth curve which indicates lack of free flow of fluids within the proximity.

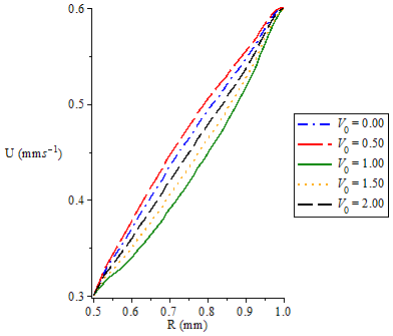


Fig. 12B: The Velocity profile U (mms^{-5}) versus Cylindrical Radius R (mm) for values of suction parameter (V_0) with reactive term and joule heating , when Re=1, Da=1, Ha=0 and G=1

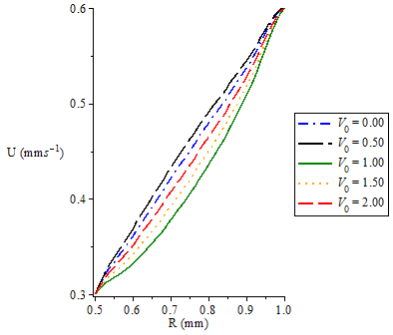


Fig. 13B: The Velocity profile U (mms^{-5}) versus Cylindrical Radius R (mm) for values of suction parameter (V_0) with reactive term and joule heating , when Re=1, Da=1, Ha=1 and G=1

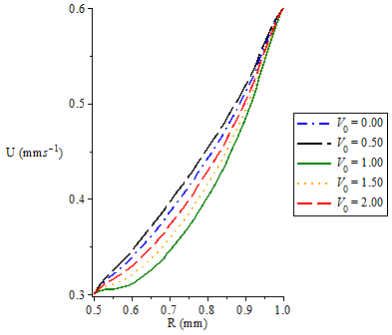


Fig. 14B: The Velocity profile U (mms^{-5}) versus Cylindrical Radius R (mm) for values of suction parameter (V_0) with reactive term and joule heating , when Ec=1, Re=1, Da=1, Ha=2, G=1 and Pr=1

4 Conclusion

Considering the results above, Hartmann number (Ha) which reveals the effect of magnetic force in this work shows that as the Hartmann number (Ha) increases on the other parameters the temperature of the system also decreases. This maximized the rate of fluid flow within the proximity of the system. This also signifies the usage of rotating concentric cylinder on even roads and without overloading of moving vehicles that are using rotating concentric cylinder. Oil with moderate viscosity must be used for proper fluid flow within the proximity. It was observed that initial stage of suction parameter(V_0) $<$ 0.50 in rotating concentric cylinders reduces the system temperature but when the suction parameter(V_0) $\geq$ 0.50 it increases the system temperature especially when the viscosity is low.
Also, as the Pressure gradient (G) increases on suction parameters the temperature of the system also increases. This also increases the rate of fluid flow within the proximity of the system with very high temperature that may easily dry or shorting the level of oil in the concentric cylinders especially if the oil viscosity is low. This signifies the usage of rotating concentric cylinder on uneven roads and overloading of moving vehicles that are using rotating concentric cylinder.
It was observed that magnetic forces reduces the temperature of the rotating concentric cylinder while pressure gradient increases the temperature of the fluids flow in rotating concentric cylinder due to the direct effect of joule heating term in the energy equation.

References

[1] Abdel-Wahed, M. S., & Emam, T. G. (2016). Effect of Joule Heating and Hall Current on MHD Flow of a Nanofluid due to a Rotating Disk with Viscous Dissipation. Thermal Science, (0), 200-218.
[2] Ali, A. W. (2014). The Effect of the Inner Cylinder Rotation on the Fluid Dynamics of Non-Newtonian. Brazilian Journal of Chemical Engineering, 31(4), 829-838.
[3] Aminfar, H., Mohammadpourfard, M., & Maroofiazar, R. (2014). Experimental study on the effect of magnetic field on critical heat flux of ferrofluid flow boiling in a vertical annulus. Experimental Thermal and Fluid Science, 9(16), 368-379.
[4] Ashoryrejad, R. A., Mohamad, A., & Sheikholesiami, M. (2013). Magnetic field effects on natural convection flow of a nanofluid in a horizontal cylindrical annulus using Lattice Boltzmann method. International Journal of Thermal Science, 37, 240-250.
[5] Beg, O. A., Makinde, O. D., Swapan, J. Z., & Ghosh, S. K. (2012). Hydromagnetic viscous flow in a rotating annular high-porosity medium with nonlinear Forchheimer drag effects: numerical study. World Journal of Modelling and Simulation, 8(2), 83-95.
[6] Darbhasayanam, S., & Shafeeurrahman, Md. (2017). Joule Heating Effect on Entropy Generation in MHD Mixed Convection Flow of Chemically Reacting Nanofluid between Two Concentric Cylinders. International Journal of Heat and Technology, 35(3), 487-497.

[7] Darbhashayanam, S., & Pashikanti, J. (2019). Effect of Joule heating on the flow over an exponentially stretching sheet with convective thermal condition. Mathematical Science, 13, 201-211.
[8] Dulal, P., & Babulal, T. (2011). Combined effects of Joule heating and chemical reaction on unsteady magnetohydrodynamic mixed convection of a viscous dissipating fluid over a vertical plate in porous media with thermal radiation. Elsevier, 54, 3016-3036.
[9] Erdogan, M. E. (1997). Unsteady flow of a viscous fluid due to non-coaxial rotations of a disk and a fluid at infinity. International Journal of Non-Linear Mechanics, 32, 285–290.
[10] Sharma, P. R., & Sinha, S. (2017). Combined Effects of Viscous Dissipation and Joule Heating on Unsteady MHD Flow and Heat Transfer over a Stretching Sheet Saturated in Porous Medium. Annals of Pure and Applied Mathematics, 14(3), 387-399.

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp. 411–417, November 13-16, 2023

Collocation Method for the Direct Solution of Volterra and Fredholm Integro-differential Equations

Adewale Adeyemi James[1] and Dunama Williams[2]
{adewale.james@aun.edu.ng, dunamakadiri@gmail.com }

Department of Mathematics and Statistics , American University of Nigeria, Yola, Nigeria[1]
African Institute for Mathematical Sciences, South West Region, Crystal Garden, P.O. Box 608 Limbe, Cameroon[2]

Abstract
Integro-differential equations play a pivotal role in modeling a wide range of physical, biological, and engineering systems. These equations combine differential operators with integral terms, posing unique challenges for numerical solutions. This paper presents a comprehensive examination of the collocation method as a powerful and versatile technique for directly solving Volterra and Fredholm integro-differential equations. The collocation method is a numerical approach that involves discretizing the differential and integral components of the equation at specific collocation points. By appropriately choosing these points, the method transforms the integro-differential equation into a system of algebraic equations, which can be efficiently solved using standard numerical techniques. This paper explores the mathematical foundations of the collocation method and its applicability to various classes of integro-differential equations.

Keywords: Collocation, Volteral, Fredholm, Intro-differential Equations

Introduction

We taken into consideration a standard Higher-order linear Voltera, and Fredholm Integrodifferential equation of the form;

$$Q_{01}\gamma^{m}(x) + Q\gamma^{m-1}(x) + \cdots + Q_{m-1}\gamma'(x) + Q_{m}\gamma(x) + \beta\int_{\omega(x)}^{\tau(x)} \mu(x,s)\,\gamma(s)dt = f(x) \quad (1)$$

subject to the conditions

$$\gamma(a) = A\,,\ \varphi(b) = B \quad (2)$$

where $Q's$ are real constants; ω, τ are finite constants; $\mu(x,s)$ and $f(x)$ are specified given real-valued functions; φ are unknown constants to be determined. We then solved these problems by assuming an approximate solution given by Equation (4) below.

2 Basic Definition

2.1. Integrodifferential equations (Ayinde et al 2021)

The following is a typical Integrodifferential equation:

$$\gamma^{(k)}(x) = f(x) + \beta\int_{\omega(x)}^{\tau(x)} \mu(x,s)\gamma(s)ds \quad (3)$$

Here the unknown function $\gamma(x)$ is written with the integral sign and also has an ordinary derivative $\gamma^{(k)}\tau(x)$ and $\omega(x)$ are integration limits that can be constants, variables, or mixed. $f(x)$ is a specified function, and $\mu(x,s)$ stands for kernel. If the limit $\gamma(x)$ is substituted by a variable of integration x, we have the Volterra Integrodifferential equation, and if the limit of integration is constants, we have the Fredholm Integrodifferential equation.

2.2. Approximate Solution

An approximate solution denoted by $\gamma_n(x)$ is given in the form

$$\gamma_n(x) = \sum_{i=0}^{n} a_i \varphi_n(x) \tag{4}$$

where $a_i (i \geq 0)$ are to be determined.

2.3. Chebyshev polynomials of third kind (Ayinde et al, 2022)

The Chebyshev polynomial of the third kind in [-1, 1] of degree m is represented by $C_m(x)$, where:

$$C(x) = \cos \frac{\left(m+\frac{1}{2}\right)\upsilon}{\cos\left(\frac{\upsilon}{2}\right)}, \text{ where } x = \cos \upsilon \tag{5}$$

This elegance of Chebyshev polynomials satisfied the subsequent recurrence relation given by

$$C_0(x) = 1, \quad C_1(x) = 2x - 1, C_m(x) = 2xC_{m-1}(x) - C_{m-2}(x), \ m = 2, 3, \cdots \tag{6}$$

The Chebyshev polynomial of the third kind in $[\eta, \rho]$ of degree, m is represented by $C_m^*(x)$, where:

$$C_m^*(x) = \cos \frac{\left(m+\frac{1}{2}\right)\upsilon}{\cos\left(\frac{\upsilon}{2}\right)}, \cos \upsilon = \frac{2x-(\eta+\rho)}{\rho-\eta}, \quad \upsilon \ \epsilon \ [0, \pi] \tag{7}$$

3 Mathematical Formulation

Equation (1) was solved using the third kind of Chebyshev polynomials and the standard collocation method. The standard collocation method can be used to solve the well-known problem provided in equation (1), subject to the conditions given in equation (2). This is accomplished by assuming a form trial solution.

$$\gamma_m(x) = \sum_{i=0}^{M} a_i C_i^*(x) \tag{8}$$

where $a_{i,}$ $i = 0,1 \cdots m$ are undefined constants and $C_i^*(x) (i \geq 0)$ are the Chebyshev polynomials described in equations (5-7). In most instances, a larger m, produces a better approximate solution, and a_i is the specialized coordinate referred to as the degree of freedom.Thus, differentiating equation (8) m times as function of x, to obtain the following equations

$$\left.\begin{array}{l} \gamma'_m(x) = \sum_{i=0}^{M} a_i C_i^{*\prime}(x) \\ \gamma''_m(x) = \sum_{j=0}^{M} a_i C_i^{*\prime\prime}(x) \\ \vdots \\ \gamma^{(m)}(x) = \sum_{i=0}^{M} a_i C_i^{*(m)}(x) \end{array}\right\} \tag{9}$$

As a result of putting Equations (8-9) into Equation (1), we get

$$Q_{01} \sum_{i=0}^{M} a_i C_i^{*(m)}(x) \, Q_{11} \sum_{i=0}^{M} a_i C_i^{*(m-1)}(x) \, Q_{21} \sum_{i=0}^{M} a_i C_i^{*(m-2)}(x) \ \ldots$$
$$Q_{m1} \sum_{i=0}^{M} a_i C_i^*(x) + \beta \int_{\omega(x)}^{\tau(x)} \mu(x,t)\left(\sum_{i=0}^{M} a_i C_i^*(t)\right)dt = f(x) \tag{10}$$

The integral part of Equation (10) is evauated to produce

$$Q_{01}\sum_{i=0}^{M} a_i C_i^{*(m)}(x) + Q_{11}\sum_{i=0}^{M} a_i C_i^{*(m-1)}(x) + Q_{21}\sum_{i=0}^{M} a_i C_i^{*(m-2)}(x) + \ldots$$

$$+ Q_{m1}\sum_{i=0}^{M} a_i C_i^{*}(x) + \beta E(x) = f(x) \tag{11}$$

and $E(x) = \int_{\omega(x)}^{\tau(x)} \mu(x,t)(\sum_{i=0}^{MM} a_i C_i^{*}(t))dt$

We collocate the resulting equation after simplification at the point $x = x_k$

$$Q_{01}\sum_{i=0}^{M} a_i C_i^{*(m)}(x_k) + Q_{11}\sum_{i=0}^{M} a_i C_i^{*(m-1)}(x_k) + Q_{21}\sum_{i=0}^{M} a_i C_i^{*(m-2)}(x_k) + \cdots Q_{m1}\sum_{j=0}^{M} a_i C_i^{*}(x_k) + \beta E(x_k) = f(x_k) \tag{12}$$

where

$$x_k = \eta + \frac{(\rho-\eta)k}{M}; \quad M = 1, 2, \ldots, M-1 \tag{13}$$

Equation (12) is then transformed into a matrix as

$$Q\underline{x} = \underline{e}x_k \tag{14}$$

where

$$Q = \begin{pmatrix} q_{11} & q_{12} & q_{13} & & q_{1,m} \\ q_{21} & q_{22} & q_{23} & \cdots & q_{2,m} \\ q_{31} & q_{32} & q_{33} & & q_{3,m} \\ & \vdots & & \ddots & \vdots \\ q_{m,1} & q_{m,2} & q_{m,3} & \cdots & q_{m,m} \end{pmatrix} \tag{15}$$

$$\underline{x} = (x_1, x_2, x_3, \cdots, x_m)^T \tag{16}$$

$$\underline{e} = (f(e_1), f(e_2), f(e_3) \ldots, f(e_m))^T \tag{17}$$

Consequently, Equation (12) yields a (M-1) algebraic linear system of equations in (M+1) unknown constants, and the specified conditions in Equation (12) yield *m* additional equations. We now have an algebraic linear system of equations with (M+1) variables. These equations are then solved using Maple 18 software to provide (M+1) unknown constants a_i $(i \geq 0)$, which are then used to approximate the solution given by Equation (8).

4 Test Problems and Results

4.1. Problem 1 (Ayinde *et. al*, *2022*)

Here, we looked at the Fredholm Integrodifferential equation of second order.

$$\gamma''(x) = e^x - \frac{4}{3}x + \int_0^1 xt\gamma(t)dt. \tag{18}$$

with initial conditions

$$\gamma(0) = 1, \quad \gamma'(0) = 2 \tag{19}$$

The exact solution is as follows

$$\gamma(x) = x + e^{x} \tag{20}$$

4.2. Problem 2 (Ayinde et al 2022)

Here, we considered the second-order linear Volterra Integrodifferential equation

$$\gamma''(x) = 2 - 2\text{x}\sin x - \int_0^x (x-t)\gamma(t)dt. \tag{21}$$

with initial conditions

$$\gamma(0) = 0, \quad \gamma'(0) = 0 \tag{22}$$

The exact solution is given as

$$\gamma(x) = xsin\ x \tag{23}$$

4.3. Problem 3 (Ayinde et al 2022)

Here, we considered the fourth-order linear Volterra Integrodifferential equation

$$\gamma^{(iv)}(x) = -1 + x - \int_0^x (x-t)\gamma(t)dt. \tag{24}$$

with initial conditions

$$\gamma(0) = -1, \quad \gamma'(0) = 1, \quad \gamma''(0) = 1, \quad \gamma'''(0) = 1 \tag{25}$$

The exact solution is

$$\gamma(x) = \sin x - \cos x \tag{26}$$

4.4. Problem 4 (Darania and Ebadian, 2007)

Here, we considered the fourth-order linear Volterra Integrodifferential equation

$$\gamma^{(iv)}(x) = -1 + x - \int_0^x (x-t)\gamma(t)dt. \tag{24}$$

with initial conditions

$$\gamma(0) = -1, \quad \gamma'(0) = 1, \quad \gamma''(0) = 1, \quad \gamma'''(0) = 1 \tag{25}$$

The exact solution is

$$\gamma(x) = \sin x - \cos x \tag{26}$$

Note: We defined absolute error as follows:

$$Absolute\ Error = |\gamma(x) - \gamma_m(x)| \quad (27)$$

where, $\gamma(z)$ stands for the exact solution and $\gamma_m(x)$ stands for the approximate solution obtained for the various *m values*.

4.4. Tables of Errors and Approximate for the problems

Table 1. Table of Error and Approximate for problem 1

X	γ (x)	Absolute(Error) For M = 5	Absolute(Error) For M = 10	Absolute(Error) For M = 5 in [Ayinde et al 2022]	Absolute(Error) For M = 10 [Ayinde et al 2022]
0.0	1.0000000000000	7.50 e-09	5.57 e-08	2.00 e-09	4.79e-06
0.1	1.2051709180756	7.80 e-08	8.89 e-09		
0.2	1.4214027581602	2.16 e-07	3.01 e-08	2.48 e-05	5.03e-06
0.3	1.6498588075760	4.70 e-07	2.61 e-08		
0.4	1.8918246976413	9.89 e-07	1.90 e-08	5.76 e-05	6.74e-06
0.5	2.1487212707001	2.90 e-05	1.80 e-08		
0.6	2.4221188003905	1.00 e-04	2.21 e-08	9.09 e-05	7.91e-06
0.7	2.7137527074705	3.50 e-04	2.41 e-08		
0.8	3.0255409284925	1.00 e-03	2.81 e-08	1.25 e-04	7.58e-06
0.9	3.3596031111569	2.50 e-03	4.20 e-08		
1.0	3.7182818284590	5.60 e-03	1.00 e-07	1.61 e-04	1.11e-05

Table 2. Table of Error and Approximate for problem 2

X	γ (x)	Absolute(Error) For M = 5	Absolute(Error) For M = 10	Absolute(Error) For M = 5 in [Gazi]	Absolute(Error) For M = 10 [Gazi]
0.0	0.000000000000	4.79 e-10	8.78 e-08	5.00e-11	1.13e-10
0.1	0.009983341665	3.08 e-07	2.94 e-08		
0.2	0.039733866159	6.68 e-07	7.83 e-08	8.65e-05	2.56e-07
0.3	0.088656061998	1.02 e-06	2.34 e-08		
0.4	0.155767336923	1.81 e-06	9.08 e-08	1.91e-04	2.22e-07
0.5	0.239712769302	8.06 e-05	3.50 e-09		
0.6	0.338785484037	3.92 e-05	9.25 e-08	9.93e-04	1.68e-07
0.7	0.450952381066	1.44 e-04	2.98 e-08		
0.8	0.573884872711	4.20 e-04	9.19 e-08	4.21e-04	5.38e-07
0.9	0.704994218664	1.04 e-03	1.52 e-08		
1.0	0.841470984808	2.28 e-03	9.34 e-08	5.53e-04	9.55e-07

Table 3. Table of Error and Approximate for problem 3

X	γ (x)	Absolute(Error) For M = 6	Absolute(Error) For M = 10	Absolute(Error) For M = 6 in [Gazi]	Absolute(Error) For M = 10 [Gazi]

0.0	-1.000000000000	5.10 e-10	3.20 e-08	1.00e-10	6.00e-09
0.1	-0.89517074863	4.10 e-10	7.01 e-09		
0.2	-0.781397247046	9.80 e-09	3.19 e-08	2.43e-07	2.10e-09
0.3	-0.65981628246	3.76 e-08	8.01 e-09		
0.4	-0.531642651694	8.49 e-08	3.19 e-08	2.64e-05	6.20e-09
0.5	-0.39815702329	6.15 e-08	2.10 e-10		
0.6	-0.260693141515	4.84 e-07	3.29 e-08	9.81e-05	6.80e-09
0.7	-0.12062450005	2.95 e-06	9.50 e-09		
0.8	0.020649381552	1.07 e-05	3.11 e-08	2.31e-05	4.77e-09
0.9	0.161716941357	3.08 e-05	7.71 e-09		
1.0	0.301168678939	7.62 e-05	3.22 e-08	5.53e-04	9.55e-07

5 Discussion of Results

In terms of the absolute error and approximate solutions, the tables provide the numerical solutions for the Integrodifferential equations. The computations were performed using the third kind of Chebyshev polynomial basis function. The approximate solution obtained is much closer to the exact solution when evaluated at an equally spaced interior point. However, as shown in the tables of errors the results provide a good approximation to the exact solution for varying degrees of M with a few iterations. As a result, we conclude that the method was realistic and effective under the given circumstances.

Declarations

I, Adewale A. James on behalf of the co-authors declare that there are no conicts of interest in this article. The method and results were original work carried out by the authors of this article. All quoted work are rightly cited in the reference section.

Conflicts of interest/Competing interests: The authors here-by declare that there are neither conflict of interest or competing interest in this research work.

Availability of data and material: Not applicable

Funding: Not applicable

References

[1] Eslahchi, M. R., Mehdi, D., & Sanaz, A. (2012). The third and fourth kinds of Chebyshev polynomials and best uniform approximation. *Mathematical and Computer Modelling*, 55(5-6): 1746-1762.doi:10.1016/j.mcm.2011.11.023

[2] Kurt, N., & Sezer, M. (2008). Polynomial solution of high-order linear Fredholm integro-differential equations with constant coefficients. *Journal of the Franklin Institute*, 345(8): 839-850. doi:10.1016/j.jfranklin.2008.04.016

[3] Gulsu, M., Ozturk, Y., & Sezer, M. (2010). A New Collocation Method for Solution of Mixed Linear Integrodifferential equations. *Applied Mathematics and Computation*, 216(7): 2183-2198. doi:10.1016/j.amc.2010.03.054

[4] Rashidinia, J., & Tahmasebi, A. (2012). Taylor Series Method For The System Of Linear Volterra Integrodifferential equations. *The Journal Of Mathematics and Computer Science*, 4(3), 331-343. doi:10.22436/jmcs.04.03.06

[5] Sezer, M., & Gulsu, M. (2005). Polynomial solution of the most General linear Fredholm integro-differential-difference equation by Means of Taylor Matrix Method. *International Journal of Complex Variables*, 50, 367-382. doi:10.1080/02781070500128354

[6] Wazwaz, A. M. (2011). *Linear And Nonlinear Integral Equations*, Higherer Education Press Beijing and Springer

[7] Verlag, Berlin.

[8] Wazwaz, A. M. (2010).The Combined Laplace Transform-Adomian Decomposition Method For Handling Nonlinear

[9] Volterra Integrodifferential equations. *Applied Mathematics and Computation*, 216, 1304-1309.
[10] doi:10.1016/j.amc.2010.02.023
[11] Rashed, M. (2004). Lagrange interpolation to compute the numerical solutions differential, Integral, and
[12] Integrodifferential equations. *Applied Mathematics and Computation*, 151(3), 869–878,
[13] doi:10.1016/S0096-3003(03).000543-5
[14] Yusufoglu, E. (2007). An efficient algorithm for solving Integrodifferential equations system. *Applied Mathematics and Computation*, 192(1), 51-55. doi:10.1016/j.amc.2007.02.134
[15] Akgonullu, N., & Sezer, M. A.(2011). A Hermite Collocation Method For The Approximation Solutions of Higher-Order Linear Fredholm Integrodifferential equations. Numerical Methods for Partial Differential Equations. 27(6), 1707-1721. doi:10.1002/num.20604
[16] Taiwo, O. A., & Fesojaye, M. O. (2015). Perturbation Least-Square Chebyshev Method For Solving Fractional Order
[17] Integrodifferential equations. Theoretical Mathematics and Applications.5(4), 37-47.
[18] Kunjan, S., & Twinkle, S. (2015). Solution of second kind Volterra integral and integro-differential equation by
[19] Homotopy analysis method. *International Journal of Mathematical Archive*. 6(4):49-59, (2015).
[20] Loh, R. J., Phang, C. (2018). A new Numerical Scheme For Solving System of Volterra İntegro-Differential Equation.
[21] *Alexandria Enginerring Journal*, 57(2), 117-1124. doi:10.1016/j.aej.2017.01.021
[22] Mostafa, S. (2019). Numerical solutions of integral and integro-differential equations using Chebyshev polynomial of the third kind. *Applied Mathematics and Computation*, 35, 66-82. doi:10.1016/j.mcm.2019.01.030
[23] Rabiei, R., Hamid, F. A., Majid, Z. A., & Ismail, F., (2019). Numerical Solution of Volterra İntegro-Differential
[24] Equations Using General Linear Method. *Numerical Algebra, Control and Optimization*, 9(4), 433-
[25] 444. doi: 10.3934/naco.2019042
[26] Lotfi, M., & Alipanah, A.(2020). Legendre Spectral Element Method for Solving Volterra İntegro- Differential
[27] Equation. *Results in Applied Mathematics*, 7, 100116-100116.doi: 10.1016/j.rinam.2020.100116
[28] Samaher, M. Y.(2021). Reliable Iterative Method for Solving Volterra-Fredholm İntegro- Differential Equation. *Al-*
[29] *Qdisiyah Journal of Pure Science*, 26(2), 1-11. doi: 10.29350/qjps.2021.26.2.1262
[30] Adebisi, A. F., Ogunronbe, T. A., Okunlola, K. A., & Peter, O. J. (2019). Application of Chebyshev polynomials basis function on the solution of Volterra integr-differential equations using using Galerkin method. *Mathematical and Computational Sciences*, 2(1), 41-51. doi:10.30511/mcs.2021.540133.1047
[31] Muhammed Abdullahı, A. , James, A. , Ishaq, A. A. & Oyedepo, T. (2022). A New Numerical Approach Using Chebyshev Third Kind Polynomial for Solving Integrodifferential Equations of Higher Order . Gazi University Journal of Science Part A: Engineering and Innovation , 9 (3) , 259-266 . DOI: 10.54287/gujsa.1093536

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp. 418–423, November 13-16, 2023

Objective Estimation of Activity Time in Project Management

Ahmad. M. Aliyu[1] and Shamsuddeen Ahmad Sabo[2]
{ahmad.maliyu@aun.edu.ng}

Department of Mathematics & Statistics American University of Nigeria, Yola[1]

Abstract
A better project evaluation and review method is suggested and put to the test. By using this technique, the subjectivity and ambiguity surrounding the predicted time of the intended activity would be diminished. The three-time estimate is put through a normalcy test to achieve this. This method would improve activity time estimation's precision and objectivity. However, when several project works were examined, the propose PERT approach generated results for activity and project durations, variances, and project duration probability that were comparable to those of traditional PERT. The goal of the paper is to eliminate the uncertainty that exists when project evaluation review technique estimates activity time. The data demonstrates that all three-time estimates are normally distributed. The unique strategy utilized in this work is the first to overcome ambiguity in activity time estimation.

Keywords: Project Evaluation Review Technique

1 Introduction

Project Evaluation Review Technique (PERT) is a method used for analyzing and organizing tasks and activities in a project. It is widely used in various industries and sectors for project planning, scheduling and control. This research work introduces a simple addition to the planning tool known as the Program Evaluation Review Technique (PERT), which is used in project management. PERT has received a range of grievances and suggestions for changes since the early 1960s. Its relies on estimates, which may be arbitrary and incorrect, of the job's duration and possibility of completion in a timely manner. This could lead to an exaggeration or underestimate of the amount of time needed to complete a job. On the basis of the aforementioned challenges, we offer a strategy to enhance the assessment of activity time. The article's structure is as follows:

PERT is first and foremost is introduced and described; Second, a review of PERT literature is done; third The creative concept is given; Fourth, the idea is examined and assessed. The outcomes are contrasted with those from traditional PERT. Finally, the conclusions are presented. The research seeks to do away with the ambiguity that arises in project assessment review technique's estimation of activity time.

A technique called Project Evaluation Review Technique (PERT) is used to examine and arrange the tasks and activities inside a project. For project planning, scheduling, and control, it is extensively used across numerous industries and sectors. PERT was developed in 1957 for the Special Projects Office of the U.S. Navy to aid in the development of the Polaris nuclear submarine project. A project is viewed by the method as an acyclic network of activities and events. The project as a whole would be put in danger if any of the tasks along the critical path were to be postponed. PERT can be used to calculate the likelihood that a project or a specific activity will be finished by a given deadline. It is also feasible to figure out how long a certain probability will last (Winston, 2004). PERT have been utilized successfully in numerous applications, such as:

1. PERT is often used in construction projects to schedule and manage activities, identify the critical path, and allot resources. Examples of these projects include office buildings, roadways, swimming pools, and the creation of a countdown and "hold" mechanism for space flight launch. Construction managers can use it to spot potential delays and make the required corrections to stay on schedule.

2. In the manufacturing sector, PERT is used to review production processes, identify areas for improvement, and complete corporate mergers, such as designing a ship and producing and marketing a brand-new product. The technique is used to create production schedules, assess production capability, and maximize resource use.
3. To manage complicated activities, pinpoint key paths, and assign resources, PERT is frequently used in information technology (IT) projects (such building up a new computer system). It assists in helping project managers envision the project's timeline, recognize potential risks, and allocate resources sensibly.
4. For project planning, scheduling, and administration, PERT is being used more and more in the healthcare industry (for example, the planned transfer of a 400-bed hospital from Portland, Oregon to a suburban area). It is used to plan and oversee patient care procedures, research projects, and clinical trials.

1.1 Figure

Figure 1 depicts a project from beginning to end. While nodes represent the completion of an activity, arrows represent the task. The arrows indicate how long each activity will take to complete. Displays that have dotted lines are a task that cannot be completed.

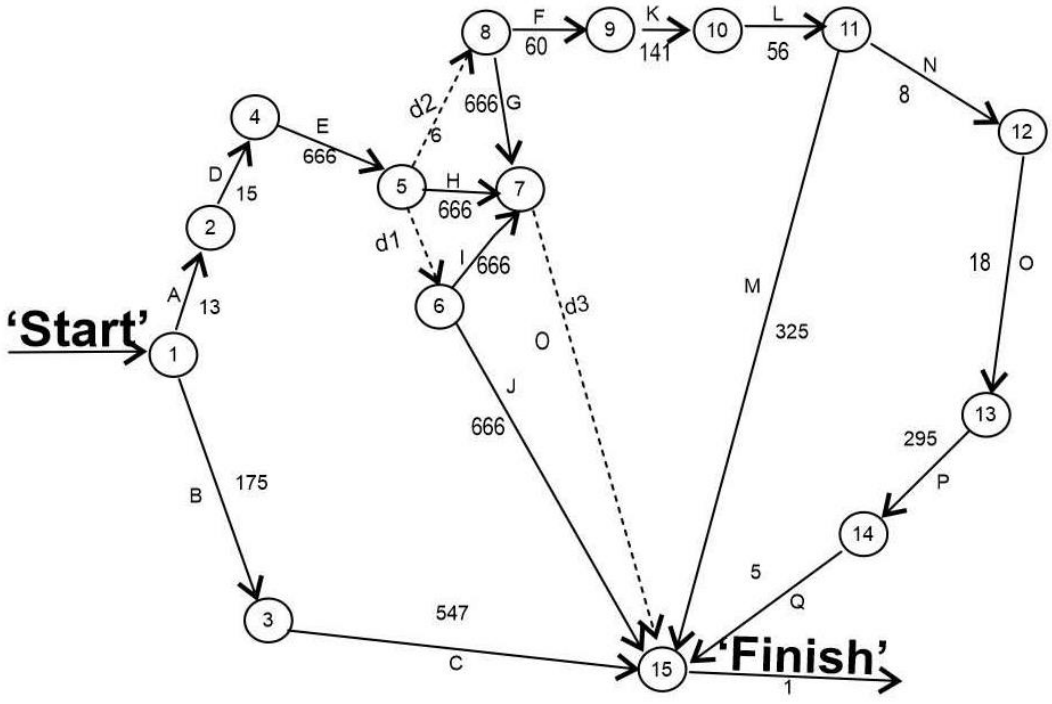


Figure 1: A-Yuniams Project Network diagram

2 PERT Evaluation in Literature

Creating a network model of the project, like the one in figure 1, in which each arc stands for an action and each node for an event, is the first step in using PERT. The activity time is used as a random variable in the PERT model. The project manager needs to estimate each of the following three things: a calculation of the activity's maximum time frame, as represented by (a). Estimation of the activity's duration under the most difficult conditions is shown by (b). The value that represents the most likely length of the activity is represented by (m). estimating the length of jobs and the likelihood that

they will be completed on time, which might be arbitrary and wrong. This might result in either an overestimate or underestimate of the time required to finish a project. From the early 1960s, a number of PERT criticisms and suggested adjustments have been published in the literature. In the first place, it is challenging for project engineers and planners to determine with accuracy the optimistic, most likely, and pessimistic durations of an activity. Subjective estimates of a, m, and b are based on judgment and may not be closely related to statistical sampling of the real times, according to (Wayne and Cottrell, 1999) and (Grubbs, 1962) and (Moder et al., 1983) and (Cynthia, 2020).

3 Methodology

This study uses a four-stage statistical test to determine the data set's normality: first, the Kolmogorov-Smirnov test (Simard R, 2011; NIST, 2021), Shapiro-Wilks test (Nornadiah and Yap, 2011), pearson index (Bluman, 2009), and outlier check.

3.1 Kolmogorov Smirnov Test

A statistical test called the Kolmogorov-Smirnov test is used to verify whether a sample belongs to a particular distribution, such as the normal distribution. It is a non-parametric test, which means that it makes no assumptions about the data's distribution (NIST, 2021).

The Kolmogorov-Smirnov test's null hypothesis is that the sample data come from a certain distribution, such as the normal distribution. A different possibility is that the sample data are not representative of the specified distribution (Simard R, 2011).

3.1.1 Kolmogorov Smirnov Test

The largest absolute difference between the cumulative distribution function (CDF) of the sample data and the CDF of the given distribution serves as the test statistic in the Kolmogorov-Smirnov test. The following formula is used to determine the test statistic D:

$$D = max|F(x) - S(x)|$$

Where

$$D = Kolmogorov\ Smirnov\ test\ statistic$$
$$F(x) = Cumulative\ distribution\ function\ (CDF)$$
$$S(x) = Empirical\ distribution\ function\ (ECDF)$$

3.1.2 Results

Table 1 below displays the summary results for the Kolmogorov-Smirnov test.

Table 1: Summary Result for Kolmogorov Smirnov Test

Statistics	MLT	PST	OPT
D	0.16585	0.18654	0.19638
P - Value	0.8038	0.6736	0.6094

Key: D = Test Statistic, MLT = Most likely Time, PST = Pessimistic Time, OPT = Optimistic Time

3.1.3 Interpretations

The Kolmogorov smirnov test for normality shows that both variables were normally distributed as P-values are greater than 0.05.

3.2 Shapiro Wilks Test

A statistical test called the Shapiro-wilk test is used to discover whether a dataset has a normal distribution. Martin wilk and samuel Shapiro created it in 1965(Nornadiah and Yap, 2011). The community from which the sample is drawn must have a normally distributed population in order for

the test to be considered valid. To evaluate the significance of the deviation from normality, the test gives a p-value. The Shapiro-Wilk test is frequently used to determine whether the collected data conforms to a normal distribution, a prevalent assumption in many statistical analyses, in a variety of disciplines including biology, social sciences, engineering, and finance. To assess the normality assumption, it is important to keep in mind that while the test is helpful, it is not infallible, so it should be used in conjunction with other tests and visualizations.

3.2.1 Shapiro Test Statistic

W stands for the Shapiro-wilks test statistic, which is displayed below.

$$W = \frac{(\Sigma a_i x_i)^2}{\Sigma (x_i - \bar{x})^2}$$

where:

W = W is the Shapiro-Wilk test statistic
ai = Coefficients that depend on the sample size and are obtained from pre-calculated tables
xi = Ordered sample values
$\bar{x}$ = Sample Mean

The test statistic W ranges from 0 to 1, with values closer to 1 indicating that the sample is more likely to have been drawn from a normally distributed population. The p-value is then calculated based on the value of W and the sample size.

3.2.2 Results

Table 2 below displays the summary results for the Shapiro-Wilks test.

Table 2: Summary Results for Shapiro-Wilk test

Statistics	MLT	PST	OPT
D	0.94186	0.92808	0.92518
P - Value	0.4063	0.2554	0.2310

Key: W = Shapiro-Wilk value, MLT = Most likely Time, PST = Pessimistic Time, OPT = Optimistic Time

3.2.3 interpretation

According to the Shapiro-Wilks test results the Most Likely Time, Pessimistic Time, and Optimistic Time estimations are all normally distributed. Otherwise, you must throw the estimates away and create a new one until they are distributed normally. All computation was done with the statistical package R (Chambers, 2020).

3.3 Skewness

To determine whether an estimated time is normal, one can utilize the Pearson index. Using Pearson's Index (PI) of skewness can be verified. The equation is

$$PI = \frac{3(\bar{x} - median)}{s}$$

Where:

$\bar{x}$ = Sample Mean
s = Sample standard deviation

It can be said that the data are highly skewed if the index is larger than or equal to plus one (+1) or less than or equal to negative one (−1).

3.3.1 Results

Table 3 displays the pearson index's summary results.

Table 3: Summary Results for Pearson's Index (PI) test for skewness

Statistics	MLT	PST	OPT
PI	0.4974556	1.065967	0.3656811
Mean	15.26667	17.6	12.86667
Median	14	15	12
Standard Deviation	7.638873	7.317298	7.11002

Since the PI in the instance of MLT is 0.4974 and is below 1, the distribution cannot be said to be considerably skewed. However, since the PI value for PST is larger than 1, we infer that the distribution is strongly skewed to the right. Meanwhile, since the PI value for OPT is less than 1, we infer that the distribution is not significantly skewed. Using the R software (Chambers, 2020), all calculations were completed.

3.4 Check for Outliers

Any data point that considerably deviates from the observation is considered an Outliers (Bluman, 2009). Gather the data set first, then arrange it in ascending order. Next, we determine the data's 25th and 75th percentiles. The difference between the 75th and 25th percentile is then used to construct the interquartile range, or IQR. We determine the lower and upper outlier thresholds. Then, if there are any outliers, we find any data values that are either smaller than the lower threshold or larger than the upper threshold and print them.

3.4.1 Results

Table 4 shows the outlier identification summary results.

Table 4: Summary Results for Outliers Detection

Statistics	MLT	PST	OPT
Q_1	10	12.5	9
Q_3	19.5	24.0	15.5
IQR	9.5	11.5	6.5
(1.5)IQR	14.25	17.25	9.75
Q_1 – (1.5)IQR	- 4.25	- 4.75	- 0.75
Q_3 – (1.5)IQR	33.75	41.25	25.25
Minimum	5	7	3
Maximum	32	30	30

3.4.2 interpretation

Any predicted result that falls outside of the normal range (25th percentile minus 1.5 times interquartile range) or exceeds the normal range (75th percentile plus 1.5 times interquartile range) is referred to as

an outlier. There are no outliers in any of the observed estimations as a result. Otherwise, you must throw the estimates away and create a new one until they are no outlier.

4 Summary

The project evaluation review technique (PERT), a planning tool utilized in project management, is given a straightforward addition in this research work. The strategy depends on an assessment of the activity's time and likelihood of timely completion, which may be arbitrary and wrong. This can cause someone to overestimate or underestimate how long it will take to complete a task. Information is gathered for each action regarding the task's most likely completion time, the task's completion time under the worst scenario, and the task's completion time under the best scenario. This study carried out the investigation using published data sets. In order to determine the normality of the data set, we employed the Kolmogorov-smirnov test, the Shapiro-wilks test, the skewness test, and the check for outliers. As P-values are greater than 0.05, the Kolmogorov-Smirnov test for normality reveals that all variables were normally distributed. The most likely time, the most pessimistic time, and the most optimistic time are both Normally distributed, according to the Shapiro-Wilks test results. With the exception of the most optimistic time prediction, which shows skewness to the right, all the variables indicate that the Pearson Index is not considerably skewed. All of the observed estimations lack outliers. This study opened up new possibilities for project management and control, and also improved the usefulness of existing planning tools.

5 Conclusion

There are numerous actions that must be completed as part of a project. Every activity has a start time and an end time. These estimates were made at random based on the expert's knowledge and discretion. The most probable, pessimistic, and optimistic estimates are the three categories. However, because these estimations are made subjectively, they are vulnerable to under- or overestimation. The fact that they are regularly distributed is demonstrated by the three estimates (i.e., pessimistic, most likely, and optimistic). Otherwise, you must throw the estimates away and create a new one until they are distributed normally. The purpose of the article is to remove any uncertainty from activity time estimations made using project assessment review technique. The unique method will undoubtedly ensure the impartiality of the activity time calculation.

References

[1] Bluman, A. G. (2009). *Elementary Statistics: A Step by Step Approach* (7th Edition). McGraw-Hill Companies, Inc.

[2] Chambers, J. M. (2020). "S R and Data Science." *The R Journal*, 12(1), 462–476.

[3] Cynthia, O. U. (2020). "Implementation of project evaluation and review technique (PERT) and critical path method (CPM): A comparative study." *International Journal of Industrial and Operations Research*, 1(1), 1–9.

[4] Grubbs, F. E. (1962). "Attempts to validate certain PERT statistics or picking on PERT." *Operations Research*, 10(6), 912–915.

[5] Moder, J. J., Phillips, C. R., & Davis, E. (1983). *PROJECT MANAGEMENT with CPM, PERT and Precedence Diagramming* (3rd Edition). Van Nostrand Reinhold.

[6] NIST. (2021). "Kolmogorov-Smirnov goodness-of-fit test." Technical Report. National Institute of Standards and Technology.

[7] Nornadiah, M. R., & Yap, B. W. (2011). "Power comparisons of Shapiro-Wilk, Kolmogorov-Smirnov, Lilliefors, and Anderson-Darling tests." *Journal of Statistical Modeling and Analytics*, 2(1), 21–33.

[8] Simard R, L. P. (2011). "Computing the two-sided Kolmogorov-Smirnov distribution." *Journal of Statistical Software*, 39(11), 1–18.

[9] Wayne, D., & Cottrell, P. (1999). "Simplified program evaluation and review." *Journal of Construction Engineering and Management*, 125(1), 16–22.

[10] Winston, W. L. (2004). *Operations Research APPLICATIONS AND ALGORITHMS* (4th Edition). Brooks/Cole, Thomson Learning.

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp. 424–450, November 13-16, 2023

Mathematical Modeling and Optimal Control Approach to Boko Haram Menace

Solomon Musa [1], Abdulfatai Atte Momoh[2*], Muhammad Adamu Alkali[2], Ali Michael Inalegwu[3]
{musasolomon273@gmail.com[1], abdulfatai@mau.edu.ng[2], alkali3013@gmail.com}

[1]Department of Mathematics, Adamawa State University, Mubi, Nigeria.
[2]Department of Mathematics, Modibbo Adama University, Yola, Nigeria.
[3]Department of Mathematics and Statistics, Federal University Wukari, Wukari, Nigeria.

Abstract
This paper proposes an optimal control of intervention strategies for the Boko Haram menace, taking into account media campaigns against Boko Haram $u_1(t)$, rehabilitation of Boko-Haram detainees $u_3(t)$, , and the deployment of military force against Boko Haram $u_4(t)$, as controls. The Boko-Haram free equilibrium, present equilibrium and the basic Boko-Haram reproduction number R_{0H} were obtained. Based on the results of the stability analysis, it appears that the Boko-Haram free equilibrium is locally asymptotically stable when $R_{0H}<1$ and otherwise when $R_{0H}>1$. The Boko Haram presence equilibrium is globally asymptotically stable when $R_{0H}>1$ and unstable if $R_{0H}<1$. The Boko-Haram model was updated while using the three control strategies. The Pontryagin's Maximum Principle was utilized to control Boko Haram, revealing a significant decrease in leaders, foot soldiers, and recruiters, and recommending government funding for rehabilitation programs.

Keywords: Boko-Haram, Mathematical Modeling, Numerical Simulation, Rehabilitation, Optimal control problem.

1 Introduction

2.3 Boko Haram is an Islamic sect that thinks a gang of corrupt, fraudulent Muslims has taken control of northern Nigerian politics. It aspires to wage war on them, as well as the Federal Republic of Nigeria as a whole, in order to establish a “pure” Islamic state governed by sharia law. Boko Haram has been planting bombs in public places and churches in Nigeria's northeast practically weekly since August 2011. The group's goals have also been expanded to include setting fire to schools. Twelve public schools in Maiduguri were burned down in the middle of the night in March 2012, displacing up to 10,000 students. Nigerian Islamist militant organization, *Jam'at ahl as-sunnah li-d-da'wa wa-l-jihd*, began with young radicals in Maiduguri, Borno state. The group's name, "Boko Harm," translates to "Western education is immoral or a sin," referring to its antagonism to Western civilization and its corrupting Muslims [1].

In 2014, the Islamist extremist group Boko Haram kidnapped 276 schoolgirls in Chibok, shocking Nigeria and the rest of the world. The large number of children taken, as well as the ease with which Boko Haram carried out its attack, drew international condemnation. However, a recent epidemic of mass school kidnappings makes the Chibok girls' ordeal seem less unusual. A few months later, the Bandits abducted around 800 children from four boarding schools in northwest Nigeria in a mass abduction.

Boko Haram, unlike Algeria's al-Qaeda or Somalia's Al Shabab, has not targeted Western interests. Instead, it targets softer targets in the northeast and is likely to become involved in the Jos situation, targeting Christian indigenes from the north. The group's growth has led to changes in enforcement strategy and police reform, with incarcerating officers responsible for human rights violations as a starting step [1]

In the 1980s, Northern Nigerians viewed Muslim acceptance of the 1960 settlement as a mistake. Mohammed Yusuf, born in 1970 as Ustaz, founded Boko Haram in 2002 with the goal of establishing a fully Islamic State in Nigeria. Yusuf gained support by speaking out against poverty and corruption in the Nigerian government. The group's name, Boko Haram, translates to "Western education is a sacrilage."[4]

Boko Haram's main sources of finance include daily levies, loot from bank robberies, oil theft, kidnapping, ransoms, and donations from Nigerian politicians, government officials, and organizations. They also extort money from locals and those they fear [2] [3].

In addition, the majority of the Boko Haram fighters, including Yusuf and Shekau, have benefited from financial support from Borno and the adjacent areas of Cameroon's far northern region. The group rejects democracy and Western education and continues to advocate for Nigeria's Islamization [4].

Various factors lead young people to join Boko Haram. Some of these factors include youths' lack of knowledge about religious teachings against violence making them more susceptible to recruitment, unemployment and poverty, kids from challenging backgrounds are more susceptible to extremist views, a high level of illiteracy linked to youth radicalization and extremism, and widespread corruption supportive of recruitment and radicalization [16].

In [5], the authors introduce a model of criminality and victimization, dividing the human population into three compartments: non-criminal individuals, criminals, and victims of crime. Criminal subpopulations include individuals with compromised moral integrity, core criminals, and those whose crimes warrant reformation or correction. The authors found that implementing the deterministic model can reduce criminal acts.

Consequently, terrorism is no longer a breaking news topic in Africa, and specifically Nigeria. Nigerians have suffered damage from terrorist groups like Boko-Haram. In northeast and central part of Nigeria, Boko-Haram's conflict has killed a lot of people.

As an effort to lessen or address this menace, [6] have explored the dynamics of terrorism using a nonlinear mathematical model. Their major counterterrorism efforts focused on reducing the number of foot soldiers. In the same vein, we also looked at [7] work. Their work is only focused on de-radicalization. To assure de-radicalization, they used law enforcement. They included a treatment compartment in their model, allowing them to analyze de-radicalization.

Therefore, taking into account the operational activities of Boko Haram as well as the numerous complaints from top government officials on the matter, that is the reason why we now came up to study the dynamics of menace caused by the Boko-Haram.

As a result to that, we modified the model due to [6] and [7], by incorporating compartment for Boko Haram leaders, detained Boko-Haram compartment rehabilitated Boko-Haram class in our model. We also incorporate optimal control strategies to reduce the propagation of terrorists' activity. These are media campaign against Boko Haram (u_1), use of military forces on Boko-Haram (u_3) and rehabilitating the detained members (u_4) of the group.

2 Model Formulation

In this section, we formulate the Boko-haram model using the system of nonlinear Ordinary Differential Equations (ODEs). The total population of the Boko-Haram terrorist of our model is denoted by $N(t)$ and is sub-divided into eight sub-population susceptible $S(t)$, moderate Boko Haram population $M_H(t)$, Boko Haram foot soldiers $T_S^H(t)$, Boko Haram leaders $T_L^H(t)$, Boko Haram recruiters $R^H(t)$, detention centre for Boko Haram $D_T^H(t)$, Boko Haram members who have been rehabilitated $R_E^H(t)$ and military forces $M_F(t)$, so that

$$N(t) = S(t) + M^H(t) + T_S^H(t) + T_L^H(t) + R^H(t) + D_T^H(t) + \mathrm{R}_E^H(t) + M_F(t)$$

The following assumptions were made during the formulation of the model:

[11] Military forces (men) can arrest and detain Boko Haram.
[12] Detainees can be rehabilitated and sent to a susceptible population.
[13] As a result of combat and too much casualties due to combat by military, individuals may surrender and moved to rehabilitation centre willingly.
[14] Stubborn Boko Haram individuals are moved to detention centre and latter to rehabilitation centre after excessive torturing.
[15] Every segment of the model has a natural death rate.
[16] The actions of Boko Haram spread through contact.
[17] Through contact, susceptible populations can be transformed into moderate Boko Haram recruiters.
[18] Moderate Boko Haram members can be either foot soldiers or leaders of the group.
[19] Boko Haram leaders cannot be Boko Haram foot soldiers.
[20] Military action against Boko Haram (soldiers, leaders, and recruiters) force the terrorists to flee to prison centers.
[21] Boko Haram soldiers and leaders cannot be moderate Boko Haram members.

Having the above assumptions in mind, the model diagram in Figure 1 and system of differential equations 1 were established as:

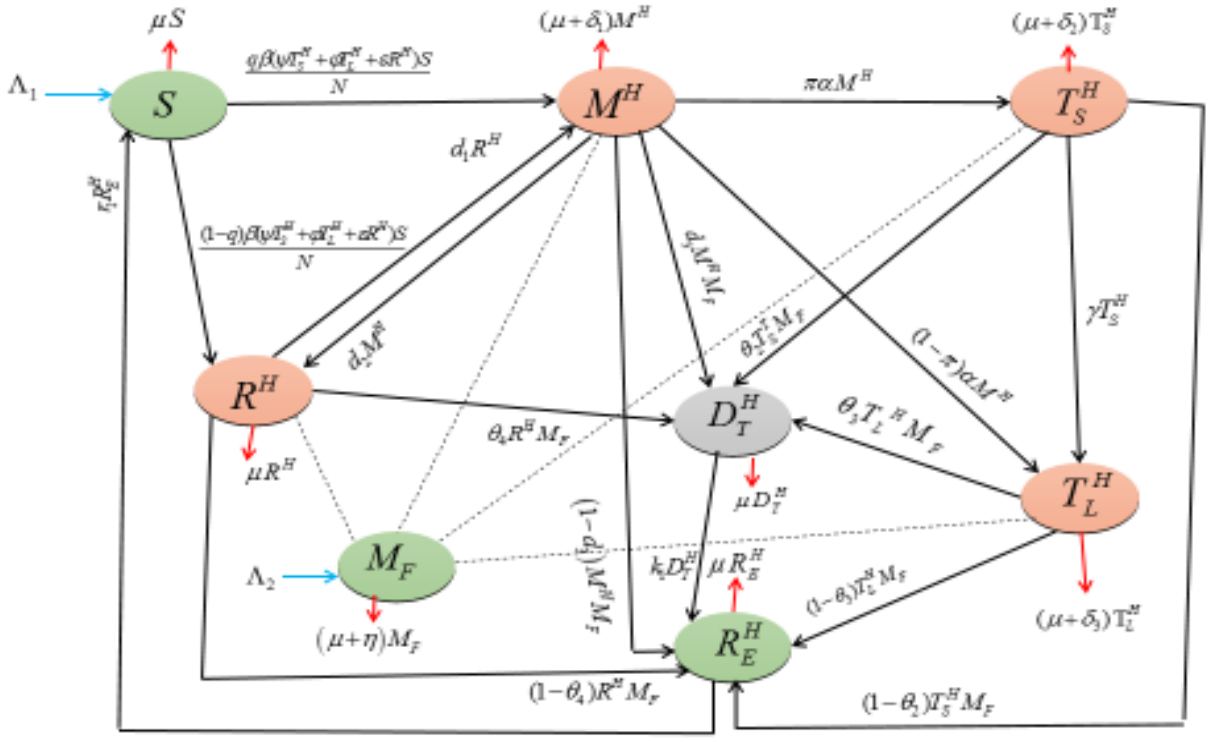


Figure 2.1. Schematic diagram of Boko Haram menace with constant controls.

$$\begin{cases} \dfrac{dS}{dt} = \Lambda_1 + r_1 R_E^H - \dfrac{q\beta(\psi T_S^H + \varphi T_L^H + \varepsilon R^H)S}{N} - \dfrac{(1-q)\beta S(\psi T_S^H + \varphi T_L^H + \varepsilon R^H)}{N} - \mu S \\ \dfrac{dM^H}{dt} = \dfrac{q\beta(\psi T_S^H + \varphi T_L^H + \varepsilon \mathrm{R}^H)S}{N} + d_1 R^H - d_2 M^H - d_3 M^H M_F - (1-d_3) M^H M_F - \pi\alpha M^H \\ \qquad - (1-\pi)\alpha M^H - (\mu+\delta_1) M^H \\ \dfrac{dT_S^H}{dt} = \pi\alpha M^H - \gamma T_S^H - \theta_2 T_S^H M_F - (1-\theta_2) T_S^H M_F - (\mu+\delta_2)\,\mathrm{T}_S^H\,. \\ \dfrac{dT_L^H}{dt} = \gamma T_S^H + (1-\pi)\alpha M^H - \theta_3 T_L^H M_F - (1-\theta_3) T_L^H M_F - (\mu+\delta_3) T_L^H. \\ \dfrac{dR^H}{dt} = \dfrac{(1-q)\beta(\psi T_S^H + \varphi T_L^H + \varepsilon R^H)S}{N} + d_2 M^H - d_1 R^H - \theta_4 R^H M_F - (1-\theta_4) R^H M_F - \mu R^H. \\ \dfrac{dD_T^H}{dt} = \theta_2 T_S^H M_F + \theta_3 T_L^H M_F + \theta_4 R^H M_F + d_3 M^H M_F - k_1 D_T^H - \mu D_T^H. \\ \dfrac{dR_E^H}{dt} = \omega\xi I_B^H M_F + k_1 D_T^H + (1-d_3) M^H M_F + (1-\theta_2) T_S^H M_F + (1-\theta_3) T_L^H M_F \\ \qquad + (1-\theta_4) R^H M_F - r_1 R_E^H - \mu R_E^H. \\ \dfrac{dM_F}{dt} = \Lambda_2 - (\mu+\eta) M_F \end{cases} \tag{1}$$

With the initial conditions

$$\begin{cases} S(0) = S_0(0) \geq 0, \mathrm{M}^H(0) = M_0{}^H(0) \geq 0, \mathrm{T}_S^H(0) = T_S{}^H{}_0(0) \geq 0, \mathrm{T}_L^H(0) = T_L{}^H{}_0(0) \geq 0, \\ \mathrm{R}^H(0) = R_0{}^H(0) \geq 0, \mathrm{D}_T^H(0) = D_T{}^H{}_0(0) \geq 0, \\ R_E^H(0) = R_E{}^H{}_0(0) \geq 0, \mathrm{M}_F(0) = M_{F_0}(0) \geq 0. \end{cases} \tag{2}$$

Recruitment Λ_1 into susceptible population $S(t)$, at time t is done by birth or immigration. The population is also increased by the incoming of rehabilitated members of Boko Haram, $r_1 R_E^H$ from rehabilitation compartments. The population is reduced by adopting Boko Haram and ideologies and moving to a moderate compartment, by the quantity $\dfrac{q\beta(\psi\,\mathrm{T}_S^H + \varphi T_L^H + \varepsilon R_H)S}{N}$ and Boko Haram recruiter class by the quantity $\dfrac{(1-q)\beta(\psi T_S^H + \varphi T_L^H + \varepsilon R_H)S}{N}$. The population further reduced by the natural death rate μ, so that

$$\frac{dS}{dt} = \Lambda_1 + r_1 R_E^H - \frac{q\beta(\psi T_S^H + \varphi T_L^H + \varepsilon R^H)S}{N} - \frac{(1-q)\beta(\psi T_S^H + \varphi T_L^H + \varepsilon R_H)\mathrm{S}}{N} - \mu S \tag{3}$$

The advancement of freshly recruited individuals or those who accepted Boko Haram's ideology from a vulnerable community increases the population of Boko Haram moderates at the quantity $\dfrac{q\beta(\psi\,\mathrm{T}_S^H + \varphi T_L^H + \varepsilon R_H)S}{N}$. The population also increased by progression of Boko Haram recruiters into the moderate class at the rate d_1. The population reduced when some members decided to be recruiters

of Boko Haram and move to the compartment by d_2. It also reduced when some proportion π of moderate class move to the compartment of Boko Haram foot soldiers by the quantity $\pi\alpha M^H$. The population again reduced when some members represented by the quantity $(1-\pi)\alpha M^H$ move to the Boko Haram leaders' compartment, where $(1-\pi)$ the proportion of population that join Boko Haram leaders. Further reduction in the population here resulted when some Boko Haram members at the sight of the military men with heavy weapons and large number of causalities willingly surrender and move to Boko Haram rehabilitation center by the quantity $(1-d_3)\mathrm{M}^H M_F$. The remaining hardened hearted Boko Haram individuals are moved to the Boko Haram detention centre by the parameter d_3. The population again reduced due to the natural death rate μ and death due to military attack on the centre at the rate δ_1, so that

$$\frac{dM^H}{dt} = \frac{q\beta(\psi T_S^H + \varphi T_L^H + \varepsilon \mathrm{R}^H)S}{N} + d_1 R^H - d_2 M^H - \alpha M^H - M^H M_F - (\mu + \delta_1)M^H \qquad (4)$$

The population of Boko Haram foot soldiers at time t, is increased by progression of individuals from moderate class of Boko Haram by the quantity $\pi\alpha M^H$ at the rate, α. The population here has decreased as a result of progression to the Boko Haram leader compartment at a rate of γ and military forces' actions against foot soldiers, who have been sent to the detention apartment at a rate of θ_2. It further reduced when fear catch some Boko Haram foot soldiers then surrendered and progress to Boko Haran rehabilitation centre by the parameter $(1-\theta_2)$. The population also reduced by the natural death rate μ and killings by the military men at the rate, δ_2, so that

$$\frac{dT_S^H}{dt} = \pi\alpha M^H - \gamma T_S^H - \theta_2 T_S^H M_F - (1-\theta_2)T_S^H M_F - (\mu + \delta_2)\mathrm{T}_S^H . \qquad (5)$$

The population of Boko Haram leaders increased due to progression from Boko Haram foot soldiers at the rate γ and from Boko Haram moderate class at the rate of α. This population is reduced due to military attack on Boko Haram leaders that made them to move to Boko Haram detention centre at the rate of θ_2. It further reduced when fear catch some Boko Haram leaders then surrendered and move to Boko Haran rehabilitation centre by the parameter $(1-\theta_2)$. The population also reduced by natural death rate μ and killings due to military forces at the rate of δ_3, so that

$$\frac{dT_L^H}{dt} = \gamma T_S^H + (1-\pi)\alpha M^H - \theta_3 T_L^H M_F - (1-\theta_3)T_L^H M_F - (\mu + \delta_3)T_L^H . \qquad (6)$$

The population of Boko Haram recruiters at time t, $R_H(t)$ is increased due to progression of newly recruited population or individuals from susceptible population at the quantity, $\frac{(1-q)\beta S(\psi T_S^H + \varphi T_L^H + \varepsilon R_H)}{N}$. It is also increased due immigration of moderate Boko Haram members at the rate d_2. The population here is reduced when some members moved to moderate class of Boko Haram at the rate, d_1. It also reduced by military attack on the recruiter compartment at the

rate, θ_4. When fear catch some weak hearted Boko Haram recruiters at the site of Military men, they moved to Boko Haram rehabilitation centre by the parameter It further reduced when fear catch some Boko Haram foot soldiers the surrendered and progress to Boko Haran rehabilitation centre by the parameter $(1-\theta_4)$. The population further reduced due to natural death rate, μ so that

$$\frac{dR^H}{dt} = \frac{(1-q)\beta(\psi T_S^H + \varphi T_L^H + \varepsilon R_H)S}{N} + d_2 M^H - d_1 R^H - R^H M_F - \mu R^H. \tag{7}$$

The number of detained Boko Haram members has risen as a result of military operations against Boko Haram soldiers, leaders, recruiters, and individuals with a combined ideology at the rates $\theta_2, \theta_3, \theta_4$ and θ_5 respectively. The population here also increased by tough minded moderate Boko Haram individuals who refused to surrender. They then moved to the Boko Haram detention compartment at the rate d_3. The population is shrinking as Boko Haram members are being rehabilitated at a rapid pace of k_1. Because of the natural death rate, the population is shrinking even more at, μ, so that

$$\frac{dD_T^H}{dt} = \theta_2 T_S^H M_F + \theta_3 T_L^H M_F + \theta_4 R_H M_F + d_3 M^H M_F - k_1 D_T^H - \mu D_T^H. \tag{8}$$

The population individuals at the Boko Haram rehabilitation centre is increased due to progression of rehabilitated population from Boko Haram detention facilities at the rate k_1. The population also increased by the number of moderate Boko Haram, Boko Haram foot soldiers, Boko Haram leaders and Boko Haram recruiters who willingly surrendered and moved to Boko haram rehabilitation centre at the rate $(1-d_3)$, $(1-\theta_2)$, $(1-\theta_3)$ and $(1-\theta_4)$ respectively. The population here is reduced when the individuals are rehabilitated and moved to the susceptible population at the at the rate, r_1. Natural death rate μ also reduced the population here, so that

$$\frac{dR_E^H}{dt} = k_1 D_T^H + (1-d_3)M^H M_F + (1-\theta_2)T_S^H M_F + (1-\theta_3)T_L^H M_F + (1-\theta_4)R^H M_F - r_1 R_E^H - \mu R_E^H. \tag{9}$$

The population of military forces is increased by government reinforcement of military personnel and other defensive weapons at the rate, Λ_2. The population here is reduced due to natural death μ and killing of military men by Boko Haram or bandits at the rate η, so that

$$\frac{dM_F}{dt} = \Lambda_2 - (\mu + \eta)M_F. \tag{10}$$

The variables, parameters and descriptions are given in tables 1 and 4

Table 1: Variables used in the model

Variables	Description
$S(t)$	Population of susceptible individuals at time t.
$M^H(t)$	Moderate Boko Haram at time t.

$R^H(t)$	Population of Boko Haram recruiters at time t.
$T_S^H(t)$	Population of Boko Haram foot soldiers at time t.
$T_L^H(t)$	Population of Boko Haram leaders at time t.
$D_T^H(t)$	Detention centre for Boko Haram at time t.
$R_E^H(t)$	Rehabilitated Boko Haram individuals at time t.
$M_F(t)$	Number of military forces at time t.

2.1 Basic properties of the model

We demonstrate the fundamental attributes of the Boko-Haram model 1 in this section.

Theorem 1. *Let the initial solution set be*

$$\left\{S_0 \geq 0, M_0{}^H \geq 0, \mathrm{T}_{S\,0}^H \geq 0, T_{L\,0}^H \geq 0, R_0{}^H \geq 0, D_{T\,0}^H \geq 0, R_{E\,0}^H \geq 0, , M_{F0} \geq 0\right\} \in R_+^8,$$

then the solution set

$\left\{S(t), M^H(\mathrm{t}), \mathrm{T}_S^H(\mathrm{t}), T_L^H(\mathrm{t}), R^H(\mathrm{t}), D_T^H(\mathrm{t}), R_E^H(\mathrm{t}), M_F(t)\right\}$ *is positive for all time* $t > 0$

Proof. Since the first equation of the model (1) is

$$\frac{dS}{dt} = \Lambda_1 + r_1 R_E^H - \frac{q\beta(\psi T_S^H + \varphi T_L^H + \varepsilon R^H)S}{N} - \frac{(1-q)\beta S(\psi T_S^H + \varphi T_L^H + \varepsilon R^H)}{N} - \mu S,$$

then,

$$\frac{dS}{dt} \geq -\left[\frac{q\beta(\psi T_S^H + \varphi T_L^H + \varepsilon R^H + \varepsilon R^H)}{N} + \frac{(1-q)\beta(\psi T_S^H + \varphi T_L^H + \varepsilon R^H)}{N} + \mu\right] S \tag{11}$$

which gives

$$\frac{dS}{dt} \geq -\left[\frac{q\beta(\psi T_S^H + \varphi T_L^H + \varepsilon R^H) + (1-q)\beta(\psi T_S^H + \varphi T_L^H + \varepsilon R^H)}{N} + \mu\right] S \tag{12}$$

it results to

$$\frac{dS}{dt} \geq -\left(\frac{\lambda}{N} + \mu\right) S \tag{13}$$

Where

$$\lambda = q\beta(\psi T_S^H + \varphi T_L^H + \varepsilon R^H) + (1-q)\beta(\psi T_S^H + \varphi T_L^H + \varepsilon R^H). \tag{14}$$

Solving equation (13) by the method of separating the variables, integrating the result, taking exponential and applying the initial condition at $t = 0$, we have

$$S(t) \geq S(0) e^{\int -(\frac{\lambda}{N} + \mu)\mathrm{dt}} > 0.$$

For all $t \geq 0$.

Similar technique can be applied to formulate that $M^H(\mathrm{t}), \mathrm{T}_S^H(\mathrm{t}), T_L^H(\mathrm{t}), R^H(\mathrm{t}), D_T^H(\mathrm{t}), R_E^H(\mathrm{t}), M_F(t)$ are positive for all $t > 0$.

Theorem 2. *The solutions of the model (1) with initial conditions as in Theorem 1 satisfy*

$$S_0 > 0, M_0{}^H > 0, \mathrm{T}_{S\,0}^H > 0, T_{L\,0}^H > 0, R_0{}^H > 0, D_{T\,0}^H > 0, R_{E\,0}^H > 0, M_{F0} > 0$$

for all $t \geq 0$. *The region* $\Omega^* \in R_+^8$ *is positively invariant and attracting with respect to the model (1)*

$$N = S + M^H + \mathrm{T}_S^H + T_L^H + R^H + D_T^H + R_E^H + M_F$$

(15)

such that $\Omega = \Omega^* \in R_+^8$

with

$$\Omega^* = \left\{ \begin{array}{l} \left(S, M^H, \mathrm{T}_S^H, T_L^H, R^H, D_T^H R_E^H, M_F\right) \in R_+^8 : S + M^H + \mathrm{T}_S^H + T_L^H + R^H + D_T^H + R_E^H \\ + M_F \le \dfrac{\Lambda_1 + \Lambda_2}{\mu} \end{array} \right\}$$

(16)

Proof. Since $\dfrac{dN}{dt} = \dfrac{d}{dt}\left(S + M^H + \mathrm{T}_S^H + T_L^H + R^H + D_T^H + R_E^H + M_F\right)$

(17)

then,

$$\frac{dN}{dt} = \frac{dS}{dt} + \frac{dM^H}{dt} + \frac{dT_S^H}{dt} + \frac{dT_L^H}{dt} + \frac{dR^H}{dt} + \frac{dD_T^H}{dt} + \frac{dR_E^H}{dt} + \frac{dM_F}{dt}$$

(18)

$$\frac{dN}{dt} \le \Lambda_1 + \Lambda_2 - \mu N$$

(19)

At $\dfrac{dN}{dt} = 0$, equation (19) becomes

$$N = \frac{\Lambda_1 + \Lambda_2}{\mu}$$

(20)

Using separation of variables technique on (19), integrating the result and multiplying both sides by $(-\mu)$, we obtain

$$\ln\left(\Lambda_1 + \Lambda_2 - \mu N\right) \le -\mu(t + C)$$

(21)

Taking the exponent of both sides of (20), applying the initial condition $t = 0,$ we have

$$N(\mathrm{t}) \le \frac{\Lambda_1 + \Lambda_2 - \left(\Lambda_1 + \Lambda_2 - \mu N(0)\right)}{\mu} e^{-\mu t}$$

(22)

As $t \to \infty, e^{-\mu t} \to 0$ in (22), the population size $N \to \dfrac{\Lambda_1 + \Lambda_2}{\mu}$, implying

$$0 \le N \le \frac{\Lambda_1 + \Lambda_2}{\mu}.$$

(23)

Thus, the feasible solution set of the system of the model (1) is positively invariant in the region Ω, hence it is mathematically well-posed. Therefore, it is sufficient to study the dynamic values s of the model in Ω.

Table 2: Parameter description and values used

Parameter	Description	Value	Reference
Λ_1	Constant recruitment rate of susceptible population.	1000	Assumed
Λ_2	Constant recruitment rate of military.	600	[7]
β	Contact rate of Boko Haram soldiers, leaders and recruiters with susceptible population.	0.000007	[8]
q	Progression rate from susceptible to moderate	0.72	Assumed
μ	Natural mortality rate.	0.000034247	[6]
δ_1	Death rate due to military attack on moderate Boko Haram	0.005	Assumed
δ_2	Death rate due to military attack on Boko Haram foot soldiers	0.008	Assumed
δ_3	Death rate due to military attack on Boko Haram leaders	0.00005	Assumed
α	Rate of progression from moderate Boko Haram to Boko Haram foot soldiers	0.12	[6]
η	Death rate of military by Boko Haram	0.02	[8]
π	Proportion of moderate Boko Haram that moved to Boko Haram soldiers	0.9	[6]
k_1	Rate at which detained Boko Haram moved to rehabilitation compartment	0.6	Assumed
γ	Rate at which Boko Haram soldiers become a leader	0.02	[9]
r_1	Transfer rate of rehabilitated Boko Haram to susceptible compartment.	0.5	[10]
d_1	Transfer rate of Boko Haram recruiters to moderate class	0.2	Assumed
d_2	Transfer rate of moderate Boko Haram members to Boko Haram recruiter class	0.4	Assumed
d_3	The rate at which stubborn moderate Boko Haram moved to Boko Haram detention centre	0.4	Assumed
θ_2	The rate at which Boko Haram soldiers moved to Boko Haram detention compartment	0.4	[11]
θ_3	Rate at which captured Boko Haram leader moved to detention class	0.06	Assumed
θ_4	Rate at which captured Boko Haram recruiters moved to Boko Haram detention centre.	0.06	Assumed
ψ	Proportion of susceptible population that can be converted to Boko Haram soldiers	0.4	[11]
φ	Proportion of susceptible population that can be converted to Boko Haram leaders	0.003	[12]
ε	Proportion of susceptible population that can be converted to recruiters	0.4	Assume

P_1	Weight constant for Boko-Haram foot soldiers	65	Assumed
P_2	Weight constant for Boko-Haram leaders	30	Assumed
P_3	Weight constant for Boko-Haram recruiters	45	Assumed
Q_1	Relative cost of media campaign on Boko-Haram	100	Assumed
Q_2	Relative cost of rehabilitation on Boko-Haram	70	Assumed
Q_2	Relative cost military forces on Boko-Haram	30	Assumed

3 Model Analysis

This section identifies the equilibrium points of model (1) and verifies the type of stability that model (1) displays

3.1 Equilibrium points

Setting system (1) to zero yields the equilibrium points derived by model (1) as

$$\begin{cases} 0 = \Lambda_1 + r_1 R_E^H - \dfrac{q\beta(\psi T_S^H + \varphi T_L^H + \varepsilon R^H)}{N} S - \dfrac{(1-q)\beta(\psi T_S^H + \varphi T_L^H + \varepsilon R^H)}{N} S - \mu S \\ 0 = \dfrac{q\beta(\psi T_S^H + \varphi T_L^H + \varepsilon R^H)}{N} S + d_1 R^H - M^H M_F - (d_2 + \alpha + \mu + \delta_1) M^H \\ 0 = \pi\alpha M^H - T_S^H M_F - (\gamma + \mu + \delta_2)\mathrm{T}_S^H \\ 0 = \gamma T_S^H + (1-\pi)\alpha M^H - T_L^H M_F - (\mu + \delta_3) T_L^H \\ 0 = \dfrac{(1-q)\beta(\psi T_S^H + \varphi T_L^H + \varepsilon R^H)}{N} S + d_2 M^H - R^H M_F - (\mathrm{d}_1 + \mu) R^H \\ 0 = \theta_2 T_S^H M_F + \theta_3 T_L^H M_F + \theta_4 R^H M_F + d_3 M^H M_F - (\mu + k_1) D_T^H \\ 0 = k_1 D_T^H + (1-d_3) M^H M_F + (1-\theta_2) T_S^H M_F + (1-\theta_3) T_L^H M_F + (1-\theta_4) R^H M_F - (\mu + r_1) R_E^H \\ 0 = \Lambda_2 - (\mu + \eta) M_F \end{cases} \tag{24}$$

3.1.1 Boko-Haram free equilibrium

The Boko-Haram free equilibrium of the model (1), denoted by E_{0H} is given by

$$E_{oH} = \left(S^o, M^{H^o}, \mathrm{T}_S^{Ho}, T_L^{H^o}, R^{Ho}, D_T^{H^o}, R_E^{H^o}, M_F^o\right) = \left(\frac{\Lambda_1}{\mu}, 0, 0, 0, 0, 0, 0, \frac{\Lambda_2}{\mu + \eta}\right) \tag{25}$$

3.1.2 Boko-Haram presence equilibrium

Let $E_H^* = \left(S^*, M^{H^*}, \mathrm{T}_S^{H^*}, T_L^{H^*}, R^{H^*}, D_T^{H^*}, R_E^{H^*}, M_F{}^*\right)$

be the Boko-Haram presence equilibrium of model (1). Solving system (1) at steady, we get

$$\begin{cases} S^* = \dfrac{(\mu+r_1)(\mu+\eta)\Lambda_1 + r_1[(\mu+r_1)(\mu+\eta)k_1 D_T^{H*} + (1-d_3)M^{H*} + (1-\theta_2)\mathrm{T}_S^{H*} + (1-\theta_3)\mathrm{T}_L^{H*} \\ +(1-\theta_4)R^{H*}]\Lambda_2}{(\mu+r_1)(\mu+\eta)(\lambda_1+\lambda_2+\mu)} \\ M^{H^*} = \dfrac{(\mu+\eta)(\lambda_1 S^* + d_1 R^{H^*})}{(\mu+\eta)[d_2+\alpha+(\mu+\delta_1)]+\Lambda_2} \\ \mathrm{T}_S^{H*} = \dfrac{(\mu+\eta)\pi\alpha M^{H^*}}{(\mu+\eta)\gamma+\Lambda_2+(\mu+\delta_2)(\mu+\eta)} \\ T_L^{H^*} = \dfrac{(\mu+\eta)\left[\lambda T_S^{H^*} + (1-\pi)M^{H^*}\right]}{\Lambda_2+(\mu+\delta_3)(\mu+\eta)}, \\ R^{H^*} = \dfrac{(\mu+\eta)(\lambda_2 S^* + d_2 M^{H^*})}{(\mu+\eta)d_1+\Lambda_2+(\mu+\eta)\mu}, \\ D_T^{H^*} = \dfrac{(\theta_2 T_S^{H^*} + \theta_3 T_L^{H*} + \theta_4 R^{H^*} + +d_3 M^{H^*})\Lambda_2}{(\mu+k_1)(\mu+\eta)} \\ R_E^{H^*} = \dfrac{(\mu+\eta)k_1 D_T^{H^*} + [(1-d_3)M^{H^*} + (1-\theta_2)T_S^{H^*} + (1-\theta_3)T_L^{H^*} + (1-\theta_4)R^{H^*})]\Lambda_2}{(\mu+\mathrm{r}_1)(\mu+\eta)}, \\ M_F{}^* = \dfrac{\Lambda_2}{(\mu+\eta)}, \end{cases} \tag{26}$$

3.2 Basic reproduction number

We derived the basic reproduction number, R_o for model (1) using the approaches in [3], [14], [15] and [16] to get the Jacobian matrices of F and V at Boko-Haram free equilibrium, with F and V represent the matrices that contain new infections and transition terms respectively in model (1). Evaluating at the free equilibrium point, resulted to

$$F = \begin{bmatrix} 0 & \dfrac{q\beta\psi S^0}{N^0} & \dfrac{q\beta\varphi S^0}{N^0} & \dfrac{q\beta\varepsilon S^0}{N^0} \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & \dfrac{(1-q)\beta\psi S^0}{N^0} & \dfrac{(1-q)\beta\varphi S^0}{N^0} & \dfrac{(1-q)\beta\varepsilon S^0}{N^0} \end{bmatrix} \tag{27}$$

and

$$V = \begin{bmatrix} d_2+\alpha+\mu+\delta_1 & 0 & 0 & -d_1 \\ -\alpha\pi & \gamma+\mu+\delta_2 & 0 & 0 \\ -(1-\pi)\alpha & -\gamma & \mu+\delta_3 & 0 \\ -d_2 & 0 & 0 & \mu+d_1 \end{bmatrix} \tag{28}$$

Therefore, the basic reproduction number of the model (1), denoted $R_{0H} = \rho(FV^{-1})$, where ρ is the spectral radius of FV^{-1} is given by

$$R_{0H}=\frac{q\beta\Lambda_1\left(\pi\alpha(\mu+\delta_3)(\mu+d_1)\psi+\left(\gamma+\mu+\delta_2\right)(\mu+d_1)(1-\pi)\alpha\varphi+(\mu+d_1)\pi\alpha\gamma+\left(\gamma+\mu+\delta_2\right)(\mu+\delta_3)\varepsilon\right)}{\Lambda\left(\left(\mu^2+\mu y+\gamma\delta_3+\delta_2\delta_3\right)\left(\mu^2+\mu z+\alpha d_1+\delta_1 d_1\right)\right)}$$
$$+\frac{(1-q)\beta\Lambda_1\left\{d_1\pi\alpha(\mu+\delta_3)\psi+\varphi\left(\gamma+\mu+\delta_2\right)d_1(1-\pi)\alpha+\varphi\pi\alpha\gamma d_1+\varepsilon\left(d_2+\alpha+\mu+\delta_1\right)\left(\gamma+\mu+\delta_2\right)(\mu+\delta_3)\right\}}{\Lambda\left(\left(\mu^2+\mu y+\gamma\delta_3+\delta_2\delta_3\right)\left(\mu^2+\mu z+\alpha d_1+\delta_1 d_1\right)\right)} \tag{29}$$

where

$$y=d_1+d_2+\delta_1+\alpha \text{ and } z=\gamma+\delta_2+\delta_3$$

3.3 Local stability of boko-haram equilibrium point

Theorem 3. *Boko-Haram free equilibrium point is locally asymptotically stable if* $R_{0H}<1$ *and unstable if* $R_{0H}>1$

Proof. Let the Jacobian matrix of the system (1) at Boko-Haram free equilibrium E_{0H} denoted by $J(E_{0H})$

$$J_{E_{0H}}=\begin{bmatrix}
-\mu & 0 & -\frac{\beta\psi\Lambda_1}{\Lambda} & -\frac{\beta\varphi\Lambda_1}{\Lambda} & -\frac{\beta\varepsilon\Lambda_1}{\Lambda} & 0 & r_1 & 0\\
0 & -\left(\frac{\Lambda_2}{(\mu+\eta)}+d_2+\mu+\delta_1\right) & \frac{q\beta\psi\Lambda_1}{\Lambda} & \frac{q\beta\varphi\Lambda_1}{\Lambda} & \frac{q\beta\varepsilon\Lambda_1}{\Lambda} & 0 & 0 & 0\\
0 & \pi\alpha & -\left(\frac{\Lambda_2}{(\mu+\eta)}+\gamma+\mu+\delta_2\right) & 0 & 0 & 0 & 0 & 0\\
0 & (1-\pi) & \gamma & -\left(\frac{\Lambda_2}{\mu+\eta}+a_4\right) & 0 & 0 & 0 & 0\\
0 & d_2 & \frac{(1-q)\beta\psi\Lambda_1}{\Lambda} & \frac{(1-q)\beta\varphi\Lambda_1}{\Lambda} & -\left(\frac{(1-q)\beta\psi\Lambda_1}{\Lambda}+d_1+\frac{\Lambda_1}{\mu+\eta}+\mu\right) & 0 & 0 & 0\\
0 & \frac{d_3}{\mu+\eta} & \frac{\theta_2\Lambda_2}{\mu+\eta} & \frac{\theta_3\Lambda_2}{\mu+\eta} & \frac{\theta_4\Lambda_2}{\mu+\eta} & -(k_1+\mu) & 0 & 0\\
0 & \frac{\theta_6\Lambda_2}{\mu+\eta} & \frac{\theta_7\Lambda_2}{\mu+\eta} & \frac{\theta_8\Lambda_2}{\mu+\eta} & \frac{\theta_9\Lambda_2}{\mu+\eta} & k_1 & -(r_1+\mu) & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -\left(\frac{\rho_3\Lambda_2}{\mu+\eta}+\frac{\Lambda_2}{\mu+\eta}+a_{11}\right)
\end{bmatrix} \tag{30}$$

From matrix $J_{E_{0H}}$, we have $\lambda_1=-\mu<0,\ \lambda_8=-(\mu+\eta)<0$, the matrix $J_{E_{0H}}$ reduced to

$$\begin{bmatrix}
-\left(\frac{\Lambda_2}{(\mu+\eta)}+d_2+\mu+\delta_1\right) & \frac{q\beta\psi\Lambda_1}{\Lambda} & \frac{q\beta\varphi\Lambda_1}{\Lambda} & \frac{q\beta\varepsilon\Lambda_1}{\Lambda} & 0 & 0\\
\pi\alpha & -\left(\frac{\Lambda_2}{(\mu+\eta)}+\gamma+\mu+\delta_2\right) & 0 & 0 & 0 & 0\\
(1-\pi) & \gamma & -\left(\frac{\Lambda_2}{\mu+\eta}+a_4\right) & 0 & 0 & 0\\
d_2 & \frac{(1-q)\beta\psi\Lambda_1}{\Lambda} & \frac{(1-q)\beta\varphi\Lambda_1}{\Lambda} & -\left(\frac{(1-q)\beta\psi\Lambda_1}{\Lambda}+d_1+\frac{\Lambda_1}{\mu+\eta}+\mu\right) & 0 & 0\\
\frac{d_3}{\mu+\eta} & \frac{\theta_2\Lambda_2}{\mu+\eta} & \frac{\theta_3\Lambda_2}{\mu+\eta} & \frac{\theta_4\Lambda_2}{\mu+\eta} & -(k_1+\mu) & 0\\
\frac{\theta_6\Lambda_2}{\mu+\eta} & \frac{\theta_7\Lambda_2}{\mu+\eta} & \frac{\theta_8\Lambda_2}{\mu+\eta} & \frac{\theta_9\Lambda_2}{\mu+\eta} & k_1 & -(r_1+\mu)
\end{bmatrix} \tag{31}$$

From equation (31) also, we further observed that $\lambda_7=-(\mu+r_1)<0, \lambda_6=-(\mu+k_1)<0$, thus

the system (1) will be locally asymptotically stable at $J_{E_{0H}}$ if the remaining eigenvalues satisfy the condition of Routh-Hurwitz from the following characteristic equation of (31) is

$$\lambda^4 + B_1\lambda^3 + B_2\lambda^2 + B_3\lambda + B_4 = 0 \tag{32}$$

where

$$\begin{cases} B_1 = A_1 + A_2 + A_3 + A_4 - M_9 \\ B_2 = A_3(A_1 + A_2) + A_1A_2 + (A_4 - M_9)(A_1 + A_2 + A_3) \\ \quad -(M_1M_4 + M_2M_5 + d_2(M_5 + d_1) \\ B_3 = A_3(A_1A_2 - M_1M_9) + (A_4 - M_9)(A_3(A_1 + A_2) \\ \quad A_1A_2 - M_1M_4 - M_2M_5 - M_2M_5(A_1 + A_2) \\ \quad - M_4M_7(M_3 + d_1) - M_5M_8(M_3 + d_1) + A_1d_2(M_3 + d_1) \\ \quad - d_2(M_3 + d_1)(A_1 + A_2 + A_3) + A_1M_2M_5 - M_2M_4M_6 \\ B_4 = A_2A_3(A_1A_4 - d_1d_2)(1 - R_{0H}) \end{cases} \tag{33}$$

Using the Routh- Hurwitz which states that all roots of the polynomial (31) have negative real parts if and only if the coefficient B_i are positive and matrix $H_i > 0$ for $i = 0,1,2,3,4$

From (31), it is easy to see that $B_3 > 0$, $B_2 > 0$, $B_1 > 0$ and $B_0 > 0$ since A_i's are positive. Further, if $R_{0H} < 1$, it follows from (31) that $B_4 > 0$. Also, the Hurwitz matrix for the polynomial in (30) are found to be positive, that is

As a result, all the eigenvalues of the Jacobian matrix J_{E_0} have negative real parts when $R_{0H} < 1$ and the Boko-Haram-free equilibrium point is locally asymptotically stable [17]. However, when $R_{0H} < 1$, we see that $B_0 > 1$ and by Descartes' rule of signs, there is exactly one sign change in the sequence, B_0, B_1, B_2, B_3, B_4, of coefficients of the polynomial in (31). Therefore, since one eigenvalue has a positive real part, the Boko-Haram-free equilibrium point is unstable.

3.4 Boko-Haram presence global stability

In this section, we investigate the global asymptotic stability of the Boko-Haram for model (1) using the Lyapunov function in [18], [19] and [20].

Theorem 4. *If $R_{0H} > 1$, then the Boko-Haram present equilibrium is globally asymptotically stable and unstable if $R_{0H} < 1$.*

Proof. Consider the Lyapunov function defined by

$$\begin{cases} L(V) = (\mathrm{S} - \mathrm{S}^* - \mathrm{S}^* \ln \frac{S^*}{S}) + (\mathrm{M}^H - M^{H*} - M^{H*} \ln \frac{M^{H*}}{M^H}) + (T_S^H - T_S^{H*} - T_S^{H*} \ln \frac{T_S^{H*}}{T_S^H}) \\ \quad + (\mathrm{T}_L^H - \mathrm{T}_L^{H*} - \mathrm{T}_L^{H*} \ln \frac{\mathrm{T}_L^{H*}}{\mathrm{T}_L^H}) + (\mathrm{R}^H - \mathrm{R}^{H*} - \mathrm{R}^{H*} \ln \frac{\mathrm{R}^{H*}}{\mathrm{R}^H}) + \mathrm{M}_F - \mathrm{M}_F{}^* - M_F{}^* \ln \frac{M_F{}^*}{\mathrm{M}_F} \end{cases} \tag{34}$$

The derivatives of the L along the solution of the system of equations is

$$\frac{dL}{dt}=\left(1-\frac{S^*}{S}\right)\frac{dS}{dt}+\left(1-\frac{M^{H*}}{M^H}\right)\frac{dM^H}{dt}+\left(1-\frac{T_S^{H*}}{T_S^H}\right)\frac{dT_S^H}{dt}+\left(1-\frac{T_L^{H*}}{T_L^H}\right)\frac{dT_L^H}{dt}+\left(1-\frac{R^{H*}}{R^H}\right)\frac{dR^H}{dt}+\left(1-\frac{M_F{}^*}{M_F}\right)\frac{dM_F}{dt} \tag{35}$$

After rigorous expansion and rearranging, we have

$$\begin{cases}\frac{dL}{dt}=\mu\left(2-\frac{S^*}{S}-\frac{S}{S^*}\right)+\beta\psi T_S^{H*}S^*\left(1-\frac{S^*}{S}\right)+\beta\varphi T_L^{H*}S^*\left(1-\frac{S^*}{S}\right)+\beta\varepsilon R^{H*}S^*\left(1-\frac{S^*}{S}\right)+r_1R_E^H\left(1-\frac{R^{H*}}{R^H}\right)\\ \quad+r_1R_E^H\frac{S^*}{S}\left(1-\frac{R^H}{R^{H*}}\right)+\beta\varphi T_L^{H*}S^*\left(1-\frac{S}{S^*}\right)+\beta\varepsilon R^{H*}S^*\left(1-\frac{S}{S^*}\right)+q\beta\varphi T_L^{H*}S\left(1-\frac{M^{H*}}{M^H}\right)+d_1R^*\left(1-\frac{M^{H*}}{M^H}\right)\\ \quad+\beta\varepsilon R^{H*}S\left(1-\frac{M^{H*}}{M^H}\right)+M_FM^{H*}\left(1-\frac{M^H}{M^{H*}}\right)+\pi\alpha M^H\left(1-\frac{T_S^{H*}}{T_S^H}\right)+\pi\alpha M^H\left(1-\frac{T_S^H}{T_S^{H*}}\right)+\gamma T_S^H\left(1-\frac{T_L^{H*}}{T_L^H}\right)\\ \quad+(\mu+M_F+\delta_3)T_L^{H*}\left(1-\frac{T_L^H}{T_L^{H*}}\right)+(1-\pi)\alpha M^H\left(1-\frac{T_L^{H*}}{T_L^H}\right)+(1-q)\beta\varphi T_S^{H*}S\left(1-\frac{R^{H*}}{R^H}\right)+(1-q)\beta\varphi T_S^HS\left(1-\frac{R^{H*}}{R^H}\right)\\ \quad+(1-q)\beta\varepsilon R^HS\left(1-\frac{R^{H*}}{R^H}\right)+d_2M^H\left(1-\frac{R^{H*}}{R^H}\right)+(M_F+\mu+d_1)R^{H*}\left(1-\frac{R^H}{R^{H*}}\right)+(\mu+\gamma)M_F^*\left(2-\frac{M_F}{M_F^*}-\frac{M_F^*}{M_F}\right)\end{cases} \tag{36}$$

Since the geometric mean is less than the arithmetic mean [21], the following inequality from equation (36) holds

$$\frac{S}{S^*}-\frac{S^*}{S}\geq 2,\ 1\leq\frac{S^*}{S},\ 1\leq\frac{S}{S^*},1\leq\frac{R^H}{R^{H*}},1\leq\frac{R^{H*}}{R^H},1\leq\frac{M^{H*}}{M^H},1\leq\frac{M^H}{M^{H*}},1\leq\frac{T_S^{H*}}{T_S^H},$$

$$1\leq\frac{T_S^H}{T_S^{H*}},1\leq\frac{T_L^H}{T_L^{H*}},1\leq\frac{T_L^{H*}}{T_L^H},1\leq\frac{R^{H*}}{R^H},1\leq\frac{R^H}{R^{H*}},1\leq\frac{M_F}{M_F^*},1\leq\frac{M_F^*}{M_F},$$

Therefore, $\frac{dL}{dt}\leq 0$ for $R_{0H}>1$ and $\frac{dL}{dt}=0$ if and only if

$S=S^*, M^H=M^{H*}, T_S^H=T_S^{H*}, T_L^H=T_L^{H*}, R^H=R^{H*}, M_F=M_F^*$

Hence, L is a Lyapunov function on the region of the system which agrees with the LaSalle's Principle, which states that every solution to the equations of the model tends to endemic equilibrium of the model as $t\to\infty$ for $R_{0H}>1$. Therefore, the Boko-Haram presence equilibrium point is globally asymptotically stable in the invariant region Ω if $R_{0H}>1$.

4 Sensitivity Analysis

We used the parameter values on table 4.1 to calculate the sensitivity index of Boko-Haram model. The sensitivity indices of the basic reproduction number are calculated in order to determine how important each parameter is in the initiation of Boko-Haram: that is, in the control of Boko-Haram, the parameters that have the greatest influence on the basic reproduction number, as well as intervention strategies that target such parameter, should be used.

We adopted the local sensitivity analysis based on the normalized forward sensitivity index R_{0H}. The sensitivity index R_{0H}.with respect the parameters in our model are derived as

$$S_{\alpha}^{R_0} = \frac{\partial R_0}{\partial \eta} \times \frac{\alpha}{R_0} \tag{37}$$

and applied as follows:- for parameter μ its sensitivity index is

$$S_{\alpha}^{R_{0H}} = \frac{\partial R_{0H}}{\partial \alpha} \times \frac{\alpha}{R_{0H}} = \frac{\partial\left(\frac{q\beta\Lambda_1\left(\pi\alpha J_3 J_4 \psi + J_2 J_4 (1-\pi)\alpha\varphi + J_4 \pi\alpha\gamma + J_2 J_3 \varepsilon\right)}{\Lambda\left(J_2 J_3 (J_1 J_4 - d_1 d_2)\right)}\right)}{\partial \alpha} \times \frac{\alpha\Lambda\left(J_2 J_3 (J_1 J_4 - d_1 d_2)\right)}{q\beta\Lambda_1\left(\pi\alpha J_3 J_4 \psi + J_2 J_4 (1-\pi)\alpha\varphi + J_4 \pi\alpha\gamma + J_2 J_3 \varepsilon\right)}$$
$$= 0.12093 \tag{38}$$

The remaining sensitivity indices of the Boko-Haram are obtained in a similar way and the results is presented in table 3

Table 3. Sensitivity index for basic reproduction number for Boko Haram

Parameter	Value	Sensitivity Index
β	0.000007	+0.0023
Λ_1	1000	-1
Λ_2	600	-0.57681
μ	0.000034247	+2.8407
Λ_1	1000	+0.00233
d_2	0.4	+0.3049
π	0.9	+0.0040
γ	0.02	+0.0864
φ	0.003	+0.509
ε	0.4	+0.9163
α	0.12	+ 0.12093
q	0.72	+0.0032
ψ	0.4	+0.00098
δ_3	0.008	+0.1420
δ_2	0.6	+1.6374
δ_1	0.005	+0.0114
d_1	0.2	+0.5198

We observed from table 4.1 that the parameters β , Λ_1, μ , d_2, γ, φ , ε, α , ψ , δ_3, δ_2, $\delta_1$and d_1 are all having positive indices which means that increasing any one of these leads the raise in the reproduction number of Boko Haram, as a result of that, increase the chance of Boko Haram activities. Contrary, the parameters, Λ , π and q have negative indices indicating that increasing one of these parameters while maintaining the others reduces effective reproduction number, hence lowering the activities of Boko Haram in our communities.

5 Optimal Control Analysis

The optimal control interventions for effective control of the Boko Haram menace is presented in this section. From the result of the sensitivity analysis carried out, we observed that some parameters in the model have impact on basic reproduction number of Boko-Haram R_{0H}.

To address it, some controls are incorporated in the model to have

$$\begin{cases} \frac{dS}{dt} = \Lambda_1 + r_1 R_E^H - \frac{(1-u_1)q\beta(\psi T_S^H + \varphi T_L^H + \varepsilon R^H)S}{N} - \frac{(1-u_1)(1-q)\beta(\psi T_S^H + \varphi T_L^H + \varepsilon \mathrm{R}^H)\mathrm{S}}{N} - \mu S \\ \frac{dM^H}{dt} = \frac{(1-u_1)q\beta(\psi T_S^H + \varphi T_L^H + \varepsilon \mathrm{R}^H)S}{N} + d_1 R^H - d_2 M^H - u_3 d_3 M^H M_F - \alpha M^H - (\mu + \delta_1) M^H \\ \frac{dT_S^H}{dt} = \pi\alpha M^H - \gamma T_S^H - u_3 T_S^H M_F - (\mu + u_3\delta_2)\mathrm{T}_S^H \\ \frac{dT_L^H}{dt} = \gamma T_S^H + (1-\pi)\alpha M^H - u_3 T_L^H M_F - (\mu + u_3\delta_3) T_L^H \\ \frac{dR^H}{dt} = \frac{(1-\mathrm{u}_1)(1-q)\beta(\psi T_S^H + \varphi T_L^H + \varepsilon R^H)S}{N} + d_2 M^H - d_1 R^H - u_3 R^H M_F - \mu R^H \\ \frac{dD_T^H}{dt} = u_3\theta_2 T_S^H M_F + u_3\theta_3 T_L^H M_F + u_3\theta_4 R^H M + u_3 d_3 M^H M_F - u_4 k_1 D_T^H - \mu D_T^H \\ \frac{dR_E^H}{dt} = u_4 k_1 D_T^H + u_3(1-d_3) M^H M_F + u_3(1-\theta_2) T_S^H M_F + u_3(1-\theta_3) T_L^H M_F + u_3(1-\theta_4) R^H M_F - r_1 R_E^H - \mu R_E^H \\ \frac{dM_F}{dt} = \Lambda_2 - (\mu + \eta) M_F \end{cases} \tag{39}$$

The steps due to [17] is adopted to formulate the objective functional J for the Boko Haram menace model to investigate the optimal level of the effort required to control the Boko Haram menace. Here, we introduce three control measures, namely, mass campaign against Boko- Haram $u_1(t)$, use of military force against Boko Haram $u_3(t)$, and rehabilitation of Boko Haram detainees $u_4(t)$. Thus the objective functional J is

$$J(u_{1,3,4}) = \int_0^{tf} (P_1 T_S^H + P_2 T_L^H + P_3 R^H + \frac{1}{2} Q_1 \mathrm{u}_1^2 + \frac{1}{2} Q_2 \mathrm{u}_3^2 \frac{1}{2} Q_3 \mathrm{u}_4^2) dt \tag{40}$$

where t_f is the final time and the coefficient $P_1, P_2, P_3, Q_1, Q_2, Q_3$ are positive weight to balance the factors. Our major aim is to minimize the number of Boko Haram soldiers' T_S^H, number of Boko Haram leaders T_L^H and Boko Haram leaders R^H in the society while we keep cost of controls $u_1(t)$, $u_3(t)$, and $u_4(t)$ at a very low cost. Thus seek an optimal controls u_1^*, u_3^*, u_4^* such that

$J(u_i^*) = \min\{J(u_i) : \mathrm{u}_i \in U\}, i = 1,3,4$

where U is the set of all measurable functions defined from $[0, t_f]$ onto $[0,1]$.

The necessary conditions that an optimal control must satisfy were derived from Pontryangin's Maximum Principle (PMP) [22] and the existence result for optimal control from the adjoint variable of the state variables satisfy the following set of differential equations. This principle converts system (1) into a problem of minimizing point-wise a Hamiltonian H, with respect to the controls (u_1, u_3, u_4,). The Hamiltonian is given by

$$
\begin{cases}
H = P_1 T_L^H + P_2 T_L^H + P_3 R^H + \frac{1}{2} Q_1 u_1^2 + \frac{1}{2} Q_2 u_3^2 + \frac{1}{2} Q_3 u_4^2 \\
+\lambda_S \left[\Lambda_1 + r_1 R_E^H - - \frac{(1-u_1) q \beta (\psi T_S^H + \varphi T_L^H + \varepsilon R^H) S}{N} - \frac{(1-u_1)(1-q)\beta(\psi T_S^H + \varphi T_L^H + \varepsilon \mathrm{R}^H)\mathrm{S}}{N} - \mu S \right] \\
+\lambda_{M^H} \left[\frac{(1-u_1) q \beta (\psi T_S^H + \varphi T_L^H + \varepsilon \mathrm{R}^H) S}{N} + d_1 R^H - d_2 M^H - u_3 d_3 M^H M_F - \alpha M^H - (\mu + \delta_1) M^H \right] \\
+\lambda_{T_S^H} \left[\pi \alpha M^H - \gamma T_S^H - u_3 T_S^H M_F - (\mu + u_3 \delta_2) \mathrm{T}_S^H \right] \\
+\lambda_{T_L^H} \left[\gamma T_S^H + (1-\pi) \alpha M^H - u_3 T_L^H M_F - (\mu + u_3 \delta_3) T_L^H \right] \\
+\lambda_{R^H} \left[\frac{(1-\mathrm{u}_1)(1-q)\beta(\psi T_S^H + \varphi T_L^H + \varepsilon R^H) S}{N} + d_2 M^H - d_1 R^H - u_3 R^H M_F - \mu R^H \right] \\
+\lambda_{D_T^H} \left[u_3 \theta_2 T_S^H M_F + u_3 \theta_3 T_L^H M_F + u_3 \theta_4 R^H M + u_3 d_3 M^H M_F - u_4 k_1 D_T^H - \mu D_T^H \right] \\
+\lambda_{R_E^H} \left[u_4 k_1 D_T^H + u_3 (1-d_3) M^H M_F + u_3 (1-\theta_2) T_S^H M_F + u_3 (1-\theta_3) T_L^H M_F + u_3 (1-\theta_4) R^H M_F - r_1 R_E^H - \mu R_E^H \right] \\
+\lambda_{M_F} \left[\Lambda_2 - (\mu + \eta) M_F \right]
\end{cases}
\tag{41}
$$

where λ_S, λ_{M^H}, $\lambda_{T_S^H}$, $\lambda_{T_L^H}$, λ_{R^H}, $\lambda_{D_T^H}$, $\lambda_{R_E^H}$, λ_{M_F}, are adjoint variables and

$N = S + M^H + T_S^H + T_L^H + R^H + D_T^H + R_E^H + M_F$

Theorem 5. *Let* u_1^*, u_3^*, *and* u_4^*, *be optimal controls and let* $S^*, M^{H*}, T_S^{H*}, T_L^{H*}, R^{H*}, D_T^{H*}, R_E^{H*}, M_F$, *be the solutions of the optimal control problems of (38) and (39) that minimizes* $J(u_1, u_3, u_4,)$ *over* U, *then there exists adjoint variables* $i = S, M^H, T_S^H, T_L^H, R^H, D_T^H, R_E^H, M_F$ *that satisfies*

$$
\frac{d\lambda_i}{dt} = -\frac{\partial H}{\partial \lambda_i} \tag{42}
$$

where λ_i *for* $i = S, M^H, T_S^H, T_L^H, R^H, D_T^H, R_E^H, M_F$ *are the adjoint variables and the controls* u_1^*, u_3^*, *and* u_4^* *obey the optimal conditions, such that*

$$
u_1^* = \max \left\{ 0, \min \left(1, \frac{q\beta W^* S^* \left(\lambda_{M^H} - \lambda_S \right) + (1-q)\beta W^* S^* \left(\lambda_{R^H} - \lambda_S \right)}{Q_1 N^*} \right) \right\}
$$

$$u_3^* = \max\left\{0, \min\left(1, \frac{\begin{array}{l} M^H M_F\left(\lambda_{M^H} - \lambda_{R_E^H}\right) + T_S^H M_F\left(\lambda_{T_S^H} - \lambda_{R_E^H}\right) + T_L^H M_F\left(\lambda_{T_L^H} - \lambda_{R_E^H}\right) + R^H M_F\left(\lambda_{R^H} - \lambda_{R_E^H}\right) \\ + d_3 M^H M_F\left(\lambda_{R_E^H} - \lambda_{D_T^H}\right) + \theta_2 T_S^H M_F\left(\lambda_{R_E^H} - \lambda_{D_T^H}\right) + \theta_3 T_L^H M_F\left(\lambda_{R_E^H} - \lambda_{D_T^H}\right) \\ + \theta_4 R^H M_F\left(\lambda_{R_E^H} - \lambda_{D_T^H}\right) + \delta_3 T_L^H \lambda_{T_L^H} \end{array}}{Q_2}\right)\right\}$$

$$u_4^* = \max\left\{0, \min\left(1, \frac{\left(\lambda_{D_T^H} - \lambda_{R_E^H}\right) k_1 D_T^{H*}}{Q_3}\right)\right\}$$

Proof. To obtain the differential equations that governs the adjoint variable, we assessed the differential Hamiltonian functions at the optimal control. Hence, we have

$$\begin{cases} \dfrac{\partial H}{\partial S} = \dfrac{(1-u_1)q\beta(\psi T_S^H + \varphi T_L^H + \varepsilon R^H)S}{N}(\lambda_S - q\lambda_{M^H}) + \dfrac{(1-u_1)(1-q)\beta(\psi T_S^H + \varphi T_L^H + \varepsilon \mathrm{R}^H)\mathrm{S}}{N}(\lambda_S - \lambda_{R^H}) \\ \quad + \mu\lambda_S \\ \dfrac{\partial H}{\partial M^H} = d_1(\lambda_{M^H} - \lambda_{R^H}) + \mathrm{u}_3 M_F(\lambda_{M^H} - \lambda_{R_E^H}) + \alpha(\lambda_{M^H} - \lambda_{T_L^H}) + \alpha\pi(\lambda_{T_L^H} - \lambda_{T_S^H}) + \mathrm{u}_3 d_3 M_F(\lambda_{R_E^H} - \lambda_{D_T^H}) \\ \quad + (\mu + \delta_1)\lambda_{M^H} \\ \dfrac{\partial H}{\partial T_S^H} = \dfrac{(1-u_1)q\beta\psi S}{N}(\lambda_S - \lambda_{M^H}) + \dfrac{(1-u_1)(1-q)\beta\psi \mathrm{S}}{N}(\lambda_S - \lambda_{R^H}) + \gamma(\lambda_{T_L^H} - \lambda_{T_S^H}) + \mathrm{u}_3 M_F(\lambda_{T_S^H} - \lambda_{R_E^H}) \\ \quad + \mathrm{u}_3\theta_2 M_F(\lambda_{R_E^H} - \lambda_{D_T^H}) + (\mu + u_3\delta_2)\lambda_{T_S^H} - P_1 \\ \dfrac{\partial H}{\partial T_L^H} = \dfrac{(1-u_1)q\beta\varphi S}{N}(\lambda_S - \lambda_{M^H}) + \dfrac{(1-u_1)(1-q)\beta\varphi \mathrm{S}}{N}(\lambda_S - \lambda_{R^H}) + \mathrm{u}_3 M_F(\lambda_{T_L^H} - \lambda_{R_E^H}) + \mathrm{u}_3\theta_3 M_F(\lambda_{R_E^H} - \lambda_{D_T^H}) \\ \quad + (\mu + u_3\delta_3)\lambda_{T_L^H} - P_2 \\ \dfrac{\partial H}{\partial R^H} = \dfrac{(1-u_1)q\beta\varepsilon S}{N}(\lambda_S - \lambda_{M^H}) + \dfrac{(1-u_1)(1-q)\beta\varepsilon \mathrm{S}}{N}(\lambda_S - \lambda_{R^H}) + \mathrm{u}_3 M_F(\lambda_{R^H} - \lambda_{R_E^H}) + d_1(\lambda_{R^H} - \lambda_{M^H}) \\ \quad + \mathrm{u}_3\theta_4 M_F(\lambda_{R_E^H} - \lambda_{D_T^H}) + \mu\lambda_{R^H} - P_3 \\ \dfrac{\partial H}{\partial D_T^H} = \mathrm{u}_3 u_4 k_1(\lambda_{D_T^H} - \lambda_{R_E^H}) + \mu\lambda_{D_T^H} \\ \dfrac{\partial H}{\partial R_E^H} = r_1(\lambda_{T_S^H} - \lambda_{R_E^H}) + \mu\lambda_{R_E^H} \\ \dfrac{\partial H}{\partial M_F} = \mathrm{u}_3 M_F(\lambda_{M^H} - \lambda_{R_E^H}) + u_3 T_S^H(\lambda_{T_S^H} - \lambda_{R_E^H}) + \mathrm{u}_3 T_L^H(\lambda_{T_L^H} - \lambda_{R_E^H}) + \mathrm{u}_3 R^H(\lambda_{R^H} - \lambda_{R_E^H}) + \mathrm{u}_3 d_3 M^H(\lambda_{R_E^H} - \lambda_{D_T^H}) \\ \quad + \mathrm{u}_3\theta_2 T_S^H(\lambda_{R_E^H} - \lambda_{D_T^H}) + \mathrm{u}_3\theta_3 T_L^H(\lambda_{R_E^H} - \lambda_{D_T^H}) + \mathrm{u}_3\theta_4 R^H(\lambda_{R_E^H} - \lambda_{D_T^H}) - (\mu + \eta)\lambda_{M_F} \end{cases}$$

(43)

with transversality conditions:

$$\left.\begin{array}{l} \lambda_S(t_f) = \lambda_{M^H}(t_f) = \lambda_{T_S^H}(t_f) = \lambda_{T_L^H}(t_f) = \lambda_{R^H}(t_f) = \lambda_{D_T^H}(t_f) \\ = \lambda_{R_T^H}(t_f) = \lambda_{M_F}(t_f) = 0 \end{array}\right\}$$

(44)

The optimal functions u_1^*, u_3^*, and u_4^*, which satisfies

$$\frac{\partial H}{\partial u_i} = 0, \ i = 1,3,4.$$

(45)

Let $W^* = \left(\psi T_S^{H^*} + \varphi T_L^{H^*} + \varepsilon R^{H^*}\right)$

(46)

Therefore,

$$u_1^* = \frac{q\beta W^* S^* \left(\lambda_{M^H} - \lambda_S\right) + (1-q)\beta W^* S^* \left(\lambda_{R^H} - \lambda_S\right)}{Q_1 N^*}$$

(47)

$$u_3^* = \frac{\begin{pmatrix} M^{H^*} M_F^* \left(\lambda_{M^H} - \lambda_{R_E^H}\right) + T_S^{H^*} M_F^* \left(\lambda_{T_S^H} - \lambda_{R_E^H}\right) + T_L^{H^*} M_F^* \left(\lambda_{T_L^H} - \lambda_{R_E^H}\right) \\ + R^{H^*} M_F^* \left(\lambda_{R^H} - \lambda_{R_E^H}\right) + d_3 M^{H^*} M_F^* \left(\lambda_{R_E^H} - \lambda_{D_T^H}\right) + \theta_2 T_S^{H^*} M_F^* \left(\lambda_{R_E^H} - \lambda_{D_T^H}\right) \\ + \theta_3 T_L^{H^*} M_F^* \left(\lambda_{R_E^H} - \lambda_{D_T^H}\right) + \theta_4 R^{H^*} M_F^* \left(\lambda_{R_E^H} - \lambda_{D_T^H}\right) + \delta_3 T_L^{H^*} \lambda_{T_L^H} \end{pmatrix}}{Q_2}$$

(48)

$$u_4^* = \frac{(\lambda_{R_E^H} - \lambda_{D_T^H}) k_1 D_T^{H^*}}{Q_3}$$

(49)

Based on the earlier boundedness of the system (38) and the adjoint system (40) [23], we get the uniqueness of the optimality systems (43), (44) and (47)-(49). To ascertain the uniqueness of the optimality system, we considered the length of the time interval $\left[0, t_f\right]$ [11]. We ended by the standard central argument taking into account the bounds in the control, we get What is the Vancouver reference style

$$u_1^* = \begin{cases} 0 & if \quad u_1^* \le 0 \\ u_1^* & if \quad 0 \le u_1^* \le 1 \\ 1 & if \quad u_1^* \ge 1 \end{cases} \quad u_3^* = \begin{cases} 0 & if \quad u_3^* \le 0 \\ u_3^* & if \quad 0 \le u_3^* \le 1 \\ 1 & if \quad u_3^* \ge 1 \end{cases} \quad u_4^* = \begin{cases} 0 & if \quad u_4^* \le 0 \\ u_4^* & if \quad 0 \le u_4^* \le 1 \\ 1 & if \quad u_4^* \ge 1 \end{cases}$$

(50)

6 Computational Results

This section talks about how interventions affect how Boko-Haram spreads among a population. We adopted the strategy provided by [23] and [11] to quantitatively solve the optimal control systems (42), (43) and the adjoint variable (40). The Runge-Kutta forward and backward approach is used in these procedures. We employ the variables and parameter values in table 5.1 to reduce or eliminate the Boko-Haram population. The work will take place over the course of thirty (30) months. The simulations in Figures 5.1–5.4 demonstrate how the following intervention strategies can be used:

i. Strategy A: Media campaign and Rehabilitation of Boko-Haram

ii. Strategy B: Media campaign and use of military force against Boko-Haram

iii. Strategy C: Rehabilitation of Boko-Haran and use of Military forces.

vi. Strategy D: Media campaign, rehabilitation of Boko-Haram and use of military forces.

Table 4: Initial values for variables used in the model

variables	Value	Reference
$S(0)$	3000	[8]
$\mathrm{M}^{H}(0)$	300	[6]
$T_S^H(0)$	120	[6]
$T_L^H(0)$	5	[6]
$R^H(0)$	100	Assumed
$D_T^H(0)$	100	[6]
$R_E^H(0)$	350	Assumed
$M_F(0)$	700	[8]

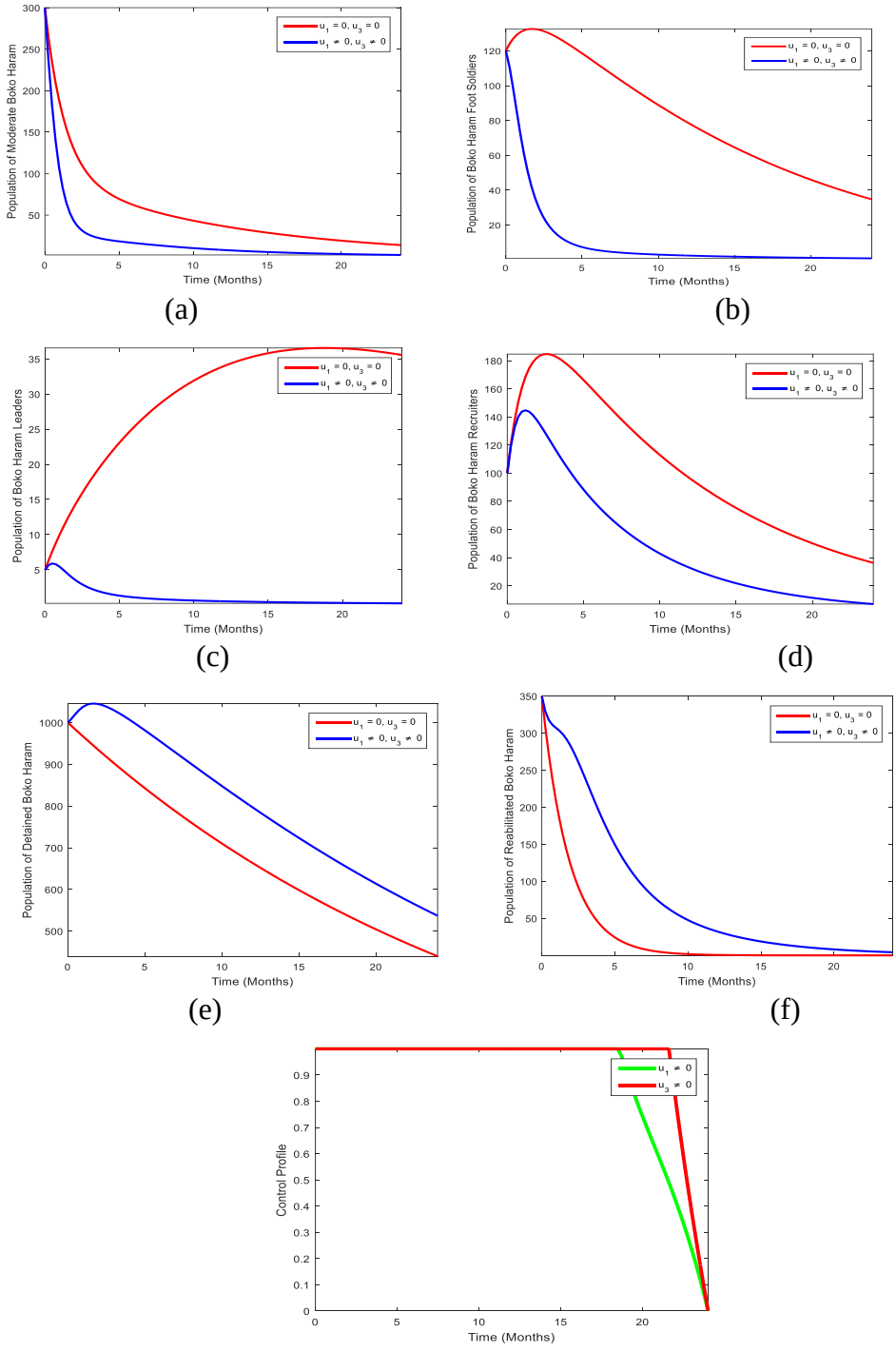
Strategy A: Media campaign against Boko-Haram and rehabilitation

When the use of military force is set at zero, intervention strategy A shows the simulation of an optimal control system (39) for the implementation of a media campaign against Boko-Haram (u_1) and the rehabilitation of Boko-Haram (u_3). It was observed from Fig. 5.1 (a,b,c,d) that in the absence of media campaign against Boko-Haram (u_1) and the rehabilitation of Boko-Haram (u_3), indicated by red line, the population of moderate Boko-Haram (M^H), Boko-Haram foot soldiers (T_S^H), Boko-Haram leaders (T_L^H), and Boko-Haram recruiters (R^H) are at higher level, but that of detained Boko-Haram (D_T^H) and rehabilitated Boko-Haram, (R_E^B) are at lower level. When the method is applied (indicated by blue line) compared to the scenario without control, we see a drop in the population of moderate Boko-Haram (M^H), Boko-Haram foot soldiers (T_S^H), Boko-Haram leaders (T_L^H), and Boko-Haram recruiters (R^H), but the population of detained Boko-Haram (D_T^H) and rehabilitated Boko-Haram, (R_E^B) increased as shown in Figure 5.1(e,f) . The control profile for strategy A is shown in Figure 5.1 (g). The control curve for both media campaign against Boko-Haram and its rehabilitation remains at the extreme higher bound before it drops to the lower bound after twenty five months and twenty eight months respectively.

Strategy B: Media campaign and use of military force against Boko-Haram

When the use of rehabilitation of Boko-Haram is set at zero, intervention strategy B shows the simulation of an optimal control system (39) for the implementation of a media campaign against Boko-Haram (u_1) and the military forces (u_4). We observed from Figure 5.2 (a,b,c,d) that in the absence of media campaign against Boko-Haram (u_1) and the use of military forces against Boko-Haram (u_4), indicated by red line, the population of moderate Boko-Haram (M^H), Boko-Haram foot soldiers (T_S^H), Boko-Haram leaders (T_L^H), and Boko-Haram recruiters (R^H) are at higher level, but that

of detained Boko-Haram (D_T^H) and rehabilitated Boko-Haram, (R_E^B) is at lower level. When the method is applied (indicated by blue line) compared to the scenario without control, there is a drop in the population of moderate Boko-Haram (M^H), Boko-Haram foot soldiers (T_S^H), Boko-Haram leaders (T_L^H), and Boko-Haram recruiters (R^H), but the population of detained Boko-Haram (D_T^H) and rehabilitated Boko-Haram, (R_E^B) increased as shown in Figure. 5.2(e,f). The control profile for strategy B is shown in Figure.5.2 (g). The control curve for both media campaign against Boko-Haram and the use of military forces remains at the extreme higher bound for twenty months and twenty nine months respectively before sharply drop down to the lower bound .



(g)

Figure 5.1: Graphical solutions for implementation of media campaign against Boko-Haram and Rehabilitation of Boko-Haram

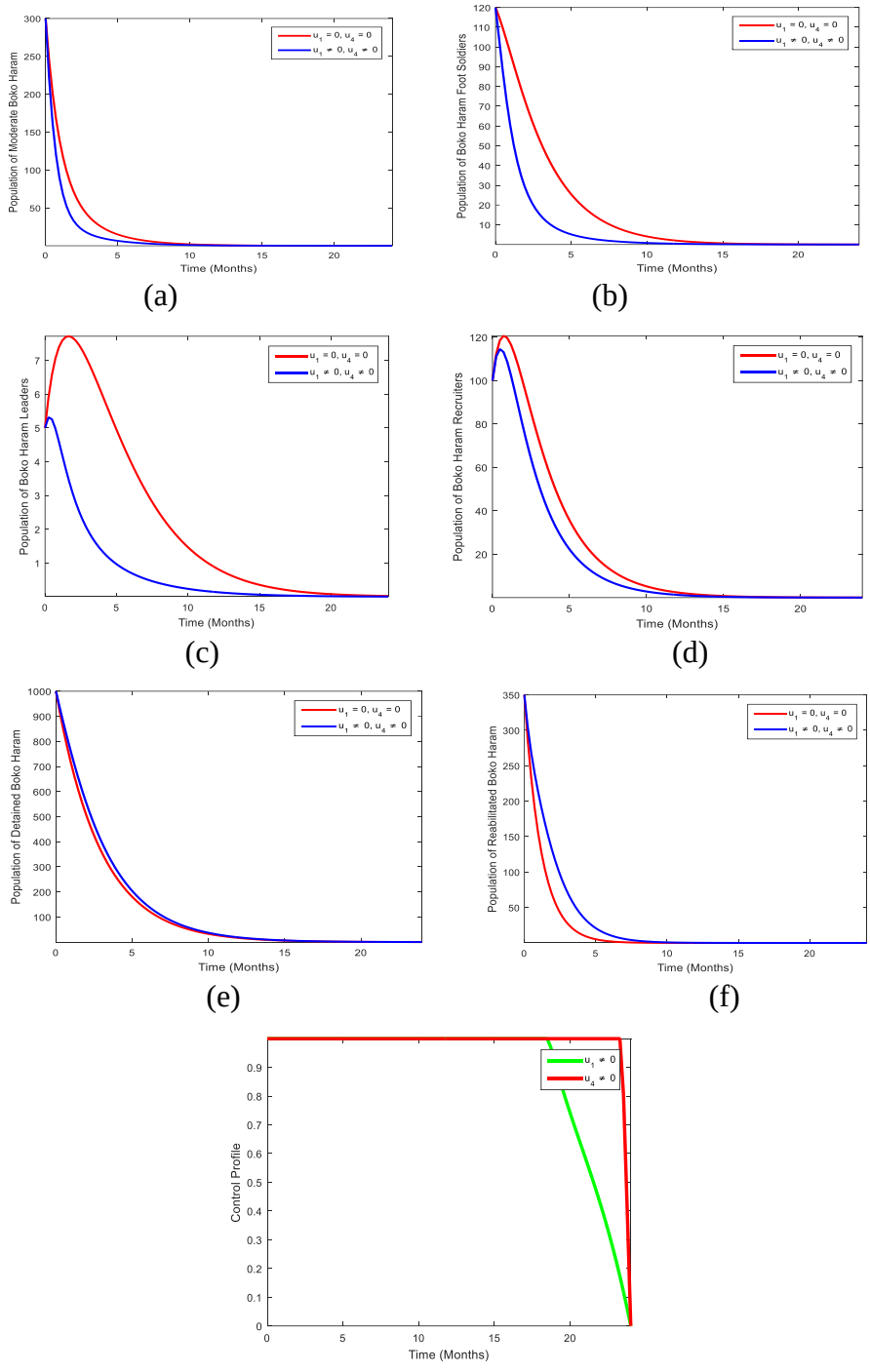


Figure 5.2: Graphical solutions for implementation of media campaign against Boko-Haram and use of military force.

Strategy C: Rehabilitation of Boko-Haram and use of military force

When the use of media campaign against Boko-Haram is set at zero, intervention strategy C shows the simulation of an optimal control system (39) for the implementation of rehabilitation of Boko-Haram (u_3) and the military forces (u_4). We observed from Fig. 5.3 (a,b,c,d) that in the absence of rehabilitation of Boko-Haram (u_3) and the use of military forces against Boko-Haram (u_4), indicated by red line, the population of moderate Boko-Haram (M^H), Boko-Haram foot soldiers (T_S^H), Boko-Haram leaders (T_L^H), and Boko-Haram recruiters (R^H) are at higher level, but that of rehabilitated Boko-Haram, (R_E^B) is at lower level. When the method is applied (indicated by blue line) compared to the scenario without control, we see a drop in the population of moderate Boko-Haram (M^H), Boko-Haram foot soldiers (T_S^H), Boko-Haram leaders (T_L^H), and Boko-Haram recruiters (R^H), but the population of detained Boko-Haram (D_T^H) and rehabilitated Boko-Haram, (R_E^B) increased as shown in Figure. 5.3(e,f). The control profile for strategy G is shown in Figure 5.3 (g). The control curve for rehabilitation of Boko-Haram remain at 100% at upper level for twenty months before it dropped to the lower level. The curve for the use of military forces remains at the extreme higher bound for twenty nine months before it drop to the lower bound.

Strategy D: Media campaign, Rehabilitation of Boko-Haram and use of military force

The use of a media campaign against Boko-Haram, the rehabilitation of Boko-Haram, and the military force are presented in the simulation of intervention strategy D of the optimal control system (39). We observed from Figure 5.8 (a,b,c,d) that in the absence media campaign against Boko-Haram (u_1), rehabilitation of Boko-Haram (u_3) and the use of military forces against Boko-Haram (u_4), indicated by red line, the population of moderate Boko-Haram (M^H), Boko-Haram foot soldiers (T_S^H), Boko-Haram leaders (T_L^H), and Boko-Haram recruiters (R^H) are at higher level, but that of detained Boko-Haram (D_T^H) and rehabilitated Boko-Haram, (R_E^H) is at lower level. When the method is applied (indicated by blue line) compared to the scenario without control, we see a drop in the population of moderate Boko-Haram (M^H), Boko-Haram foot soldiers (T_S^H), Boko-Haram leaders (T_L^H), and Boko-Haram recruiters (R^H), but the population of detained Boko-Haram (D_T^H) and rehabilitated Boko-Haram, (R_E^B) raised sharply as shown in Figure 5.4 (e,f) .The control profile for strategy D is shown in Figure 5.4 (g). The control curve for media campaign against Boko-Haram has is maintained at 100% for eighteen months to 0% and remain at the lower level to the end of the period of study, the curve for rehabilitation of Boko-Haram (u_3) remain at the topmost bound for the period of twenty five months before it drops to the lower bound and the curve for the use of military forces on Boko-Haram (u_4) stays at the upper bound for twenty nine months before reaching the lower bound.

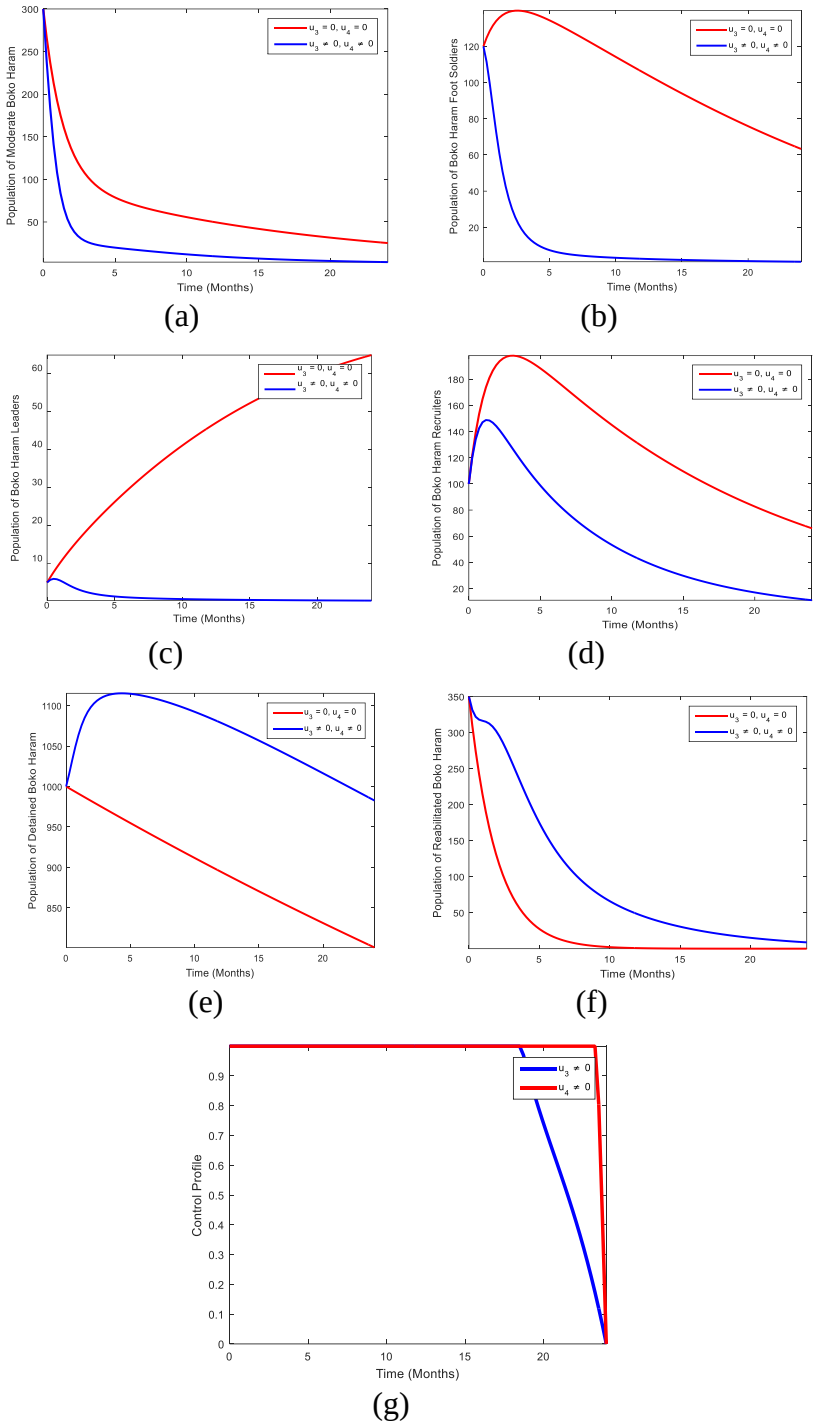


Figure 5.3: Graphical solutions for implementation of rehabilitation of Boko-Haram and use of military force.

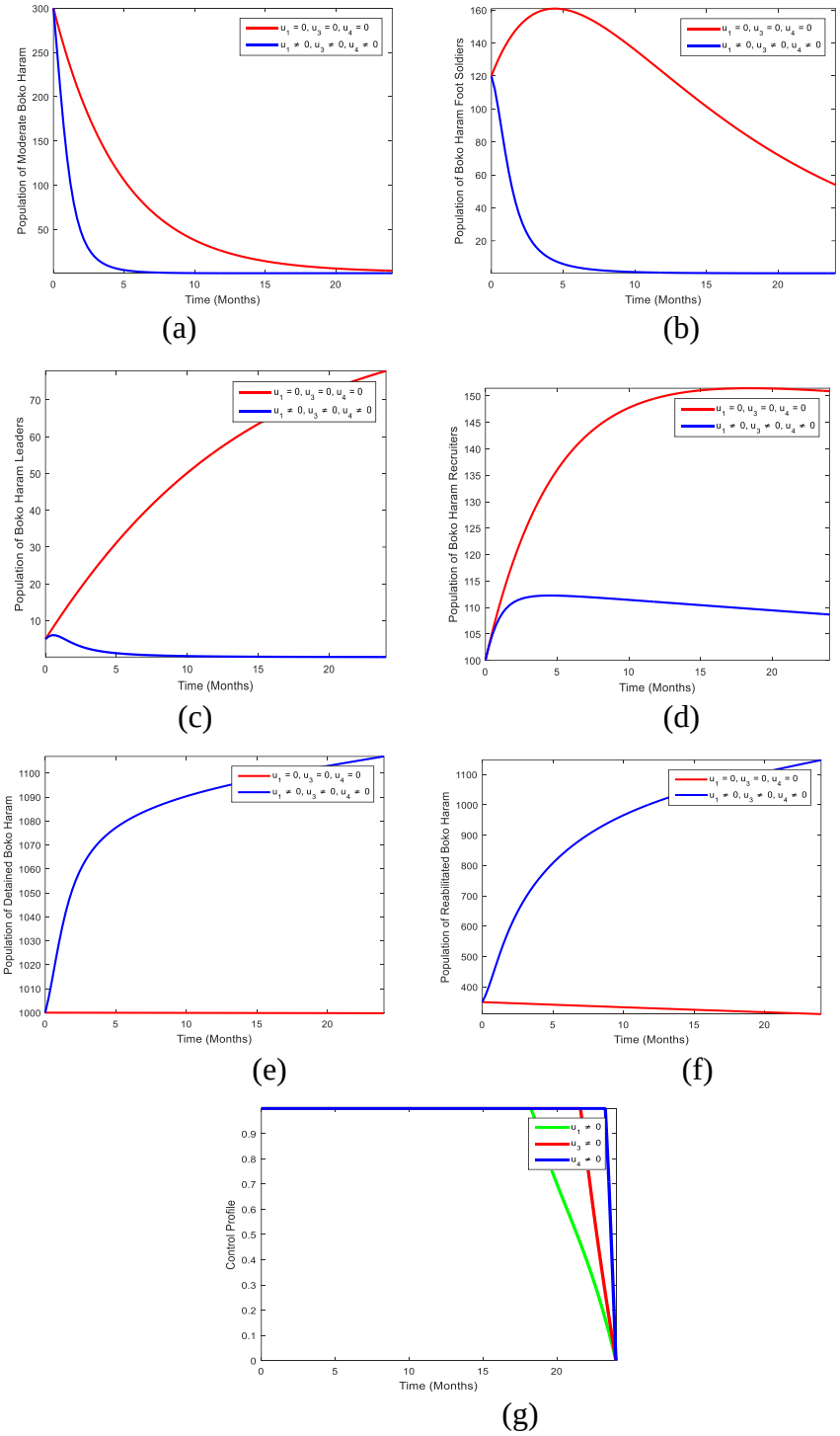


Figure 5.4: Graphical solutions for implementation of media campaign against Boko-Haram, rehabilitation of Boko-Haram and use of military forces.

7 Conclusion

The research examines a mathematical model and optimal control methods to prevent Boko-Haram spread in societies, combining media campaigns, rehabilitation programs, detention, and military force. [7] [6]

The positivity and uniqueness of the model equations' solutions were established, and it was found that they do indeed exist and are distinct. The model's menace free equilibrium state were identified. The Boko-Haram menace free equilibrium point was found to be

$$E_{0H} = \left(S^o, M^{H^o}, \mathrm{T}_S^{Ho}, T_L^{H^o}, R^{Ho}, D_T^{H^o}, R_E^{H^o}, M_F^o\right) = \left(\frac{\Lambda_1}{\mu}, 0, 0, 0, 0, 0, 0, \frac{\Lambda_2}{\mu+\eta}\right)$$

By rigorously examining these, we get to the conclusion that the susceptible population and military forces alter accordingly with their recruitment rate to their mortality rate when Boko Haram is absent. The basic reproduction number of the Boko-Haram model was also analyzed and obtained to be

$$R_{0H} = \frac{q\beta\Lambda_1\left(\pi\alpha(\mu+\delta_3)(\mu+d_1)\psi + \left(\gamma+\mu+\delta_2\right)(\mu+d_1)(1-\pi)\alpha\varphi + (\mu+d_1)\pi\alpha\gamma + \left(\gamma+\mu+\delta_2\right)(\mu+\delta_3)\varepsilon\right)}{\Lambda\left(\left(\mu^2+\mu y+\gamma\delta_3+\delta_2\delta_3\right)\left(\mu^2+\mu z+\alpha d_1+\delta_1 d_1\right)\right)}$$

$$+\frac{(1-q)\beta\Lambda_1\left\{d_1\pi\alpha(\mu+\delta_3)\psi + \varphi\left(\gamma+\mu+\delta_2\right)d_1(1-\pi)\alpha + \varphi\pi\alpha\gamma d_1 + \varepsilon\left(d_2+\alpha+\mu+\delta_1\right)\left(\gamma+\mu+\delta_2\right)(\mu+\delta_3)\right\}}{\Lambda\left(\left(\mu^2+\mu y+\gamma\delta_3+\delta_2\delta_3\right)\left(\mu^2+\mu z+\alpha d_1+\delta_1 d_1\right)\right)}$$

As an interpretation, the basic reproduction number R_{0H} is the sum of two constituent reproductions numbers, R_1 and R_2. The R_1 shows the average number of people initiated into Boko-Haram by single moderate Boko-Haram member (M^H) while R_2 indicates the average number of people who can be initiated into Boko-Haram by single Boko-Haram recruiter (R^H). If the population of moderate Boko-Haram $M^H = 0$ and $R_1 < 1$, and again if the population Boko-Haram recruiter $R^H = 0$ and $R_2 < 1$ (which implies $R_{0H} < 1$), then the population of new Boko- Haram members they initiate will eventually vanish; otherwise, the number of new converts will continue to grow.

We used Pontryagins' Maximum Principle and the optimal control approach to evaluate and analyzed the ideal level for regulating the extensive media campaign against banditry, the rehabilitation of caught bandits, and the use of armed forces as control variables. The results show that the best strategy to counter the Boko-Haram menace is to combine all three strategies.

Refrences

[1] Walker, A. What Is Boko Haram? . *The United States Institute of Peace* (2012). West and Central Africa: Weekly Regional Humanitarian Snapshot (27 April – 3 May 2021). Retrieved from https://reliefweb.int/report/nigeria/west-and-central-africa-weekly-regional-humanitarian-snapshot-27-april-3-may-2021,:1.

[2] Ezirm, G. E and Onuoha, F.C. Terrorism and transnational organized crime in West Africa. Aljazeera center for studies (2013). Retrieved from P http://studiesajazeera.net/en/2013/2013/02946689517.htmls Fanatic Behavoiur. DOI:10.1137/1.9780898717518.ch7

[3] Onuoha, F. Why do youths join Boko Haram *United State Institute of Peace* (2014). : 1-12. Optimal Control of Abstinence Behavio of Registration on the Electoral Lists. *Discrete Dynamics in Nature and Society Volume 2020, Article ID 9738934, 12 pageshttps://doi.org/10.1155/2020/9738934 (Hindawi)*

[4] Forster-Bower, E.and Sander, A. Security thereats in Sahel and beyong (2012): AQVIM, Boko Haram and al-shaba. Civil-military fusion centre. Retrievd from www. Cimicweb.org.

[5] Ungwuishiwu, C. H., Sarki, D. S. and Mbah, G.C.E. Nonlinear Analysis of the dynamics of criminality and victimization .A Mathematical Model with case generation and forwarding. *Journal of Applied Mathematics (*2019):1-4.

[6] Gambo, A. & Ibrahim, M. O.. Mathematical Modeling of dynamics behavior of terrorism and control. *Caspian Journal of Mathematical Sciences (CJMS)* (2020); *University of Mazandaran, Iran http://cjms.journals.umz.ac.ir ISSN:* 2676-7260: 69-80.

[7] Fei Xu, S. M.. Global stability in Mathematical Model of de-radicalization. *Journal of Statistical mechanics and its Application (JSMA)* (2018); 509(1):151-161
[8] Mebratie, A. M. and Dawed, Y. M. Mathematical model analysis of crime dynamics incorporating media coverage and police. *J. math. Computer Sci.* (2021) ;11 (1): 125-148.
[9] Lacey, A. A. and Tsardakas, M. A Mathematical model of serious and minor criminal activities. *European Journal of Applied Mathematics (EJAM)* (2016).
[10] González-Parra, G., Chen-Charpentier, B., & Kojouharov, H. V. Mathematical modeling of crime as a social epidemic. *Journal of Interdisciplinary Mathematics (JIM)* **2**(2018). ; **1**(3):623- 643, DOI: 10.1080/09720502.2015.1132574
[11] Momoh, A.A. *etal.* Curtailing the Spread of Drug-abuse and Violence Co-menace. An Optimal Control Approach. *Alexandria Eng.J. (2021), http://doi.org/10.106/j.aej.2021.10.002*
[12] Mohammed, I. A. & Musa, S., Mathematical Model on the Dynamics of Domestic Violence. *Abacus (Mathematics Science Series)* (2019) ; *Vol. 44, No 1, 427*
[13] Diekmann, O.; Heesterbeek, J. A. P.; Metz, J. A. J."On the definition and the computation of the basic reproduction number in models for infection diseases in heterogeneous population . *Journal of mathematical Biology* (1990) 28:365–382. DOI:10.1017/S0956792516000139
[14] Driessche, P. V. D. & Watmough, J. Reproduction Numbers and Sub-threshold Endemic Equilibria for Compartmental Models of Disease Transmission. *Mathematical Biosciences* (2002); 180 (2002) 29-48.
[15] Driessche, P. V. D. Reproduction Numbers of Infectious Disease Models.. *Ke Ai Advancing Research Evolving Science* (2017); *Canada.http://dX.doi.org/10.1016/j.idm.2017.06.002.*
[16] Van den Driessche, P. *and Watmough, J.* Reproduction numbers and sub-threshold endemic equilibria for compartmental models of disease transmission. *Mathematical Biosciences. (2002;* **180** (1–2): 29–48.
[17] Olaniyi,S. and Obabiyi, O. S. Mathematical model for malaria transmission dynamics in human and mosquito population with nonlinear force of infection . *International journal of pure and applied Mathematics* (2013); 88(1), 125-156.
[18] Ojo, M. M. and Akipelu, F. O. Lyapunov Function and Global Properties of SEIR Epidemic Model. *International journal of Chemistry, Mathematics and Physics.* (2017); 1(1)
[19] Pykh, Yu. A. Luapunov Function for Lotka-Volterra System: An overview and Problems. Russian Academy of Sciences Center for International Environmental Cooperation (INENCO) (2001);
[20] Shuai, Z. and Van Den Driessche, P. Global Stability of Infectious Disease Models Using Lyapunov Functions. *Siam J. Appl. Math. Society for Industrial and Applied Mathematics* (2013); **73** (4).
[21] Maia, R. An introduction to Mathematical epidemiology. Springer (2015); New York Heidelberg Dordredit London.
[22] Pontryagin,L.S., Boltyanskii, V.G., Gamkrelize, R.V. and Mishchenko, E.F. (1962). The Mathematical theory of Optical process. New York, London; John Wiley & Sons.
[23] Suzanne, M. L. & John, T. W. *Optimal Control Applied to Biological Model* (2007). (Volume15). CRC Press.

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp. 451–476, November 13-16, 2023

Mathematical Modelling for the Transmission Dynamics of *Chikungunya* Virus Incorporating Primate Population

Abdulmumini Husseini[1], Abdulfatai A. Momoh[2], Musa Abdulahi[3], Yahaya Aliyu Abdullahi[4], Halimat O. Abdulkadir[5]

Department of Mathematics, Nigerian Army University Biu,PMB 1500,Biu, Borno State, Nigeria[1]. Department of Mathematics, Modibbo Adama University, PMB 2076, Yola, Nigeria[2,3,5]. Department of Mathematics and Statistics, Gombe State Polytechnic Bajoga, PMB 0190, Gombe State, Nigeria[5]

ABSTRACT
In this research work a mathemat ical model for the transmission dynamics of *Chikungunya* virus in human, vector, (mosquito) and primate population is presented. *Chikungunya* fever is a viral disease that is spread by the bite of an infected mosquito most often *Aedes aegypti* and *Aedes albopictus* of the *Aedes* genus. The population of humans is divided into five compartments; human who may become infected susceptible humans $S_h(t)$, exposed humans, $E_h(t)$, humans infected by CHIKV $I_h(t)$, humans who recovered from CHIKV $R_h(t)$ and recovered with disability humans $C_h(t)$. The mosquito population is divided into three compartments. mosquitoes who may become infected, susceptible mosquitos $S_v(t)$), exposed mosquito $E_v(t)$), mosquitoes infected by the *Chikungunya* virus $I_v(t)$. Primates population denoted by $N_p(t)$ is subdivided into four compartments, i.e. susceptible $S_p(t)$ primates, exposed ($E_p(t)$ primates, infected primate $I_p(t)$, primates who have recovered from the *chikungunya* infection (recovered) $R_p(t)$. The *Chikungunya* -free, *Chikungunya* present equilibrium states were obtained. The basic reproduction number is the threshold that determines how disease spread in a population and was computed using the method of next generation matrix. Routh-Hurwitz criterion was used to obtain the local stability and the global stability has been established using Castilo-Chavez conditions. From the analysis $R_0 < 0$ and the stability also revealed that the *Chikungunya*-free balance is asymptotically stable locally and globally. The numerical simulation was carried out using MATLAB R2015a, showed that transmission rate and biting rate of mosquito has a great impact on the transmission of *Chikungunya* virus. During outbreak of the disease, the best way of controlling the epidemic is by creating awareness among people about the preventives measures to be taken to curtail the disease.

2.3.1 Keywords: *Chikungunya* virus, Mathematical Modeling, Stability analysis, Reproduction Number.

1 Introduction

Chikungunya Fever is a viral disease that is spread by mosquitos and is caused by the *Alphavirus Chikungunya* Virus (CHIKV). Fever and joint pain are the most prevalent *Chikungunya* symptoms, with joint discomfort lasting for years in some cases. Headache, muscular discomfort, joint swelling, or a rash may accompany the fever. Since 2004, epidemics of *chikungunya* have occurred in Asia, Africa, Europe, and the Americas on a scale never seen before. Around two million individuals have been affected by the disease, with attack rates reaching 68 percent in certain locations [15]
The *Chikungunya* virus is spread to humans by the bite of infected mosquito, most often *Aedes aegypti* and *Aedes albopictus* mosquitos of the *Aedes* genus [6]. The abrupt start of fever two to four days after exposure is the first indicator of *Chikungunya.* The fever normally lasts two to seven days, and it is commonly followed by joint problems that last for weeks, months, and even years. Other symptoms include muscular soreness, headaches, nausea, exhaustion, and a rash [19]. *Chikungunya* has a fatality incidence of about 1 in 1000 people. Complications are more likely in the elderly, babies, and individuals with underlying chronic medical issues [8].

The incubation period for the *Chikungunya* virus can range from one to twelve days, although it is most commonly three to seven days [20]. That is, it usually takes three to seven days for a person to display symptoms after being exposed to the disease. There are two phases to the condition. The first stage generally starts with a high temperature, usually over and occasionally beyond. The fever might

linger anywhere from a week to ten days, during which time *viremia* can develop. Other symptoms like as headaches and acute tiredness, on the other hand, might linger for another five to seven days [4].Symptoms improve as the virus leaves the blood during the second stage of the sickness, which lasts around 10 days. This is followed by severe joint aches and muscular stiffness that can continue for weeks or even years. Joint discomfort affects 87 percent to 98 percent of patients, and it frequently causes near immobilization of the affected joints. During the 2006 La Reunion epidemic (on the Indian Ocean island of Reunion), more than 60% of patients had sore joints three years after contracting *Chikungunya* [16]. Similarly, one year after a local *Chikungunya* epidemic in Italy, 66% of persons complained muscular or joint aches [9].

The term *'Chikungunya'* is said to be derived from the *Makonde* word '*Kungunyala*,' which means "that which bends up" and relates to the deformed position of those suffering from the intense joint pain associated with this condition [3]. After an epidemic in 1952 on the *Makonde* Plateau, on the mainland of modern-day Tanzania, [14,7] discovered *Chikungunya*. They discovered that in Africa, the virus mostly circulates between human outbreaks and other non-human primates such as monkeys, birds, cattle, and rodents, as well as mosquitos [13]. The virus can readily spread between humans and mosquitos due to the high concentration of virus in the blood of persons affected (or in the acute stage of illness). Hence outbreaks are usually related to heavy rainfall which implies increase in mosquito population [1].Periodic outbreaks have been reported in Africa, South Asia, and Southeast Asia since its discovery. After a period of inactivity, *Chikungunya* resurfaced in 2005, causing significant epidemics throughout Africa and Asia. In India, for example, it resurfaced in 2006 after a 32-year hiatus in an outbreak that resulted in 1.25 million probable cases [6]. Prior to then, the greatest *Chikungunya* outbreak had been observed in 2005 in the Indian Ocean's Runion Island. On the island, which had a population of over 770,000 people, it was estimated that 266,000 individuals were affected [15].

The intensity of the epidemic, which began in 2005, is related to a shift in the virus's genetic code, which allows it to proliferate more easily in mosquito cells. In addition to the virus's principal vector or carrier, *Aedes aegypti*, the mutation permits the virus to be spread by the Asian tiger mosquito, *Aedes albopictus*. *Because Aedes aegypti* only grows in tropical climates, whereas *Aedes albopictus* is a more invasive species that has spread throughout Europe, the Americas, the Caribbean, Africa, and the Middle East [17,21], this could increase the risk of outbreaks.

Gilberto *et al.* (2019)[5] presented a mathematical model for the spread of the *Chikungunya* disease at the population level that incorporates the transmission vector by including cross-transmission between the human and vector populations. They found the parameters that affect the basic reproduction number R_0 and therefore what would be the best policies to control the spread of the *Chikungunya* disease. They verified that when the reproduction number R_0 is less than unity, the disease disappears, while when the reproduction number is greater than one, the disease persists in the population.
However, we are proposed a model that incorporates susceptible primates, exposed primates, infected primates and recovered primates into our model in order to improve on the work studied by [5].

2 Model Formulation

The total population of humans $N_h(t)$ is divided into five compartments; human who may become infected susceptible humans $S_h(t)$, exposed humans, but still not infected due to the existence of an incubation period of the virus $E_h(t)$, humans infected by CHIKV and develops the disease $I_h(t)$,

humans who recovered from CHIKV infection $R_h(t)$ and recovered with disability humans $C_h(t)$. Mathematically,

$N_h(t) = S_h(t) + E_h(t) + I_h(t) + R_h(t) + C_h(t)$

Recruitment into the $S_h(t)$ is by birth at a rate $\mu_h N_h(t)$ and the $S_h(t)$ reduces due to natural death at rate d_h and force of infection at a rate $\frac{\varepsilon_v \beta_v I_v(t) S_h(t)}{N_h(t)}$, where ε_v is the biting rate of mosquitoes and β_v is the transmission rate of the virus to humans due to a bite from the infected mosquitoes. The exposed human $E_h(t)$ population increases by $\frac{\varepsilon_v \beta_v I_v(t) S_h(t)}{N_h(t)}$ and it is reduced by $\alpha_h E_h(t)$ and $d_h E_h(t)$, where α_h is the infection rate at which the latent human moves to the infected class and d_h is the natural death rate. The infected human $I_h(t)$ population increases by $\alpha_h E_h(t)$ and it is reduced by $\gamma_h I_h(t)$ and $d_h I_h(t)$ where γ_h is the rate at which the infected class moves to the recovered class and $d_h I_h(t)$ is the natural death rate. The recovered human population increases by $\gamma_h I_h(t)$ and it reduces by $d_h R_h(t)$ where γ_h is the fraction of the infected human that recovers (that is they do not have the disease anymore) while $d_h R_h(t)$ is the natural death rate of the recovered class. Recovered with disability human is denoted by $C_h(t)$. Individuals in this particular class cannot transmit the disease but have some type of chronic rheumatic symptoms. This class was considered because health institutions are interested in the numbers of chronic cases of *Chikungunya and* its evolution. The Recovered human with disability human class increased by $\rho_h R_h(t)$ and it is reduced by $d_h C_h(t)$.

The total population of mosquitoes (vector) is denoted by $N_v(t)$. the mosquito population is divided into three compartments namely: mosquitoes who may become infected, susceptible mosquitos $S_v(t)$), exposed mosquito that is not infected due to the existence of an incubation period of the virus $E_v(t)$), mosquitoes infected by the *Chikungunya* virus and that develop the disease (infected mosquitos) $I_v(t)$. Mathematically, the total mosquito population is given by $N_v(t) = S_v(t) + E_v(t) + I_v(t)$.

Recruitment into the susceptible mosquito population $S_v(t)$ is by birth at a rate $\mu_v N_v(t)$ and it reduces by $\frac{\beta_h I_h(t) S_v(t)}{N_h(t)} + \frac{\beta_p I_p(t) S_v(t)}{N_p(t)}$ and $d_h S_v(t)$, where $d_h S_v(t)$ is natural death rate of the mosquitoes, β_h and β_p are the transmissions rate of the virus to a susceptible mosquitoes when it bites an infected human and primate respectively. The exposed mosquitoes population $E_v(t)$ increased by $\frac{\beta_h I_h(t) S_v(t)}{N_h(t)} + \frac{\beta_p I_p(t) S_v(t)}{N_p(t)}$ and it reduces by $\phi_v E_v(t)$ and $d_v E_v(t)$, where ϕ_v is the rate at which the exposed mosquitoes moves to the infected class by the virus and d_v is the natural death rate. The infected mosquitoes $I_v(t)$ population increases by $\phi_v E_v(t)$ and it reduces by $d_v I_v(t)$ where $d_v I_v(t)$ is the natural death rate of the infected mosquitos.

The model incorporates other non-human (primates) which are also reservoirs apart from human. The total primates population denoted by $N_p(t)$ is subdivided into four compartments, i.e. primates who may become infected (susceptible) $S_p(t)$, primates exposed but still not infected due to the existence of an incubation period of the virus $E_p(t)$, primates infected by the *chikungunya* virus $I_p(t)$, primates who have recovered from the *chikungunya* infection (recovered) $R_p(t)$.

Recruitment into susceptible primate population is by natural birth at a rate $\mu_p N_p(t)$ and it reduces by natural death at a rate $d_p S_p(t)$ and force of infection at a rate $\frac{\varepsilon_v \beta_v I_v(t) S_p(t)}{N_p(t)}$, where β_v is the transmission rate of the disease, ε_v is the biting rate of mosquito. The exposed primates population $E_p(t)$ increased by $\frac{\varepsilon_v \beta_v I_v(t) S_p(t)}{N_p(t)}$ and it is reduced by $a_p E_p(t)$ and $d_p E_p(t)$, where a_p is the fraction at which the primate moves to the infected class by contracting virus and d_p is the natural death rate. The infected primates' population $I_p(t)$ increases by $a_p E_p(t)$ and it reduces by $\gamma_p I_p(t)$ and $d_p I_p(t)$, where γ_p is the rate at which the infected class moves to the recovered class and $d_p I_p(t)$ is the natural death rate. The recovered class increases by $\gamma_p I_p(t)$ and it is reduced by $d_p R_p(t)$ where γ_p is the fraction of the infected primates that recovers while $d_p R_p(t)$ is the natural death rate of the recovered class. From the model description, it implies that the total primate population is $N_p(t) = S_p(t) + E_p(t) + I_p(t) + R_p(t)$.

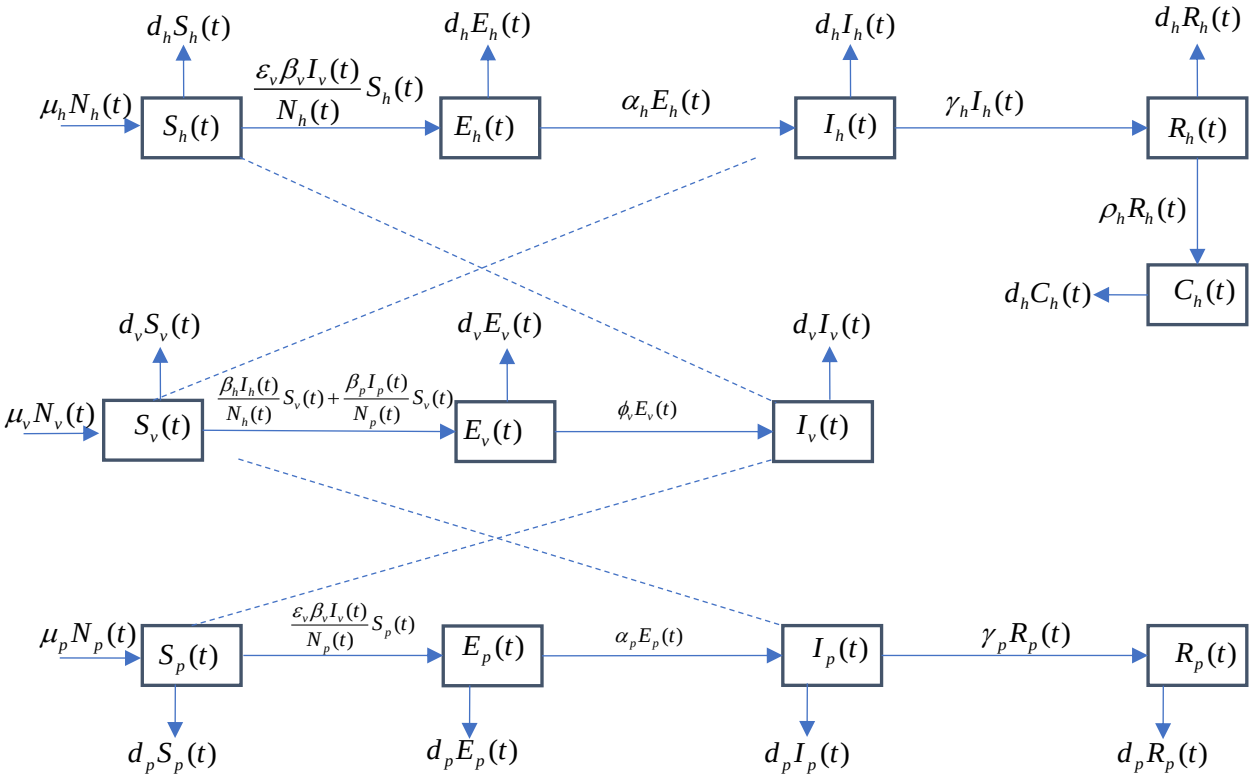


Figure 1. Schematic Diagram of the model

Table 1: Variables of the Model

Variable	Description
$S_h(t)$	Susceptible human population at time t
$E_h(t)$	Exposed human population at time t
$I_h(t)$	Infected human population at time t

$R_h(t)$	Recovered human population at time t
$C_h(t)$	Recovered with disability human population at time t
$S_v(t)$	Susceptible mosquito population at time t
$E_v(t)$	Exposed mosquito population at time t
$I_v(t)$	Infectious mosquito population at time t
$S_p(t)$	Susceptible primates population at time t
$E_p(t)$	Exposed primate population at time t
$I_p(t)$	Infected primate population at time t
$R_p(t)$	Recovered primate population at time t

Table 2: Parameters of the Model

Parameter	Description
μ_h	Birth rate of Human population
d_h	Death rate of Human population
μ_v	Birth rate of Mosquito population
d_v	Death rate of Mosquito population
β_v	Transmission rate to human when an infected mosquito bites human
β_p	Transmission rate of CHIKV to mosquito when it bites infected primate
α_h	Rate of latent humans that passed to infected due to CHIKV
ρ_h	Rate of recovered humans that moves to chronic class
γ_h	Rate of infected humans that recovered
ϕ_h	Rate of exposed mosquito that progress to infected mosquito
β_h	Transmission rate of CHIKV to mosquito when it bites infected human
a_p	A fraction of primates that are infected
γ_p	A fraction of infected primates that recovered
ε_v	Biting rate of mosquitoes

3 Model Equation

The modified model equation is presented in equations (1)

$$
\left.
\begin{aligned}
\frac{dS_h(t)}{dt} &= \mu_h N_h(t) - \left(\frac{\varepsilon_v \beta_v I_v(t)}{N_h(t)} + d_h \right) S_h(t) \\
\frac{dE_h(t)}{dt} &= \frac{\varepsilon_v \beta_v S_h(t) I_v(t)}{N_h(t)} - \left(\alpha_h + d_h \right) E_h(t) \\
\frac{dI_h(t)}{dt} &= \alpha_h E_h(t) - \left(\gamma_h + d_h \right) I_h(t) \\
\frac{dR_h(t)}{dt} &= \gamma_h I_h(t) - \left(\rho_h + d_h \right) R_h(t) \\
\frac{dC_h(t)}{dt} &= \rho_h R_h(t) - d_h C_h(t) \\
\frac{dS_v(t)}{dt} &= \mu_v N_v(t) - \left(\frac{\beta_h I_h(t)}{N_h(t)} + \frac{\beta_p I_p(t)}{N_p(t)} + d_v \right) S_v(t) \\
\frac{dE_v(t)}{dt} &= \left(\frac{\beta_h I_h(t)}{N_h(t)} + \frac{\beta_p I_p(t)}{N_p(t)} \right) S_v(t) - \left(\phi_v + d_v \right) E_v(t) \\
\frac{dI_v(t)}{dt} &= \phi_v E_v(t) - d_v I_v(t) \\
\frac{dS_p}{dt} &= \mu_p N_p(t) - \left(\frac{\varepsilon_v \beta_v I_v(t)}{N_p(t)} + d_p \right) S_p(t) \\
\frac{dE_p(t)}{dt} &= \frac{\varepsilon_v \beta_v S_p(t) I_v(t)}{N_p} - \left(a_p + d_p \right) E_p(t) \\
\frac{dI_P(t)}{dt} &= \alpha_p E_p(t) - \left(\gamma_p + d_p \right) I_p(t) \\
\frac{dR_p(t)}{dt} &= \gamma_p I_p(t) - d_p R_p(t)
\end{aligned}
\right\} \qquad (1)
$$

3.1 Model Analysis

3.1.1 Positivity of Solutions

For the model to be epidemiologically meaningful, it is important to prove that all variables are non-negative for all time, and bounded solution exists

Theorem 1

The variables of the model (1) are nonnegative for all the time. Then, the solutions of the model system with nonnegative initial data will remain nonnegative for all time $t \geq 0$.

Proof:

Let

thus $t_\infty > 0$. then it follows that, the model system (1) are solved as follows :

$$
\frac{dS_h(t)}{dt} = \mu_h N_h(t) - \left(\frac{\varepsilon_v \beta_v I_v(t)}{N_h(t)} + d_h \right) S_h(t) \qquad (2)
$$

Using separation of variables, equation (4.4) becomes

$$
\frac{dS_h(t)}{dt} \geq -\left(\frac{\varepsilon_v \beta_v I_v(y)}{N_h(t)} + d_h \right) S_h(t) \qquad (3)
$$

$$\frac{dS_h(t)}{S_h(t)} \geq -\left(\frac{\varepsilon_v \beta_v I_v(y)}{N_h(t)} + d_h\right)dt \quad (4)$$

Integrating both sides and taking the antilog, we have

$$\ln S_h(t) \geq -\int_0^t \left(\frac{\varepsilon_v \beta_v I_v(y)}{N_h(t)}\right)dy - \int d_h dt \quad (5)$$

So that,

$$S_h(t) \geq \exp\left(-\int_0^t \left(\frac{\varepsilon_v \beta_v I_v(y)}{N_h(t)}\right)dy - \int d_h dt\right) \quad (6)$$

At $t = 0$, and with the initial condition $S_h(0)$

$$S_h(t) \geq S_h(0)\exp\left(-\int_0^t \left(\frac{\varepsilon_v \beta_v I_v(y)}{N_h(t)}\right)dy - d_h\right) \geq 0 \quad (7)$$

Since $\left(\frac{\varepsilon_v \beta_v I_v(y)}{N_h(t)}\right)$ >0 and d_h >0.

Hence, $S_h(t) > 0$ (Positive).

Similarly, it has also been demonstrated

$$S_h(t) > 0, E_h(t) > 0, I_h(t) > 0, R_h(t) > 0, C_h(t) > 0,$$
$$S_v(t) > 0, E_v(t) > 0, I_v(t) > 0,$$
$$S_p(t) > 0, E_p(t) > 0, I_p(t) > 0, R_p(t) > 0.$$

therefore, the disease is uniformly persistent for every positive solution.
This proves that the solutions of system (1) are positive for all t ≥ 0. This guarantee the model is mathematically and epidemiologically well posed.

3.1.2 Invariant Region

Theorem 2

The region $\Omega = \Omega_h \times \Omega_v \times \Omega_p \subset \mathbb{R}_+^5 \times \mathbb{R}_+^3 \times \mathbb{R}_+^4$

where

$$\Omega_h = (S_h, E_h, I_h, R_h, C_h) \in \mathbb{R}_+^5,$$
$$\Omega_v = (S_v, E_v, I_v) \in \mathbb{R}_+^3$$
$$\Omega_p = (S_p, E_p, I_p, R_p) \in \mathbb{R}_+^4,$$

Thus $\Omega = \Omega_h + \Omega_v + \Omega_p \in \mathbb{R}_+^{12}$ is positively invariant and attract all positive solutions of the model.

Proof:

The total human population at time t, given by equation

$$N_h(t) = S_h(t) + E_h(t) + I_h(t) + R_h(t) + C_h(t)$$

The rate of change of the human populations is obtained by adding human population equations

$$\frac{dN_h(t)}{dt} = \mu_h N_h - \frac{\varepsilon_v \beta_h S_h I_h}{N_h} - d_h S_h + \frac{\varepsilon_v \beta_h S_h I_h}{N_h} - \alpha_h E_h - d_h E_h + \alpha_h E_h - \gamma_h I_h - d_h I_h + \gamma_h I_h - \rho_h R_h - d_h R_h + \rho_h R_h - d_h C_h \quad (8)$$

which gives

$$\frac{dN_h}{dt} = \mu_h - d_h N_h \tag{9}$$

Similarly, the rate of change of mosquito populations is obtained by adding the mosquito population equations

Then we have;

$$\frac{dN_v}{dt} = \mu_v - d_v N_v \tag{10}$$

And also the rate of change of primate populations is obtained by adding primates population equations

Then we have;

$$\frac{dN_p}{dt} = \mu_p - d_p N_p \tag{11}$$

Solving equations (4.2,4.3 and 4.4) gives,

$$N(t) = \frac{\mu_i}{d_i} = \left[N(0) - \frac{\mu_i}{d_i} \right] e^{-\mu t} \tag{12}$$

If $N(t) \le \frac{\mu_i}{d_i}$ for all value of $t > 0$.

If $N(0) > \frac{\mu_i}{d_i}$, then either solution enter Ω in finite time or $N(t)$ approaches to $\frac{\mu_i}{d_i}$ as $t \to \infty$.

Hence the Ω attracts all solution in $\mathbb{R}^{12}_{+}$

where $i = h, v, p$

***Chikungunya*-free equilibrium point (CFE)**

$$E_0^* \equiv \left(S_h^0, E_h^0, I_h^0, R_h^0, C_h^0, S_v^0, E_v^0, I_v^0, S_p^0, E_p^0, I_p^0, R_p^0 \right)$$

$$= \left(\frac{\mu_h N_h}{d_h}, 0, 0, 0, 0, \frac{\mu_v N_v}{d_v}, 0, \frac{\mu_p N_p}{d_p}, 0, 0, 0 \right) \tag{13}$$

***Chikungunya*-present Equilibrium point (CPEP)**

From equation (1), the case where there is infection in the population, we obtain

$$E_1^* \equiv \left(S_h^*, E_h^*, I_h^*, R_h^*, C_h^*, S_v^*, E_v^*, I_v^*, S_p^*, E_p^*, I_p^*, R_p^* \right)$$

$$\begin{cases} S_h^* = \dfrac{\mu_h N_h}{\pi_h + d_h},\ E_h^* = \dfrac{\pi_h \mu_h N_h}{(\alpha_h + d_h)(\pi_h + d_h)},\ I_h^* = \dfrac{\alpha_h \pi_h \mu_h N_h}{(\alpha_h + d_h)(\pi_h + d_h)(\gamma_h + d_h)}, \\ R_h^* = \dfrac{\gamma_h \alpha_h \pi_h \mu_h N_h}{(\alpha_h + d_h)(\pi_h + d_h)(\gamma_h + d_h)(\rho_h + d_h)}, C_h^* = \dfrac{\rho_h \gamma_h \alpha_h \pi_h \mu_h N_h}{(\alpha_h + d_h)(\pi_h + d_h)(\gamma_h + d_h)(\rho_h + d_h) d_h} \\ S_v^* = \dfrac{\mu_v N_v}{\tau_h + \tau_p + d_v},\ E_v^* = \dfrac{(\tau_h + \tau_p)\mu_v N_v}{(\tau_h + \tau_p + d_v)(\phi_v + d_v)},\ I_v^* = \dfrac{\phi_v (\tau_h + \tau_p)\mu_v N_v}{(\tau_h + \tau_p + d_v)(\phi_v + d_v) d_v} \\ S_p^* = \dfrac{\mu_p N_p}{N_p}, E_p^* = \dfrac{\pi_p \mu_p N_p}{(\pi_p + d_p)(\alpha_p + d_p)}, I_p^* = \dfrac{\alpha_p \pi_p \mu_p N_p}{(\pi_p + d_p)(\alpha_p + d_p)(\gamma_p + d_p)}, \\ R_p^* = \dfrac{\gamma_p \alpha_p \mu_p N_p}{(\pi_p + d_p)(\alpha_p + d_p)(\gamma_p + d_p) d_p} \end{cases} \tag{14}$$

where

$$\pi_h = \frac{\varepsilon_v \beta_v I_v}{N_h}$$

$$\pi_p = \frac{\varepsilon_v \beta_v I_v}{N_p}$$

$$\tau_h = \frac{\beta_h I_h}{N_h}$$

$$\tau_p = \frac{\beta_p I_p}{N_p}$$

Basic Reproduction Number

Adopting the next-generation matrix criterion as in [6], we have

$$R_0 = \rho\left(FV^{-1}\right) = \sqrt{\frac{\beta_v \phi_v \varepsilon_v (\alpha_h \beta_h P_5 P_6 + \alpha_p \beta_p P_1 P_2)}{P_1 P_2 P_3 P_4 P_5 P_6}} \tag{15}$$

Where

$$P_1 = \alpha_h + d_h,\quad P_2 = \gamma_h + d_h,\quad P_3 = \phi_v + d_v,\quad P_4 = \alpha_p + d_p,\quad P_5 = \gamma_p + d_p$$

3.1.3 Local Stability of Disease-Free Equilibrium

The following result is a proof of local stability of the *chikungunya*-free equilibrium points.

Theorem 3

The *chikungunya*-free equilibrium states is locally asymptotically stable if $R_0 < 1$ and is unstable if $R_0 > 1$.

Proof

The Jacobian matrix of the system (1) evaluated at *chikungunya*-free equilibrium is obtained as

$$J_1\left(E_0^*\right)=\begin{bmatrix} \mu_h-d_h & 0 & 0 & 0 & 0 & 0 & 0 & \varepsilon_v\beta_v & 0 & 0 & 0 & 0 \\ 0 & -(\alpha_h+d_h) & 0 & 0 & 0 & 0 & 0 & \varepsilon_v\beta_v & 0 & 0 & 0 & 0 \\ 0 & \alpha_h & -(\gamma_h+d_h) & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & \gamma_h & -(\rho_h+d_h) & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \rho_h & \mu_h-d_h & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & -\beta_h & 0 & 0 & \mu_v-d_v & 0 & 0 & 0 & 0 & -\beta_p & 0 \\ 0 & 0 & \beta_h & 0 & 0 & 0 & -(\phi_v+d_v) & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \phi_v & \mu_v-d_v & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\varepsilon_v\beta_v & \mu_p-d_p & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & \varepsilon_v\beta_v & 0 & -(\alpha_p+d_p) & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \alpha_p & -\left(\gamma_p+d_p\right) & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \gamma_p & \mu_p-d_p \end{bmatrix} \quad (16)$$

We need to show that all eigen values of (16) are negative. As the first, fifth, sixth, ninth and last columns contains only the diagonal term which forms the eigen value, $\mu_h-d_h, \mu_h-d_h, \mu_v-d_v, \mu_p-d_p$ and μ_p-d_p, the other seven eigen values can be obtained from the sub-matrix $J_2\left(E^0\right)$. Hence, we have

$$J_2\left(E_0^*\right)=\begin{bmatrix} -\left(\alpha_h+d_h\right) & 0 & 0 & \varepsilon_v\beta_v & 0 & 0 \\ \alpha_h & -\left(\gamma_h+d_h\right) & 0 & 0 & 0 & 0 \\ 0 & \beta_h & -\left(\phi_v+d_v\right) & 0 & 0 & 0 \\ 0 & 0 & \phi_v & -(d_v-\mu_v) & 0 & 0 \\ 0 & 0 & 0 & \varepsilon_v\beta_v & -\left(\alpha_p+d_p\right) & 0 \\ 0 & 0 & 0 & 0 & \alpha_p & -\left(\gamma_p+d_p\right) \end{bmatrix} \quad (17)$$

Similarly, the sixth and the fifth column of (17) contains only the diagonal elements that forms the eigen values, $-\left(\gamma_p+d_p\right)$ *and* $-\left(a_p+d_p\right)$. The remaining four eigen values can be obtained from the sub-matrix $J_3\left(E_0^*\right)$ as:

$$J_3\left(E_0^*\right)=\begin{bmatrix} -\kappa_1 & 0 & 0 & \varepsilon_v\beta_v \\ \alpha_h & -\kappa_2 & 0 & 0 \\ 0 & \beta_h & -\kappa_3 & 0 \\ 0 & 0 & \phi_v & -\kappa_4 \end{bmatrix} \quad (18)$$

where:

$\kappa_1=\alpha_h+d_h,\ \kappa_2=\gamma_h+d_h,\ \kappa_3=\phi_v+d_v,$ *and* $\kappa_4=d_v-\mu_v$

The Characteristic polynomial of matrix (4.91) is given as:

$$m_1\lambda^4+m_2\lambda^3+m_3\lambda^2+m_4\lambda+m_5 \quad (19)$$

By adopting the Routh-Hurwitz criterion for stability to investigate the stability of (18) where:

$m_1=1$

$m_2=\kappa_1+\kappa_2+\kappa_3+k_4$

$$m_3 = (\kappa_3(\kappa_1 + \kappa_2) + \kappa_1\kappa_2 + \kappa_4(\kappa_1 + \kappa_2 + \kappa_3)$$
$$m_4 = (\kappa_4(\kappa_3\kappa_1 + \kappa_2) + \kappa_1\kappa_2) + \kappa_1\kappa_2\kappa_3)$$
$$m_5 = \kappa_1\kappa_2\kappa_3\kappa_4 - \alpha_h\beta_h\beta_v\phi_v\varepsilon_v$$

By setting up Routh-Hurwitz array matrix we obtained:

$$\Rightarrow \begin{vmatrix} D_1 & D_3 & D_5 & 0 & 0 \\ 1 & D_2 & D_4 & 0 & 0 \\ 0 & D_1 & D_3 & D_5 & 0 \\ 0 & 1 & D_2 & D_4 & 0 \\ 0 & 0 & D_1 & D_3 & D_5 \end{vmatrix}$$

$$H_1 = D_1 > 0 \tag{20}$$
$$\therefore H_1 > 0$$
$$\Rightarrow H_2 = \begin{vmatrix} D_1 & 0 \\ 1 & D_2 \end{vmatrix}$$
$$|H_2| = D_1D_2 - 0 \tag{21}$$
$$\therefore |H_2| = D_1D_2 > 0$$
$$\Rightarrow H_3 = \begin{vmatrix} D_1 & D_3 & 0 \\ 1 & D_2 & D_4 \\ 0 & D_1 & D_3 \end{vmatrix}$$
$$|H_3| = -D_4D_1^2 + D_1D_2D_3 - D_3^2 \tag{22}$$
$$\therefore |H_3| = D_1D_2D_3 > D_4AD^2 + D_3^2$$
$$\Rightarrow H_4 = \begin{vmatrix} D_1 & D_3 & 0 & 0 \\ 1 & D_2 & D_4 & 0 \\ 0 & D_1 & D_3 & 0 \\ 0 & 1 & D_2 & D_4 \end{vmatrix}$$
$$|H_4| = -D_{42}D_1^2 + D_1D_2D_3D_4 - D_3^2D_4$$
$$\therefore |H_4| = D_1D_2D_3D_4 > D_1^2D_4^2 + D_3^2D_4$$
$$\Rightarrow H_5 = \begin{vmatrix} D_1 & D_3 & D_5 & 0 & 0 \\ 1 & D_2 & D_4 & 0 & 0 \\ 0 & D_1 & D_3 & D_5 & 0 \\ 0 & 1 & D_2 & D_4 & 0 \\ 0 & 0 & D_1 & D_3 & D_5 \end{vmatrix}$$
$$|H_5| = -D^2D_4^2D_5 - D_1D_2^2D^2 + D_1D_2D_3D_4D_5 + 2D_1D_4D_5^2 + D_2D_3D_5^2 - D_3^2D_4D_5 - D_5^3 \tag{23}$$
$$\therefore |H_5| = D_1D_2D_3D_4D_5 + 2D_1D_4D_5^2 + D_2D_3D_5^2 > D^2D_4^2D_5 + D_1D_2^2D^2 + D_3^2D_4D_5 + D_5^3$$

Since $H_1 = H_2 = H_3 = H_4 = H_5 > 0$ as observed, by applying Routh-Hurwitz criteria which asserts that all roots of the polynomial (18) have a negative real component if and only if the coefficient are positive and the determinant of the matrix $H_i > 0$ for $i = 1...5$. It is clear that $A_i > 0$ for $i = 1...5$ are

positive when $R_0 < 0$. Since the necessary condition for Routh-Hurwitz criteria for the fifth-order characteristics polynomial in (18) is satisfied, we conclude that, the *chikungunya* free equilibrium is locally asymptotically stable (LAS) when $R_0 < 0$.

3.1.4 Global Stability of *Chikungunya*-free Equilibrium State

We use the Castillo-Chavez theorem as in [2] to investigate the global asymptotic stability of the *Chikungunya*-free state.

$$\frac{dX}{dt} = H(X,Z)$$
$$\frac{dZ}{dt} = G(X,Z), G(X,0) = 0 \tag{24}$$

Where $X = (S_h, R_h, C_h, S_v, S_p, R_p)$ and $Z = (E_h, I_h, E_v, I_v, E_p, I_p)$. Here, the components of $X \in \mathbb{R}^6$ denote the uninfected individuals and the components of $Z \in \mathbb{R}^6$ denote the infected individuals. The *Chikungunya*-free equilibrium of the system now becomes $E_0^* = (X^*, 0)$. To guarantee global asymptotic stability, the following two conditions must be met.

i. $\frac{dX}{dt} = H(X,0)$, X^* is globally asymptotically stable (GAS)

ii. $G(X,Z) = PZ - \hat{G}(X,Z)$, $\hat{G}(X,Z) \geq 0$ for $(X,Z) \in \Omega$

Where $P = D_Z G(X^*, 0)$ is a M matrix (the off diagonal elements of P are non-negative) and Ω is the region where the model is biologically meaningful. If the system (1) satisfies conditions (i) and (ii) then the following theorem holds.

Theorem 4

The fixed point $E_0^* = (X^*, 0)$ is a globally asymptotic stable equilibrium of (1) provided that $R_0 < 1$ and the assumptions (i) and (ii) are satisfied.

Proof

Since $X = (S_h, R_h, C_h, S_v, S_p, R_p)$ and $Z = (E_h, I_h, E_v, I_v, E_p, I_p)^T$ then

$$H(X,Z) = \begin{bmatrix} \mu_h N_h(t) - \left(\frac{\varepsilon_v \beta_v I_v(t)}{N_h(t)} + d_h\right) S_h(t) \\ \gamma_h I_h(t) - (\rho_h + d_h) R_h(t) \\ \rho_h R_h(t) - d_h C_h(t) \\ \mu_v N_v(t) - \left(\frac{\beta_h I_h(t) + \beta_p I_p(t)}{N_v(t)} + d_v\right) S_v(t) \\ \mu_p N_p(t) - \left(\frac{\varepsilon_v \beta_v I_v(t)}{N_p(t)} + d_p\right) S_p(t) \\ \gamma_p I_p(t) - d_p R_p(t) \end{bmatrix} \tag{25}$$

Then

$$H(X,0)=\begin{bmatrix}\mu_h N_h - d_h S_h\\ 0\\ 0\\ \mu_v N_v - d_v S_v\\ \mu_p N_p - d_p S_p\\ 0\end{bmatrix} \tag{26}$$

and

$$\hat{G}(X,Z)=PZ-G(X,Z) \tag{27}$$

Where:

$$G(X,Z)=\begin{bmatrix}\dfrac{\varepsilon_v\beta_v S_h(t)I_v(t)}{N_h(t)}-(\alpha_h+d_h)E_h(t)\\ \alpha_h E_h(t)-(\gamma_h+d_h)I_h(t)\\ \left(\dfrac{\beta_h I_h(t)+\beta_p I_p(t)}{N_v(t)}\right)S_v(t)-(\phi_v+d_v)E_v(t)\\ \phi_v E_v(t)-d_v I_v(t)\\ \dfrac{\varepsilon_v\beta_v S_p(t)I_v(t)}{N_p}-(\alpha_p+d_p)E_p(t)\\ \alpha_p E_p(t)-(\gamma_p+d_p)I_p(t)\end{bmatrix} \tag{28}$$

and $P=D_Z G(X^*,0)$ is the Jacobian of $G(X,Z)$ with respect to Z, such that

$$P=\begin{bmatrix}-(\alpha_h+d_h) & 0 & 0 & \dfrac{\varepsilon_v\beta_v\mu_h}{d_h} & 0 & 0\\ \alpha_h & -(\gamma_h+d_h) & 0 & 0 & 0 & 0\\ 0 & \dfrac{\beta_h\mu_v}{d_v} & -(\phi_v+d_v) & 0 & 0 & \dfrac{\beta_p\mu_v}{d_v}\\ 0 & 0 & \phi_v & -d_v & 0 & 0\\ 0 & 0 & 0 & \dfrac{\varepsilon_v\beta_v S_p}{N_p} & -(\alpha_p+d_p) & 0\\ 0 & 0 & 0 & 0 & \alpha_p & -(\gamma_p+d_p)\end{bmatrix} \tag{29}$$

and

$$PZ=\begin{bmatrix} -(\alpha_h+d_h)E_h & 0 & 0 & \frac{\varepsilon_v\beta_v\mu_h}{d_h}I_v & 0 & 0 \\ \alpha_hE_h & -(\gamma_h+d_h)I_h & 0 & 0 & 0 & 0 \\ 0 & \frac{\beta_h\mu_v}{d_v}I_h & -(\phi_v+d_v)E_v & 0 & 0 & \frac{\beta_p\mu_v}{d_v}I_p \\ 0 & 0 & \phi_vE_v & -d_vI_v & 0 & 0 \\ 0 & 0 & 0 & \frac{\varepsilon_v\beta_v\mu_p}{d_p}I_v & -(\alpha_p+d_p)E_p & 0 \\ 0 & 0 & 0 & 0 & \alpha_pE_p & -(\gamma_p+d_p)I_p \end{bmatrix} \quad (30)$$

Therefore,

$$\hat{G}(X,Z)=\begin{bmatrix} \hat{G}_1(X,Z) \\ \hat{G}_2(X,Z) \\ \hat{G}_3(X,Z) \\ \hat{G}_4(X,Z) \\ \hat{G}_5(X,Z) \\ \hat{G}_6(X,Z) \end{bmatrix}=\begin{bmatrix} \varepsilon_v\beta_vI_v\left(1-\frac{S_h}{N_h}\right) \\ 0 \\ \beta_hI_h+\beta_pI_p\left(1-\frac{S_v}{N_v}\right) \\ 0 \\ \varepsilon_v\beta_vI_v\left(1-\frac{S_p}{N_p}\right) \\ 0 \end{bmatrix} \quad (31)$$

Therefore, $\hat{G}(X,Z)\geq 0$. If and only if:

$\hat{G}_1(X,Z)\geq 0 \Rightarrow S_h\leq N_h$ (32a)

$\hat{G}_3(X,Z)\geq 0 \Rightarrow S_v\leq N_v$ (32b)

$\hat{G}_5(X,Z)\geq 0 \Rightarrow S_p\leq N_p$ (32c)

Conditions (i) and (ii) have been met and therefore E_0^* is globally asymptotically stable.

2.4 4 Sensitivity Analysis

From the results of [18], it follows that, a positive index sign indicates that an increase in the parameter's value will result in an increase in the value of the reproduction number and a reduction in the parameter's value will reduce the value of the reproduction number. A negative index sign indicates that an increase in the parameter's value will result in a reduction in the value of the reproduction number and a reduction in the parameter's value will result in an increase in the value of the reproduction number.

Table 3: Parameters, solutions and baseline values used in the model and their sensitivity index

parameter	solution	Baseline value	Sensitivity index

ϕ_v	$\frac{d_v}{2d_v+2\phi_v}$	0.033	0.3418
β_v	$\frac{\beta_v}{\sqrt{\frac{\beta_v\phi_v\varepsilon_v(\alpha_h\beta_h(a_p+d_p)(\gamma_p+d_p)+\alpha_p\beta_p(\alpha_h+d_h)(\gamma_h+d_h)}{(\alpha_h+d_h)(\gamma_h+d_h)(\phi_v+d_v)(\alpha_p+d_p)(\gamma_p+d_p)d_v}}}$	0.005	0.5
ε_v	$\frac{d_v}{2d_v+2\phi_v}$	0.090	0.5
β_h	$\frac{(a_p+d_p)(\gamma_p+d_p)\alpha_p\beta_h}{2\alpha_h\beta_h(\alpha_p+d_p)(\gamma_p+d_p)\alpha_p\beta_p(\alpha_h+d_h)(\gamma_h+d_h)}$	0.001	0.4240
β_p	$\frac{(a_p+d_p)(\gamma_p+d_p)\alpha_p\beta_p}{2\alpha_h\beta_h(\alpha_p+d_p)(\gamma_p+d_p)\alpha_p\beta_p(\alpha_h+d_h)(\gamma_h+d_h)}$	0.003	0.0760
α_h	$\frac{\beta_h d_h(a_p+d_p)(\gamma_p+d_p)\alpha_h}{2(\alpha_h+d_h)(((\gamma_p+d_p)\beta_h+\beta_p(\gamma_h+d_h))\alpha_p+\beta_h d_p(\gamma_p+d_p)\alpha_h+\alpha_p\beta_p d_h(\gamma_h+d_h)}$	0.133	0.0761
d_h	$-\frac{a_h\beta_h(a_p+d_p)(\alpha_p+d_p)(\gamma_h+2d_h)d_h}{2(\gamma_h+d_h)(\alpha_h+d_h)(((\beta_p d_h+\beta_p\gamma_h+(\gamma_p+d_p)\beta_h)\alpha_p+\beta_h d_p(\gamma_p+d_p)\alpha_h+\alpha_p\beta_p d_h(\gamma_h+d_h)}$	0.0000	0.00036
γ_h	$-\frac{2d_v-\phi_v}{2d_v+2\phi_v}$	0.066	-0.4238
α_p	$\frac{\beta_p d_p(\gamma_h+d_h)(\alpha_h+d_h)\alpha_p}{2(\alpha_p+d_p)(((\gamma_p+d_h)\beta_h+\beta_p+(\gamma_h+d_h)\alpha_h+\beta_p d_p(\gamma_h+d_h))\alpha_p+\alpha_h\beta_h d_h(\gamma_p+d_p)}$	0.330	0.0036
d_p	$-\frac{\beta_p\alpha_p(\gamma_h+d_h)(\gamma_p+2d_p+\alpha_p)(\alpha_h+d_h)d_p}{2(\alpha_p+d_p)(\gamma_p+d_p)((\beta_p d_p+\beta_p\gamma_p+\beta_p(\gamma_h+d_h)\alpha_h+\beta_p d_h(\gamma_h+d_h))\alpha_h+\alpha_h\beta_h d_h(\gamma_p+d_p)}$	0.003	-0.0287
γ_p	$-\frac{2d_v-\phi_v}{2d_v+2\phi_v}$	0.1428	-0.0744

d_v	$-\frac{2d_v-\phi_v}{2d_v+2\phi_v}$	0.0713	-0.8418

Table 3: Parameters, baseline values and sensitivity index used for R_0 used in the model.

Table 4: Parameter values for numerical simulations

Symbols	Values	Reference
β_h	0.001	[12]
β_v	0.005	[12]
β_p	0.003	Assumed
ε_v	0.09	[11]
α_h	0.133	[5]
γ_h	0.066	[5]
μ_h	0.00004	[5]
d_h	0.00004	[5]
ρ_h	0.033	[5]
μ_v	0.07133	[5]
μ_p	0.003	Assumed
ϕ_v	0.033	[5]
d_v	0.07133	[5]
d_p	0.003	Assumed
γ_p	0.1428	[9]
α_p	0.33	[5]

Table 5: Variable values for numerical simulations

Symbols	Values	Reference
$S_h(0)$	7788	[5]
$E_h(0)$	4000	[5]
$I_h(0)$	2300	[5]
$R_h(0)$	58	[5]
$C_h(0)$	3	[5]

$S_v(0)$	2500	Assumed
$E_v(0)$	1700	Assumed
$I_v(0)$	1000	Assumed
$S_p(0)$	3000	Assumed
$E_p(0)$	1800	Assumed
$I_p(0)$	1000	Assumed
$R_p(0)$	400	Assumed

5 Numerical Simulation

Numerical simulation on the dynamics of the sub-populations, the variation of transmission rate and the impact of biting rate plotted against time via MATLAB R2015 computational software as shown in figure 4.1 to figure 4.6. For the purpose of illustration, the initial values together with the parameter values in Table 4.1 and Table 4.2 are used to obtain all the plots, the numerical results presented in Figure 4.1 to Figure 4.6 are discussed in cases 1 to 6.

5.1 Dynamics of the sub-populations over time t

The dynamics of sub-populations are presented in figure 2a to figure 2l

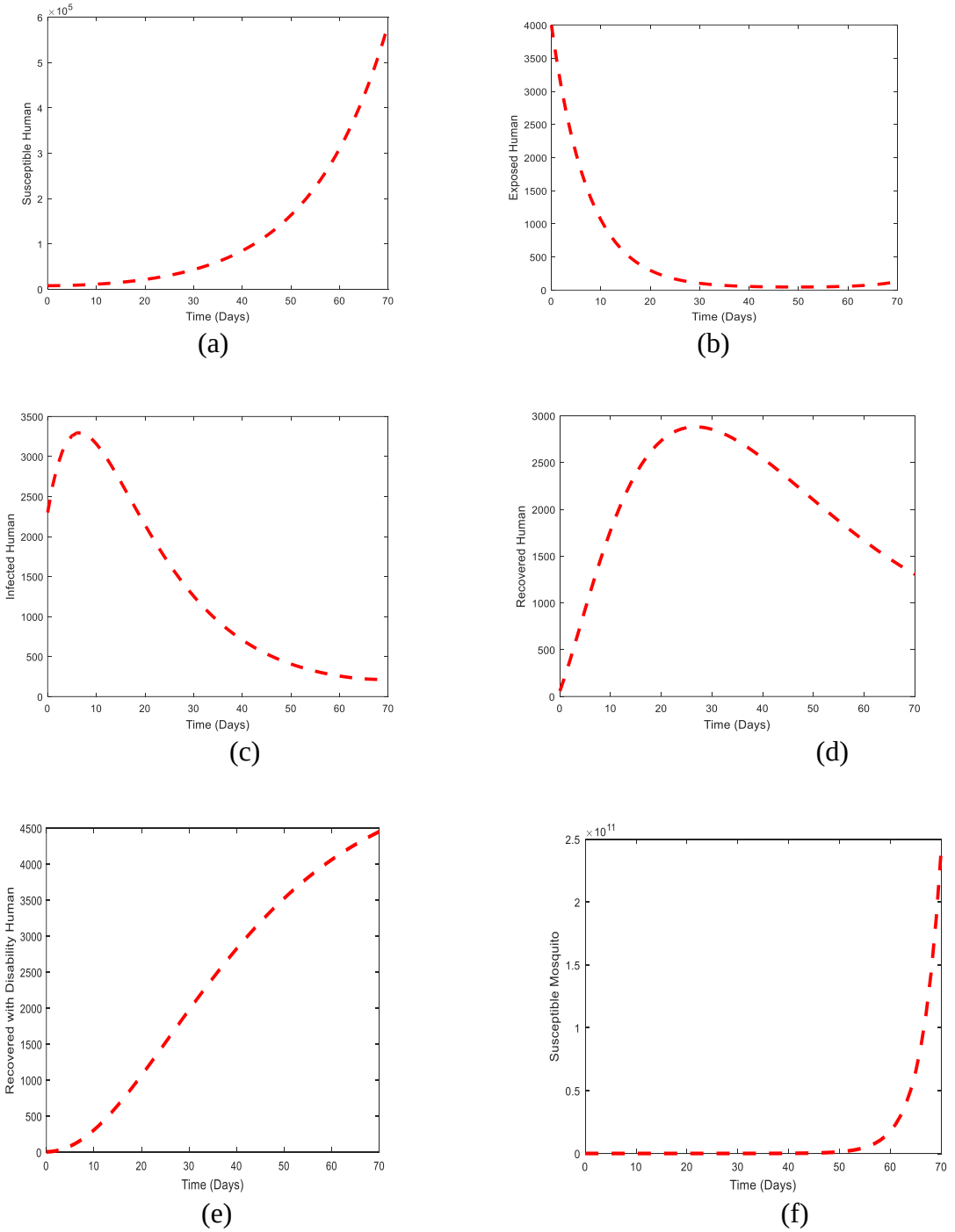


Figure 2: Behaviour of susceptible human, exposed human, infected human, recovered human, recovered with disability human and susceptible mosquito plotted against time.

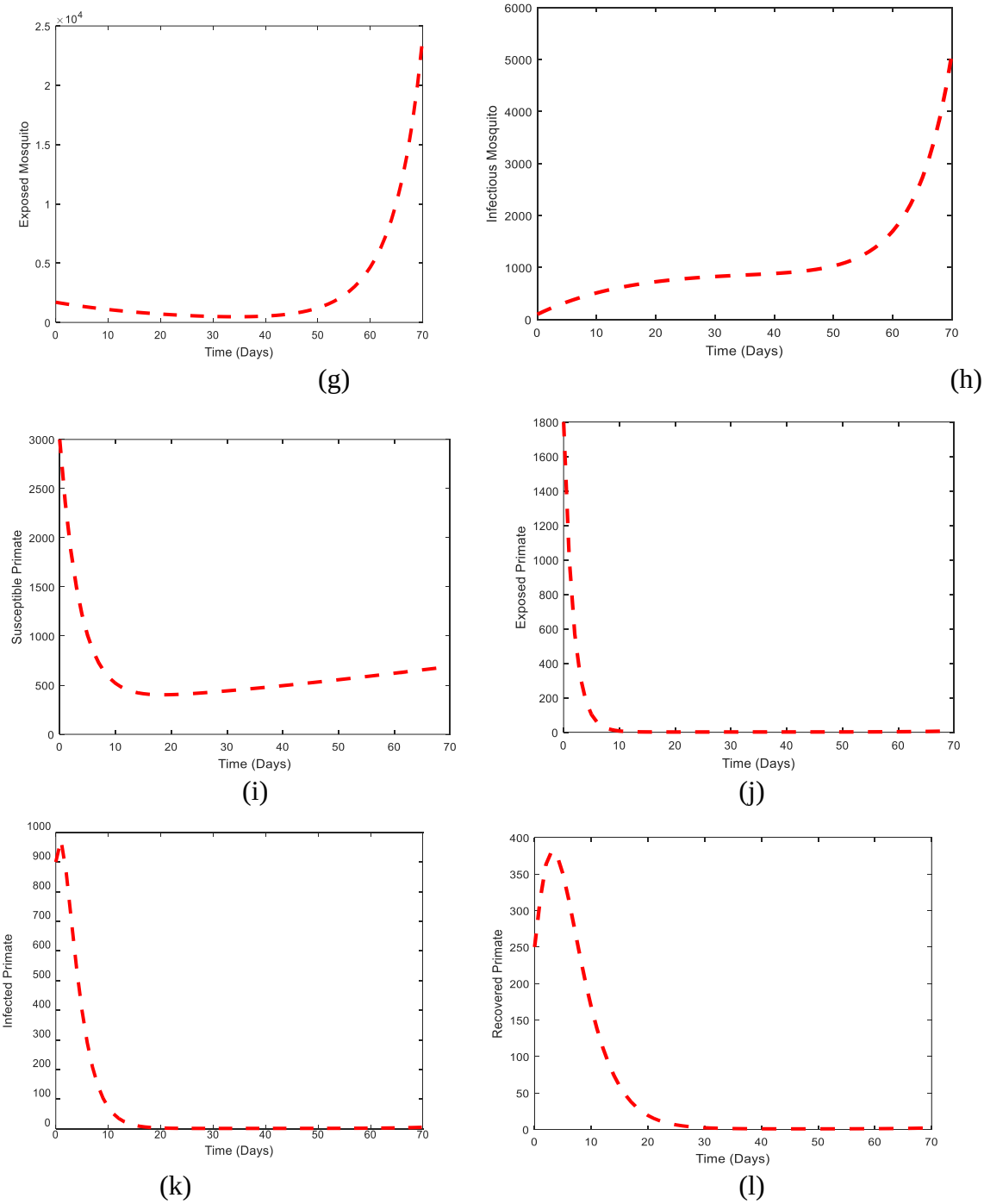


Figure 3: Behaviour of exposed mosquito, infected mosquito, susceptible primate, exposed primate, infected primate and recovered primate plotted against time.

5.2 Variation of β_h over time t

The transmission rate was varied to show the impact of parameter on the disease and presented in figure 4.2a to figure 4.2l

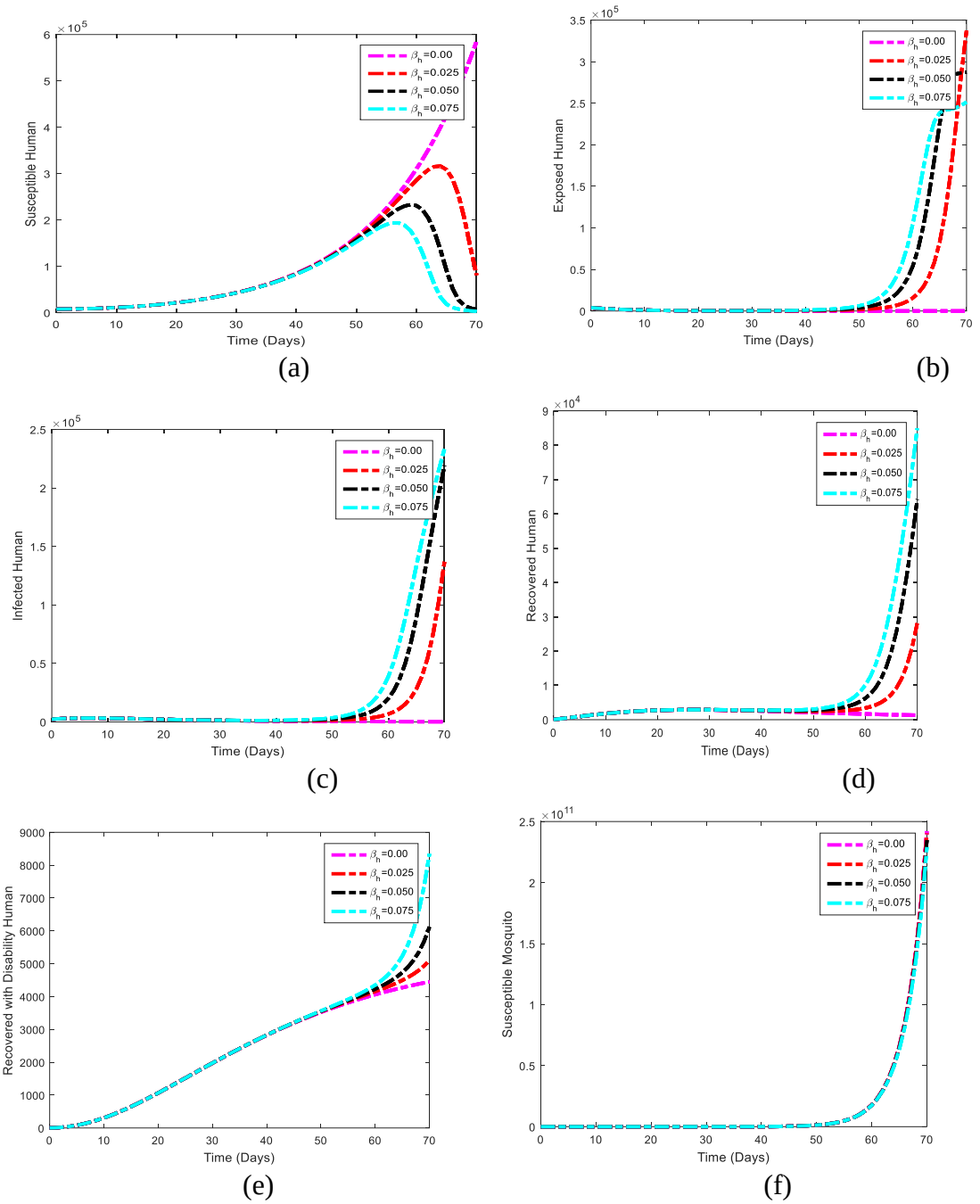
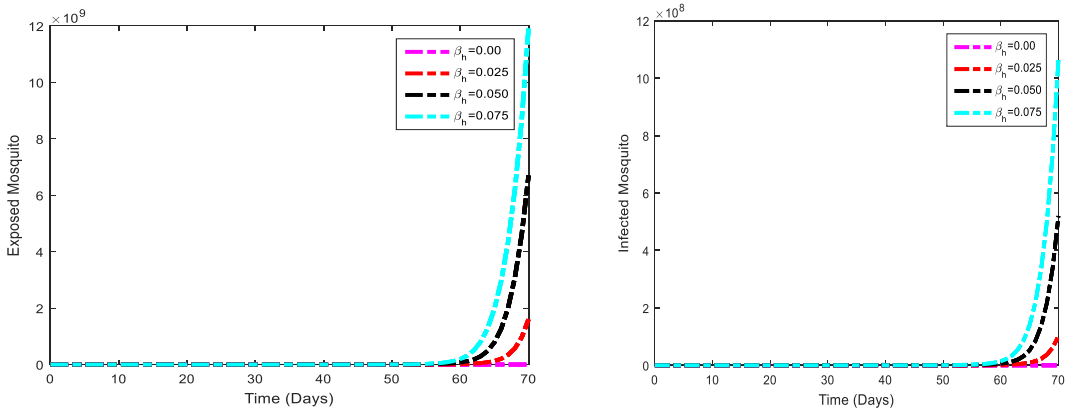
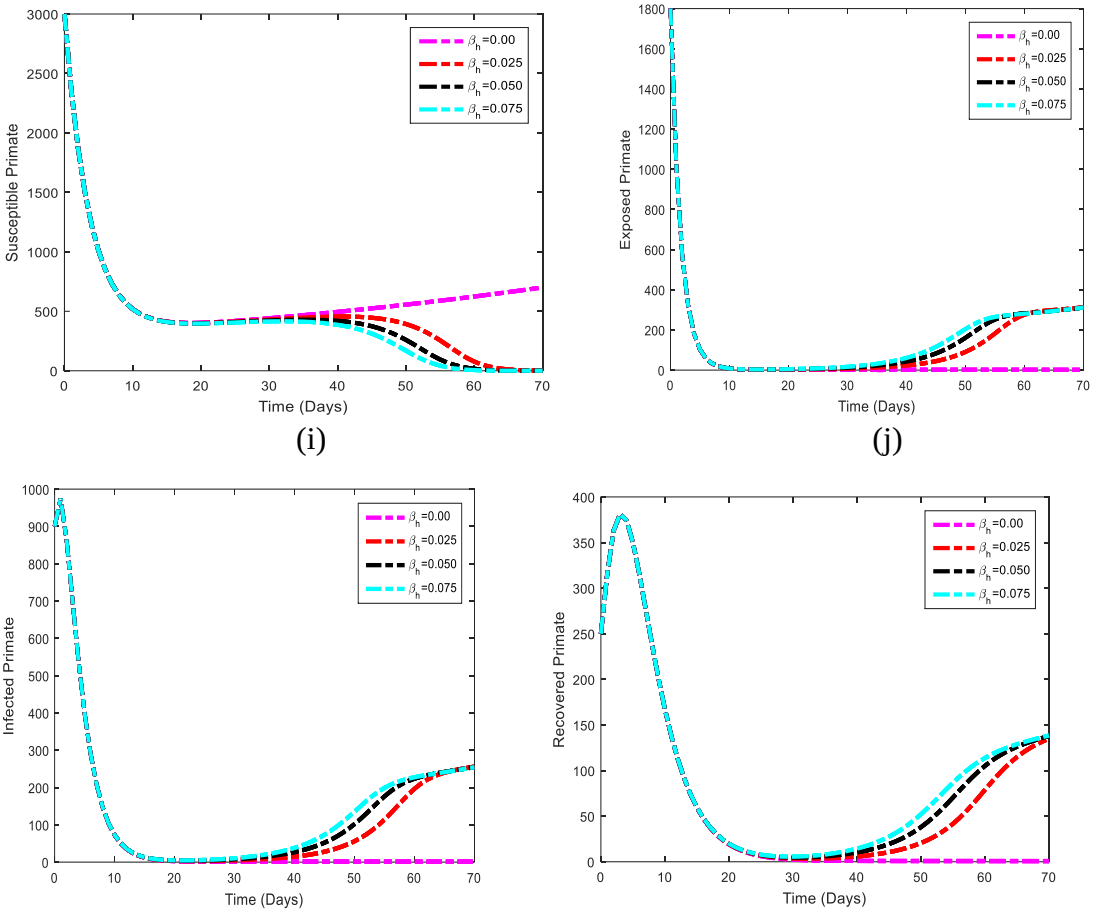


Figure 4: The impact of the transmission rate of mosquito on susceptible human, exposed human, infected human, recovered human, recovered with disability human and susceptible mosquito.



(g) (h)



(i) (j)

(k) (l)

Figure 5: The impact of the transmission rate of mosquito on exposed mosquito, infected mosquito, susceptible primate, exposed primate, infected primate and recovered primate.

5.3 Variation of ε_v over time t

The biting rate of mosquito was varied to show the impact of the parameter on the disease and presented in figure 6a to figure 7l

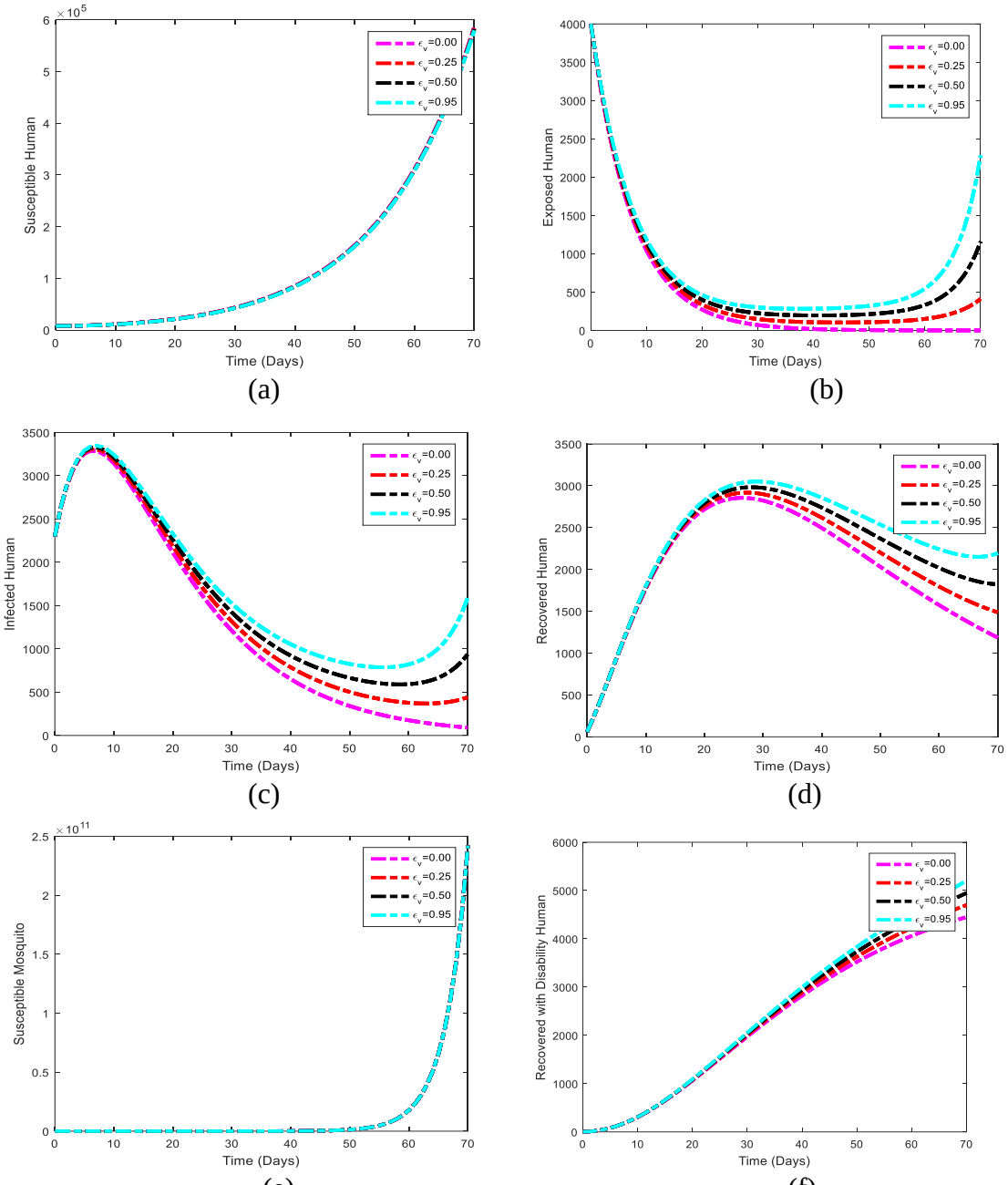


Figure 6: The impact of the biting rate of mosquito on susceptible human exposed human, infected human, recovered human, susceptible primate and recovered human with disability.

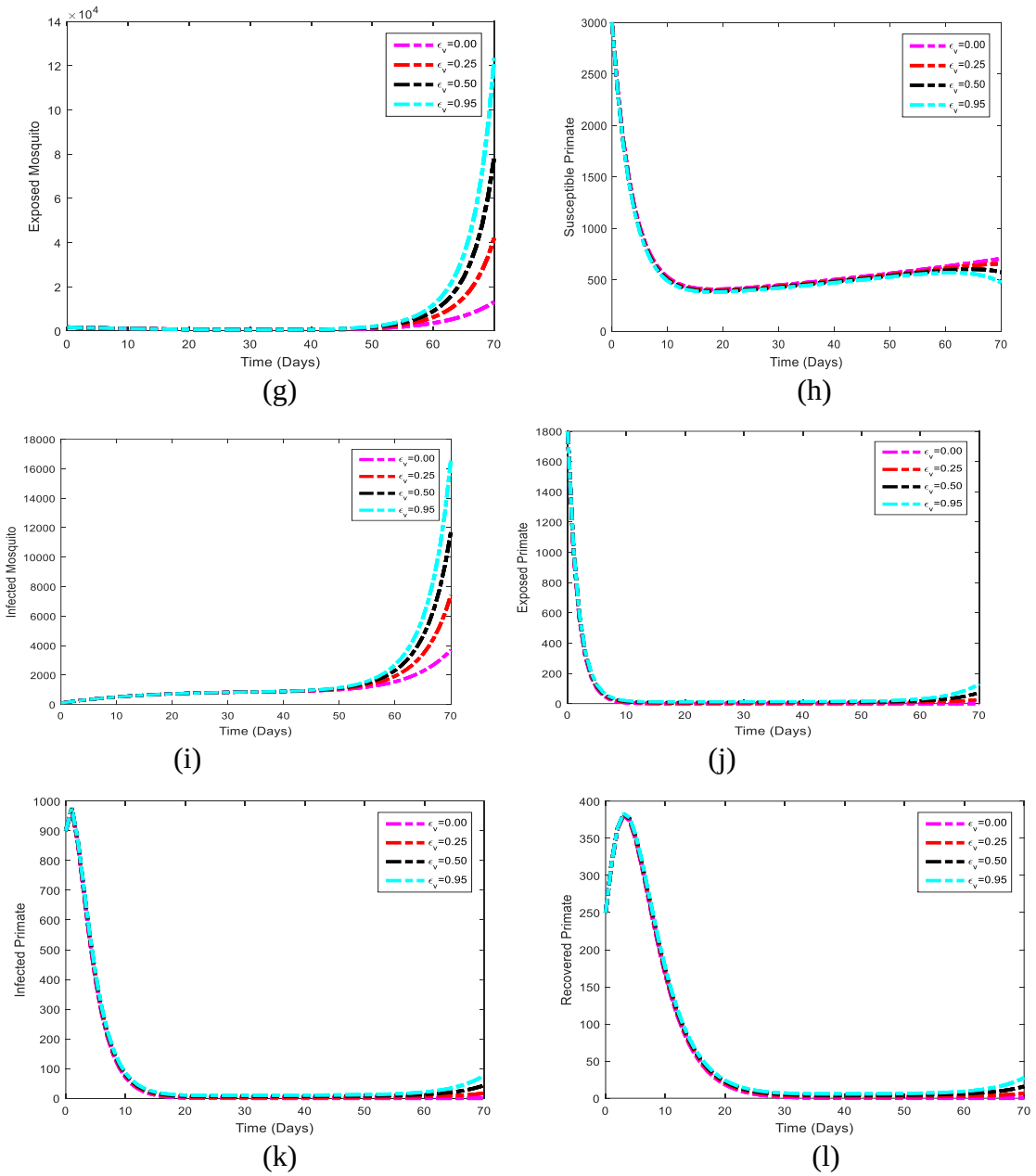


Figure 7: The impact of the biting rate of mosquito on exposed mosquito, susceptible primate, infected mosquito, exposed primate, infected primate and recovered primate.

6 Discussion of Analytical results

This research presents a deterministic mathematical model for investigating the dynamics of *Chikungunya* virus transmission in human, vector (mosquito) and primate population. A system of nonlinear differential equations was used to formulate the mathematical model. The *Chikungunya* model consist of (12) system of nonlinear differential equations. The positivity of the solution shows that the system of differential equations has non-negative solution for all time t, and is bounded within the given region. The *chikungunya*-free and *chikungunya* present equilibrium state were obtained. We used Routh-hurwitz criterion to determine the local stability while Castillo-Chavez conditions were applied to prove the global stability. From the analysis $R_0 < 1$ and the stability also revealed that the *chikungunya* -free equilibrium state is asymptotically stable locally and globally. This implies that the disease will completely die out since the system is stable.

Case 1: Behaviour of susceptible human, exposed human, infected human, recovered human, recovered with disability human and susceptible mosquito plotted against time

Dynamics of the sub-populations over time *t* considering susceptible human, exposed human, infected human, recovered human, recovered with disability human and susceptible mosquito plotted against time. It is observed that both susceptible human (figure 2a) and susceptible mosquito (figure 2f) increases gradually over time, this is due to the variable recruitment of the population over time. The exposed human (figure 2b) population decline gradually and becomes asymptotic over time, which results in a corresponding increase in the number of the infected human (figure 2c), recovered human (figure 2d) and recovered with disability human (figure 2e). The infected human (figure 2c) and recovered human (figure 2d) population shows a steady increase until it reaches its maximum in 10 days and 30 days respectively before maintaining a steady decline but never varnishes. Recovered individuals gain permanent immunity to the disease and hence individuals do not become susceptible again.

Case 2: Behaviour of exposed mosquito, infected mosquito, susceptible primate, exposed primate, infected primate and recovered primate plotted against time

The dynamics of the sub-populations over time *t* of exposed mosquito, infected mosquito, susceptible primate, exposed primate, infected primate and recovered primate plotted against time as shown in figure 3 (g-l). The result shows a steady increase in the number of exposed mosquito (figure 3g) and infected mosquito over time (figure 3h). This is as a result of frequent interaction of the mosquito population with either infected human or infected primate. There is a continuous decrease in the population of susceptible primate (figure 2i) and exposed primate (figure 3j) which results in a sharp rise in the infected primate (figure 3k) and recovered primate (figure 3l) until it reaches a maximum and then maintains a steady decline to become asymptotically stable. This is due to the presence of precautionary measures in curtailing the spread CHIKV in the population. Recovered primate population gain permanent immunity to *chikungunya* and hence they do not become susceptible again.

Case 3: Dynamics Showing the impact of the transmission rate of mosquito on susceptible human, exposed human, infected human, recovered human, recovered with disability human and susceptible mosquito.

Sub-population model with variation of β_h over time *t* considering the impact of the transmission rate of mosquito on susceptible human, exposed human, infected human, recovered human, recovered with disability human and susceptible mosquito as shown in (figure 4a-f). It is observed that varying the transmission rate on the susceptible human population (figure 4a) causes a rapid decline before maintaining a steady decline over time which shows a corresponding sharp rise in exposed human (figure 4b), infected human (figure 4c) and recovered human (figure 4d), this is as a result of progressive movement between compartments. Recovered with disability human (figure 4e) compartment also shows positive relationship with the transmission rate, that is, as the transmission rate increases, recovered with disability human (figure 4e) also increases over time.

Case 4: Dynamics showing the impact of the transmission rate of mosquito on exposed mosquito, infected mosquito, susceptible primate, exposed primate, recovered primate and recovered primate.

The graph demonstrates that the transmission rate has a significant impact on the spread of the disease through the population. If the transmission rate is observed to be high then the rate of infection of the *chikungunya* will also be high. In figure4.4 it is observed that over time, the population of exposed mosquito (figure 5g) and infected mosquito (figure 5h) increases steadily over varying transmission rate. Also it is observed that varying transmission rate causes the susceptible primate population to decrease which in turn has an increasing effect on exposed primate (figure 4.4i), infected primate (figure 5j) and recovered primate (figure 5k). The reason is that, when the *chikungunya* is present in

the population, there is a progression from the susceptible class to exposed class, from exposed class to infected and from infected to recovered class. This supports the theoretical perspective.

Case 5: The impact of the biting rate of mosquito on susceptible human, exposed human, infected human, recovered human, susceptible mosquito and recovered with disability human.

In the graph, it is observed that biting rate show no significant effect on both susceptible human (figure 6a) and susceptible mosquito (figure 6e) over the period of time under consideration. Whereas, varying biting rate of mosquito shows positive impact on exposed human (figure 6b), infected human (figure 6c), recovered human (figure 4.5d) and recovered with disability human (figure 6f). This shows that the graph demonstrates that biting rate has a significant impact on the spread of the *chikungunya* through the population which confirmed theoretical perspective.

Case 6: The impact of the biting rate of mosquito on exposed mosquito, susceptible primate, infected mosquito, exposed primate, infected primate, and recovered primate.

The graph demonstrates that biting rate has a significant impact on the spread of the disease through the population. If the biting is observed to be high then the rate of infection of the disease will also be high. By varying biting rate of mosquito shows a wide increasing effect on exposed mosquito (figure 7g) and infected mosquito (figure 7i) compartments which also has a slide or little increasing effect on susceptible primate (figure 7h), exposed primate (figure 7j), infected primate (figure 7k) and recovered primate (figure 7l) compartments.

References

[1] Burt, F. J., Rolph, M. S., Rulli, N. E., Mahalingam, S., & Heise, M. T. (2012). Chikungunya: Re-emerging Virus. Lancet, 379, 662–671.

[2] Castillo-Chavez, C., Feng, Z., & Huang, W. (2002). Dynamic Model of Tuberculosis and their Application. Mathematical Biosciences and Engineering Journal, 1(2).

[3] Centers for Disease Control and Prevention. (2006). Chikungunya Fever Diagnosed Among International Travelers-United States. MMWR Morbidity and Mortality Weekly Report, 55(38), 1040-1042.

[4] Chabra, M. V., Mittal, D., Bhattacharya, U., Rana, U., & Lal, S. (2008). Chikungunya Fever: A Re-Emerging Viral Infection. Indian Journal of Medical Microbiology, 26(1), 5–12.

[5] Gilberto, C., González-Parra, D. F., Aranda, B., Chen-Charpentier, M. D., & Jaime, E. C. (2019). Mathematical Modeling and Characterization of the Spread of Chikungunya in Colombia. ResearchGate. https://www.researchgate.net/publication/330117771

[6] Lahariya, C., & Pradhan, S. (2006). Emergence of Chikungunya virus in Indian subcontinent after 32 years: a review. Journal of Vector Borne Diseases, 43(4), 151.

[7] Lumsden, W. H. R. (1955). An Epidemic of Virus Disease in Southern Province, Tanganyika Territory, in II. General Description and Epidemiology. Transactions of the Royal Society of Tropical Medicine and Hygiene, 49(1), 33-57.

[8] Mavalankar, D. P., Shastri, T., Bandyopadhyay, J., Parmar, H. P., & Ramani, K. V. (2008). Increased Mortality Rate Associated with Chikungunya Epidemic, Ahmedabad, India. Emerging Infectious Diseases, 14(3), 412–415.

[9] Moro, M. L., Grilli, E., Corvetta, A., Silvi, G., Angelini, R., Mascella, F., Miserocchi, F., Sambo, P., Finarelli, A. C., Sambri, V., Gagliotti, C., Massimiliani, E., Mattivi, A., Pierro, A. M., & Macini, P. (2012). Long-Term Chikungunya Infection Clinical Manifestations after an Outbreak in Italy: A Prognostic Cohort Study. Journal of Infection, 65(2), 165–172.

[10] Moulay, D., Aziz-Alaoui, M. A., & Cadivel, M. (2011). The Chikungunya Disease: Modeling, Vector and Transmission Global Dynamics. Mathematical Biosciences, 229(1), 50-63.

[11] Ndamazi, E., & Gahungu, P. (2021). Mathematical Modeling of Malaria Transmission Dynamics; Case of Burundi. Journal of Applied Mathematics and Physics, 9, 2447-2460.

[12] Pialoux, G., Gauzere, B. A., Jaureguiberry, S., & Strobel, M. (2007). Chikungunya, an Epidemic Arbovirosis. The Lancet Infectious Diseases, 7(5), 319-327.

[13] Powers, A. M., & Logue, C. H. (2007). Changing Patterns of Chikungunya Virus: Reemergence of Zoonotic Arbovirus. Journal of General Virology, 88(9), 2363-2377.

[14] Robinson, M. C. (1955). An Epidemic of Virus Disease in Southern Province, Tanganyika Territory, in 1952–53. I. Clinical Features. Transactions of the Royal Society of Tropical Medicine and Hygiene, 49, 28-32.

[15] Roth, A., Hoy, D., Horwood, P. F., Ropa, B., Hancock, T., Guillaumot, L., Rickart, K., Frison, K., Pavlin, B., & Souares, Y. (2014). Preparedness for Threat of Chikungunya in the Pacific. Emerging Infectious Diseases, 20(8).
[16] Schilte, C. F., Staikovsky, T., Couderc, Y., Madec, F., Carpentier, S., Kassab, M. L., Albert, M., Lecuit, M., & Michault, A. (2010). Chikungunya Virus-Associated Long Term Arthralgia: A 36-Month Prospective Longitudinal Study. PLoS Neglected Tropical Diseases, 7(3).
[17] Schuffenecker, I., Iteman, A., Michault, S., Murri, L., Frangeul, M. C., Vaney, R., Lavenir, N., Pardigon, J. M., Reynes, F., Pettinelli, L., Biscornet, L., Diancourt, S., Michel, S., Duquerroy, G., Guigon, M. P., Frenkiel, M. A., Brin, N., Cubito, P., Despres, F., Kunst, F., A. Rey, H., Zeller, A. G., & Brisse, S. (2006). Genome Microevolution of Chikungunya Viruses Causing the Indian Ocean Outbreak. PLoS Medicine, 3(7).
[18] Sirajo, A., Akinwande, N., Abubakar, U., & Awojoyogbe, B. (2013). Sensitivity Analysis of the Parameters of a Mathematical Model of Hepatitis B Virus Transmission. Universal Journal of Applied Mathematics, 1(4), 230-241.
[19] Sourisseau, M. C., Schilte, N., Casartelli, C., Trouillet, F., Guivel-Benhassine, D., Rudnicka, N., Sol-Foulon, K. L., Roux, M. C., Prevost, H., Fsihi, M. P., Frenkiel, F., Blanchet, P. V., Afonso, P. E., Ceccaldi, S., Ozden, A., Gessain, A., Schuffenecker, B., Verhasselt, A., Zamborlini, A., & Saïb, F. A. Rey, F., Arenzana-Seisdedos, P., Desprès, A. Michault, M. L. Albert, & O. Schwartz, A. (2007). Characterization of Reemerging Chikungunya Virus. PLoS Pathogens, 3(6).
[20] Thiberville, S. D., Moyen, N., Dupuis-Maguiraga, L., Nougairede, A., Gould, E. A., Roques, P., & de Lamballerie, X. (2013). Chikungunya Fever: Epidemiology, Clinical Syndrome, Pathogenesis and Therapy. Antiviral Research, 99(3), 345-370.
[21] Tsetsarkin, K. A., Vanlandingham, D. L., McGee, E. C., & Higgs, S. (2007). A Single Mutation in Chikungunya Virus Affects Vector Specificity and Epidemic Potential. PLoS Pathogens, 3(12).

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp. 477–488, November 13-16, 2023

Common Fixed Point and Best Proximity Point Theorems for Contraction Mapping in Metric Spaces

S. Yahaya[1] and I. A. Fulatan[2]
{sirajo.yahaya@aun.edu.ng[1], ialiyu@abu.edu.ng[2]}

Department of Mathematics and Statistics American University of Nigeria, Yola
Tel.+2348039094856[1]
Department of Mathematics Ahmadu Bello University, Zaria Tel.+2348037030479[2]

Abstract: The aim of this paper is to use the notion of contraction and cyclic contraction mappings to introduce new contraction mappings that don't imply continuity and prove the existence and uniquenessof fixed point theorems and best proximity point theorems in the settings of complete metric space. An example is provided to illustrate our main result.

Keywords Common fixed point; Best proximity point; Contraction Map, Cyclic Contraction Map, and MT - Function.

3

4 1. Introduction and Preliminaries

[1] Banach presented a most outstanding result concerning contraction mapping, this famous result is known as the Banach Contraction mapping principle. It states that every contraction mapping on a complete metric space has a unique fixed point. This principle marks the beginning of fixed point theory. Fixed point theory become a subject of great interest due to its application in mathematics and other areas of research. Fixed point theorem in metric spaces plays a significant role in constructing methods to solve problems in mathematics and sciences. Many researchers worked in this area and extended or even generalized the theorem either by considering a more general space imposing some conditions on the domain of the contraction mapping or by considering more general contractive conditions.

Further generalizations resulted in the following theorems: In [2], it was shown that every continuous function in a closed ball of any finite-dimensional Euclidean space has a fixed point. More extensions of [2] can be seen in [4], [7], [9], [24], etc. Also, Branciari [8] introduced the concept of generalized metric spaces by putting a general inequality condition in place of the usual triangular inequality in metric space. Agarwal et al. [13] discussed some fixed point results related to monotone operators in the setting of metric space equipped with partial order using a weak generalized contraction type mapping. Suzuki [11] characterized metric completeness by the generalized Banach contraction principle. Moreover, Aydi [12] obtained fixed point results for weak contraction mappings in complete Hausdorff generalized metric spaces. In Bouhadjera [17], a general common fixed point theorem for two pairs of weakly subsequentially continuous mapping satisfying a significant estimated implicit function is established. In addition, a generalization of Darbo's fixed point theorem is established in [18]. In the complex-valued *b*-metric space, Yadav [4] proves common fixed point theorems of compatible mappings and also the existence and uniqueness of common fixed point of a contraction mappings are established in [22]. Also, [24] proves a common fixed point for a class of contraction mapping in metric spaces.

However, the contraction conditions in the Banach Contraction mapping principle guarantee the continuity of the mapping, the natural question to ask is whether we can have a contraction mapping that will not imply continuity. Hence, the emergence of [3], [5], and [6]. For more details on related fixed point results, see [5], [3], [20], [21],[23], etc.

Moreover, almost all such results depend upon the existence of a fixed point for self-mapping. indeed, if the mapping is a nonself-mapping, the continuity of the Banach contraction mapping will not hold. As such, a question arises on what will happen to the Banach contraction mapping principle.

In this case, [4] introduced the concept of best approximation theorems, which investigate the existence of an approximate solution, that is, if A is a non-empty subset of a considered space X and T: $A \to X$, then we can find a point $x \in A$ such that $d(x, Tx) = d(Tx, A)$. Although best approximation theorems generate an approximate solution to the equation $Tx = x$, they do not give an approximate solution that is optimal. In contrast, best proximity point theorems give an approximate solution that is optimal, that is, if A and B are non-empty subsets of a considered space X such that $d(x, Tx) = d(A,B)$, where $d(A, B) = \inf\{d(x,y)$: $x \in A$ and $y \in B\}$. The cyclic map is an interesting class of mappings for considering best proximity point theorems, which says that, if A and B are non-empty subsets of a non-empty set X, a map T: $A \cup B \to A \cup B$ is a cyclic map if $T(A) \subset B$ and $T(B) \subset A$. [10] established interesting best proximity point theorems for relatively nonexpansive mappings. Also, By using *function*, [15] established best proximity point theorems in metric spaces. Moreover, [19], also introduced a new class of cyclic contraction mappings and considered best proximity point theorems in the context of metric spaces.
To establish our result, we consider the following definitions and notations which will be used in the sequel.

Definition 1.1 *Let X be a nonempty set and $f,T : X \to X$ be maps. Then $x \in X$ is a fixed point of T if $T(x) = x$ and if $T(x) = f(x)$ we say that x is a coincidence point of T and f. Moreover, if $T(x) = f(x) = x$, we say that x is a common fixed point of T and f. We denote the set of all fixed points of T by $F(T) = \{x \in X: T(x) = x\}$.*

Definition 1.2 *A mapping T: $X \to X$ is called contraction if there exists a positive real number $\alpha > 0$ such that $d(Tx, Ty) \leq \alpha d(x,y)$.*

Definition 1.3 *Let A and B be non-empty subsets of a metric space (X,d). Consider a map T: $A \cup B \longrightarrow A \cup B$. T is called a cyclic map if $T(A) \subset B$ and $T(B) \subset A$.*

Definition 1.4 *Let A and B be nonempty subsets of a metric space (X,d). A cyclic map T: $A \cup B \longrightarrow A \cup B$ is called a cyclic contraction map if $\exists\ k \in [0,1)$ such that $d(Tx, Ty) \leq kd(x,y)+(k-1)d(A, B)$ for all $x \in A$ and $y \in B$*

Proposition 1.5 *[16] Let $\psi : [0,\infty) \to [0,1)$ be a function. Then, ψ is an MT-function if and only if for any nonincreasing sequence $\{x_n\}_{n\in(0,\infty)}$, we have $0 \leq \sup\psi\{x_n\} < 1$*

Let us recall that a function $\varphi : [0,\infty) \to [0,1)$ is said to be an *MT-function* if $\limsup_{s\to t^+} \varphi(s) < 1$ for all $t \in [0,\infty)$.

Definition 1.6 *[16] A function $\varphi : [0,\infty) \to [0,1)$ is said to be an MT−function (or* R*−function) if* $\limsup_{s\to t^+} \varphi(s) < 1$ *for all* $t \in [0,\infty)$.
Du [16] first proved some characterizations of *MT functions* as follows.

Theorem 1.7 ([16]) *Let $\varphi : [0,\infty) \to [0,1)$ be a function. Then, the following statements are equivalent*

(a) *φ is an MT function,*
(b) *For each $t \in [0,\infty)$, there exists $r_t^{(1)} \in [0,\infty)$ and $\epsilon^{(1)}{}_t > 0$ such that $\varphi(s) \leq r_t^{(1)}$ for all $s \in (t, t+\epsilon^{(1)}{}_t)$,*
(c) *For each $t \in [0,\infty)$, there exists $r_t^{(2)} \in [0,\infty)$ an $\epsilon_t^{(2)} > 0$ such that $\varphi(s) \leq r_t^{(2)}$ for all $s \in [t, t+\epsilon_t^{(2)}]$,*
(d) *For each $t \in [0,\infty)$, there exists $r_t^{(3)} \in [0,\infty)$ an $\epsilon_t^{(3)} > 0$ such that $\varphi(s) \leq r_t^{(3)}$ for all $s \in (t, t+\epsilon_t^{(3)}]$,*
(e) *For each $t \in [0,\infty)$, there exists $r_t^{(4)} \in [0,\infty)$ and $\epsilon^{(4)}{}_t > 0$ such that $\varphi(s) \leq r_t^{(4)}$ for all $s \in [t, t+\epsilon^{(4)}{}_t)$, (f) For any non-increasing sequence $\{x_n\}_{n\in\mathbb{N}}$ in $[0,\infty)$, we have*
$0 \leq \sup_{n\in\mathbb{N}} \varphi(x_n) < 1$,
(g) *φ is a function of contractive factor [14]; that is, for any strictly decreasing sequence $\{x_n\}_{n\in\mathbb{N}}$ in $[0,\infty)$, we have $0 \leq \sup_{n\in\mathbb{N}} \varphi(x_n) < 1$.*

It is obvious that if $\psi : [0,\infty) \to [0,1)$ is a nondecreasing function or a nonincreasing function, then ψ is an *MT*-function. So the set of *MT*-function is a rich class. In this paper, we proved some fixed and best proximity points theorems using the concepts of contraction and cyclic respectively.

5 2. Fixed Point Theorem in Metric Spaces

In this section, we proved some common fixed point theorems in the setting of metric spaces.

Theorem 2.1 *Let T and S be two self-mappings on a complete metric space (X,d) and x_0 be an arbitrary point in X. Suppose that there exists a function* $[0,1)$ $d(Tx,Sy) \leq \varphi(d(x,y)) \max\{d(x,y), \frac{1}{2}\{d(x,Tx)+d(y,Sy)\}$ $\frac{1}{2}\{d(x,Sy)+d(y,Tx)\}, d(y,Tx)\}$ $[0,\infty)\to$ *such that,*

(1)

is satisfied for any $x \in A$ and $y \in B$. Then there exists a unique common fixed point of T and S.
Proof. Consider a point $x_0 \in X$. We construct the sequence $\{x_n\}$ in X iteratively such that $x_n = Tx_{n-1}$, $x_{n-1} = Sx_n$ for $n = 1,2,3,...$ From the definition of the sequence $\{x_n\}$ and the above contraction condition we have,

$$
\begin{aligned}
d(x_n, x_{n-1}) &= d(Tx_{n-1}, Sx_n) \\
&\leq \varphi(d(x_{n-1}, x_n)) \max\{d(x_{n-1}, x_n), \frac{1}{2}\{d(x_{n-1}, Tx_{n-1}) \\
&\quad + d(x_n, Sx_n)\}, \frac{1}{2}\{d(x_{n-1}, Sx_n) + d(x_n, Tx_{n-1})\}, d(x_n, Tx_{n-1})\} \\
&\leq \varphi(d(x_{n-1}, x_n)) \max\{d(x_{n-1}, x_n), \frac{1}{2}\{d(x_{n-1}, x_n) + d(x_n, x_{n-1})\}, \\
&\quad \frac{1}{2}\{d(x_{n-1}, x_{n-1}) + d(x_n, x_n)\}, d(x_n, x_n)\} \\
&\leq \varphi(d(x_{n-1}, x_n)) \max\{d(x_{n-1}, x_n), \frac{1}{2}\{d(x_{n-1}, x_n) + d(x_n, x_{n-1})\}, \\
&\quad \frac{1}{2}\{0 + 0\}, 0\} \\
&\leq \varphi(d(x_{n-1}, x_n)) \max\{d(x_{n-1}, x_n), \frac{1}{2}\{d(x_{n-1}, x_n) + d(x_n, x_{n-1})\}, \\
&\quad 0, 0\} \\
&\leq \varphi(d(x_{n-1}, x_n)) \max\{d(x_{n-1}, x_n), \frac{1}{2}\{d(x_{n-1}, x_n) + d(x_n, x_{n-1})\}\} \\
&= \varphi(d(x_{n-1}, x_n)) \max\{d(x_{n-1}, x_n), d(x_n, x_{n-1})\}\} \\
&= \varphi(d(x_{n-1}, x_n)) d(x_{n-1}, x_n)
\end{aligned}
$$

we see that

$$d(x_n, x_{n-1}) \leq \varphi(d(x_{n-1}, x_n)) d(x_{n-1}, x_n) \quad (2)$$

Similarly,

$$
\begin{aligned}
d(x_{n-1}, x_{n-2}) &= d(Tx_{n-2}, Sx_{n-1}) \\
&\leq \varphi(d(x_{n-2}, x_{n-1})) \max\{d(x_{n-2}, x_{n-1}), \frac{1}{2}\{d(x_{n-2}, Tx_{n-2}) \\
&\quad + d(x_{n-1}, Sx_{n-1})\}, \frac{1}{2}\{d(x_{n-2}, Sx_{n-1}) + d(x_{n-1}, Tx_{n-2})\} \\
&\quad d(x_{n-1}, Tx_{n-2})\} \\
&\leq \varphi(d(x_{n-2}, x_{n-1})) \max\{d(x_{n-2}, x_{n-1}), \frac{1}{2}\{d(x_{n-2}, x_{n-1}) \\
&\quad + d(x_{n-1}, x_{n-2})\}, \frac{1}{2}\{d(x_{n-2}, x_{n-2}) + d(x_{n-1}, x_{n-1})\}, \\
&\quad d(x_{n-1}, x_{n-1})\} \\
&\leq \varphi(d(x_{n-2}, x_{n-1})) \max\{d(x_{n-2}, x_{n-1}), \frac{1}{2}\{d(x_{n-2}, x_{n-1}) \\
&\quad + d(x_{n-1}, x_{n-2})\}, \frac{1}{2}\{0 + 0\}, 0\} \\
&\leq \varphi(d(x_{n-2}, x_{n-1})) \max\{d(x_{n-2}, x_{n-1}), \frac{1}{2}\{d(x_{n-2}, x_{n-1}) \\
&\quad + d(x_{n-1}, x_{n-2}), 0, 0\} \\
&\leq \varphi(d(x_{n-2}, x_{n-1})) \max\{d(x_{n-2}, x_{n-1}), \frac{1}{2}\{d(x_{n-2}, x_{n-1}) \\
&\quad + d(x_{n-1}, x_{n-2})\} \\
&= \varphi(d(x_{n-2}, x_{n-1})) \max\{d(x_{n-2}, x_{n-1}), d(x_{n-2}, x_{n-1})\} \\
&= \varphi(d(x_{n-2}, x_{n-1})) d(x_{n-2}, x_{n-1})
\end{aligned}
,
$$

we see that

(3)

$$d(x_{n-1}, x_{n-2}) \leq \varphi(d(x_{n-2}, x_{n-1})) d(x_{n-2}, x_{n-1})$$

Since, φ is an *MT function* we have $0 \leq \varphi(d(x_{n-1}, x_n)) < 1$.

Letting $\lambda = \sup_{n \in \mathbb{N}} \varphi(d(x_{n-1}, x_n))$, then

$0 \leq \varphi(d(x_{n-1},x_n)) \leq \sup_{n\in N} \varphi(d(x_{n-1},x_n)) \leq \lambda < 1$ for all $n \in N$.

From inequality (2) and (3) we have

$$d(xn-1,xn-2) \leq \lambda d(xn-2,xn-1) \quad (4)$$

for all $n \in N$, where $\lambda = \frac{\varphi(d(x_{n-2},x_{n-1}))}{2-\varphi(d(x_{n-2},x_{n-1}))}$.

Using (4) we have,

$$d(x_n-1,x_n-2) \leq \lambda d(x_n-2,x_n-1) \leq \lambda^2 d(x_n-3,x_n-2) \leq ... \leq \lambda^n d(x_0,x_1)$$

for all $n \in N$. Continuing in this fashion we have $d(x_n-1,x_n-2) \leq \lambda^n d(x_0,x_1)$ for all $n \in N$.

Let $m,n \in N$ such that $m > n$, then we get

$$\begin{aligned} d(x_m,x_n) &\leq d(x_m,x_{m-1}) + d(x_{m-1},x_{m-2}) + d(x_{m-2},x_{m-3}) + ... + d(x_{n+1},x_n) \\ &\leq k^{m-1}d(x_1,x_0) + k^{m-2}d(x_1,x_0) + k^{m-3}d(x_1,x_0) + ... + k^n d(x_1,x_0) \\ &\leq (k^{m-1} + k^{m-2} + k^{m-3} + ... + k^n)d(x_1,x_0) \\ &\leq \frac{k^n}{1-k}d(x_1,x_0), where\ 0 < k < 1 \end{aligned}$$

This implies that, $d(x_m,x_n) \longrightarrow 0$ as $n,m \longrightarrow \infty$. Hence the sequence $\{x_n\}$ is Cauchy.

By the completeness of X, it follows that there exists $u \in X$. such that $x_n \longrightarrow u$ as $n \longrightarrow \infty$. Now, we want to show that $Su = u$.

$$\begin{aligned} d(u,Su) &\leq d(u,x_{k+2}) + d(x_{k+2},Su) \\ &= d(u,x_{k+2}) + d(Tx_{k+1},Su) \\ &\leq d(u,x_{k+2}) + \varphi(d(x_{k+1},u)) \max\{d((x_{k+1},u)), \frac{1}{2}\{d(x_{k+1},Tx_{k+1})) \\ &\quad +d(u,Su)\}, \frac{1}{2}\{d(x_{k+1},Su)) + d(u,Tx_{k+1})\}, d(u,Su)\} \\ &\leq d(u,x_{k+2}) + \varphi(d(x_{k+1},u)) \max\{d((x_{k+1},u)), \frac{1}{2}\{d(x_{k+1},x_{k+2})) \\ &\quad +d(u,Su)\}, \frac{1}{2}\{d(x_{k+1},Su)) + d(u,x_{k+2})\}, d(u,Su)\} \end{aligned}$$

as $k \longrightarrow \infty$, we obtain

$$\begin{aligned} d(u,Su) &\leq d(u,u) + \varphi(d(u,u)) \max\{d((u,u)), \frac{1}{2}\{d(u,u)) + d(u,Su)\}, \\ &\quad \frac{1}{2}\{d(u,Su)) + d(u,u)\}, d(u,Su)\} \\ &\leq 0 + \varphi(0) \max\{0, \frac{1}{2}\{0 + d(u,Su)\}, \frac{1}{2}\{d(u,Su)) + 0\}, d(u,Su)\} \\ &\leq \varphi(0) \max\{\frac{1}{2}\{d(u,Su)\}, \frac{1}{2}\{d(u,Su))\}, d(u,Su)\} \\ &\leq \varphi(0) \max\{\frac{1}{2}\{d(u,Su)\}, d(u,Su)\} \\ &\leq \varphi(0)d(u,Su) \end{aligned}$$

but $d(u,Su) \geq 0$. It follows that $d(u,Su) = 0$, hence $d(u,Su) = 0$. This implies

$$Su = u \quad (5)$$

Next, we want to show that $Tu = u$.

Now,

$$\begin{aligned} d(u,Tu) &\leq d(u,x_{k+1}) + d(x_{k+1},Tu) \\ &= d(u,x_{k+1}) + d(Tu,S_{x_k}) \\ &\leq d(u,x_{k+1}) + \varphi(d(u,x_k)) \max\{d((u,x_k)), \frac{1}{2}\{d(u,Tu)) \\ &\quad +d(x_k,Sx_k)\}, \frac{1}{2}\{d(u,Sx_k)) + d(x_k,Tu)\}, d(x_k,Tu)\} \\ &\leq d(u,x_{k+1}) + \varphi(d(u,x_k)) \max\{d((u,x_k)), \frac{1}{2}\{d(u,Tu)) \\ &\quad +d(x_k,x_{k+1})\}, \frac{1}{2}\{d(u,x_{k+1})) + d(x_k,Tu)\}, d(x_k,Tu)\} \end{aligned}$$

as $k \longrightarrow \infty$, we obtain

$$\begin{aligned} d(u,Tu) &\leq d(u,u) + \varphi(d(u,u)) \max\{d((u,u)), \frac{1}{2}\{d(u,Tu)) + d(u,u)\}, \\ &\quad \frac{1}{2}\{d(u,u)) + d(u,Tu)\}, d(u,Tu)\} \\ &\leq 0 + \varphi(0) \max\{0, \frac{1}{2}\{d(u,Tu) + 0\}, \frac{1}{2}\{0 + d(u,Tu))\}, d(u,Tu)\} \\ &\leq \varphi(0) \max\{\frac{1}{2}\{d(u,Tu)\}, \frac{1}{2}\{d(u,Tu))\}, d(u,Tu)\} \\ &\leq \varphi(0) \max\{\frac{1}{2}\{d(u,Tu)\}, d(u,Tu)\} \\ &\leq \varphi(0) d(u,Tu) \end{aligned}$$

a contradiction, since $\varphi(0) \in [0,1)$ which implies that $d(u,Tu) = 0$. And so,

$$Tu = u \tag{6}$$

From inequality (5) and (6), we have $Su = Tu = u$. Hence u is a common fixed point of S and T.

Now Let $v \neq u$ and v a fixed point of T and S

Now,

$$\begin{aligned} d(u,v) &= d(Tu,Sv) \\ &\leq \varphi(d(u,v)) \max\{d(u,v), \frac{1}{2}\{d(u,Tu) + d(v,Sv)\}, \frac{1}{2}\{d(u,Sv) \\ &\quad +d(v,Tu)\}, d(v,Tu)\} \\ &\leq \varphi(d(u,v)) \max\{d(u,v), \frac{1}{2}\{d(u,u) + d(v,v)\}, \frac{1}{2}\{d(u,v) + d(v,u)\} \\ &\quad d(v,u)\} \\ &\leq \varphi(d(u,v)) \max\{d(u,v), \frac{1}{2}\{0+0\}, \frac{1}{2}\{d(u,v) + d(v,u)\}, d(v,u)\} \\ &\leq \varphi(d(u,v)) \max\{d(u,v), \frac{1}{2}\{d(u,v) + d(v,u)\}, d(v,u)\} \\ &= \varphi(d(u,v)) \max\{d(u,v), \frac{1}{2}\{d(u,v) + d(v,u)\}, d(u,v)\} \\ &\leq \varphi(d(u,v)) \max\{d(u,v), \frac{1}{2}\{d(u,v) + d(v,u)\}\} \\ &= \varphi(d(u,v)) \max\{d(u,v), \frac{1}{2}\{d(u,v) + d(u,v)\}\} \\ &= \varphi(d(u,v)) \max\{d(u,v), d(u,v)\} \\ &\leq \varphi(d(u,v)) d(u,v) \end{aligned}$$

a contradiction since $\varphi(d(u,v)) \in [0,1)$ this implies that $d(u,v) = 0$ that is, $u = v$. □

Corollary 2.2 *If T is a self-mapping defined on a complete metric space* (X,d) *satisfying the condition,*

$$\begin{aligned} d(Tx,Ty) &\leq \varphi(d(x,y)) \max\{d(x,y), \frac{1}{2}\{d(x,Tx) + d(y,Ty)\}, \frac{1}{2}\{d(x,Ty) \\ &\quad +d(y,Tx)\}, d(y,Tx)\} \end{aligned}$$

for all $x,y \in X$. *Then T has a unique fixed point.*

Corollary 2.3 *(see Banach [1]) Let* (X,d) *be a complete metric space and* $T : X \longrightarrow X$ *be a given mapping. Assume that there exists* $\alpha \in (0,1)$ *such that*

$$d(Tx,Ty) \leq \alpha d(x,y)$$

for all $x,y \in X$*. Then T has a unique fixed point in X.*

Corollary 2.4 *(see Kannan [3]) Let* (X,d) *be a complete metric space and* $T : X \longrightarrow X$ *be a given mapping. Assume that there exists* $\alpha \in (0,1)$ *such that*

$$d(Tx,Ty) \leq \alpha[d(x,Tx) + d(y,Ty)]$$

for all $x,y \in X$*. Then T has a unique fixed point in X.*

Corollary 2.5 *(see Chatterjea [5]) Let* (X,d) *be a complete metric space and T*:
$X \longrightarrow X$ *be a given mapping. Assume that there exists* $\alpha \in (0,1)$ *such that*

$$d(Tx,Ty) \leq \alpha[d(x,Ty) + d(y,Tx)]$$

for all $x,y \in X$*. Then T has a unique fixed point in X.*

Example 2.6 *Let* $X = [0,1]$ *be equipped with the usual metric* $d(x,y) = |x - y|$ *for all* $x,y \in X$*. Clearly,* (X,d) *is a complete metric space. Define the mapping* $T: X \longrightarrow X$ *by*

$$Tx = \begin{cases} \frac{1}{4}, & \text{if } x \in [0,1) \\ \frac{1}{3}, & \text{if } x = 1. \end{cases}$$

Note that the mapping T is not continuous. Also, let $\varphi : [0,\infty) \longrightarrow [0,1)$ *be defined by* $\varphi(t) = \frac{1}{2}$ *for all* $t \geq 0$*. Obviously,* φ *is an MT function. Now, we verify the contractive inequality in Theorem 2.1 under the following cases:*
Case 1. If $x = y$*, then,*

$$d(Tx,Ty) = 0 \leq \varphi(d(x,y)) \max\{d(x,y), \frac{1}{2}\{d(x,Tx) + d(y,Ty)\} \frac{1}{2}\{d(x,Ty) + d(y,Tx)\}, d(y,Tx)\},$$

Case 2. If $x \in [0,1)$ *and* $y = 1$*, then,*

$$\begin{aligned} d(Tx,Ty) = \left|\frac{1}{4} - \frac{1}{3}\right| &\leq \frac{5}{6}\left(\frac{1}{2}\right) \\ &= \varphi(d(x,y))[\frac{1}{2}\{d(x,Ty) + d(y,Tx)\}] \\ &\leq \varphi(d(x,y)) \max\{d(x,y), \frac{1}{2}\{d(x,Tx) + d(y,Ty)\} \frac{1}{2}\{d(x,Ty) + d(y,Tx)\}, d(y,Tx)\}, \end{aligned}$$

Case 3. If $x = 1$ *and* $y \in [0,1)$*, then,*

$$\begin{aligned} d(Tx,Ty) = \left|\frac{1}{3} - \frac{1}{4}\right| &\leq \frac{5}{12}\left(\frac{1}{2}\right) \\ &= \varphi(d(x,y))[\frac{1}{2}\{d(x,Ty) + d(y,Tx)\}] \\ &\leq \varphi(d(x,y)) \max\{d(x,y), \frac{1}{2}\{d(x,Tx) + d(y,Ty)\} \frac{1}{2}\{d(x,Ty) + d(y,Tx)\}, d(y,Tx)\}, \end{aligned}$$

Hence, equation (1) *holds for all* $x,y \in X$*. It follows that all the conditions of Theorem 2.1 are satisfied with* $S = T$*. Therefore, T has a unique fixed point in X. Thus, we see that* $Tu = u = \frac{1}{4}$*. On the other hand, since T is not a continuous mapping, any fixed point theorem that requires continuity to hold like the Banach, contraction principle (or Corollary 2.3) cannot be applied in this example to obtain the fixed point of T.*

6 3 Best Proximity Point Theorem in Metric Spaces

In this section, we use the concept of cyclic contraction on the contraction condition in Theorem 2.1 and prove the existence of best proximity points instead of fixed points. First, we establish the following theorem that relates to cyclic *MT*-contractions mappings.

Theorem 3.1 *Let A and B be non-empty subsets of a metric space* (*X,d*) *and T*: *A* → *B and S*: *B* → *A*
be two maps satisfying the following condition

$$d(Tx,Sy) \leq \varphi(d(x,y))\max\{d(x,y),\frac{1}{2}\{d(x,Tx)+d(y,Sy)\},\frac{1}{2}\{d(x,Sy)+d(y,Tx)\},d(y,Tx)\}+(1-\varphi(d(x,y)))d(A,B) \quad (7)$$

for any x ∈ *A and y* ∈ *B. Where φ is an MT function. Let* $x_1 \in A$ *be given arbitrarily and define an iterative sequence* $\{x_n\}_{n\in\mathbb{N}}$ *by* $x_{n+1} = Tx_n$, $n \in$ N. *Then,*

$$\lim_{n\to\infty} d(x_n,x_{n+1}) = \inf_{n\in\mathbb{N}} d(x_n,x_{n+1}) = dist(A,B).$$

Proof. Clearly $d(A,B) \leq d(x_n,x_{n+1})$ for all $n \in$ N. If there exists $j \in$ N such that $x_j = x_{j+1} \subset A \cap B$, then by definition $Tx_j = x_{j+1} = x_j$,
$Sxj = xj-1 = xj$ also $xj+2 = Txj+1 = T(Txj) = Txj = xj$, $x_{j+2} = Sx_{j+1} = S(Sx_j) = Sx_j = x_j$ So, $x_j = x_{j+1} = x_{j+2} = ...$ and therefore
$\lim d(x_n,x_{n+1}) = 0$ $n\to\infty$
then
$\lim d(x_n,x_{n+1}) = \inf d(x_n,x_{n+1}) = dist(A,B) = 0$ $n\to\infty$ $n\in$N
So it suffices to consider the case $x_j \neq x_{j+1}$ for all $n \in$ N. Now we want show that the sequence $\{d(x_n,x_{n+1})\}$ is non-increasing.

$$\begin{aligned}
d(x_n,x_{n+1}) &= d(Tx_{n-1},Sx_n)\\
&\leq \varphi(d(x_{n-1},x_n))\max\{d(x_{n-1},x_n),\frac{1}{2}\{d(x_{n-1},Tx_{n-1})+\\
&\quad d(x_n,Sx_n)\},\frac{1}{2}\{d(x_{n-1},Sx_n)+d(x_n,Tx_{n-1})\},d(x_n,Tx_{n-1})\}\\
&\quad +(1-\varphi(d(x_{n-1},x_n)))d(A,B)\\
&\leq \varphi(d(x_{n-1},x_n))\max\{d(x_{n-1},x_n),\frac{1}{2}\{d(x_{n-1},x_n)+d(x_n,x_{n+1})\}\\
&\quad \frac{1}{2}\{d(x_{n-1},x_{n+1})+d(x_n,x_n)\},d(x_n,x_n)\}\\
&\quad +(1-\varphi(d(x_{n-1},x_n)))d(A,B)\\
&= \varphi(d(x_{n-1},x_n))\max\{d(x_{n-1},x_n),\frac{1}{2}\{d(x_{n-1},x_n)+d(x_n,x_{n+1})\},\\
&\quad \frac{1}{2}\{d(x_{n-1},x_{n+1})+0\},0\}+(1-\varphi(d(x_{n-1},x_n)))d(A,B)\\
&= \varphi(d(x_{n-1},x_n))\max\{d(x_{n-1},x_n),\frac{1}{2}\{d(x_{n-1},x_n)+d(x_n,x_{n+1})\},\\
&\quad \frac{1}{2}\{d(x_{n-1},x_{n+1})\}\}+(1-\varphi(d(x_{n-1},x_n)))d(A,B)
\end{aligned},$$

Suppose that

$$\max\{d(x_{n-1},x_n),\frac{1}{2}\{d(x_{n-1},x_n)+d(x_n,x_{n+1})\},\frac{1}{2}\{d(x_{n-1},x_{n+1})\}\} = d(x_{n-1},x_n)$$

we see that

$d(xn,xn+1) \leq \varphi(d(x_{n-1},x_n))d(x_{n-1},x_n) + (1-\varphi(d(x_{n-1},x_n)))d(A,B)$

$$\leq \quad \varphi(d(x_{n-1},x_n))d(x_{n-1},x_n) + (1-\varphi(d(x_{n-1},x_n)))d(x_{n-1},x_n)$$
$$= \quad d(xn-1,xn) \quad (8)$$

Suppose also that

$$\max\{d(x_{n-1},x_n), \frac{1}{2}\{d(x_{n-1},x_n)+d(x_n,x_{n+1})\}, \frac{1}{2}\{d(x_{n-1},x_{n+1})\}\} = \frac{1}{2}\{d(x_{n-1},x_n)+d(x_n,x_{n+1})\}$$

we see that

$$\begin{aligned}
d(x_n,x_{n+1}) &\leq \frac{1}{2}\varphi(d(x_{n-1},x_n))\{d(x_{n-1},x_n)+d(x_n,x_{n+1})\} \\
&\quad +(1-\varphi(d(x_{n-1},x_n)))d(A,B) \\
&\leq \frac{1}{2}\varphi(d(x_{n-1},x_n))d(x_{n-1},x_n) + \frac{1}{2}\varphi(d(x_{n-1},x_n))d(x_n,x_{n+1}) \\
&\quad +(1-\varphi(d(x_{n-1},x_n)))d(A,B) \\
&\leq \frac{1}{2}\varphi(d(x_{n-1},x_n))d(x_{n-1},x_n) + \frac{1}{2}\varphi(d(x_{n-1},x_n))d(x_n,x_{n+1}) \\
&\quad +(1-\varphi(d(x_{n-1},x_n)))d(x_{n-1},x_n) \\
&= \frac{1}{2}\varphi(d(x_{n-1},x_n))d(x_{n-1},x_n) + \frac{1}{2}\varphi(d(x_{n-1},x_n))d(x_n,x_{n+1}) \\
&\quad +d(x_{n-1},x_n)-\varphi(d(x_{n-1},x_n))d(x_{n-1},x_n) \\
&= (1-\frac{1}{2}\varphi(d(x_{n-1},x_n)))d(x_{n-1},x_n) + \frac{1}{2}\varphi(d(x_{n-1},x_n))d(x_n,x_{n+1}) \\
&= d(x_{n-1},x_n \qquad (9)
\end{aligned}$$

Also, suppose that

$$\max\{d(x_{n-1},x_n), \frac{1}{2}\{d(x_{n-1},x_n)+d(x_n,x_{n+1})\}, \frac{1}{2}\{d(x_{n-1},x_{n+1})\}\} = \frac{1}{2}\{d(x_{n-1},x_{n+1})\}$$

we see that

$$\begin{aligned}
d(x_n,x_{n+1}) &\leq \varphi(d(x_{n-1},x_n))\frac{1}{2}\{d(x_{n-1},x_{n+1})\} + (1-\varphi(d(x_{n-1},x_n)))d(A,B) \\
&\leq \varphi(d(x_{n-1},x_n))\frac{1}{2}\{d(x_{n-1},x_n)+d(x_n,x_{n+1})\} \\
&\quad +(1-\varphi(d(x_{n-1},x_n)))d(A,B) \\
&\leq \frac{1}{2}\varphi(d(x_{n-1},x_n))d(x_{n-1},x_n) + \frac{1}{2}\varphi(d(x_{n-1},x_n))d(x_n,x_{n+1}) \\
&\quad +(1-\varphi(d(x_{n-1},x_n)))d(x_{n-1},x_n) \\
&= \frac{1}{2}\varphi(d(x_{n-1},x_n))d(x_{n-1},x_n) + \frac{1}{2}\varphi(d(x_{n-1},x_n))d(x_n,x_{n+1}) \\
&\quad +d(x_{n-1},x_n)-\varphi(d(x_{n-1},x_n))d(x_{n-1},x_n) \\
&= (1-\frac{1}{2}\varphi(d(x_{n-1},x_n)))d(x_{n-1},x_n) \\
&\quad +\frac{1}{2}\varphi(d(x_{n-1},x_n))d(x_n,x_{n+1}) \\
&= d(x_{n-1},x_n \qquad (10)
\end{aligned}$$

From inequality (8), (9) and (10), we see that $\{d(x_n,x_{n+1})\}$ is non-increasing.
Since, φ is an *MT*-function we have $0 \leq \varphi(d(x_{n-1},x_n)) < 1$.
Letting $\lambda = \sup_{n\in N} \varphi(d(x_{n-1},x_n))$, then

$0 \leq \varphi(d(x_{n-1},x_n)) \leq \sup_{n\in\mathbb{N}} \varphi(d(x_{n-1},x_n)) \leq \lambda < 1$ for all $n \in \mathbb{N}$.
If $x_1 \in A$ then by the cyclicity of T and S we have $x_{n-1} \in A$ and $x_n \in B$ for all $n \in \mathbb{N}$.
Since T and S are cyclic contractions, we have

$$\begin{aligned} d(x_2,x_3) &= d(Tx_1,Sx_2) \\ &\leq \varphi(d(x1,x2))d(x1,x2) + (1-\varphi(d(x_1,x_2)))d(A,B) \\ &\leq \varphi(d(x1,x2))d(x1,x2) + + d(A,B) - \varphi(d(x_1,x_2))d(A,B) \\ &\leq \varphi(d(x1,x2))d(x1,x2) + d(A,B) \\ &\leq \lambda d(x1,x2) + d(A,B) \end{aligned}$$

and

$$\begin{aligned} d(x_3,x_4) &= d(Tx_2,Sx_3) \\ &\leq \varphi(d(x_2,x_3))d(x_2,x_3) + (1-\varphi(d(x_2,x_3)))d(A,B) \\ &\leq \varphi(d(x_2,x_3))\{\lambda d(x_1,x_2) + d(A,B)\} + (1-\varphi(d(x_2,x_3)))d(A,B) \\ &= \lambda\varphi(d(x_2,x_3))d(x_1,x_2) + \varphi(d(x_2,x_3))d(A,B) + (1-\varphi(d(x_2,x_3)))d(A,B) \\ &= \lambda\varphi(d(x_2,x_3))d(x_1,x_2) + d(A,B) \\ &= \lambda^2 d(x_1,x_2) + d(A,B) \end{aligned}$$

Also,

$$\begin{aligned} d(x_4,x_5) &= d(Tx_3,Sx_4) \\ &\leq \varphi(d(x_3,x_4))d(x_3,x_4) + (1-\varphi(d(x_3,x_4)))d(A,B) \\ &\leq \varphi(d(x_3,x_4))\{\lambda^2 d(x_1,x_2) + d(A,B)\} + (1-\varphi(d(x_3,x_4)))d(A,B) \\ &= \lambda^2\varphi(d(x_3,x_4))d(x_1,x_2) + \varphi(d(x_3,x_4))d(A,B) + (1-\varphi(d(x_3,x_4)))d(A,B) \\ &= \lambda^2\varphi(d(x_3,x_4))d(x_1,x_2) + d(A,B) \\ &= \lambda^3 d(x_1,x_2) + d(A,B) \end{aligned}$$

Hence continuing in this fashion, one can obtain

$$d(A,B) \leq d(x_n,x_{n+1}) \leq \lambda^n d(x_1,x_2) + d(A,B) \tag{11}$$

for all $n \in \mathbb{N}$.
Since $\lambda \in [0,1)$ then $\lim_{n\to\infty} \lambda^n = 0$. Using (11) and non-increasing nature of $\{d(x_n,x_{n+1})\}$, we obtain

$$\lim_{n\to\infty} d(x_n,x_{n+1}) = \inf_{n\in\mathbb{N}} d(x_n,x_{n+1}) = dist(A,B).$$

The proof is complete. □
Applying Theorem 3.1, we establish the following best proximity point theorem.

Theorem 3.2 *Let A and B be non-empty subsets of a metric space* (X,d) *and* $T: A \to B$ $S: B \to A$ *be two maps satisfying*

$$\begin{aligned} d(Tx,Sy) &\leq \varphi(d(x,y))\max\{d(x,y), \frac{1}{2}\{d(x,Tx)+d(y,Sy)\}, \frac{1}{2}\{d(x,Sy) \\ &\quad +d(y,Tx)\}, d(y,Tx)\} \end{aligned} \tag{12}$$

Define an iterative sequence $\{x_n\}_{n\in\mathbb{N}}$ *by* $x_{n+1} = Tx_n$, $x_n = Sx_{n-1}$ *for all* $x \in A$ *and* $y \in B$.

Let $x_1 \in A$ $n \in \mathbb{N}$ *be given arbitrarily. for all. Suppose further that*

i. $\{x_{2n-1}\}$ *has a convergent subsequence in A ii.* $\lim_{k\to\infty} d(x,x_{2nk}) = d(A,B)$

Then there exists $x \in A$ *such that* $d(x, Tx) = d(A, B)$.

Proof. Let $\{x_{2nk-1}\}$ be a subsequence of $\{x_{2n-1}\}$ converging to a point $x \in A$. Now, observe that

$$dist(A,B) \leq d(x,x_{2nk}) \leq d(x,x_{2nk-1}) + d(x_{2nk-1},x_{2nk})$$

for all $n \in \mathbb{N}$. Since $\lim_{k\to\infty} d(x,x_{2nk-1}) = 0$ and condition (ii) is satisfied, we know that $\lim_{k\to\infty} d(x,x_{2nk-1}) = d(A, B)$

On the other hand, by inequality (12), we have

$$\begin{aligned} d(A,B) &\leq d(x_{2n_k+1},Tx) \\ &\leq \max\{d(x_{2n_k},x), \frac{1}{2}\{d(x_{2n_k},Tx_{2n_k})+d(x,Tx)\}, \frac{1}{2}\{d(x_{2n_k},Tx) \\ &\quad +d(x,Tx_{2n_k})\}, d(x,Tx_{2n_k})\} \end{aligned}$$

Letting $k \to \infty$, we obtain

$$\begin{aligned} d(A,B) &\leq d(x,Tx) \\ &\leq \max\{d(A,B), \frac{1}{2}\{d(A,B)+d(x,Tx)\}, \frac{1}{2}\{d(x,Tx) \\ &\quad +d(x,x)\}, d(x,x)\} \\ &= \max\{d(A,B), \frac{1}{2}\{d(A,B)+d(x,Tx)\}, \frac{1}{2}\{d(x,Tx)+0\}, 0\} \\ &= \max\{d(A,B), \frac{1}{2}\{d(A,B)+d(x,Tx)\}, \frac{1}{2}\{d(x,Tx)\}\} \\ &= \max\{d(A,B), \frac{1}{2}\{d(A,B)+d(x,Tx)\}\} \end{aligned} \tag{13}$$

Now we consider the following two cases:

Case I: If $\max\{d(A,B), \frac{1}{2}\{d(A,B)+d(x,Tx)\}\} = d(A,B$

$d\ A,B\ \leq d\ x,Tx\ \leq d\ A,B$

This implies, $d(A,B) = d(x,Tx)$

Case II: If $\max\{d(A,B), \frac{1}{2}\{d(A,B)+d(x,Tx)\}\} = \frac{1}{2}\{d(A,B)+d(x,Tx)\}$.

Then from inequality (13), we have

$$d(x,Tx) \leq \frac{1}{2}\{d(A,B)+d(x,Tx)\}$$

$$d(x,Tx) - \frac{1}{2}d(x,Tx) \leq \frac{1}{2}d(A,B)$$

$$\frac{1}{2}d(x,Tx) \leq \frac{1}{2}d(A,B)$$

$$d(x,Tx) \leq d(A,B)$$

then we see that $d(A,B) \leq d(x,Tx) \leq d(A,B)$

and it follows that $d(x,Tx) = d(A,B)$. Hence the result.

4 Concluding Remarks

In this paper, we proved some fixed and best proximity points theorems using the concepts of contraction and cyclic respectively.

5 Acknowledgements

The author would like to thank the anonymous referee whose comments improved the original version of this manuscript.

6 References

[1] **S**. Banach, *Sur les operations dans les ensembles abstraits et leur application aux equations integrales*, Fundamental Mathematics, **3** 133 - 181, 1922.
[2] F. E. Browder, *Nonexpansive nonlinear operators in Banach space*, Proceedings National Academy Science USA, **54** 1041-1044, 1965.
[3] R. Kannan, *Some results on fixed points*, Bulletin of the Calcutta Mathematical Society, **10** 71-76, 1968.
[4] K. Fan, *Extension of two fixed points theorems of F. E. Browder*, Mathematische Zeitsch rift, **112**(3) 234 - 240, 1969.
[5] S. K. Chatterjee, *Fixed point theorems*, Comptes Rendus del Academic Bulgare des Sciences, **25** 727730, 1972.
[6] T. Zamfirescu, *Fixed point theorems in metric spaces*, Archiv der Mathematik, **23**(1) 292-298, 1972.
[7] S. L. Singxi, B. M. Tiwari and V. K. Gupta, *Common fixed points of commuting mappings in 2-metric spaces and an application*, mathematics Nachr, **96** 293-297, 1980.
[8] A. Branciari, *A fixed point theorem of Banach-Cacciopoli type on a class of generalized metric spaces*, Publication mathematics Debrecen, **57** 31-37, 2000.
[9] J. Merryfield, B. Rothschild and J.D. Stein, *An application of Ramsey's theorem to the Banach contraction principle*, proceedings of the American Mathematical Society, **130**(4) 927 - 933, 2002.
[10] A. A. Eldred and P. Veeramani, *Existence and Convergence of Best Proximity Points*, Math. Anal. Appl., **323** 1001 - 1006, 2006.
[11] T. Suzuki, A generalized Banach contraction principle that characterizes metric completeness, *Proceedings of the American Mathematical Society* **136**(5) 1861 - 1869, 2008.
[12] H. Aydi, E. Karapinar, and H. Lakzian, *Fixed point results on a class of generalized metric spaces*, Journal Mathematical Analysis Application, **337** 36 - 48, 2008.
[13] R. P. Agarwal, M. A. El-Gebily and D. ORegan, *Generalized contractions in partially ordered metric spaces*, Applied Analysis, **87** 109-116, 2008.
[14] W. S. Du, *Some new results and generalizations in metric fixed point theory*, Nonlinear Analysis: Theory, Methods and Applications, **73** 1439-1446, 2010.
[15] W. S. Du, *Nonlinear Conditions for the Existence of Best Proximity Points*, Journal of Inequalities and Applications, **206**, 2012.
[16] W. S. Du, *On approximate coincidence point properties and their applications to fixed point theory*, Journal of Applied Mathematics, **159** 49-56, 2012.
[17] H. Bouhadjera, *More general common fixed point theorems under a new concept*, Demonstratio Mathematica, **49**(1) 64-78, 2016.
[18] S. Arab, *Some generalization of Darbo fixed point theorem and its application*, Miskolc Math. Notes, **18**(2) 595-610, 2017.
[19] S. Niyom, P. Boriwan, and N. Petrot, *Existence of best proximity points for a class of generalized cyclic contraction mappings*, Thai Journal of Mathematics, **16**, 793 - 182, 2018.
[20] S. Manro, *Common fixed point theorem in intuitionistic fuzzy metric spaces using compatible mappings of type (A)*, Madridge Journal of Bioinformatics and System Biology, **1** (1) 5-9, 2018.
[21] N. Hussain, Z. Mitrovic and S. Radenovic, *A Common fixed point theorem of fisher in B- Metric Spaces*, RACSAM, **113** 949-956, 2019.
[22] G. Yadav, R. Sharma, and G. L. Prajapati, *Common Fixed Point Theorem of Compatible Maps in Complex Valued b-Metric Spaces*, Journal of Scientific Research, **12** (4) 431-446, 2020.
[23] S. Yahaya, *Common fixed Points of Contraction Mapping in Metric Space*, Pan American Mathematical Journal **30** (4) 1-10, 2020.
[24] M. S. Shagari, I. A. Fulatan and S. Yahaya, *Fixed Point of p-Hybrid L-Fuzzy Contraction*, Sahand Communication in Mathematical Analysis (SCM) **18** (3) 1-25, 2021.

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp. 489–497, November 13-16, 2023

The Pure Sub-gradient Method for Constraint Optimization problems

Iliyasu Abubakar Hamma'adama
{abubakariliyasu229@gmail.com}

Modibbo Adama University (MAU) Yola, Adamawa[1], No. 2, Opp. Central Mosque Bazza, Michika Adamawa State, Nigeria[2]

7 Abstract
In this paper, pure sub-gradient method has been investigated and a comprehensive study of high-level research knowledge about the concept of sub-gradient method have been developed. This method arises as a result of in-efficiency of direct method and conjugate gradient method to handle large sparse optimization problems, and therefore, sub-gradient optimization is one of the most important topics in the field of optimization. The method has been applied effectively in solving concave and convex optimization problems using programing system code language, as in the case of large-scale practical problems in the maximization of linear and nonlinear integer programming problem. This was achieved through the use of its properties and algorithms to taste the efficiency for convergence in finding an optimal solution to optimization problems. Hence, sub-gradient methods can be employed to effectively find solutions to large sparse optimization problems which are too large for direct methods or conjugate gradient methods to handle.

Keywords: Constraint Optimization. Concave function. Convex function. Pure sub-gradient method. Linear and nonlinear methods. Iterative algorithms.

1 Introduction

This research paper is targeted on the concept of pure sub-gradient optimization method for the solution of linear and nonlinear constraint optimization problems, through the use of programing system code language. This study captured two numerical problems on which we used the methods of pure sub-gradient in finding solutions to the problems.

2 Optimization

This is a process of iterative procedures for finding optimal solution to an optimization problem.

2.1 Convex set:

Let the set $S \subset \Re^n$. Then we said that S is a convex set if, for any $x_1, x_2 \in S$, we have $\alpha x_1 + (1 - \alpha)x_2 \in S, \forall \alpha \in [0,1]$, In geometry, this definition shows that for any two points $x_1, x_2 \in S$, the line segment joining x_1 and x_2 is completely contained in S. It also states that S is a path connected by segmented points, i.e., two arbitrary points in S can be linked by a continuous path. This can also be shown by induction, that the set $S \subset \Re^n$is convex if and only if, for any $x_1, x_2, \dots, x_m \in S$, there exist

$$y = \sum_{i=1}^{m} \alpha_i x_i \in S, \qquad (1.1)$$

which is a linear combination of m vectors.
Where $\sum_{i=1}^{m} \alpha_i = 1,\ \alpha i \geq 0, i = 1, \cdots, m.$
Therefore, $x = \alpha x_1, + (1 - \alpha)x_2)$ where $\alpha \in [0,1]$, is called a convex combination of x_1 and x_2.
While $\sum_{i=1}^{m} \alpha_i x_i$ is called a convex combination of
$x_1, x_2, \cdots, x_m$, where $\sum_{i=1}^{m} \alpha_i = 1, \alpha_i \geq 0, i = 1, \cdots, m.$
Diagrammatically, these sets can be represented as:

2.2 Concave set

Let $m, v: [0, S] \to \Re$ be two Lebasque integrable, monotone functions, say m decreasing and v increasing and set:

$$M(s) := \int_0^S m(\sigma)\, d\sigma \text{ and } V(s) := \int_0^S v(\sigma)\, d\sigma. \quad (1.2)$$

Obviously M is concave and V is convex. Furthermore, a set is said to be concave if and only if the complement of the set is convex.

Example 1.1

The hyper plane $H = \{x \in \Re^n \mid P^T x = \alpha\}$ is a convex set, where a nonzero vector $P \in \Re^n$ is referred to as the normal vector to the hyper plane and α is a scalar.
In fact, for any $x_1, x_2 \in H$ and each $\theta \in [0, 1]$,

$$P^T [\theta x_1 + (1 - \theta) x_2] = \alpha, \quad (1.3)$$

then,

$$x_1 + (1 - \theta) x_2 \in H.$$

Note that, in the hyper plane $H = \{x \in \Re^n \mid P^T x = \alpha\}$ if $\alpha = 0$, then it can be reduced to a subspace of vectors that are orthogonal to P.
Similarly, the closed half spaces

$$H^- = \{x \in \Re^n \mid P^T x \leq \beta\} \text{ and } H^+ = \{x \in \Re^n \mid P^T x \geq \beta\} \quad (1.4)$$

are closed convex sets.
The open half spaces

$$(\dot{H})^- = \{x \in \Re^n \mid P^T x < \beta\} \text{ and } (\dot{H})^+ = \{x \in \Re^n \mid P^T x > \beta\} \quad (1.5)$$

are open convex sets.

Example 1.2

The ray $S = \{x \in \Re^n \mid x = x_0 + \lambda d,\ \lambda \geq 0\}$ is a convex set, where $d \in \Re^n$a nonzero vector and $x_0 \in \Re^n$ is a fixed point. In fact, for any $x_1, x_2 \in S$ and each $\lambda \in [0, 1]$, we have

$$x_1 = x_0 + \lambda_1 d, \quad x_2 = x_0 + \lambda_2 d, \quad (1.6)$$

where $\lambda_1, \lambda_2 \in [0, 1]$.
Hence,

$$\lambda x_1 + (1 - \lambda) x_2 = \lambda(x_0 + \lambda_1 d) + (1 - \lambda)(x_0 + \lambda_2 d)$$
$$= x_0 + [\lambda\lambda_1 + (1 - \lambda)\lambda_2] d. \quad (1.7)$$

Since

$$\lambda\lambda_1 + (1 - \lambda)\lambda_2 \geq 0, \text{ then } \lambda x_1 + (1 - \lambda) x_2 \in S.$$

The finite intersection of closed half spaces is

$$S = \{x \in \Re^n \mid P_i^T x \leq \beta_i,\ i = 1, \cdots, m\} \quad (1.8)$$

which is called a polyhedral set, where P_i are nonzero vector and β_i is a scalar. The polyhedral is a convex set. Since equality can be represented by two inequalities, the following sets are examples of polyhedral sets:

$$S = \{x \in \Re^n \mid Ax = b, x \geq 0\}, \quad (1.9)$$
$$S = \{x \in \Re^n \mid Ax \geq 0, x \geq 0\}. \quad (1.10)$$

The intersection of two convex sets is convex, the algebraic sum of two convex sets is convex, the interior of a convex set is convex, and the closure of a convex set is convex.

Theorem 1.1
Let S_1 and S_2 be two convex sets in $\Re^n$. Then,

i. $S_1 \cap S_2$ is convex;
ii. $S_1 \pm S_2 = \{x_1 \pm x_2 \mid x_1 \in S_1,\ x_2 \in S_2\}$ is convex.

Proof: Following the definition of convex set above, it is obvious that condition (i) is true for any intersection of two convex sets to be convex also. Similarly, it holds for condition (ii), that is for the sum or difference of two convex sets their union or difference must also be convex.

Theorem 1.2

Let $S \subset \Re^n$ be a convex set. Then

i. The interior $int.S$ of S is a convex set;
ii. The closure $\hat{S}$ of S is a convex set.

Proof: (i)

Let x and x' be in $int.S$ and $x'' = \alpha x + (1 - \alpha)\, x',\ \alpha \in (0,1)$.
Choose $\delta > 0$ such that $B(x', \delta) \subset S$, where $B(x', \delta)$ is the δ-neighborhood of x'. It is easy to see that $\frac{x'' - x}{x' - x} = 1 - \alpha$.
We know that $B(x'', (1 - \alpha)\delta)$ is just the set $\alpha x + (1 - \alpha)B(x', \delta)$ which is in S.
Therefore
$B(x'',\ (1 - \alpha)\delta) \subset S$ which shows that $x'' \in intS$.
Proof: (ii)
Take $x, x' \in \hat{S}$. Select two sequences in S as $\{x_k\}$ and $\{x'_k\}$ converging to x and x' respectively. Then, for $\alpha \in [0,1]$, we have

$$[\alpha x_k + (1 - \alpha)x'_k] - [\alpha x + (1 - \alpha)x'] = \alpha(x_k - x) + (1 - \alpha)(x'_k - x') \leq \alpha x_k - x + (1 - \alpha)x'_k - x'. \quad (1.11)$$

Taking the limit of both sides yields

$$\lim_{k\to\infty} \left| [\alpha xk + (1 - \alpha)\, x'k] - [\alpha x + (1 - \alpha)\, x'] \right| = 0, \quad (1.12)$$

which shows that $\alpha x + (1 - \alpha)\, x' \in \hat{S}$.

2.3 Concave function

Let f be a function on a convex set S and $S \subset \Re^n \longrightarrow \Re$. Then f is said to be concave and closed if for any $x_1, x_2 \in S$ and $\alpha \in [0,1]$, we have that

$$f((1-\alpha)x_1 + \alpha x_2) \geq (1-\alpha)f(x_1) + \alpha f(x_2), \text{ for } x_1 \neq x_2 \quad (1.13)$$

We say that, f is strictly concave if

$$f((1 - \alpha)x_1 + \alpha x_2) > (1 - \alpha)f(x_1) + \alpha f(x_2). \quad (1.14)$$

2.4 Convex function

Let f be a function on a convex set S and $S \subset \Re^n \longrightarrow \Re$. Then f is said to be concave if for any $x_1, x_2 \in S$ and $\alpha \in (0,1)$, we have that

$$f(\alpha x_1 + (1-\alpha)x_2) \leq \alpha f(x_1) + (1-\alpha)f(x_2), \text{ for } x_1 \neq x_2 \quad (1.15)$$

We say that, f is strictly convex if

$$f(\alpha x_1 + (1-\alpha)x_2) < \alpha f(x_1) + (1-\alpha)f(x_2). \quad (1.16)$$

3 Differentiability of a function

A function $f(u)$ is said to be differentiable at the point u, if the derivative $f'(u)$ exists at every point u in its domain. And also, f is *continuously differentiable* if its derivatives exist continuously over its domain.

8 3.1 A Close function

A function $f: \Re^n \rightarrow \Re \cup \{+\infty\}$ is said to be closed if it is lower semi-continuous everywhere, or if its epigraph is closed, or if its level sets are also closed. Consequently, the indicator function I_S is closed if and only if S is closed. Also, $epi\ I_S = S \times \Re^+$. The support function σ_s is closed as well.

3.2 Sub-differential

The Sub-differential of a function f at x', is the set of all sub-gradients of f at x' which is given by

$$\partial f(x') = \{s: f(x') + s(x - x') \geq f(x)\ \forall x \in \Re^n\}. \quad (1.17)$$

Furthermore, if $\delta f(x)$ is non-empty, then f is said to be sub-differentiable at a point x', which implies that a concave function is sub-differentiable at every point in its domain, and the sub-differential is a non-empty convex, closed and bounded set. Note that, a concave function is not always differentiable at all points in its domain but closed.

3.3 Sub-gradient

Let $f: \Re^n \rightarrow \Re$ be concave. The vector $g \in \Re^n$ is called a Sub-gradient of f at $x' \in \Re^n$ if

$$f(x') + g(x - x') \geq f(x),\ \forall x \in \Re^n. \quad (1.18)$$

Similarly,

$$f(x') - f(x) \geq \langle g, x - x' \rangle,\ \forall x \in \Re^n, \quad (1.19)$$

if $f(x') = g$ and $f(x') = 0$, then it implies that $g = 0$ and $(0, g) \in \partial f(x')\ \forall x \in \Re^n$.

3.4 Important Results

Let $u = (u_1, u_2, I, u_n)$ and $v = (v_1, v_2, \ldots, v_n)$ be two vector spaces in $\Re^n$. Then we say that,

i. $u_i v_i := P_n \sum_{i=1}^{m} u_i v_i$, is a linear combination of independent vectors, whether they are raw or column vectors.
ii. $u \geq 0$ means $u_i \geq 0$ for each $i = 1, 2, \ldots n$.
iii. $||u|| := \sqrt{uu}$ – the Euclidean norm.
iv. $P_\Omega(u) = argminz \in \Omega\ \{||z - u||\}$ – is the Euclidean projection of u onto a closed convex set Ω; i.e. the point in closed set Ω to u.
v. $\text{int}(\Omega) = \{x \in \Omega: ||y - x|| < \varepsilon \implies y \in \Omega, \text{for some } \varepsilon > 0\}$ – is the set of interior points of Ω, where $\Omega \subseteq \Re^n$.
vi. $\Omega^*$is the set of optimal solutions of an optimization problem whose feasible set is Ω.
vii. ϕ^*- Optimal objective value of an optimization problem whose objective function is $\phi(.)$.

3.5 Constraints

These are logical criteria or conditions that a solution of an optimization problem must satisfy.

4 Iterative Algorithms for Sub-gradient Methods

In this chapter, we considered two iteration procedures as methodologies used for understanding and finding of solutions to both linear and nonlinear optimization problems. These methods are:

4.1 The Pure Sub-gradient Method Algorithm

Consider the integer programing (IP) problem of the form

(IP) $\max\{\phi(u): u \in \Omega\}$,

using the following generic procedure:

i. Choose an initial point $u^0 \in \Omega$.
ii. Construct a sequence of points $\{u^k\} \in \Omega$**,** which eventually converges to an optimal solution following the rule:

$$u^{k+1} = P_\Omega (u^k + \lambda_k s^k) \text{ for } k = 0, 1, 2, \ldots \quad (2.1)$$

Step 1: Set u^0 for k=0
$u^{k+1} = P_\Omega (u^k + \lambda_k s^k)$, k = 0, 1, 2, …
$u^1 = P_\Omega (u^0 + \lambda_0 s^0)$ k = 0, 1, 2, …
Step 2: $u^{k+1} = P_\Omega (u^k + \lambda_k s^k)$, k = 1, 2, …
$u^2 = P_\Omega (u^1 + \lambda_1 s^1)$, k = 1, 2, …
Step 3: repeat the process continuously until the solution converges to an optimal solution. Where s^k is a sub-gradient of the concave function ϕ at a point u^k, which is been determined at each iterate point until some certain stopping condition, $\lambda_k > 0$ is an appropriately chosen step length and $P_\Omega(.)$ is the Euclidean projection on the feasible set **Ω**.

4.2 Numerical Solutions

In this chapter, we will find and discuss of two numerical examples, using the iterative algorithms of the stated methods and compare the results of the sub-gradient methods to see their efficiency for finding optimum solutions to optimization problems.

Example 2.1: Let

$$f(x) = \max_{x \in \Re} \left\{2x,\ x + 2,\ \frac{5}{3}x + 5\right\} \tag{3.1}$$

Then f is a piecewise linear concave function given by

$$f(x) = \begin{cases} 2x & x \le 1 \\ x + 2 & 1 \le x \le 3 \\ \frac{5}{3}x + 5 & x \ge 3 \end{cases} \tag{3.2}$$

f is differentiable at every point $\bar{x} \in \Re \setminus [1,3]$. Hence, for any $\bar{x} \notin [1,3]$ the sub-gradient $s(\bar{x})$ of f at $\bar{x}$ is given by $s(\bar{x}) = f'(x)$
That is,

$$s(\bar{x}) = \begin{cases} 2, & \bar{x} < 1 \\ 1, & 1 < \bar{x} < 3 \\ \frac{5}{3}, & \bar{x} > 3 \end{cases} \tag{3.3}$$

However, at $\bar{x} = 1$ both $S_1 = 3$ and $S_2 = 1$ are sub-gradients of f. Moreover, any convex combination of S_1 and S_2 is also a sub-gradient of f at $\bar{x} = 1$. Similarly, both $S_2 = 1$ and $S_3 = \frac{5}{3}$ as well as any of their convex combinations are the sub-gradients of f at $\bar{x} = 3$.

Table 1. Solution of the linear concave problem of example 2.1

Input Grid: f(x) = {2x, x+ 2, $\frac{5}{3}x + 5$}					
	X_1	X_2	X_3	Enter <, >, or =	R H S
f (x, y)	2x	X + 2	$\frac{5}{3}x + 5$		
Maximize	2.00	1.00	1.67		
Constraint 1	1.00	1.00	3	> =	3.00
lower Bound	0.10	1.00	3		
Upper Bound	1.00	3.00	300		
Unrestr'd (y/n)	n	N			
Iteration Values:					
Iteration 1	X_1	X_2	X_3		
Basic	LX_1	LX_2	LX_3	SX_4	Solution
z(max)	-2.00	-1.00	-1.67	0.00	6.21

SX_4	-1.00	-3.00	-3.00	1.00	9.10
Lower Bound	0.10	1.00	3.00		
Upper Bound	1.00	3.00	300.00		
Unrestr'd (y/n)	n	N			
Iteration 2	X_1	X_2	X_3		
Basic	ULX_1	LX_2	LX_3	SX_4	Solution
z(max)	2.00	-1.00	-1.67	0.00	8.01
SX_4	1.00	-3.00	-3.00	1.00	10.00
Lower Bound	0.10	1.00	3.00		
Upper Bound	1.00	3.00	300.00		
Unrestr'd (y/n)	n	N			
Iteration 3	X_1	X_2	X_3		
Basic	ULX_1	LX_2	ULX_3	SX_4	Solution
z(max)	2.00	-1.00	1.67	0.00	504.00
SX_4	1.00	-3.00	3.00	1.00	901.00
Lower Bound	0.10	1.00	3.00		
Upper Bound	1.00	3.00	300.00		
Unrestr'd (y/n)	n	N			
Iteration 4	X_1	X_2	X_3		
Basic	ULX_1	ULX_2	ULX_3	SX_4	Solution
z(max)	2.00	1.00	1.67	0.00	506.00
SX_4	1.00	3.00	3.00	1.00	907.00
Lower Bound	0.10	1.00	3.00		
Upper Bound	1.00	3.00	300.00		
Unrestr'd (y/n)	n	N			
Iteration 5	X_1	X_2	X_3		
Basic	ULX_1	ULX_2	LX_3	SX_4	Solution
z(max)	2.00	1.00	-1.67	0.00	10.01
SX_4	1.00	3.00	-3.00	1.00	16.00
Lower Bound	0.10	1.00	3.00		
Upper Bound	1.00	3.00	300.00		
Unrestr'd (y/n)	n	N			
Iteration 6	X_1	X_2	X_3		
Basic	ULX_1	ULX_2	LX_3	SX_4	Solution
z(max)	2.00	1.00	-1.67	0.00	10.01
SX_4	1.00	3.00	-3.00	1.00	16.00
Lower Bound	0.10	1.00	3.00		
Upper Bound	1.00	3.00	300.00		

Unrestr'd (y/n)	n	N			
Iteration 7	X_1	X_2	X_3		
Basic	ULX_1	ULX_2	ULX_3	SX_4	Solution
z(max)	2.00	1.00	1.67	0.00	506.00
SX_4	1.00	3.00	3.00	1.00	907.00
Lower Bound	0.10	1.00	3.00		
Upper Bound	1.00	3.00	300.00		
Unrestr'd (y/n)	n	N			
Output Summary: Final Solution					
f (x)	Value	Obj. Coeff.	Obj. Value Contr		
X_1: 2x	1.00	2.00	2.00		
X_2: x+2	3.00	1.00	3.00		
X_3: $\frac{5}{3}x + 5$	300.00	1.67	501.00		
Constraint	R H S	Slack-/Surplus+			
1(<)	3.00	907.00-			
LB-X_1:	0.10	0.90+			
UB-X_1:	1.00	0.00			
LB-X_2:	1.00	2.00+			
UB-X_2:	3.00	0.00			
LB-X_3:	3.00	297.00+			
UB-X_3	300.00	0.00			
*** Sensitivity Analysis ***					
f (x)	Curr Obj. Coeff	Min Obj. Coeff	Max Obj. Coeff	Reduced Cost	
X_1: 2x	2.00	0.00	∞	-2.00	
X_2: x + 2	1.00	0.00	∞	-1.00	
X_3: $\frac{5}{3}x + 5$	1.67	0.00	∞	-1.67	
Constraint	Curr. R H S	Min R H S	Max R H S	Dual Price	
1(<)	3.00	-∞	910.00	0.00	
L B: X_1	0.10	0.00	1.00	0.00	
U B: X_1	1.00	0.00	∞	2.00	
L B: X_2	1.00	0.00	3.00	0.00	
U B: X_2	3.00	0.00	∞	1.00	
L B: X_3	3.00	0.00	300.00	0.00	
U B: X_3	300.00	0.00	∞	1.67	
Objective Value (Max): = 506.00 (Iteration 4)					

Hence, the pure sub-gradient procedure is best applied to solve these type of non-smooth concave problems, because it compute the sub-gradient vector say $\bar{s} \in \partial\phi(x)$ at each iterate point say $\bar{x} \in \Omega$ by fulfilling that $\Omega = \Re_{+}^{m}$ for any linear concave but nondifferentiable function and maintaining the search direction.

Example 2.2

Let consider the non-linear constraint optimization problem $\min_{x,y\in\Re} f(x,y)$ defined by

$f(x, y) = (1-x)^2 + 100(y - x^2)^2$, $\forall\ x, y \in (1, 2)$,

s. t. $x^2 + y^2 \leq 2$.

The computation of the results for optimum solutions of the problem, we take the range of the variables as: $x \in (1, 2)$, $y \in (1, 2)$.

Table 2 Solution of the non-linear constraint optimization problem of example 2.2

Input Grid: $f(x, y) = (1-x)^2 + 100(y - x^2)^2$, $x^2 + y^2 \leq 2$, $1 \leq x \leq 2$, $1 \leq y \leq 2$.				
	X_1	X_2	Enter <, >, or =	R. H. S.
f (x, y)	(1-x) ^2	100*(y-x^2) ^2		
Minimize	1.00	100.00		
Constraint 1	1.00	1.00	< =	2.00
lower Bound	1.00	1.00		
Upper Bound	2.00	2.00		
Unrestr'd (y/n)	n	n		
Iteration Values:				
Iteration 1	(1-x) ^2	100*(y-x^2) ^2		
Basic	LX_1	LX_2	SX_3	Solution
z(max)	-1.00	-100.00	0.00	101.00
SX_3	1.00	1.00	1.00	0.00
Lower Bound	1.00	1.00		
Upper Bound	2.00	2.00		
Unrestr'd (y/n)	n	n		
Iteration 2	(1-x) ^2	100*(y-x^2) ^2		
Basic	LX_1	LX_2	SX_3	Solution
z(max)	99.00	0.00	100.00	101.00
LX_2	1.00	1.00	1.00	0.00
Lower Bound	1.00	1.00		
Upper Bound	2.00	2.00		
Unrestr'd (y/n)	n	n		
Iteration 3	(1-x) ^2	100*(y-x^2) ^2		
Basic	LX_1	LX_2	SX_3	Solution
z(max)	0.00	-99.00	1.00	101.00
LX_1	1.00	1.00	1.00	0.00
Lower Bound	1.00	1.00		
Upper Bound	2.00	2.00		
Unrestr'd (y/n)	n	n		
Output Summary: (Final Solution)				
f (x, y)	Value	Obj. Coeff.	Obj Value Contri	
X_1: (1-x) ^2	1.00	1.00	1.00	
X_2: 100*(y-x^2) ^2	1.00	100.00	100.00	
Constraint	R H S	Slack - / Surplus +		

1(<)	2.00	0.00		
LB-X_1: (1-x) ^2	1.00	0.00		
UB-X_1: (1-x) ^2	2.00	1.00-		
LB-X_2:100*(y-x^2) ^2	1.00	0.00		
UB-X_2:100*(y-^2) ^2	2.00	1.00-		
*** Sensitivity Analysis ***				
f (x, y)	Curr Obj Coeff	Min Obj Coeff	Max Obj Coeff	Reduced Cost
X_1: (1-x) ^2	1.00	-∞	100.00	-99.00
X_2: 100*(y-x^2) ^2	100.00	1.00	∞	0.00
Constraint	Current R H S	Min R H S	Max R H S	Dual Price
1(<)	2.00	2.00	3.00	100.00
Lower Bound: X_1	1.00	0.00	1.00	-99.00
Upper Bound: X_1	2.00	1.00	∞	0.00
Lower Bound: X_2	1.00	0.00	1.00	0.00
Upper Bound: X_2	2.00	1.00	∞	0.00
Objective Value (max): = 101.00 (Iteration 2)				

References

[1] Bertsekas, D. P. (2015). Convex optimization algorithms (pp. 54–104). Athena Scientific. Retrieved from www.athenasc.com, Nashua, USA.

[2] Caprara, A., Fischetti, M., & Toth, P. (1999). A heuristic method for the set covering problem. Operations Research, 47(5), 730–743. https://doi.org/10.1287/opre.47.5.730

[3] Geoffrion, A. M. (1974). Lagrangian relaxation for integer programming. Mathematical Programming Study, 2, 82–114.

[4] Guta, B. (2003). Subgradient optimization methods in integer programming with an application to a radiation therapy problem. VDM Verlag Dr. Müller.

[5] Sun, W., & Yuan, Y. (2006). Optimization Theory and Methods, Nonlinear Programming. Springer Science + Business Media, New York, NY, USA.

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp. 498–516, November 13-16, 2023

Estimating the Population Parameters for Open Population Capture-Recapture Data Using Generalized Estimating Equations Approach

Pascalis Kadaro Matthew[1], Danjuma Jibasen[2], I.J Dike[3]
{pkadaro@yahoo.com[1], djibasen@mau.edu.ng[2], dikeij@mau.edu.ng[3]}

Department of Statistics, Modibbo Adama University, Yola – Nigeria[1,2,3]

Abstract
In this study, a Generalized Estimating Equation (GEE) approach accounting for heterogeneity, behavioural effects and environmental effects to estimate the probability of capture, the survival probability and the population size for open population capture-recapture experiment is proposed. A non-spatial open population capture-recapture data was simulated using two different trapping occasions $(m = 4,5)$ and the number of monte-carlo simulation $(N = 500)$ .The GEE estimates for behavioural/heterogeneity covariates, behavioural/heterogeneity/environmental covariates model under different working correlation. The study revealed that, the 4 recapture occasions yields less QIC, which implies that, the less the capture occasion the better the estimates. The results also show that, the estimated population size decreases when the number of capture occasion is increased. Comparison between heterogeneity/behavioural model and heterogeneity/behavioural/environmental model for the simulations and real life data shows that, the heterogeneity/behavioural/environmental model performs better in estimating the probability of capture the survival probability and the population size, because of the lower standard error. The study concludes that, environmental covariates be considered when estimating the probability of capture, the survival probability and the estimated population size.

Keywords: Capture-recapture, Open Population, Capture Probability, Survival Probability, Population Size, GEE, QIC

8.1 **1 Introduction**

Capture-recapture is a method for estimating population size and other parameters that is based on ratios of marked to unmarked individuals [1]. [2] noted that if the population of study consists of *N* elements, *N* being unknown and finite, capture-recapture methods can be applied to estimate the size of *N*. [3] also affirmed that the population under study is sampled two or more times. At each time, every unmarked animal caught is uniquely marked (usually with a numbered leg band in bird studies); previously marked animals have their capture recorded and then most or all of the animals are released back into the population. Thus, at the end of the study the experimenter has the complete capture history of each animal handled. Capture-recapture methods are extensively used in animal population estimation and in other fields such as quality control and epidemiology [4]. A set of models and their inference procedures have been proposed in the capture-recapture literatures for the estimation of animal population size from capture-recapture data [5]. Capture-recapture models can be broadly divided into two categories: (A) models for populations which do not change during the study (closed population models), and (B) models for populations which may change during the course of the study (open population models). Open population models can also be categorized according to whether the recaptures are observations on live animals or dead animals. The focus of this work is on open population models. Capture–recapture data are collected on the same individuals across successive capture occasions, these are viewed as binary longitudinal or repeated measurements data [6]. These repeated observations are often correlated over time. The dependency or correlation structure may be induced by incorporating individual heterogeneity. Failure to account for this dependency may provide biased estimates. Generalized Estimating Equations (GEE) account for a working correlation structure among capture occasions [7] as cited in [8] and use observed individual characteristics to model heterogeneity in capture probabilities. A mixed effects modeling approach may also be used to model heterogeneity of individual observed and unobserved characteristics in capture–recapture experiments, thus motivating the use of generalized linear mixed models (GLMM). [9] introduced the use of GLMM (logit models with normal random effects). An advantage of using GLMM for the estimation of capture probabilities is to accommodate not only the heterogeneity attributed to individual characteristics, but

also the heterogeneity that cannot be explained by the observed individual characteristics [9]. A valid GEE approach was proposed by [10] to improve power in small-sample longitudinal study settings in which the temporal spacing of outcomes is the same for each subject. Specifically, the study used a modified empirical sandwich covariance matrix estimator within correlation structure selection criteria and test statistics. The resulting impacts on power were demonstrated via a simulation study and application example. The study concluded that, the use of this estimator can improve the accuracy of selection criteria and increase the degrees of freedom to be used for inference. [11] applied GLM and GEE to model at-haulback mortality of blue sharks (Prionace glauca) captured in a pelagic longline fishery in the Atlantic Ocean. The data consists of 26,383 blue sharks with 13.3% of the specimens captured dead at-haulback. It was concluded that, the GLM and GEE models are valid for predicting blue shark at-haulback mortality, and can be used by fisheries management organizations for assessing the efficacy of management and conservation initiatives for the species in the future. A novel method proposed by [12] to model the mean and within-subject correlation coefficients for longitudinal binary data. The study introduced latent normally distributed random variables, the correlation coefficients of binary responses are connected to those for the latent variables, of which the correlation coefficients are modeled accordingly. A joint (GEE) method is developed for the purpose of the study and the resulting correlation coefficients are shown to satisfy the constraints. Asymptotic normality of the parameter estimators is derived and simulation studies are made under various scenarios, showing that the proposed joint GEE method works very well even if the working co-variance structures are mis-specified. [13] compares the performance of three techniques of analyzing incomplete longitudinal binary outcome data when the missing data is due to dropout. The study considers three modifications of the (GEE) based on inverse probability weighting (IPW) and multiple imputation (MI). In the weighted GEE (WGEE), observations were weight by the inverse of the probability of being observed. The multiple imputation (MI) combined with GEE analysis is commonly known as MI-GEE. In this approach, the missing observations are filled multiple times with the predicted values from the imputation model followed by a GEE analysis. The so-called doubly-robust (DR) technique combines the multiply imputed binary responses with IPW and then applying GEE to the completed data sets. The simulation and empirical example results revealed better performance for DR-GEE compared to WGEE and MI-GEE, but MI-GEE was evidently superior than WGEE and quite close to DR-GEE. [14] applied GEE on sputum status data of pulmonary tuberculosis patients at PKU Muhammadiyah Hospital at Bantul, Yogyakarta. The repeated observations cause autocorrelation and to be addressed by implementing the GEE method. The study aims to apply GEE and choose the best correlation structure based on the QIC value. Based on the analysis, the model of sputum status is $\log it(\pi_i) = 2.017 + 1.491\,job - 0.025time$, with unstructured correlation structure. [15] reported that, due to the nature of pure-tone audiometry test, hearing loss data often has a complicated correlation structure. The study proposed to model the correlation coefficients and use second-order GEE to estimate the correlation parameters. In simulation studies, the study assessed the finite sample performance of the proposed method and compared it with other methods, such as GEE with independent, exchangeable and unstructured correlation structures. The proposed method achieves an efficiency gain which is larger for the coefficients of the covariates corresponding to the within-cluster variation (e.g., ear-level covariates) than the coefficients of cluster-level covariates. The efficiency gain is also more pronounced when the within-cluster correlations are moderate to strong, or when comparing to GEE with an unstructured correlation structure. [16] used the data from the 2010 Nationwide Inpatient Sample (NIS), which has 8,001,068 patients and 1049 clusters, with average cluster size of 7627 to proposed a one-step GEE estimator that; matches the asymptotic efficiency of the fully-iterated GEE; uses a simpler formula to estimate the intra-cluster correlation (ICC) that avoids summing over all pairs; and completely avoids matrix multiplications and inversions. These three features make the proposed estimator much less computationally intensive, especially with large cluster sizes. A unique contribution of the study is that it expresses the GEE by incorporating the ICC as a simple sum of vectors and scalars. Consistent parameter estimates can be obtained naively by

assuming independence, which are inefficient when the intra-cluster correlation (ICC) is high. Efficient (GEE) incorporate the ICC and sum all pairs of observations within a cluster when estimating the ICC. [17] used (GEE) analysis as one of the longitudinal data regression methods for composite index data on children's welfare (CWCI) in West Java Province. The West Java CWCI longitudinal data used consists of 5 independent variables, each of which is a dimension of survival, protection, growth and development, participation, and identity in 27 districts and cities in West Java for the period 2015–2017. The study concluded that the research is important as an alternative approach of longitudinal data regression analysis when a correlation problem is found in the condition of observed data. [18] conducted a study to proposed a method for the analysis of spatially clustered real data based on GEE which were originally developed for analyzing longitudinal data. The performance of the model for known clusters was tested in terms of how well it estimates the regression parameters and how well it captures the true spatial process. A simulation study was conducted, and the proposed GEE approach yields better results than the popular conditional auto-regressive model from the both perspectives of parameter estimation and spatial process capturing. [19] examined the impact of height on the occurrence of Type II diabetes, where a longitudinal binary data set was analyzed. The relevant covariates were selected by using quasi-likelihood-based information criteria (QIC) and correlation information criteria (CIC) was used to select the correlation structure appropriate for the repeated binary responses. The consistent and efficient estimates of regression parameters were obtained from the GEE. With the selected covariates; height, education level, gender and unstructured correlation structure, it is found that there exists a statistically significant inverse relationship between height of an individual and the development of Type II diabetes. [20] designed a study to compare the efficiency of parameter estimates using data from one blinded randomized clinical trial on the impact of probiotic drops on infantile colic. The effect of probiotic drops on crying time was modeled by GEE and quadratic inference function (QIF) methods. Based on parameter estimates, the efficiency of the two methods was compared. The coefficient estimates of the two methods changed only slightly however, the relative efficiency of the parameter estimates from GEE and QIF was 1.23, when used on a mis-specified first-order autoregressive correlation structure. The study concludes that, when selecting an incorrect correlation structure, the QIF method is more efficient than GEE. Thus, GEE can help researchers obtain more reliable results herein. [21] conducted a study to select a working correlation structure for GEE. The study proposed a selection criterion based on the Stein's loss function. The proposed criterion consistently selects the true correlation structure when the unknown parameters are sqrt(n)-consistent, where n is the sample size. The demonstrate the performance of the proposed methodology by a numerical study. [22] presented a paper that considers a model selection criterion in regression models using GEE. Using the prediction mean squared error (PMSE) normalized by the covariance matrix, the study proposed a new model selection criterion called PMSEG that reflects the correlation between responses. A numerical study reveals that the PMSEG has better performance than previous other criteria for model selection. The applications of GEE on capture-recapture data by [23,24] focusses on open population taking into accounts behavioural and individual heterogeneity effects. The aim of this study is to apply GEE on capture-recapture open population data taking into accounts behavioural, individual heterogeneity and environmental effects.

8.2 **2 Generalized Estimating Equations**

Let *N* be the total number of individuals in the population of study, and let *m* be the possible number of capture occasions, $(m \geq 2)$.Let Y_{ij} the indicator of the i^{th} subject being caught in the j^{th} sample, that is, $Y_{ij} = 1$ if i^{th} subject is captured in the j^{th} sample, and $Y_{ij} = 0$, otherwise. Let T_i be the number of samples that the i^{th} subject belongs to, then let $T_i = \sum_{j=1}^{m} Y_{ij}$ .Let $Y_{ij} = \left(y_{i1},...,y_{im}\right)^T$ be the $m \times 1$

random vector to record the capture history of the i^{th} individual for the *m* occasions. Covariates z_i and x_{ij} are associated with the i^{th} individual and the j^{th} occasion, for $i = 1,...,N$, $j = 1,...,m$. Let z_i be an individual measurable covariate, such as age, sex or weight, etc. Let x_{ij} be a measurable occasion related covariate for the i^{th} individual, and let

$$X_i = \begin{bmatrix} 1 & 1 & \cdots & 1 \\ z_i & z_i & \cdots & z_i \\ x_{i1} & 0 & \cdots & 0 \\ 0 & x_{i2} & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & x_{im} \end{bmatrix}^T$$

be the covariance matrix.

[23] proposed the probability P_{ij} that the i^{th} individual is captured on j^{th} occasion is given by

$$P_{ij} = \Pr(Y_{ij} = 1 | z_i, x_j) = h(\beta_0 + \beta_1 z_i + \beta_{j+1} x_{ij}) \quad (1)$$

for $i = 1,...,N$, $j = 1,...,m$, where $h(u) = \dfrac{e^u}{1+e^u} = (1+(e^{-u}))^{-1}$ is the logistic function. If $x_{i_1 j} = x_{i_2 j} = x_j$ for $i_1 \neq i_2$, model (2) may be used for simplicity

$$P_{ij} = \Pr(Y_{ij} = 1 | z_i, x_j) = h(\beta_0 + \beta_1 z_i + \beta_{j+1} x_j) \quad (2)$$

for $i = 1,...,N$, $j = 1,...,m$. The covariance matrix now becomes

$$X_i = \begin{bmatrix} 1 & 1 & \cdots & 1 \\ z_i & z_i & \cdots & z_i \\ x_1 & x_2 & \cdots & x_m \end{bmatrix}^T \quad (3)$$

The assumptions of the model are: (i) All individuals are equally at risk of capture on every trapping occasion. (ii) The model accounts for heterogeneity among capture probabilities.

[24] introduced v_{ij} into the model (2) which is an indicator that, the i^{th} individual is captured prior to j^{th} occasion, and which depends on occasions as well as the individual i.e

$$v_{ij} = \begin{cases} 1, & caught \\ 0, & otherwise \end{cases} \quad (4)$$

They proposed the probability P_{ij} that the i^{th} individual is captured on j^{th} occasion is given by

$$P_{ij} = \Pr(Y_{ij} = 1 | z_i, x_j, v_{ij}) = h(\beta_0 + \beta_1 z_i + \beta_{j+1} x_j + \beta_b v_{ij}) \quad (5)$$

for $i = 1,...,N$, $j = 1,...,m$. In this case the covariance matrix now becomes

$$X_i = \begin{bmatrix} 1 & 1 & \cdots & 1 \\ z_i & z_i & \cdots & z_i \\ x_1 & x_2 & \cdots & x_m \\ v_{i1} & v_{i2} & \cdots & v_{im} \end{bmatrix}^T \quad (6)$$

The assumptions of the model are:(i) Capture probabilities vary according to individual capture history. (ii) Capture probabilities vary only by time. (iii) The probability of capture changes after initial capture.

Introducing f_{ij} into (2) which denote the environmental covariates such as mean temperature, humidity or rainfall recorded for i^{th} individual at j^{th} occasions.

Therefore, the probability P_{ij} that the i^{th} individual is captured on j^{th} occasion is given by

$$P_{ij} = \Pr(Y_{ij} = 1 | z_i, x_j, v_{ij}, f_{ij}) = h(\beta_0 + \beta_1 z_i + \beta_{j+1} x_j + \beta_3 f_{ij} + \beta_b v_{ij}) \quad (7)$$

for $i = 1,...,N$, $j = 1,...,m$. In this case the covariance matrix now becomes

$$X_i = \begin{bmatrix} 1 & 1 & \cdots & 1 \\ z_i & z_i & \cdots & z_i \\ x_1 & x_2 & \cdots & x_m \\ v_{i1} & v_{i2} & \cdots & v_{im} \\ f_{i1} & f_{i2} & \cdots & f_{im} \end{bmatrix}^T \quad (8)$$

The assumptions of the model are:(i) Capture probabilities vary according to environmental characteristics. (ii) Capture probabilities vary according to individual heterogeneity and environment. (iii) probabilities of capture vary according to an individual's prior capture history and the environmental covariates.

The mean vector of Y_i is specified as

$$\mu_i = \begin{bmatrix} E(Y_{i1}) \\ E(Y_{i2}) \\ \vdots \\ E(Y_{im}) \end{bmatrix} = \begin{bmatrix} P_{i1} \\ P_{i2} \\ \vdots \\ P_{im} \end{bmatrix} = P_i \quad (9)$$

$P_{ij} = \mu_{ij} = \Pr(Y_{ij} = 1/ z_i, x_{ij}, f_{ij}, v_{ij})$; for $i = 1,...,N$; $j = 1,...,m$. The probability of not capturing the i^{th} individual on the j^{th} occasion is given by $(1 - P_{ij})$, and the variance of Y_{ij} is $P_{ij}(1 - P_{ij}) = \mu_{ij}(1 - \mu_{ij})$, Therefore, the $m \times m$ variance-covariance matrix of Y_i is given by

$$Var(Y_i) = \begin{bmatrix} Var(Y_{i1}) & Cov(Y_{i1}, Y_{i2}) & \cdots & Cov(Y_{i1}, Y_{im}) \\ Cov(Y_{i1}, Y_{i2}) & Var(Y_{i2}) & \cdots & Cov(Y_{i2}, Y_{im}) \\ \vdots & \vdots & \ddots & \vdots \\ Cov(Y_{i1}, Y_{im}) & Cov(Y_{i2}, Y_{im}) & \cdots & Var(Y_{im}) \end{bmatrix} \quad (10)$$

an $m \times m$ working correlation matrix for each Y_i be used was suggested by [7]. Therefore, let $R_i(\alpha)$ denote the working correlation matrix, which is an approximation of the actual correlation matrix of Y_i. Then $R_i(\alpha)$ is assumed to be specified fully by the vector of unknown parameters α and the structure is determined based on the study design which is often assumed to be constant across individuals. The working correlation matrix can be expressed in the form:

$$V_i = A_i^{\frac{1}{2}} R_i(\alpha) A_i^{\frac{1}{2}} \quad (11)$$

Where, $A_i = diag\left[Var(Y_{i1}),...,Var(Y_{im})\right]$ is a $m \times m$ diagonal matrix with

$$A_i = \begin{bmatrix} Var(Y_{i1}) & 0 & \cdots & 0 \\ 0 & Var(Y_{i2}) & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & Var(Y_{im}) \end{bmatrix}$$

$$= \phi \begin{bmatrix} \frac{e^{u_{i1}}}{(1+e^{u_{i1}})^2} & 0 & \cdots & 0 \\ 0 & \frac{e^{u_{i2}}}{(1+e^{u_{i12}})^2} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \frac{e^{u_{im}}}{(1+e^{u_{im}})^2} \end{bmatrix} \quad (12)$$

ϕ is a known or estimated variance parameter (depending on the distribution of the response variable) to allow for over dispersion, such that, $Var(Y_{ij}) = \phi Var(P_{ij})$. Thus, in this model setting, $\phi = 1$ since the response variable follows a Bernoulli distribution.

The vector of parameters is given by $\beta = (\beta_0, \beta_1, \beta_2)^T$ and $R_i(\alpha) = Corr(Y_i)$ is a $m \times m$ working correlation structure among $Y_{i1}, ..., Y_{im}$ which describes the average dependency of individuals being captured from occasion to occasion, then the $R_i(\alpha)$ has the form: $R_i(\alpha) = I$, where I is a $m \times m$ identity matrix.

By adopting the notation in [23], Let D_i be the matrix of derivatives $\frac{du_i}{d\beta^T}$. Since $z_i, x_{ij}, f_{ij}, v_{ij}$ are observable covariates for each captured individual, then the vector of parameters $\beta = (\beta_0, \beta_1, \beta_2, \beta_3, \beta_b)^T$ for model (7) can be estimated by solving the following generalized estimation equations

$$U(\beta) = \sum_{i-1}^{N} D_i^T V_i^{-1} (Y_i - \mu_i) = 0 \quad (13)$$

However, N being the number of total individuals is unknown and is to be estimated. The covariates $z_i, x_{ij}, f_{ij}, v_{ij}$ are not known for individuals that have never been captured.

Let Ω be a set of distinct individuals that are captured at least in one occasion and are indexed by $i = 1, ...n$ and individuals that are not captured would be indexed by $i = n+1, ..., N$ without loss of generality. Thus, Y_{ij} is conditional on the captured individuals n (i.e., $T_i \geq 1$) as in [23,24,]. If $Y_{i1}, Y_{i2}, ..., Y_{im}$ are independent, given that the i^{th} individual is captured at least in one occasion, the probability that, the i^{th} individual is captured on j^{th} occasion is given by

$$P(Y_{ij} = 1 | T_i \geq 1) = \frac{P_{ij}}{1 - \prod_{j=1}^{m} (1 - P_{ij})} \quad (14)$$

An estimator of β, the vector of parameters defined by (4), can be obtained by solving the following generalized estimation equations

$$U(\beta) \equiv \sum_{i-1}^{N} D_i^T V_i^{-1} (Y_i - \mu_i) = 0 \quad (15)$$

Therefore, (15) is a transformed GEE for capture-recapture models. To solve (15), let the vector mean be $\mu_i = (\mu_{i1}, ..., \mu_{im})^T$ and variance covariance matrix be V_i. The variance covariance matrix varies according to the nature of correlation structures $R_i(\alpha)$. Fisher scoring was used to handle convergence problems associated with the fully iterated GEE. If the independent working correlation structure $(R(\alpha) = I)$ is assumed i.e., $Y_{i1}, ..., Y_{im}$ and letting $D_i = A_i X_i$, then the working correlation matrix (11) becomes

$$V_i = A_i^{\frac{1}{2}} I A_i^{\frac{1}{2}} = A = \begin{bmatrix} Var(Y_{i1}) & 0 & \cdots & 0 \\ 0 & Var(Y_{i2}) & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & Var(Y_{im}) \end{bmatrix} \quad (16)$$

The vector of parameters, β can be obtained by solving the following generalized estimation equations

$$\sum_{i=1}^{n} X_i^T (Y_i - \mu_i) = 0 \quad (17)$$

The equation (17) is the same with the one obtained by [24,25] where the assumption that the observations of each individual are independent of each other holds.

The vector of parameters, β can be obtained by solving the following generalized estimation equations for exchangeable and autoregressive correlation structures

$$\sum_{i=1}^{n} X_i^T A_i V_i^{-1} (Y_i - \mu_i) = 0 \quad (18)$$

where the covariance matrix V_i for Y_i changes according to the assumption of exchangeable and autoregressive working correlation structures within repeated observations. Equation (18) can be solved by an iterative procedure, and at each iteration, the correlation parameter α can be estimated from Pearson's residuals defined by

$$\hat{r}_{ij} = \frac{Y_{ij} - \hat{\mu}_{ij}}{\sqrt{\hat{\mu}_{ij}(1 - \hat{\mu}_{ij})}} \quad (19)$$

Where $\hat{\mu}_{ij}$ depends upon the current value for β. The estimation of α by [7] is given by,

$$\hat{\alpha} = \frac{\sum_{i=1}^{n} \sum_{j>1}^{m} \hat{r}_{ij} \hat{r}_{il}}{\left\{ \frac{1}{2} nm(m-1) - p \right\}} \quad (20)$$

Where p denotes the number of parameters in the model.

The vector of parameters, β can be obtained by solving the following generalized estimation equations under pairwise correlation structure,

$$\sum_{i=1}^{n} X_i^T A_i (A_i^{\frac{1}{2}} \hat{R}(\alpha) A_i^{\frac{1}{2}})^{-1} (Y_i - \mu_i) = 0 \quad (21)$$

The estimate of $R(\alpha)$ given by [7] as cited by [26] is

$$\mathbf{8.3}\ \hat{R}(\alpha) = \frac{1}{n} \sum_{i=1}^{n} A_i^{-\frac{1}{2}} (Y_i - \hat{\mu}_i)(Y_i - \hat{\mu}_i)^T A_i^{\frac{1}{2}} \quad \mathbf{(22)}$$

9 **2.1 The Proposed Models Approach**

1. **Model for Independence**

$$\log\left(\frac{p_{ij}}{1 - p_{ij}} \right) = \beta_0 \ (i = 1, ..., n;\ j = 1, ..., m) \quad (23)$$

This model assumes all the individuals are equally at risk of capture on every trapping occasion. This was presented by [23,24]. Suppose $p_{ij} = h(\beta_0) = p_0$ then, $U(\beta) \equiv \sum_{i=1}^{N} D_i^T V_i^{-1} (Y_i - \mu_i) = 0$ can be written as

$$U(\beta) \equiv \sum_{i=1}^{N} D_i^T V_i^{-1} (Y_i - \mu_i) = 0$$

$$= \sum_{i=1}^{n} (A_i X_i)^T V_i^{-1} (Y_i - \mu_i) = 0 \text{ (since } D_i = A_i X_i)$$

$$= \sum_{i=1}^{n} X^T A_i A_i^{-1} (Y_i - \mu_i) = 0 \text{ (since } V_i = A_i^{1/2} R_i(\alpha) A_i^{1/2} = A_i^{1/2} I A_i^{1/2} = A_i)$$

$$= \sum_{i=1}^{n} X^T (Y_i - \mu_i) = 0$$

$$= \sum_{i=1}^{n} (1 \quad 1 \quad \cdots \quad 1)\left(\begin{pmatrix} Y_{i1} \\ Y_{i2} \\ \vdots \\ Y_{im} \end{pmatrix} - \begin{pmatrix} \mu_{i1} \\ \mu_{i2} \\ \vdots \\ \mu_{im} \end{pmatrix} \right) = 0$$

$$= \sum_{i=1}^{n} \left(\sum_{j=1}^{m} Y_{ij} - \sum_{j=1}^{m} \mu_{ij} \right) = 0$$

$$\left(\mu_{ij} = \frac{P_{ij}}{1 - \prod_{j=1}^{m} (1 - P_{ij})} = \frac{P_0}{1 - \prod_{j=1}^{m} (1 - P_0)} = \frac{P_0}{1 - (1 - P_0)^m} \right) \text{ (since, } P_{ij} = h(\beta_0) = p_0)$$

$$= \sum_{i=1}^{n} \left(\sum_{j=1}^{m} Y_{ij} - \sum_{j=1}^{m} \frac{P_0}{1 - (1 - P_0)^m} \right) = 0$$

$$= \sum_{i=1}^{n} \left(\sum_{j=1}^{m} Y_{ij} - \frac{m p_0}{1 - (1 - p_0)^m} \right) = 0$$

$$= \sum_{i=1}^{n} \sum_{j=1}^{m} (Y_{ij} - \mu_{ij}) = 0 \qquad (24)$$

2. Model for Individual heterogeneity and Behaviour covariates

$$\log\left(\frac{p_{ij}}{1 - p_{ij}} \right) = \beta_0 + \beta_1 z_i + \beta_2 v_{ij} \ (i = 1, ..., n; j = 1, ..., m) \qquad (25)$$

This model assumes that capture probabilities vary according to individual heterogeneity and behavioural effects [24]. Let $p_{ij} = h(\beta_0 + \beta_1 z_i + \beta_2 v_{ij})$,then, $U(\beta) \equiv \sum_{i=1}^{N} D_i^T V_i^{-1} (Y_i - \mu_i) = 0$ can be written as

$$\sum_{i=1}^{n} \sum_{j=1}^{m} (Y_{ij} - \mu_{ij}) = 0$$

$$\sum_{i=1}^{n} \sum_{j=1}^{m} (Y_{ij} - \mu_{ij}) z_i = 0 \qquad (26)$$

$$\sum_{i=1}^{n} \sum_{j=1}^{m} (Y_{ij} - \mu_{ij}) v_{ij} = 0 \qquad (27)$$

3. Model for behavioural, individual heterogeneity and environmental covariates

$$\log\left(\frac{p_{ij}}{1 - p_{ij}} \right) = \beta_0 + \beta_1 v_{ij} + \beta_2 z_i + \beta_3 f_{ij} \ ; (i = 1, ..., n; j = 1, ..., m) \qquad (28)$$

This model assumes that the probabilities of capture vary according to an individual's prior capture history and the environmental covariates. Let $p_{ij} = h(\beta_0 + \beta_1 v_{ij} + \beta_2 z_i + \beta_3 f_{ij})$,then, $U(\beta) \equiv \sum_{i=1}^{N} D_i^T V_i^{-1}(Y_i - \mu_i) = 0$ can be written as

$$\sum_{i=1}^{n}\sum_{j=1}^{m}(Y_{ij} - \mu_{ij}) = 0$$

$$\sum_{i=1}^{n}\sum_{j=1}^{m}(Y_{ij} - \mu_{ij})v_{ij} = 0 \quad (29)$$

$$\sum_{i=1}^{n}\sum_{j=1}^{m}(Y_{ij} - \mu_{ij})z_i = 0 \quad (30)$$

$$\sum_{i=1}^{n}\sum_{j=1}^{m}(Y_{ij} - \mu_{ij})f_{ij} = 0 \quad (31)$$

9.1 **2.2 Fitting Generalized Estimating Equation Models**

The following steps was used in fitting the proposed GEE models as suggested by [27]:

1. **Linear predictor and best link function:** One must specify a link transformation function that will allow the response variable to be expressed as a function of parameter estimate β as a function of an additive model, to be able to model the expected value of the marginal response for the population $\mu_i = \mathrm{E}(Y_i)$ to a linear combination of the covariates. The choice of link function depends primarily on the distribution specified.
2. **Distribution of the response variable:** In fitting GEE the distribution of the response variable needs to be specified correctly so that the variance can be calculated as the function of the mean and the regression coefficients can be interpreted. The GEE allows the specifications of the distribution from the exponential family of distributions, including Normal, inverse Normal, Poisson, Binomial, Gamma distribution and negative Binomial. Prior knowledge of the distribution of the response variable is important.
3. **Structure of the correlation within the response variable:** Although GEE is robust when it comes to misspecification of the correlation structure, It is important to take precaution when it comes to specifying the structure. This is because a structure that does not incorporates all of the information on the correlation of measurements within the cluster may result in the inefficiency of the estimators.

9.2

9.3 **2.3 Modelling of Generalized Estimating Equations**

In this case of a capture- recapture experiment, α is the correlation between two consecutive capture occasions. The identity matrix and the variance function of a generalized linear models (GLM) assumes independence and this is substituted in a GEE with a correlation matrix, $R_i(\alpha)$ [28]. Therefore, the GEE approach takes into account the dependence among the observations by specifying the correlation structure. This structure is used to estimate the covariance matrix [7] as cited by [28]. A GEE approach allows various types of correlation structures $R_i(\alpha)$ and as a property, this approach provides unbiased estimates in analysing the correlated binary data [30]. Some common specifications for working correlation are as follows:

- **Independent Structure:** This correlation structure assumes that no correlation actually exists and observations within the series are independent. Therefore, the working correlation matrix becomes the identity matrix, $R_i(\alpha) = I$. No estimation of α is required. $R_i(\alpha)$ for this structure is defined as

$$R_{j,k} = \begin{cases} 1, & j=k \\ 0, & otherwise \end{cases} \tag{32}$$

In matrix notation this becomes,

$$R_i(\alpha) = \begin{bmatrix} 1 & 0 & \cdots & 0 \\ 0 & 1 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & 1 \end{bmatrix} \tag{33}$$

- **Exchangeable Structure:** This structure assumes that there is a common correlation within observations. An exchangeable correlation may be used when each pair of observations within a time frame has approximately the same correlation. For the exchangeable structure, $R_i(\alpha)$ is defined as

$$R_{j,k} = \begin{cases} 1, & j=k \\ \alpha, & otherwise \end{cases} \tag{34}$$

In matrix notation this becomes,

$$R_i(\alpha) = \begin{bmatrix} 1 & \alpha & \cdots & \alpha \\ \alpha & 1 & \cdots & \alpha \\ \vdots & \vdots & \ddots & \vdots \\ \alpha & \alpha & \cdots & 1 \end{bmatrix} \tag{35}$$

- **Autoregressive Structure:** An autoregressive correlation structure is used for the data that are correlated within cluster over time to set the time correlations as an exponential function of this lag period. This structure assumes time dependence for the association between observations and considers each time series to be a $AR(m)$ process. Because of the difficulty in determining the correct order of the autoregressive process, and $AR(1)$ is used. The structure of the $AR(1)$ is given below,

$$R_{j,k} = \begin{cases} 1, & j=k \\ \alpha^{|j-k|}, & otherwise \end{cases} \tag{36}$$

In matrix notation this becomes,

$$R_i(\alpha) = \begin{bmatrix} 1 & \alpha & \alpha^2 & \cdots & \alpha^{n-1} \\ \alpha & 1 & \alpha & \cdots & \alpha^{n-2} \\ \alpha^2 & \alpha & 1 & \cdots & \alpha^{n-3} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \alpha^{n-1} & \alpha^{n-2} & \alpha^{n-3} & \cdots & 1 \end{bmatrix} \tag{37}$$

- **Unstructured Structure:** This correlation matrix is used when there is no logical ordering of the observations in the cluster, and is recommended if the number of observations is small in a balanced and complete design. For the unstructured structure, $R_i(\alpha)$ is defined as

$$R_{j,k} = \begin{cases} 1, & j=k \\ \alpha_{j,k}, & otherwise \end{cases} \tag{38}$$

In matrix notation this becomes,

$$R_i(\alpha)=\begin{bmatrix} 1 & \alpha_{12} & \cdots & \alpha_{1m} \\ \alpha_{21} & 1 & \cdots & \alpha_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ \alpha_{m1} & \alpha_{m2} & \cdots & 1 \end{bmatrix} \tag{39}$$

9.4 **2.4 Population Size Estimator and the Variance**

We assume that n capture histories are available and that each contains information from m capture occasions. Let p_{ij} $(i=1,...,n;\ j=1,...,m)$ represent the probability of capture for the i^{th} individual during the j^{th} capture occasion. Let ϕ_{ij} $(i=1,...,n;\ j=1,...,m-1)$ represent the probability of survival for the i^{th} individual during the time period between the j^{th} and $(j+1)^{th}$ capture occasions. The open-population capture–recapture models employed here relate a differentiable function of the p_{ij} and ϕ_{ij} to a linear function of external covariates. Let x_{ijk} $(k=1,...,s)$ and s_{ijl} $(l=1,...,t)$ represent values of the k^{th} and l^{th} external covariate for the i^{th} individual during the j^{th} capture occasion. The capture probabilities, p_{ij}, is modeled as a function of the x_{ijk}. The survival probabilities, ϕ_{ij},will be modeled as a function of the s_{ijl}.Both the capture probability covariates and survival covariates is viewed as three-dimensional arrays where rows are individuals, columns are trap occasions, and pages are different covariates. These covariates might include age, sex, year, mean temperature, whether or not the individual was wearing a radio collar, amount of effort expended to capture individuals, geographic region of capture, etc. The open-population models to be used here stipulate that

$$\log\left(\frac{p_{ij}}{1-p_{ij}}\right)=\beta_0+\beta_1 x_{ij}+...+\beta_t x_{nm} \tag{40}$$

And

$$\log\left(\frac{\phi_{ij}}{1-\phi_{ij}}\right)=\theta_0+\theta_1 s_{ij}+...+\theta_t s_{n(m-1)} \tag{41}$$

The estimates for the parameters β_i and θ_i are obtained by the method of maximum likelihood. Given a set of observed capture histories, I_{ij}, where $I_{ij}=1$ if the i^{th} individual was seen at the j^{th} occasion and $I_{ij}=0$ otherwise.

The estimated capture probabilities and variances can be computed for each occasion except the first using the $\hat{\beta}_i$. The estimated capture probability and standard error for the i^{th} individual at j^{th} occasion is labelled as $\hat{p}_{ij}$ and $\hat{\pi}_{\hat{p}_{ij}}$, respectively.

The capture probability model is correct so that $E\left[\hat{p}_{ij}\right]=p_{ij}$ and $E\left[\hat{\pi}_{\hat{p}_{ij}}\right]=\pi_{\hat{p}_{ij}}$. Let the true number of individuals alive at trap j^{th} occasion be denoted N_j. Assuming capture is statistically independent across individuals (i.e., across subscript i), $E\left[I_{ij}\right]=p_{ij}$ and $\text{var}(I_{ij})=p_{ij}(1-p_{ij})$. The estimate of population size given by [1] at the j^{th} capture occasion, denoted $\hat{N}_j$ $(j=2,...,m)$, as

$$\hat{N}_j=\sum_{i=1}^{n}\frac{I_{ij}}{\hat{p}_{ij}} \tag{42}$$

$$E\left[\hat{N}_j\right]\approx N_j+\sum_{i=1}^{N_j}\frac{1}{p_{ij}^2}\left(\pi_{\hat{p}_{ij}}^2-\text{cov}(I_{ij},\hat{p}_{ij})\right) \tag{43}$$

So that $E\left[\hat{N}_j\right] \approx N_j$ provided that $\text{cov}(I_{ij}, \hat{p}_{ij}) \approx \pi^2_{\hat{p}_{ij}}$ for all i .The approximate variance of the estimator $\hat{N}_j$ is given by

$$Var\left(\hat{N}_j\right) = \sum_{i=1}^{n}\left(\frac{I_{ij}(1-\hat{p}_{ij})}{\hat{p}_{ij}^2} + \frac{I_{ij}\pi^2_{\hat{p}_{ij}}}{\hat{p}_{ij}^3} + \frac{I_{ij}(1-\hat{p}_{ij})\pi^2_{\hat{p}_{ij}}}{\hat{p}_{ij}^4}\right) \quad (44)$$

9.5 **2.5 Model Selection of Generalized Estimating Equations**

A modification of AIC known as the Quasi-Likelihood Information Criterion (QIC) was introduced by [32]. The QIC is constructed on the basis of independence of the working correlation assumption. The QIC can be used to select the appropriate working correlation structure the best subset of covariates that is nearest to the true model from a set of potential models in GEE analyses.

Then the simplified version of QIC given by [32] as cited by [33] is denoted by

$$QIC = -2Q(\hat{\mu}; I) + 2p \quad (45)$$

Therefore, QIC is use to select an optimal correlation structure. The model with the smallest QIC will be chosen as the best parsimonious model with the best correlation structure [32,34].

10 **3 Results and Discussion**

11 **3.1 Simulation 1**

In order to illustrate the GEE approach on open population capture-recapture data, a non-spatial open population data was simulated using R. The population size $n = 500$, $\phi = 0.7$, $\lambda = 1.1$, $p = 0.3$, and $m = 4$ trapping occasions was used to simulate the capture history. The individual discrete covariate, sex, was simulated based on the Binomial distribution $BIN(500,0.5)$. The individual continuous covariate, weight, and the environmental covariate, temperature, were simulated based on the Normal distribution $N(15,5)$ and $N(30,10)$ respectively. The indicator variable, behavioural effect was generated from the capture history. The simulation results for the different covariate structures are presented in Tables 1 and 2 respectively.

Table 1: GEE estimates for $p_{ij} = h(\beta_0 + \beta_1 v_{ij} + \beta_2 z_i)$ model $m = 4$

	Exchangeable		Independence	
Coefficients	Estimate	Std Err	Estimate	Std Err
Intercept	0.21969	0.08750	0.23451	0.08824
Sex	0.00917	0.00833	0.00835	0.00841
Weight	-0.00703	0.04401	-0.01292	0.04382
v_{ij}	-0.00270	0.04390	0.00941	0.00474
QIC	**85.08000**		85.12000	
	Unstructured		AR-1	
Intercept	0.21047	0.08089	0.23270	0.08819
Sex	0.01058	0.00722	0.00827	0.00834
Weight	0.02441	0.04184	-0.00968	0.04356
v_{ij}	0.00143	0.04240	0.00731	0.04383
QIC	85.21000		85.73000	

Table 1 shows the GEE estimates for individual heterogeneity and behavioural covariates model under different working correlation structure.

Table 3: GEE estimates for $p_{ij} = h(\beta_0 + \beta_1 v_{ij} + \beta_2 z_i + \beta_3 f_{ij})$ $m = 4$

	Exchangeable		Independence	
Coefficients	Estimate	Std Err	Estimate	Std Err

Intercept	0.26004	0.11377	0.26873	0.11560
Sex	-0.00684	0.04403	-0.01260	0.04379
Weight	0.00919	0.00839	0.00812	0.00848
v_{ij}	0.00824	0.04408	0.00791	0.04415
f_{ij}	-0.00263	0.00468	-0.00220	0.00474
QIC	86.9400		87.02000	
	Unstructured		AR-1	
Intercept	0.224141	0.10349	0.25958	0.06950
Sex	0.024355	0.04189	-0.00960	0.03150
Weight	0.010468	0.00730	0.00808	0.00550
v_{ij}	0.000710	0.04242	0.00623	0.02900
f_{ij}	-0.00084	0.00438	-0.00170	0.00260
QIC	**86.84000**		87.9900	

Table 3.2 shows the GEE estimates for individual heterogeneity, behavioural and environmental covariates model under different working correlation structure.

Table 3.3: Parameter estimates for open population Capture-Recapture models $m = 4$

	Models	
Parameter	$p_{ij} = h(\beta_0 + \beta_1 v_{ij} + \beta_2 z_i)$	$p_{ij} = h(\beta_0 + \beta_1 v_{ij} + \beta_2 z_i + \beta_3 f_{ij})$
Structure	Exchangeable	Unstructured
P_{ij}	0.25000	0.279000
$\hat{N}$	141.135	130.2184
$\hat{\phi}$	0.70800	0.760000
$S.E$	14.0868	12.99130

Table 3.3 shows the parameter estimates for open population Capture-Recapture models, when $m = 4$.

3.2 Discussion on Simulation 1

From Table 1, the QIC values for exchangeable, independence, unstructured and AR-1 are 85.08, 85.12, 85.21 and 85.73 respectively. The model under exchangeable working correlation structure was selected as the best model, because it has the smallest value of QIC, and was used to calculate the parameter estimates for open population capture-recapture data given in Table 3. Table 2 show, the QIC values for exchangeable, independence, unstructured and AR-1 are 86.94, 87.02, 86.84 and 87.99 respectively. The model under unstructured working correlation structure was selected as the best model, because it has the smallest value of QIC, and was used to calculate the parameter estimates for open population capture-recapture data given in Table 3. From Table 3, the estimated probability of capture $\hat{P}_{ij}$ =0.250, the estimated population size $\hat{N}$ =141.135 with a $S.E(\hat{N}) = 14.0868$, the estimated survival probability $\hat{\phi}$=0.708 when individual heterogeneity and behavioural covariates model is considered under exchangeable working correlation structure. The estimated probability of capture $\hat{P}_{ij}$

=0.279, the estimated population size $\hat{N}$ =130.2184 with a $S.E(\hat{N}) = 12.9913$, the estimated survival probability $\hat{\phi}$=0.760 when behavioural, individual heterogeneity and environmental covariates model is considered under unstructured working correlation structure. Comparison between individual heterogeneity/behavioural covariates model and individual heterogeneity/behavioural/environmental covariates model shows that, the individual heterogeneity/behavioural/environmental covariates model performs better because of the lower standard error.

3.3 Simulation 2

In order to illustrate the GEE approach on open population capture-recapture data, a non-spatial open population data was simulated using R. The population size $n = 500$, $\phi = 0.7$, $\lambda = 1.1$, $p = 0.3$, and $m = 5$ trapping occasions was used to simulate the capture history. The individual discrete covariate, sex, was simulated based on the Binomial distribution $BIN(500,0.5)$. The individual continuous covariate, weight, and the environmental covariate, temperature, were simulated based on the Normal distribution $N(15,5)$ and $N(30,10)$ respectively. The indicator variable, behavioural effect was generated from the capture history. The simulation results for the different covariate structures are presented in Tables 3.4 and 3.5.

Table 4: GEE estimates for $p_{ij} = h(\beta_0 + \beta_1 v_{ij} + \beta_2 z_i)$ model $m = 5$

Exchangeable			Independence	
Coefficients	Estimate	Std Err	Estimate	Std Err
Intercept	0.20471	0.08144	0.20408	0.08124
Sex	0.07210	0.06178	0.06574	0.05975
Weight	-0.01270	0.00872	-0.01132	0.00860
v_{ij}	0.08663	0.05161	0.00941	0.00474
QIC	197.634		197.466	
Unstructured			AR-1	
Intercept	0.237017	0.07715	0.20076	0.08244
Sex	0.060889	0.05597	0.06934	0.06139
Weight	-0.009041	0.00781	-0.01177	0.00872
v_{ij}	0.006959		0.09160	0.05213
QIC	**197.1210**		197.8340	

Table 4 shows the GEE estimates for individual heterogeneity and behavioural covariates model under different working correlation structure.

Table 3.5: GEE estimates for , $p_{ij} = h(\beta_0 + \beta_1 v_{ij} + \beta_2 z_i + \beta_3 f_{ij})$ $m = 5$

	Exchangeable		Independence	
Coefficients	Estimate	Std Err	Estimate	Std Err
Intercept	0.22887	0.09783	0.22412	0.09912
Sex	0.07137	0.06175	0.06526	0.05978
Weight	-0.01250	0.00873	-0.01110	0.00864
v_{ij}	0.08684	0.05157	0.09232	0.05200
f_{ij}	-0.00160	0.00365	-0.00130	0.00382
QIC	198.410		**198.3200**	
	Unstructured		AR-1	
Intercept	0.260470	0.09256	0.22150	0.09991
Sex	0.060130	0.05599	0.06884	0.06143

Weight	-0.00885	0.00781	-0.0115	0.00876
v_{ij}	0.070120	0.05110	0.09184	0.05203
f_{ij}	-0.00158	0.00341	-0.00170	0.00260
QIC	197.800		198.900	

Table 5 shows the GEE estimates for individual heterogeneity, behavioural and environmental covariates model under different working correlation structure.

Table 6: Parameter Estimates for open population Capture-Recapture models $m=5$

	Models	
Parameter	$p_{ij}=h(\beta_0+\beta_1 v_{ij}+\beta_2 z_i)$	$p_{ij}=h(\beta_0+\beta_1 v_{ij}+\beta_2 z_i+\beta_3 f_{ij})$
Structure	Unstructured	Independence
P_{ij}	0.341000	0.352000
$\hat{N}$	117.8986	117.9365
$\hat{\phi}$	0.886000	0.889000
$S.E$	11.75840	11.74220

Table 6 shows the parameter estimates for open population Capture-Recapture models, when $m=5$.

3.4 Discussion on Simulation 2

From Table 4, the QIC values for exchangeable, independence, unstructured and AR-1 are 197.634, 197.466, 197.121 and 197.834 respectively. The model under unstructured working correlation structure was selected as the best model, because it has the smallest value of QIC, and was used to calculate the parameter estimates for open population capture-recapture data given in Table 6.

From Table 5, the QIC values for exchangeable, independence, unstructured and AR-1 are 198.41, 198.32, 197.80 and 198.90 respectively. The model under independence working correlation structure was selected as the best model, because it has the smallest value of QIC, and was used to calculate the parameter estimates for open population capture-recapture data given in Table 6.

From Table 6, the estimated probability of capture $\hat{P}_{ij}$=0.341, the estimated population size $\hat{N}$ =117.8986 with a $S.E(\hat{N})=11.7584$, the estimated survival probability $\hat{\phi}$=0.886 when individual heterogeneity and behavioural covariates model is considered under unstructured working correlation structure. The estimated probability of capture $\hat{P}_{ij}$=0.352, the estimated population size $\hat{N}$ =117.9365 with a $S.E(\hat{N})=11.7422$, the estimated survival probability $\hat{\phi}$=0.889 when behavioural, individual heterogeneity and environmental covariates model is considered under independence working correlation structure. Comparison between individual heterogeneity/behavioural covariates model and individual heterogeneity/behavioural/environmental covariates model shows that, the individual heterogeneity/behavioural/environmental covariates model performs better because of the lower standard error.

Table 7: Comparison of the parameter estimates for $p_{ij}=h(\beta_0+\beta_1 v_{ij}+\beta_2 z_i)$ model $m=4,5$

Number of capture occasion	4	5
Correlation Structure	Exchangeable	Unstructured
Parameter		
P_{ij}	0.25000	0.34100
$\hat{N}$	141.135	117.8986

$\hat{\phi}$	0.70800	0.88600
$S.E$	14.0868	11.7584
QIC	85.0800	197.121

Table 7 shows the comparison of parameter estimates for individual heterogeneity and behavioural covariate model. The estimated probability of capture $\hat{P}_{ij}$=0.250, the estimated population size $\hat{N}=$ 141.135 with $S.E(\hat{N})=14.0868$, the estimated survival probability $\hat{\phi}$=0.708, when the number of capture occasion $m=4$. The estimated probability of capture $\hat{P}_{ij}$=0.341, the estimated population size $\hat{N}=117.898$ with $S.E(\hat{N})=11.7584$, the estimated survival probability $\hat{\phi}$=0.886, when the number of capture occasion $m=5$. Table 7 revealed that, the 4 recapture occasions yields less QIC, which implies that, the less the capture occasion the better the estimates. It shows that, the estimated population size increases when the number of capture occasion is increased. The lower the population size estimate, the lower the standard error and QIC.

Table 8: Comparison of the parameter estimates for $p_{ij}=h(\beta_0+\beta_1 v_{ij}+\beta_2 z_i+\beta_3 f_{ij})$ model $m=$ 4,5

Number of capture occasion	4	5
Correlation Structure	Unstructured	Independence
Parameter		
P_{ij}	0.27900	0.35200
$\hat{N}$	130.2184	117.9365
$\hat{\phi}$	0.76000	0.88900
$S.E$	12.9913	11.7422
QIC	86.84000	198.320

Table 8 shows the comparison of parameter estimates for individual heterogeneity, behavioural and environmental covariate model. The estimated probability of capture $\hat{P}_{ij}$=0.279, the estimated population size $\hat{N}=130.218$ with $S.E(\hat{N})=12.9913$, the estimated survival probability $\hat{\phi}$=0.760, when the number of capture occasion $m=4$. The estimated probability of capture $\hat{P}_{ij}$=0.352, the estimated population size $\hat{N}=$ 117.93 with $S.E(\hat{N})=11.7422$, the estimated survival probability $\hat{\phi}$ =0.889, when the number of capture occasion $m=5$. Table 8 revealed that, the 4 recapture occasions yields less QIC, which implies that, the less the capture occasion the better the estimates. It shows that, the estimated population size increases when the number of capture occasion is increased. The lower the population size estimate, the lower the standard error and QIC.

12

13 **3.5 Application to real data**

The data are from a randomized, double-blind, study of AIDS patients with advanced immune suppression (CD4 counts of less than or equal to 50 cells/mm^3) conducted by Henry et al., (1998). Patients in AIDS Clinical Trial Group (ACTG) Study 193A were randomized to dual or triple combinations of HIV-1 reverse transcriptase inhibitors. Specifically, patients were randomized to one of four daily regimens containing 600mg of zidovudine: zidovudine alternating monthly with 400mg didanosine; zidovudine plus 2.25mg of zalcitabine; zidovudine plus 400mg of didanosine; or zidovudine plus 400mg of didanosine plus 400mg of nevirapine (triple therapy). Measurements of CD4 counts were scheduled to be collected at baseline and at 8-week intervals during follow-up.

However, the CD4 count data are unbalanced due to mistimed measurements and missing data that resulted from skipped visits and dropout. The number of measurements of CD4 counts during the first 40 weeks of follow-up varied from 1 to 9, with a median of 4. The response variable is the log transformed CD4 counts, log(CD4 counts + 1), available on 1309 patients. The categorical variable Treatment is coded 1 = zidovudine alternating monthly with 400mg didanosine, 2 = zidovudine plus 2.25mg of zalcitabine, 3 = zidovudine plus 400mg of didanosine, and 4 = zidovudine plus 400mg of didanosine plus 400mg of nevirapine. The variable Week represents time since baseline (in weeks). The variable treatment is the behavioural covariate. The follow-up interval is the number of recapture occasion. The variables Age (years), Gender (1=M, 0=F) and log(CD4 count + 1) are the individual heterogeneity covariates. The variable Week represents time since baseline (in weeks) which is the environmental covariate.

Table 9: Parameter estimates for AIDS clinical trial group data

	Models	
Parameter	$p_{ij} = h(\beta_0 + \beta_1 v_{ij} + \beta_2 z_i)$	$p_{ij} = h(\beta_0 + \beta_1 v_{ij} + \beta_2 z_i + \beta_3 f_{ij})$
Structure	Independent	Independent
P_{ij}	0.468	0.505
$\hat{N}$	1182.25	1178.22
$\hat{\phi}$	0.998	0.999
$S.E$	34.44	34.3285
QIC	3046.76	2807.2

Table 9 shows the parameter estimates for AIDS clinical trial group data. The estimated probability of capture $\hat{P}_{ij}$=0.468, the estimated population size $\hat{N} = 1182$ with $S.E(\hat{N}) = 34.44$, the estimated survival probability $\hat{\phi}$= 0.998 when individual heterogeneity and behavioural model is considered. The estimated probability of capture $\hat{P}_{ij}$=0.505, the estimated population size $\hat{N} = 1178$ with $S.E(\hat{N})$ = 34.3285, the estimated survival probability $\hat{\phi}$= 0.999 when behavioural, individual heterogeneity and environmental model is considered. Comparison between individual heterogeneity/behavioural covariates model and individual heterogeneity/behavioural/environmental covariates model shows that, the individual heterogeneity/behavioural/environmental covariates model performs better because of lower standard error.

4 Conclusion

In this study, a Generalized Estimating Equation (GEE) approach accounting for heterogeneity, behavioural effects and environmental effects to estimate the probability of capture, the survival probability and the population size for open population capture-recapture experiment is proposed. A non-spatial open population capture-recapture data was simulated using two different trapping occasions $(m = 4,5)$ and the number of monte-carlo simulation $(N = 500)$ The GEE estimates for behavioural/heterogeneity covariates, behavioural/heterogeneity/environmental covariates model under different working correlation The study revealed that, the 4 recapture occasions yields less QIC, which implies that, the less the capture occasion the better the estimates. The results also show that,

the estimated population size decreases when the number of capture occasion is increased. Comparison between heterogeneity/behavioural model and heterogeneity/behavioural/environmental model for the simulations and real-life data shows that, the heterogeneity/behavioural/environmental model performs better in estimating the probability of capture the survival probability and the population size, because of the lower standard error. The study concludes that, environmental covariates be considered when estimating the probability of capture, the survival probability and the estimated population size.

References

[1] McDonald, T. L., & Amstrup, S. C. (2005). Estimation of population size using open capture-recapture models. *Journal of Agric, Bio, and Env Statistics, 6*(2), 206-220.

[2] Mingoti, S. A. (2006). A capture-recapture technique to estimate the size of the injecting drug user population attending syringe exchange programs. *Cad. Saúde Pública, Rio de Janeiro, 22*(4), 783–789.

[3] Pollock, K. H. (1982). A capture-recapture design robust to unequal probability of capture. *Journal of Wild Mgt, 46*(3), 752-757.

[4] Akanda, M.A.S., & Alpizar-Jara, R. (2017). A generalized Estimating Equations Approach to model heterogeneity and Time dependence in Capture Recapture Studies. *Euro Journal of Eco, 3*(1), 9–17.

[5] Koivuniemi, M., Kurkilahti, M., Niemi, M., Auttila, M., & Kunnasranta, M. (2019). A mark–recapture approach for estimating population size of the endangered ringed seal (*Phoca hispida saimensis*). *PLoS ONE, 14*(3), 64-82.

[6] Wesson, P., Jewell, N.P., Willi McFarland., M.D and Glymour., M.M. (2022). Evaluating tools for capture-recapture model selection to estimate the size of hidden populations: It works in practice, but does it work in theory? *Annals of Epidemio, 77*(4), 24–30.

[7] Liang, K. Y., & Zeger, S. L (1986). Longitudinal data analysis using generalized linear models. *Biometrika, 73*(1), 13-22.

[8] Chowdhury, R.I., & Islam, M.A. (2017). Generalized Estimating Equation. In: Analysis of Repeated Measures Data. Springer, Singapore.

[9] Stoklosa, J., & Huggins, R. M. (2012). A robust P-spline approach to closed population capture-recapture models with time dependence and heterogeneity. *Compu Stats and Data Anals, 56*(2), 408-417.

[10] Westgate, P.M., & Burchett, W.W. (2016). Improving Power in Small-Sample Longitudinal Studies when using Generalized Estimating Equations. *Stat Med, 35*(21), 3733–3744.

[11] Coelho, R., Paulo, I., & Miguel N. S. (2013). Application of Generalized Linear Models and Generalized Estimation Equations to model at-haulback mortality of blue sharks captured in a pelagic longline fishery in the Atlantic Ocean. *Fisheries Research, 145*(1), 66–75.

[12] Huang, Y., & Pan, J. (2021). Joint generalized estimating equations for longitudinal binary data. *Computational Statistics & Data Analysis, 155*, 107-110.

[13] Aluko Omololu S. and Mwambi H. (2017). A comparison of three different enhancements of the generalized estimating equations method in handling incomplete longitudinal binary outcome. *Global Journal of Pure and Applied Mathematics, 13*(10), 7669–7688.

[14] Devita Putri Mardyanti, & Rohmatul Fajriyah (2017). Generalized estimating equation (GEE) on binary longitudinal Data. *Proceedings of 1st Ahmad Dahlan International Conference on Mathematics and Mathematics Education*, Universitas Ahmad Dahlan, Yogyakarta, 13-14.

[15] Zhuoran We., Hanbing, Z., Sharon, C., Gary, C and Molin, W (2023). Generalized Estimating Equations for Hearing Loss Data with Specified Correlation Structures. *Stat.ME.*

[16] Stuart, L., Garrett, F., Debajyoti, S., Nathanael, H., Jim, H., and Louis, L. N (2017). One-Step Generalized Estimating Equations with Large Cluster Sizes. *J Comput Graph Stat.; 26*(3), 734–737.

[17] Asep, S. A., Inge, W and Hilda, N. (2020). Analysis of Longitudinal Regression Model Using the Generalized Estimating Equation (GEE) for the Child Welfare Composite Index (CWCI) in West Java. *Advances in Social Science, Education and Humanities Research*, volume 550. *Proceedings of the 1st International Conference on Mathematics and Mathematics Education (ICMMED), 1-8.*

[18] Nasrin, L., Mohammad, S.A and Syed, S. H (2021). A Generalized Estimating Equations Approach for Modeling Spatially Clustered Data. *Austrian Journal of Statistics: 50*(36), 36-52.

[19] Erfanul H., Mahfuzur R. and Wasimul B. (2015). On the Selection of Relevant Covariates and Correlation Structure in Longitudinal Binary Models: Analysing the Impact of the Height on Type II Diabetes. *Austrian Journal of Statistics, 44*(3), 3–15.

[20] Jamshid, Y., Maryam, T. and Hamed, R. (2018). Efficiency evaluation of QIF in the analysis of longitudinal data. *Russian Open Medical Journal, 7*(3), 1-5.

[21] Shinpei, I. (2015). Consistent selection of working correlation structure in GEE analysis based on Stein's loss function. *Hiroshima Mathematics Journal, 45*(3), 91–107.

[22] Yu, I. and Shinpei, I. (2018). Model selection criterion based on the prediction mean squared error in generalized estimating equations. *Hiroshima Maths Journal, 48*(3), 307–334.
[23] Zhang, S. (2012). A GEE approach for estimating size of hard-to-reach population by using capture-recapture data. *Journal of Theore and Applied Stat. 46*(2), 175–183.
[24] Akanda, M.A.S., & Alpizar-Jara, R. (2014a). A generalized estimating equations approach for capture-recapture closed population models. *Envir and Eco Stat, 21*(4), 667–688.
[25] Hwang, W.H., & Huggins, R.M. (2005). An examination of the effect of heterogeneity on the estimation of population size using capture-recapture data. *Biometri, 92*(1), 229–233.
[26] Jianwen, X., Jiamao, Z. and Liya, F. (2019). Variable selection in GEEs via Empirical Likelihood and Gaussian Pseudo-Likelihood. *Commu in Stat. 48*(4), 1239-1250.
[27] Wentao, G. (2019). Bootstrap-Adjusted Quasi-Likelihood Information Criteria for Mixed Model Selection. *PHD Dissertation, Bowling Green State University.*
[28] Hardin, J. W., & Hilbe, J.M. (2013). Generalized estimating equations, 2nd Edition. *Chapman and Hall/CRC Press, Boca Ratan, FL.*
[29] Deroche, C., B. (2015). Diagnostics and model selection for Generalized Linear Models and Generalized Estimating Equations (Doctoral Dissertation).
[30] Diggle, P., Heagerty, P., Liang, K.Y., & Zeger, S. (2013). *Analysis of longitudinal data*, 2nd Edition, Oxford University Press, New York.
[31] Lebreton, J. D., Burnham, K. P., Clobert, J., & Anderson, D. R. (1992). Modelling survival and testing biological hypothesis using marked animals: A unified approach with case studies. *Eco Monographs, 62*(1), 67-118.
[32] Pan, W. (2001). Akaike's Information Criterion in Generalized Estimating Equations. *Biometrics, 57*(1), 120-125.
[33] Wang, Y., Orla, M., Wang, Z., Bhatnagar, S.R., Schultz, J. and Moodie, E., M. (2015). The Perils of Quasi-Likelihood Information Criteria, *Stat Journal, 4*(2), 246-254.
[34] Cui, J. (2007). QIC program and model selection in GEE analyses. *The Stata Journal, 7*(2), 209–220.

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp. 517–543, November 13-16, 2023

Mapping The Nexus: A Bibliometric Study on the impact of Entrepreneurship Education on Sustainable Development Goals (SDG 1) in Nigeria

Sophia Essahmed [1]
sophia.essahmed@aun.edu.ng[1]

School of Business Entrepreneurship, American University of Nigeria [1],

Abstract
This paper is a bibliometric study to extrapolate the richness of scholarly publications in recognising the interconnectedness of entrepreneurship education and poverty alleviation in attaining Sustainable Development Goal 1 (SDG 1) in Nigeria. It examines various academic publications to highlight thematic clusters, identify key contributors, and map the intellectual dynamics in this field in Nigeria. The study assesses intellectual structures that include the number of publications, identified trends and the most prolific authors that contribute to the field. Through citation analysis, the study determines highly cited and influential publications in these fields to examine their content and contribution to scholarship. Keyword analysis was used to identify evolving themes and research topics within entrepreneurship education and SDG 1 to map their development in the last five years. The study finds strong research collaborations and recommends more collaboration between scholars from the global West and Nigeria for greater achievement of SDG.

Keywords: entrepreneurship education, SDG 1, bibliometry, poverty

1 INTRODUCTION

As we advance through the 21st century, the dynamism of research cannot be underrated. Research is seen as a light beam that directs national development through nurturing intellectual capacities across different branches of society. The United Nations Sustainable Development Goals (UN-SDG) is at the heart of this transformative endeavour. This is a set of 17 interconnected objectives that seek to foster prosperity, protect the planet and ensure the well- being of people by 2050.
The world today recognises education's critical role in driving the sustainable development of all facets of life. Among these goals, sustainable development goal 1 (SDG1) – to end poverty in all its forms and dimensions – stands out as a fundamental aspiration. To accomplish such an ambitious and multifaceted goal requires a comprehensive approach encompassing economic, social and educational dimensions. The central task of sustainable development is to eradicate poverty in all dimensions (Sustainable Development Solution Network, 2012) as the current narrative of the sustainable development goal is pursued in the context of a set of interlinked global "crises" of climate, economy and persistent poverty (Sustainable Development Solution Network 2012). Sustainable development has become a significant issue for all well-meaning administrators of countries across the globe (Laurie et al., 2016).

Many of the core dilemmas in sustainable development are seen to be long-standing, including the resource-dependent nature of developing countries, persistent poverty and rising inequality from severely restricted access to opportunities and environmental improvements.
Poverty is seen as a hindrance to millions of people who cannot access basic amenities and decent livelihoods. It is a common reality for many urban residents of the developing world. One of the most visible patterns of urban poverty in developing worlds is the prevalence of slums and large concentrations of low-income housing seen on the fringes of many cities. Understanding when poverty has become even more prevalent in recent years is important, as the public sector no longer provides many basic services.

Unemployment is closely related to poverty and, in turn, to hazardous and deteriorating living and working conditions (Sustainable Development Solution Network, 2012). Inexistent employment opportunities in the formal sector make many urban residents in the developing world look to a wide variety of both legitimate and illegitimate income opportunities. Yet, it is vital for societies to acknowledge that the greatest potential they have is their people. Therefore, the need to develop these people should be paramount. Nigeria accounts for 15% of the African population, constitutes 11% of Africa's total output and 16% of its foreign reserves, and accounts for half of the population of Africa and modern two-thirds of the capital output of the West African sub-region. Human capital development through avenues such as entrepreneurship education is paramount in ensuring the country develops sustainably.

The recent spotlight on entrepreneurship as an essential tool in the economy of any society has created the need for entrepreneurship education as a stimulant for national development. Entrepreneurship Education offers a practical approach, enables and equips with the necessary skills to become self-reliant and self-employed (Onyido and Dou, 2019).

The need to emphasise entrepreneurship education cannot be overestimated as it represents a multifaceted endeavour that resonates across global, regional and local contexts, shaping the entrepreneurial landscapes in diverse and profound ways (Gem 2020/2021 global report).
Entrepreneurship is key to sustainable socioeconomic empowerment that will fight unemployment and inequality, but it is hard to achieve this "without education that employs the proper methods, tools and objectives" (Rashid, 2019). As illustrated by the World Economic Forum's global education initiative, there is a need for multi-stakeholder partnerships for education and even more for entrepreneurship education (Idowu, F).

This paper sets out on a bibliometric exploration of the effects of entrepreneurship education on sustainable development goal 1(SDG 1) in Nigeria. Sustainable development has become a ubiquitous development paradigm, a watchword for international aid agencies and development planners, and a mantel of conferences and academic papers (Ukaga, Maser and Reichenbach, 2011). A bibliometric analysis examines various academic literature to highlight thematic clusters, identify key contributors and map the intellectual dynamism of entrepreneurship education and sustainable development with particular emphasis on poverty.

2 LITERATURE REVIEW

In an era of expanding scholarly output and rapidly evolving research, the quest for robust tools and methodologies to address and comprehend a vast corpus of literature has never been in greater demand, as this aligns with the overarching theme of this conference, "Research: A tool for National Development and Innovation in the 21st century."
Examining the extent to which entrepreneurship education contributes to the realisation of SDG1 through rigorous research is still very important, especially in the Nigerian context. Yatu et al. (2018) called the attention to a dearth of rigorous research that explores entrepreneurship education in Nigeria, encouraging rigorous research in the field. Other researchers, like Liv et al. (2019) and San-Martin et al. (2019), have called for research into the impact of entrepreneurship education with a specific focus on contextual uniqueness and how entrepreneurship education could be more effective in delivering its expected outcomes.

The findings from such research will lay the foundation for employing the transformative ability of entrepreneurship education to address the multi-dimensional challenges of poverty in Nigeria as it

aligns with sustainable development goals. It is not a fad but rather a reflection of its utility in handling large volumes of scientific data as well as producing high-impact research.
This literature reviews existing scholarly insights as well as identifies research gaps while illuminating future recommendations in presenting the effect of entrepreneurship education on SDG1. The subsequent sections of this literature will comb through current research and disclose the dynamics of entrepreneurship education's impact on SDG1 in Nigeria.
It further highlights the limited bibliometric studies on this topic in the Nigerian context, collating the level of regional disparities in the current state of bibliometric analysis and the effect of entrepreneurship education in SDG1.

In assessing this interconnection between achieving economic empowerment and inclusive growth as it aligns with the sustainable development goals, we will create a comprehensive bibliometric map that visually illustrates how entrepreneurship education research intersects with the objectives of SDG1. This will facilitate cross-disciplinary collaboration among policymakers in the field of sustainable development, entrepreneurship education and poverty eradication through knowledge sharing and dialogue.

Nwangwo (2019) opined that the failure of tertiary education to inculcate students' functional skills has led to wastage in terms of both human and natural resources. Entrepreneurship education could be defined as the willingness and ability of an individual to acquire educational skills to explore and exploit investment opportunities to establish and manage a successful business enterprise.
According to Paul (2015), entrepreneurship education is structured to achieve the following objectives:

- to offer functional education that will increase self-employment and self-reliance;
- provides graduate youth with ample training for innovativeness in identifying & solving problems in exchange for income;
- to spur economic growth and development;
- offer adequate training in risk management to graduates to make entrepreneurship skills realistic;
- to reduce high level of poverty;
- to reduce rural-urban migration.

Entrepreneurship education is a viable instrument for reducing unemployment through university education in Nigeria. Nigeria is still grasping with the problems of unemployment, poverty and corruption. The solution lies partly in improving the people through entrepreneurship education. The university curriculum was in the past directed towards the production of graduates suitable only for white-colour jobs, graduates become job seekers instead of job creators. Universities should work closely with willing employers to design curricula and programmes that are relevant to the skills needed in their sectors.

Lack of entrepreneurship education, which creates a self-reliant ideology in people, will lead to gross unemployment, which results in poverty in all its facets. These, in turn, create survival instincts in individuals and then brings about discrimination among the people. Entrepreneurship education will lead to increased employment, reduce poverty level and bring about entrepreneurs working together for the common good and establishing a stronger economy than the present Nigeria economy.
Pervasive poverty points to further issues than a simple lack of income or the productive resources to ensure sustainable livelihood. It includes the experience and results of hunger, health issues, restricted access to education and inadequate social services, discrimination and social exclusion.

Some social groups have to deal with a heavier burden of poverty. “The Nigeria Multidimensional Poverty Index (MPI) 2022 shows that poor people in Nigeria experience over one quarter of all possible deprivations. Sixty-five percent of multidimensionally poor people- 86.1 million live in the north, while 35% - nearly 47 million live in the south” (Nigeria Poverty Map, 2023). Based on the most recent official household survey data from Nigeria Bureau of Statistics (2023), 30.9% of Nigerians lived below the International extreme poverty line of $2.15 per person per day in 2018/19 before the COVID-19 pandemic. The poverty rate in the northern geopolitical zones was 46.5% in 2018/19, compared with 13.5% for southern regions. By the end of 2023 about 37.5% of Nigerians are expected to live below the International poverty line.

As many as 62.9% people in Nigeria are multidimensionally poor, they experience deprivations in more than one dimension. NPM (2023) points out that there are four dimensions to poverty – health, education, living standards, and work & shock dimensions. These help us see that poverty is a deep and multifaceted problem. It affects individuals and communities globally in different ways, and to different outcomes. Poverty occurs unevenly in society, as particular factors make the subsets of the society more prone to heavier poverty burdens, and some find it harder to escape. The unequal yoke is mostly due to “historical, structural and systematic factors” that enforce the negative pattern. The factors responsible for the heavier poverty burdens point to the need for highly-specific policies and interventions that will address the root of poverty on the journey to building a fairer world.

Employment generation is a means of assuaging poverty and growing the level of economic activities, which translates into economic growth. Although the Nigerian government puts in place policies and programs that are meant to combat this menace, but due to inadequacies of implementation, these programs have not made much impact.

According to the Northern Illinois University, Outreach (NIU, 2005), higher education has historically included economic development as part of its core mission. As reiterated by Araba (2012), higher education in Nigeria is gradually becoming an increasingly important enterprise, judging by the rise of new private institutions being licensed. He further asserted that the impact of education on the rise in unemployment is negligible, else unemployment should be on the decrease in the country.

Institutions of higher learning should create environments that nurture the entrepreneurial mindset, skills, and behaviours across their organizations. Therefore, a shift from classical models of teaching to experiential learning approaches is vital. All around the world, necessary attention is being paid to the potential of university education to facilitate high-growth enterprises. Research carried out in Germany has shown that enterprises started by individuals with university degrees tend to grow faster than enterprises founded by non-academics (Egeln, 2000).

The strength of entrepreneurship education, however, is to influence people's attention towards entrepreneurship and the prospects and possibility of becoming a growth entrepreneur.

2.1. Theoretical Framework

This study will be guided by the premise of dynamism, where innovation and transformation based on the Triple Helix model will form a conceptual structure. This will provide a foundation to help make sense of the data extrapolated for the study. Which, in this case, will be the intersection between entrepreneurship education and SDG1.

The triple helix model was first offered by Henry Etzkowtz and Loet Leydesdoff as a theoretical framework that explores dynamics of innovation, particularly among academia, industry and government to ensure economic and social development, just as described in ideas such as the knowledge economy (Galvao et al., 2019).

The framework identified as the academic, which represents the university and research institution, could symbolise the entrepreneurship education sector. As the study examines the research trends, contributions by researchers and institutions are adopting the knowledge of entrepreneurship education to address poverty (SDG1).

The policy element of the triple helix model signifies policies, initiatives, and government regulation. This study involves the sustainable development goals created by the United Nations (sdgs.un.org, 2015) as part of the Post-2015 development agenda. The industry component symbolises the business sector, including start-ups, entrepreneurs and businesses. This represents how the entrepreneurial ecosystem relates to entrepreneurship education in curbing the multi-dimensional poverty in Nigeria. The adoption of the triple helix model serves as a guide to exploring the relationship between entrepreneurship education and poverty reduction (SDG1). This will contribute further knowledge relevant to the field of sustainable development, education and entrepreneurship while augmenting global policies and initiatives.

This will further guide the research question, encompassing citation analysis, science mapping and research trends; identify and examine research gaps associated with the intersection of entrepreneurship education and the attainment of SDG1.

2.2. Research Questions

- How can bibliometric analysis extrapolate research gaps in the field of entrepreneurship education and its connection to the realisation of Sustainable Development Goal 1(SDG1) in the Nigerian context?

2.3. What is Entrepreneurship and Why does it Matter?

One way to conceptualize entrepreneurship as a scholarly concept is to view it by taking primary approaches to defining entrepreneurship, as Landotram et al. (2012) suggested. These include:

- entrepreneurship as a function of the market
- the entrepreneurship as an individual
- entrepreneurship as a process.

As Landotram et al. (2021) reiterates, today's view of entrepreneurship is mainly grounded in management theories, viewing entrepreneurship as a process. While in Steyert and Hjarth's (2003) views suggest that entrepreneurs should no longer be described as one entrepreneurship but in many terms such as focus, definitions, scope and paradigms.
They further asserted that to view entrepreneurship solely through an economic lens is to reduce entrepreneurs to mere capitalists when the reality is that they do so much more. There seems to be a "widespread recognition that entrepreneurship is the engine driving the economy and society of most nations" (Brock & Evans, 1989; Acs, 1992).

In Gibb's (2005) view, he opined that when entrepreneurship is no longer limited to the business sector, i t needs to be understood in ways that go beyond its economic or business functions. In the words of Bahader (2012), developing a culture of entrepreneurship thinking within the communities

in which we live and work has become the focus of governments and societies worldwide. He further reiterated that the building of entrepreneurship ecosystems has become the policy of many governments, in which the role of education has long been recognised as the cornerstone of any policy. Education needs to address the development of skills required to create an entrepreneurial mindset as well as prepare future leaders for complex, interlinked and fast-changing issues. There is a need for societies, organisations and individuals to improve their capacity to cope with an increasingly competitive, uncertain and complex world through innovation and knowledge building (Gibb, 2012). This is parallel to the evolution of the field of entrepreneurship that can increase interest in developing educational programs to encourage and foster entrepreneurship (Solomon et al., 2002).

2.3. The Emergence of Entrepreneurship Programs

The field of entrepreneurship development research has, since the start of the 21st century, become more theory-driven (Wikland et al., 2011), whereas this is not so in entrepreneurship education (Fayolle, 2013). The theoretical fragmentation within the field can, however, be viewed as a positive development as it allows for the continuous development of new perspectives and approaches (Kiwatko, 2005).

Entrepreneurship education (EE) developed from a niche phenomenon (Hills, 1988) to a flourishing field in both practice and research (Katz, 2003). Interest in entrepreneurship grew rapidly in the late 50s and early 60s when some of the most well-known studies of entrepreneurship, like McClelland's 'The Achieving Society' (1961), was written (Lee & Wong, 2014).

Entrepreneurship education was pioneered by Shigua Fijii, who started teaching it in 1938 at Kobe University in Japan (Alberti et al. 2004). Until the 1980s, much confusion was made between entrepreneurship education and small business, mainly because of an overlap between the two respective fields of research (Waston, 2001). Small business education was first established in the 1940s (Sexton & Bowman, 1982) to deal with the managing and operation of small established companies, while entrepreneurship education courses first appeared in the 1960s and focused on the activities involved in originating and developing new and growing ventures (Alberti et al., 2001).

Over time, as the understanding of entrepreneurship expanded, this led to a shift to a broader view of entrepreneurship education (Shapero, 1975). As the demand for entrepreneurial skills grew, educational institutions began to formalise entrepreneurship education by offering specialised courses and degrees, formally recognising entrepreneurship education as a distinct field (Katz, 2003). Then, entrepreneurship education began to incorporate innovations, social entrepreneurship and social impact that aligned with a comprehensive understanding of the role of entrepreneurship education in development (Austin et al., 2006).

McMullen and Long (1987) argued that, unlike other university degrees, the success of entrepreneurship programs could not be evaluated by the number of students that graduated, but it could only be more appropriately measured by the socio-economic impact they produce in the business they create.

Nigeria introduced an action blueprint to promote entrepreneurship education with the aim of promoting innovation and entrepreneurial skills, to inspire more youths to set up their own enterprises and be self-employed with an overall effect of removing unemployment and the scourge of poverty (Kasgak et al., 2022). The human capital model of Robert (1991) advocated the view of education as an instrument for improving human capital, stimulating labour yield, and boosting the level of technology across the globe (Raimi, nd).

Research outcomes have often linked entrepreneurship in developing nations with “informality and the necessity-driven type of entrepreneurship,” which contrasts with the formality and opportunity-driven type in developed nations (Yatu, 2021). For Nigeria to accelerate its socio-economic development, there is the need to deliberatelyfocus attention on human capital development through regular capital planners, seeing employers as builders of human capital to facilitate meaningful national development (Aropegba, 2001).

Olutunse et al. (2020), in their model of stimulating and developing entrepreneurship skills through entrepreneurship education in Africa, established that optimising the yield of the required outcome in entrepreneurship education will necessitate an entrepreneurship education that rightly aligns with contextual peculiarities of the society of focus.

For Nigeria, this can include the economic landscape, where income inequality, underemployment, a large informal sector, huge disparities in access to quality education and entrepreneurship training, insecurity and other deficiencies that can affect the extent to which entrepreneurship education can address poverty are the norm.

2.4. The Global Context of Entrepreneurship Education and its Alignment with the SDGs

Starting with the Bayh-Dole Act of 1980 in the U.S., which is to ensure closer ties and utilise resources in driving economic development, governments around the world are taking proactive measures, such as bringing universities to understand that economic contributions alone are not sufficient for mobilising sustainable development (Mowery et al. 2005).

Building the capacities of universities to respond to the challenges of sustainable development would require a rethink. In realisation of the importance of economic empowerment to achieve the SDGs, the United Nations has been focusing on entrepreneurship interventions to support ambitious youths to start their own businesses and to generate employment opportunities, particularly in the context of “fragility and poverty, where unskilled entrepreneurs predominate, and small business activities are mostly of a low-growth, survivalist nature” (Rashid, 2019).

Many of the world's government think tanks, NGOs and international organisations look to entrepreneurship as a solution to poverty and social inequality while implementing business solutions for a more vibrant global society.

To achieve these sustainable development goals, governments, higher education institutions, and universities must ensure that entrepreneurship education curricula explicitly target and enable young people to be successful.
Entrepreneurship education will bridge the gap that currently exists between students' learning outcomes and the vision of the National Education Policy; this will prepare students for more meaningful and satisfying lives, with an overall effect on the economic, social and cultural values of society (Mukhtar et al., 2021).

2.5. Sustainable Development Goal 1: Eradicating Poverty

The 2030 Agenda for Sustainable Development was publicized in 2015 by the United Nations after two years of global consultations with civil society organizations, scientists, academics and citizens from across the world. It proposed 17 SDGs, along with 169 targets and 231 indicators (sdgs.un.org, 2015).

Central to this agenda is SDG 1 – which is committed to eradicating poverty in all forms and dimensions. The critical problem of sustainable development in each country, as well as globally, is eradicating extreme poverty, as it stands in the way of achieving most goals of development.
To translate this ambitious goal into action, SDG1 is underpinned by a set of ten specific targets. These targets address the complexities of poverty reduction and the need for a comprehensive approach. They include halving the percentage of people living in poverty, ensuring social protection, promoting equal rights, and providing access to essential services (United Nations, n.d).

Eradicating poverty is fundamental for nations worldwide, especially in South Asia and Sub-Saharan Africa, which have most of the world's poorest. Extreme poverty remains stubbornly high in low-income countries of Sub-Saharan with almost half of its population living below the poverty line of $1.90 per day (unstats.un.org 2023). To give room for international comparisons, the World Bank established an international poverty line of $1.90 daily per person; this has been updated to $2.15 per person per day (worldbank.org 2022).

The task of eradicating poverty has enormous complexities, as poverty is a multi-dimensional, deeply entrenched phenomenon. To be able to understand and address the complexities of poverty, it is important to take effective poverty reduction strategies that will not just solve the immediate crises but will have a long-term effect on national development; that will foster economic growth, human capital development, social inclusion and the overall well-being of humanity.

2.6. Entrepreneurship Education and SDG1

Sustainable development, according to a World Bank study, is "a process of managing a portfolio of assets to preserve and enhance the opportunities people face" (worldbank.org n.d).

Parallel to the evolution of the field of entrepreneurship (Solomon et al., 2002) is the realisation that entrepreneurship education nurtures entrepreneurship, which in turn acts as a catalyst for poverty reduction through varied interconnected pathways, resulting in job creation, economic empowerment and the general well-being of humanity. Hytti & Kuopusjarvi (2004) highlighted on increased policymakers' awareness of entrepreneurship's relevance as a mainstay of economic development. Von Graevenitz et al. (2010) suggest that though entrepreneurship education ranks very high on the policy agenda of most economies of the world, there still exists a dearth of research that delves into assessments of the impact of entrepreneurship education.

Nabi & Linan (2011) further supported that while entrepreneurship education received high recommendations in developed nations in terms of policy formation and implementation, this is not the same in most developing nations, where a high level of migration and brain drain is the norm. This shows how critical the need to lift people out of poverty and empower them to self-reliance has become, but economic growth alone is not enough. Lifelong learning through education and training is necessary for the new job market, characterised by the knowledge economy (Soubbotin, 2004).

2.7. Methodological Views

In the realm of academic research, various methodologies can be applied to help explain or investigate the relationship between entrepreneurship education and SDG1 in Nigeria.
To fully comprehend existing knowledge and identify research gaps in this study, literature reviews that researchers and practitioners engage to provide a transparent audit trail in legitimising articles that update the field of entrepreneurship education as it impacts SDG1 are important.

Relative to traditional literature review methods, where renowned scholars like Mwasalwiba (2010), Nabi, Fayolle, Krueger, Linan & Walmsley (2017) were particularly interesting in their extensive views on entrepreneurship education, bibliometric analysis method provides objective criteria that can assess the research development in the field while providing a valuable tool in assessing the productivity and quantity of the research (Cobo et al., 2015).

Bibliometrics serves as a compass, guiding us through vast spheres of academic literature to reveal insights, patterns and trends. According to Zopic & Cater (2015), bibliometry introduces a systematic, transparent and reproducible review process, which permits a better description, evaluation and monitoring of published research, hence bringing a new perspective to the field of entrepreneurship education as it complements other research.

Bibliometric analysis holds particular relevance in this study as it enables the mapping between entrepreneurship education and sustainable development goal 1 in Nigeria by discerning influential research papers, authors and research clusters. Bibliometrics is part of scientometrics, which utilises mathematical and statistical approaches to analyse scientific activities in a field of research (Lopez-Fernandez et al., 2016). It also unveils the evolutionary trajectory of this interdisciplinary domain, shedding light on emerging research themes and knowledge gaps.

The overall objective is to arrive at actionable insights that can augment academic discourses, inform policy decisions and nurture unified responsibilities in achieving SDG1 across the globe, with particular emphasis on poorer nations.
It is important to note that an authoritative guide to bibliometric analysis in business research remains elusive. Hence, one can assume an important challenge for business scholars. Likewise, the popularity of bibliometric analysis in business research is not a fad but a reflection of its utility, which includes:

- **i)** handling large volumes of scientific data
- **ii)** producing high research impact (Donthu et al., 2021).

2.8. Research Gaps and Opportunities for Future Research

Based on a broad literature overview of the relationship between entrepreneurship education and SDG1 in Nigeria, there are several research gaps and opportunities for future research. Yatu et al. (2018) stressed a dearth of thorough research that explores Nigeria's entrepreneurship education.

Additionally, a series of other studies exist whose findings and conclusions call for research investigations into the entrepreneurship education process so that stakeholders can contribute to shaping the entrepreneurship education process from multifaceted angles (Graniodes & Meck, 2019). Many studies within this domain remain within the confines of entrepreneurship and educational research. To comprehensively address the complexity of SDG1, there is a need for interdisciplinary research that integrates insights from fields such as economics, sociology and public policy. Future research can embrace an interdisciplinary perspective to explore the multifaceted relationship between entrepreneurship education and poverty reduction. This approach can offer a more holistic understanding of the challenges and opportunities in achieving SDG1 (Studer & Teixeira, 2020).

3 METHODOLOGY

The new knowledge created by researchers is embedded in the research literature. By measuring scientific literature, we measure knowledge and how it was produced (Grant, 2015). The

methodology section of this study serves as the blueprint to assess the impact of entrepreneurship education in the attainment of Sustainable Development Goal 1(SDG1) in Nigeria, which focuses on indicating poverty and exploring the dynamic relationship among academics, government and other stakeholders such as non-governmental organisations and businesses.
Bibliometrics are quantitative analyses of academic publications. It uses academic publications as a data source to provide a better understanding of how research is produced, organised and interrelated. It is a quantitative technique that uses relational, evaluative and descriptive methods to assess the quantity and quality of publications.

- Descriptive methods are simple descriptions of bibliometric information.
- Evaluative methods are used to assess and interpret the impact of publication.
- Relational techniques are applied to explore the relationship among units such as authors, documents, sources, organisation and countries.

When done well, bibliometric analysis can build firm foundations for advancing a field in novel and meaningful ways. It enables and empowers scholars to:

- Get a one-step overview
- Identify knowledge gaps
- Drive novel ideas for investigation
- Position their intended contributions to the field (Donthu, 2015).
- The main techniques for bibliometric analysis manifest in the following ways:
  - Performance analysis - accounting for the contribution of research.
  - Science Mapping - focusing on the relationship between research.

The emergence of scientific databases such as Scopus, Web of Science and Dimensions has made acquiring large volumes of bibliometric data relatively easy, and bibliometric software such as VOSviewer, Gephi and Lexi Mencer that enables pragmatic analysis and network visualisation (Moed et al, 1995). The bibliometric method aligns with the objective of this study as it outlines the specific procedures to uncover meaningful outcomes on the impact of entrepreneurship education on Sustainable Development Goal 1 in Nigeria.

3.1. Data Collection

The source from which the bibliographic data is being collected is Dimensions. Launched in January 2018, Dimensions links over 133 million research documents across the research life cycle (Williams, 2018). Dimensions go beyond the standard publication citation ecosystem to give users a much greater sense of the context of a piece of research (Daniel et al., 2018) by including not only books, chapters and conference proceedings but also awards, great patents, clinical traits, policy documents and altmetrics information.

The original idea of the database is to facilitate the identification of experts and leaders in different scientific domains and, therefore, to favour and stimulate academic networking and partnership (Mcshea, 2018). The entrance of the science citation index (SCI) and social science citation index (SSCI) allowed, for the first time, the realisation of studies that had been impossible and unthinkable in data mapping. By 2004, Scopus and Google Scholar represented another turning point in the database ecosystem (Marzo-abril, 2018).

These data are enriched with impact information, both in times of citation received and altmetric academic profiles, Global Research Identifier Database (GRID), geotagging, and classification of subject areas based on machine learning techniques (Bode et al., 2018).

The coverage and evaluation of the Dimensions database are comparable to the Web of Science (WOS) and Scopus and even show higher coverage from 2000 to 2016 (Ordeina-Melea et al., 2015). The core aim of the Dimensions project was to do more than deliver another research database; it is to build a tool that aligns with the requirements and success of research organisations in ways that can change how the scholarly landscape is navigated and understood (William, 2018).

Dimensions is compared to Scopus, not Web of Science (WOS), since Scopus has consistently been found to have greater overall coverage of academic journals (Mongeon and Paul-Hus, 2016; Waltman, 2016). Dimensions provides access to diverse research output, including academic journal articles. This interdisciplinary coverage aligns with the multi-faceted nature of SDG1, which requires insight from various fields, including education, economics and policy (Piwower et al., 2018).

Data production, collection, processing and analysis have changed how research takes place, which has made it extremely valuable because we can understand "who is citing a paper and the diversity of fields that cite a piece of research" (Hook et al., 2018). Citations are a central part of the puzzle in databases like Dimensions. Scholarly attention in the form of citations has been a mainstay of bibliometric analysis since the 1950s and also an evaluative tool since the 1980s.

In Dimensions, standard reproducible subject categories are achieved algorithmically using a machine learning approach. An expert can build a classification based on a set of research terms with it, which can include more detailed data views in an expandable tab called "Analytical view." This tab offers more detailed metrics breakdown based on the current research criteria—a wide range of options and filters within the analytical views (http://app.dimensions.ai).

3.2. Search Query

Specific search terms or Boolean operators are used to retrieve relevant records from the Dimensions databases. The keywords used in this study include: ENTREPRENEURSHIP EDUCATION OR SUSTAINABLE DEVELOPMENT GOALS 1O RPOVERTY OR NIGERIA .

The keyword research was performed on TITLE, AUTHORS, ABSTRACT or BIBLIOGRAPHIC REFERENCES. Inclusion and Exclusion Criteria This refers to the rules and conditions used to determine which publications from the database will be included in this analysis (Inclusion) and those that will be excluded in the analysis (Exclusion). This criterion are applied to filter and refine the database to ensure that it aligns with the research objectives to maintain consistency and relevance. Inclusion is a positive filter that a publication must meet to be considered for analysis. At the same time, exclusion criteria are negative filters that filter out irrelevant data (http://app dimensions.ai).

On the focus of the publication related to entrepreneurship education and SDG 1, the following inclusion criteria were considered:

- Publication year: 2020, 2021, 2022 & 2023.
- Publication type: Articles
- Sources title: sustainability, International Journal of Entrepreneurial Behaviour and Research, Small Businesses Economics, Academy of Management Proceedings, Journal of Business Research, International Journal of Entrepreneurship and Small Businesses,

International Entrepreneurship and Management Journal, Journal of Entrepreneurship in Emerging Economies.

- Journal list: Gold and All open-access.

The following were exclusion criteria considered:

- Publication year: before 2019
- Source title: non-related sources

3.3. Data Retrieval and Preparation

The bibliographic information for selected records, including publication titles, publication years, source titles, abstracts, and citation data, were downloaded and saved in Excel using Comma Separated Values (CSV) format.

Dimensions also allows access to the full bibliographic description of each document, which includes analytical views of the number of publications, publication citations, authors, and source titles.
The clearing and preprocessing of the data were conducted in Excel to ensure accuracy and consistency, and this wasdone by deduplication, standardised authors' names and addressing missing data. The structure of the database was checked to ensure that the arrangement of rows and columns were well arranged (http//app. Dimensions.ai). This is an essential procedure in preparing data for analysis, as well as ensuring its quality and suitability for analysis.

3.4. Validity and Reliability

To ensure the bibliographic data are sound and replicable in producing accurate research results, validity and reliability tests are crucial.

Validity

Content Validity is the extent to which the measures in a study adequately cover the content of the main under investigation (Trochim, 2006). It entails the careful selection of pertinent keywords and author names that harmonise with the study's focus on the Dimensions database, chosen for its extensive coverage and free online accessibility.

It ensures that the data retrieved for analysis are representative of the scholarly landscape related to entrepreneurship education and its impact on SDG1 in Nigeria.
Construct Validity: Covers the extent to which it accurately represents the theoretical construct it is intended to access (Trochim, 2006).

Construct validity ensures that VOSviewer structures in the scholarly data align with the study's research questions.The selection and analysis of keywords are central to the study's construct. It ensures that the chosen keywords accurately capture the key concepts within the research domain Trochim (2006).

Reliability

Reliability is a critical aspect of any research study, and in the context of bibliometric analysis, using VOSviewer ensures data consistency and accurate duplication record detection is pivotal. In justifying these measures, consistent data is essential to ensure the accuracy and worthiness of the analysis conducted in VOSviewer. Accurate publication counts are vital for citation analysis and other bibliometric indicators. Detecting and resolving duplicate records ensures the reliability of these

counts. By emphasising data consistency and duplicate record detection, this study aims to maintain the integrity and accuracy of the bibliometric data used in VOSviewer.

3.5. Software and Tools

Bibliometric analysis employs quantitative and visual approaches to examine patterns and relationships within academic literature, providing valuable insight into the interactions between publications within a broader scholarly context.
VOSviewer offers an intuitive interface with the ability to transform bibliographic data into visual representations that offer a clearer understanding of the subject matter. VOSviewer provides researchers with the capability to:

- Network Mapping: visualise co-authorship and citation network, offering insights into collaboration patterns and research relationships.
- Keywords Visualisation: discern the significance of specific keywords or terms in scholarly outputs.
- Cluster Analysis: identify thematic clusters and research domains within the literature.
- Geospatial Mapping: ensure the geographical distribution of authors, institutions and research collaboration. The use of VOSviewer will unravel research trends, highlight key contributors and shed light on the intricate dynamics that establish the relationship between entrepreneurship education and poverty alleviation (Von Eck, N. J. & Waltman, L., 2010).

4. RESULTS

a) CITATION ANALYSIS

i) Citation Analysis Using Authors As Unit of Analysis

Full counting method was utilised, where documents with large numbers of authors were ignored.

- The maximum number of authors per document selected was 25.
- The minimum number of documents of authors was 7.
- The minimum number of citations of an author was 2.
- This resulted in 11 authors out of the 356 authors that met the thresholds. For each of the 11 authors, the total strength of the citation links with other authors was calculated. The authors with the greatest total link
- strength were selected (figure. 1). The following results were obtained (Table 1):

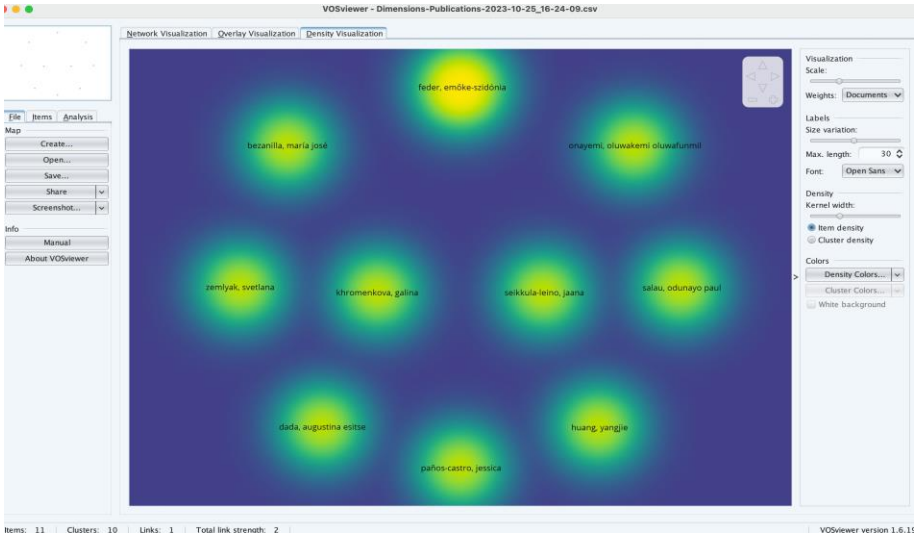


Figure. 1- Citation Analysis - Authors

i. Citation Analysis Using Countries as Unit of Analysis

Full counting method was used, where documents co-authored by a large number of countries were ignored.The maximum number of countries per document is 25.

The chosen threshold was a minimum number of the document of a country, which was 1.45 countries met the threshold (Figure. 2)

For each of the 45 countries chosen, the total strength of the citation links with other countries was calculated.The countries with the greatest total link strength were selected.

Of the 45 countries chosen, 20 countries were not linked (figure. 2)

Some of the countries that were linked included the United Kingdom, Switzerland, Romania, UAE, Nigeria, Germany, Spain, the United States, Finland, Austria, China, Poland, Sweden, Taiwan, Saudi Arabia, and Malaysia(figure. 3).

The top five countries with the highest citation counts included the following (Table 2):

Table: 2

S/N	COUNTRY	DOCUMENTS	CITATIONS	TOTAL LINK STRENGTH
1	Romania	12	252	6
2	China	22	180	3
3	Spain	7	61	3
4	U.K.	5	39	1
5	U.S.	5	30	1

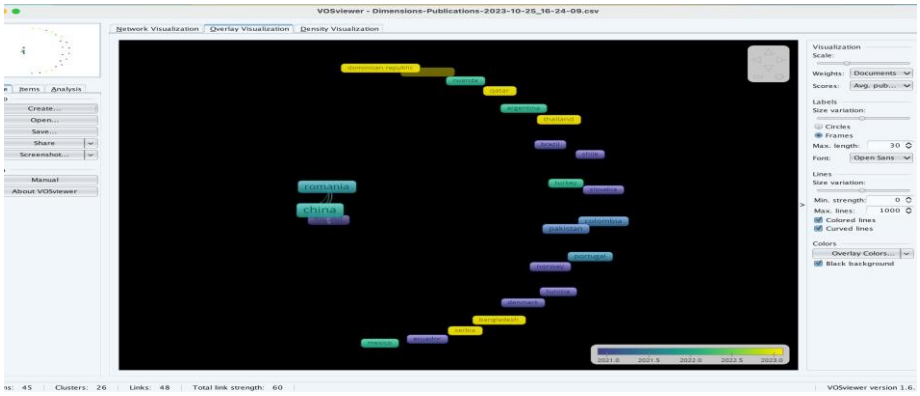


Figure. 2: Citation Analysis- linked & unlinked countries.

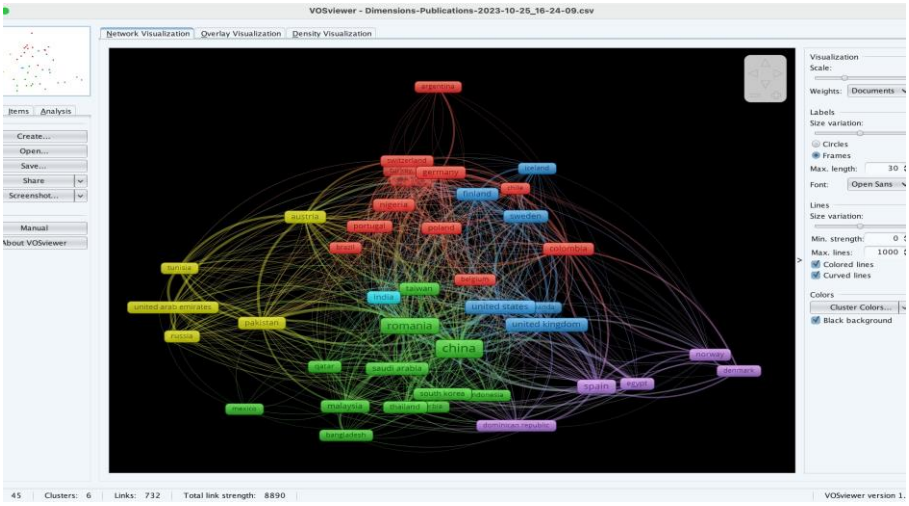


Figure 3: Citation Analysis - Countries

ii. Citation Analysis using Documents as a Unit of Analysis

Full counting method was used.

627 meet the threshold. For each of the 627 documents, the number of citation links was calculated.

The documents with the largest links were selected. Further filtering of the document was done to remove documents not relevant to the subject of study, which resulted in 103 documents (figure. 4).

Five (5) top documents, are as follows (Table 3):

Table: 3

S/N	Author	Links	Citation	Total linkstrength
1	Boldureau, (2020)	52	168	172
2	Rashid, Lubna(2019)	2	68	85
3	Filser (2019)	2	61	179
4	Grivokostopoulou(2019)	2	41	47
5	Tunio (2021)	2	52	73

Figure 4: Citation Analysis - Documents

a) BIBLIOGRAPHIC COUPLING ANALYSIS

i. Bibliographic coupling using documents as a unit of analysis

Using the full counting method, 627 documents met the household, where the total strength of the bibliographiccoupling link with other documents was calculated.

Documents with the greatest link were selected after filtration of documents that are not relevant to the subject of thestudy.

101 documents showed relevance to the subject topic (figure. 5), with the following results of the top ten documents(Table 4):

Table: 4

S/N	Document	Citation	Total linkstrength
1	Thananusak (2019)	27	219
2	Yasir (2022)	10	216
3	Lu (2021)	41	214
4	Dodescu (2021)	4	200
5	Tehseen (2021)	14	191
6	Nitu-Antonie (2022)	4	183
7	Filser (2019)	0	173
8	Contreras (2022)	2	173
9	Boldureanu (2020)	168	172
10	Hotos (2022)	2	168

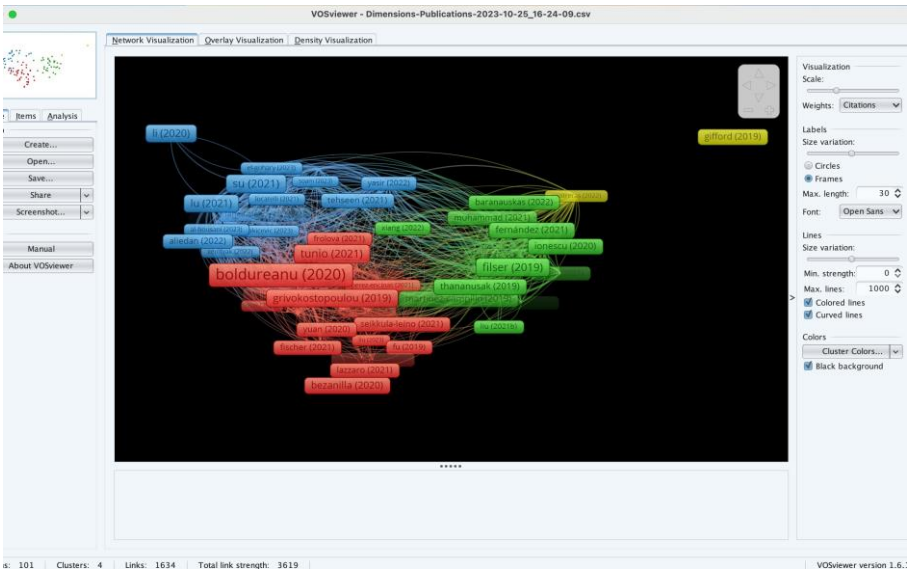


Figure 5: Bibliographic Coupling- Documents

Nigerian Authors captured in the analysis are presented in table 5 and figure 6:

Table: 5

S/N	Documents	Citation	Total link strength	Links
1	Igwe (2022)	2	110	60
2	Onyekwelu (2023)	0	83	38
3	Dada (2023)	0	43	36
4	Arejiogbe et.al (2023)	2	18	12

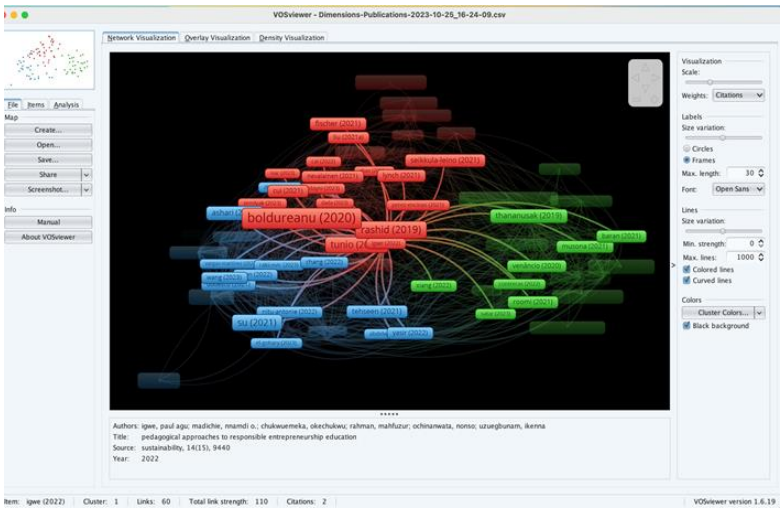


Figure. 6: Bibliographic Coupling - Documents

ii. Bibliographic analysis using authors as a unit of analysis

Using the full counting method, with a minimum number of documents of an author as one (1); of the 356 authors,12 met the thresholds. For each of the 12 authors, the total strength of

the bibliographic coupling links with other authors were calculated, and the authors with the greatest links were selected (figure. 7).

The result of authors with the highest links to the lowest links are as follows (Table 6):

Table: 6

S/N	Authors	Documents	Citations	Total LinkStrength
1	Huang, Zhaoxin	2	1	316
2	Jiang, Yujia	2	1	316
3	Huang, Yangjie	2	6	251
4	Feder, Emoke-szidonia	2	4	240
5	Nitu-Antonie, Renata dana	2	4	240
6	Dada, Augustina Esitse	2	2	224
7	Onayemi, Oluwakemi	2	2	224
8	Salau, Odunayo Paul	2	2	224
9	Khromenkova, Galina	2	4	106
10	Zemlyak, Svetiana	2	4	106
11	Seikkula-Leino, Jaana	2	17	33
12	Tian, Yu	2	0	14

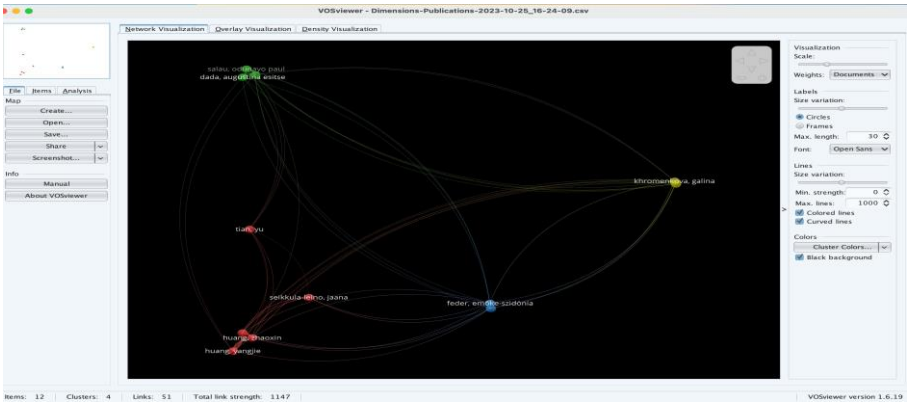


Figure 7 :Bibliographic Coupling - Authors

iii. Bibliographic coupling using countries as a unit of analysis

Using full counting method, with a maximum number of countries per document as 25, and minimum number of documents of a country is one (1). Forty-five (45) countries met the threshold, where for each of the 45 countries,the total strength of the bibliographic coupling links with other countries were computed. The countries with the greatest total link strength were computed (figure. 8), with the following results obtained (Table 7):

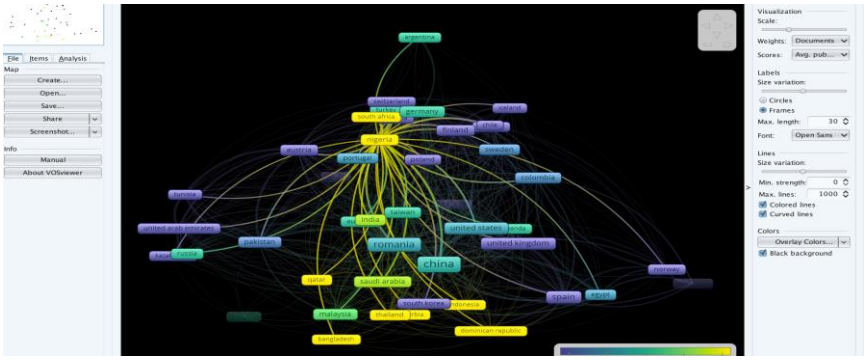


Figure. 8: Bibliographic Coupling - Countries

Table: 7

S/N	COUNTRY	DOCUMENTS	CITATIONS	TOTAL LINK STRENGTH
1	China	22	180	2026
2	Romania	12	252	1285
3	United States	5	30	921
4	United Kingdom	5	39	885
5	Pakistan	4	108	783
6.	Finland	4	80	779
7	Spain	7	61	772
8	Austria	3	112	732
9	Germany	4	11	679
10	Columbia	3	19	587
:	:	:	:	:
27	Nigeria	3	2	224

b) CO-OCCURRENCE ANALYSIS

i. Co-occurrence analysis based on text data

The fields from which terms are extracted are *Titles* and *Abstract* fields.

The counting method used was the binary counting method. The minimum number of occurrences of a term chosenwas 6, in which of the 2834 terms computed, 112 terms met the threshold.

For each of the 112 terms, a relevance score was calculated. Based on this score, the most relevant terms were selected. The default choice selected 60% of the most relevant terms, computing a result of 67 terms. This was further filtered to remove terms not related to the study, resulted in 15 terms (figure. 9 & 10), as shown below (Table 8):

Table: 8

S/N	Term	Occurrences	Relevance
1	United Nations	6	3.82
2	Sustainable development goal	17	1.34
3	Entrepreneurial Activity	11	1.23
4	Entrepreneurship education	14	1.40
5	Government	10	0.57
6	Economic Development	9	0.52
7	Sustainable development	34	0.64
8	Economic growth	11	0.56
9	Opportunity	19	0.55
10	Society	15	0.41
11	Policymaker	9	0.45
12	Enterprise	15	0.64
13	Knowledge	16	0.93
14	Poverty	6	1.07
15	Student	46	0.73

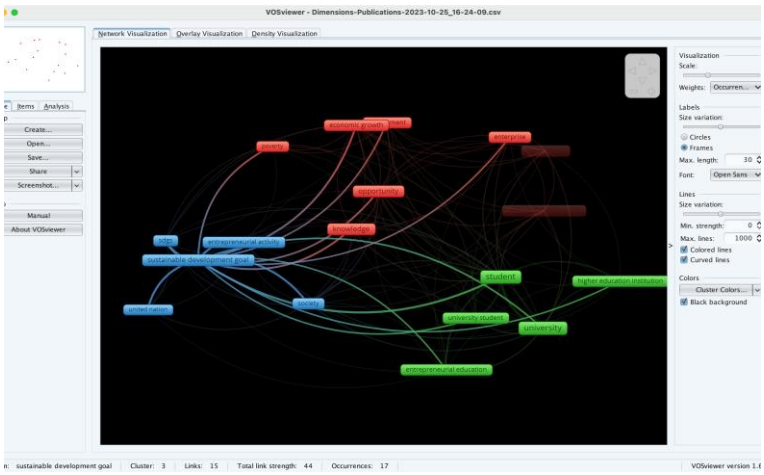


Figure 9: Co-occurence Analysis - Text Data (SDG)

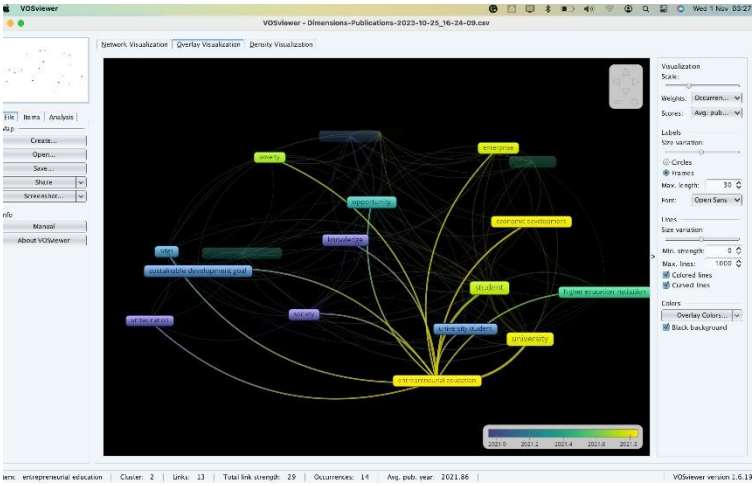


Figure 10: Co-occurence Analysis - Text data (E.E)

5. DISCUSSION

This section serves as a platform to examine and interpret the results obtained from the bibliometric study that revealed the intricate link between entrepreneurship education and sustainable development goals (SDG I) withinthe Nigerian context and other countries.

The methodology underpinned the bibliometrics study, using data sources obtained from Dimensions that provided structure and standardised bibliographic data based on keyword analysis. The keyword data obtained from Dimensions included the *title, abstract, source of data, authors, dates, times cited and cited references*. The data wasexported using CSV (Comma-Separated Values) formatting, and Excel to VOSviewer software for further analysis.

Features of VOSviewer include *network mapping, citation analysis, thematic clusters* and *visualisation of collaborative efforts*. These features are possible through scaling methods by VOSviewer to highlight the most influential or relevant items in the network, through pruning the network to remove low-level connections or nodes with fewer connections, also so as to focus on the most relevant and significant relationships within the data, related to the study (Van Eck & Waltman, 2010).

Clustering by VOSviewer groups related publications or keywords together, which can also reveal thematic structures within the data. Thresholds are set by VOSviewer to create limitations on various metrics, such as *citationcounts or co-authorship strength*, for more refined visualisations. (Van Eck & Waltman, 2010)

This study using VOSviewer transcends in creating *citation analyses, keyword co-occurrence maps* and *bibliographic coupling* in order to achieve clear insights on the relationship between entrepreneurship education and sustainable development goal 1 (SDG1) and how the findings from these results can shape the trajectory of entrepreneurship education and sustainable development in Nigeria.

i. **Citation Analysis using Authors as unit of Analysis** - the purpose of this analysis was to evaluate the impact of researchers or research groups. The analysis involved examining how often authors were cited across all their documents. It aimed to identify influential authors or research terms

(Rousseau 2021). A full counting method was utilised, where documents with over 25 authors were excluded, to allow the focus on a well-defined research area, as Jacso (2005) noted that, citation analysis can be more effective when it concentrates on a specific topic or field.

Restricting the dataset to a smaller number of recent documents can facilitate the exploration of emerging research trends, as newer papers may have a higher likelihood of influencing the current state of the field (Duricux & Gevenion, 2010). The maximum number of authors per document selected was 25, while the minimum number of documents of an author was 7; the minimum number of citations of an author was 2.

This resulted in 11 authors out of the 356 authors that met the thresholds. For each of the 11 authors, the total strength of the citation links with other authors was calculated. The authors with the greatest total link strength were selected, they included (Table 1):

- Feder, Emoke-Szidenia with two (2) documents, four (4) citations, and total strength link of two (2), means that Feder, Emoke has been associated with or has authored two (2) scholarly documents; and has been cited four (4) times in other scholarly publications in relation to the study; as a measure of the impact of his work, which other researchers have found valuable. The total link strength of two (2) is a measure of the strength of connections or collaborations between authors.
- Nitu-antonie (2022) with 2 documents, 4 citations and a total link strength 2, would have a similar representation as with Feder, Emoke-Szidenia (Figure. 1)

Three (3) authors from Nigeria ranked fourth, seventh and ninth in the hierarchy of the citation analysis ranking, they were: Dada, Augustina Esitse, with 2 documents, 2 citations and no total link strength, Onayemi, Oluwakemi with 2 citations, and no total link strength, and Salau, Odunaya Paul with 2 citations and no link strength-showed no evidence of collaborative ties with other authors (Table 1).

ii. **Citation Analysis using countries as unit of Analysis -** this type of citation analysis can be referred to as 'country-level bibliometrics'. It involved evaluating the scholarly output and impact of research at the national level. It allowed for the assessment of a country's overall research output and productivity, as researchers often use this information to compare and rank countries based on their scientific contributions (Abramo et. al, 2013).

This approach helped identify international collaboration networks between countries, where it can reveal countries that frequently co-author research papers and collaborate on scientific projects. These collaborations contribute to the global exchange of knowledge (Glanzel & Schubert, 2003). The countries with the greatest total link strength were selected. Out of the 45 countries, 20 countries were not linked (figure. 2). Countries that were linked included:-

United Kingdom, Romania, United Arab Emirates, Nigeria, Germany, Spain, United States, Finland, Austria, Switzerland, China, Poland, Sweden, Taiwan, Austria, Saudi Arabia, and Malaysia (figure. 3).

- Romania had two (2) documents, with the highest citation of 252, and the greatest total link of 6 - that indicated Romania has been associated with two (2) scholarly documents that contributed to the subject; with the document been cited 252 times in other scholarly publications, a high citation count indicates the impact and influence of entrepreneurship education and sustainable development. A total link strength of six (6), suggested that Romania has some level of scholarly collaborations with other countries (Table 2).

- This was followed by China with citations of 180 and a total link strength of 3.
- Nigeria had 3 clusters that were formed based on the strength of citation links among items. The significance of these clusters in citation analysis, as represented and visualised by VOSviewer, lies in the ability to reveal the thematic structure of a research field, the collaboration networks among researchers, or the co-citation patterns of documents (Van Eck & Waltman, 2010).

iii. **Citations Analysis using Documents as a unit of Analysis -** VOSviewer created 627 documents for visualisation based on citation analysis using 'document' as a unit of analysis. For each of the 627 documents, the number of citation links were calculated. These links formed the basis of *citation analysis* and are made from one research document to another; they serve as a means of acknowledging prior research and tracing the flow of knowledge within the scholarly landscape (White & McCain, 1998).

The resulted documents after filtering out all irrelevant terms, were 103 documents. The highest document from Boldureau, et al (2020), titled "Entrepreneurship Education through successful entrepreneurial models in higher education institutions," having the highest citations of 168 and citation links of 6 (Figure 4). This suggested that it is highly interconnected with other related documents in the field. 52 links, implies that thisparticular document is influential and has been frequently cited by other scholars.The document has a total citation count of 168 citations, which reflects the impact the document has within the field of entrepreneurship education. A total link strength of 172 represents the cumulative strength of all the connections or links associated with the document by Boldureau (2020) (Table 3).

iv. **Bibliographic Coupling Analysis using documents as unit of analysis -** bibliographic coupling focused on the similarity of the reference lists in different documents. It identified documents that shared common references, suggesting that they are related in content or subject matter (Kessler, 1963). This can be useful for identifying research clusters and trends in the broader field of entrepreneurship education and sustainable development goal 1 (SDG l).

Of the 101 documents that showed relevance to the subject, the document by Thananusak (2019), with 27 citations suggested that 27 other scholarly works have referred to or cited the document by Thanaunusak in their various research, making it a relevant document in the field. A total link strength of 219, represents the cumulative strength of all the connections associated with this document, hence having a substantial influence within its academic network. This was followed by the document by Yasir (2022), with a citation of 10, and a total link strength of 2016, and followed thirdly by Lu (2021), with 41 citations and a total link strength of 214 (figure.4).

The Nigerian authors with the highest bibliographic coupling were Igwe, Madichie, Chukwuemeka, Rahman, Ochinanwata & Uzuegbunam (2022), with 2 citations and 110 total links, in their journal article titled: "Pedagogical

Approaches to responsible Enterpreneurship Education". This was followed by Onyekwelu, Ibe,Monyel, Attamah & Ukpere (2023), with zero (0) citations and a total link strength of 83, in their article titled: "The impact ofEntrepreneurship Institutions on access to micro-financing for sustainable entreprise in an Emerging Economy." Thirdly, Dada, Austin, Adegbuyi, Omotayo, Ogbari, Mercy, Palau, Odunayo, Atolagbe, Tolulupe, Onayemi & Oladotun (2023),

with zero (0) citations and a total link strength of 43 in their article titled "Envisaging the Impact of Entrepreneurial Cultural on Venture Creation among Undergraduate Students of Selected Universities in Nigeria."This shows the burgeoning of Nigerian scholars in this field (Table 5)

v. **Bibliographic Coupling Analysis using Authors as unit of analysis -** bibliographic coupling using authors as the unit of analysis is a method that focuses on identifying commonalities in the references authors cite in their works. It is useful for uncovering collaborative networks and identifying authors with similar research interests. It helps in mapping research communities, understanding research trends, and discovering potential research partners(Bayack & Klavans, 2011).

For each of the 356 authors that met the threshold, the total strength of the bibliographic coupling links with other authors was calculated (Figure. 7). The authors with the greatest link included: Huang & Jiang, both with 2 documents, 1 citation and a total link strength of 316 each, this suggest that documents authored by Huang & Jiang are not strongly cited, but have significant relevance within the field (Table 6).

Three authors from Nigeria were captured in this bibliographic coupling: Dada, Onayemi and Salau;with two (2) documents each, two citations and total link strength of 224 (Table 6).

vi. **Bibliographic Coupling using countries as unit of analysis -** bibliographic coupling at the country level involved identifying countries that frequently cited the same set of references in their research publications (Vinkler 1996). It aims at highlighting commonalities in the references cited by researchers from various nations. This can identify countries that collaborate on topics selected on entrepreneurship education and sustainable development goal I (SDGI). It can provide the mapping of global research communities or clusters that show common bibliographic connections, giving a sense of the international intellectual structure of the research domain.

Using full counting method, with a maximum number of countries per document as 25 and a minimum number of document of a country as one (1). Forty-five (45) countries that met the threshold had 732 links and a total links strength of 8890. The top five countries with the greatest total link strength were:- Chain, Romania, United States, United Kingdom and Pakistan, accordingly. Nigeria came up as the twenty-seventh position out of the 45 countries, with 3 documents, 2 citations and a total strength of 224 (Table 7).

China with the highest documents of 22, and 180 citations, suggested that other scholarly documents from within thedataset have referenced or cited the documents from China. A total link strength of 2026 indicates that the documents from China are also strongly associated with other documents within the field. This also indicates that China has contributed significantly to the field of entrepreneurship education and sustainable development (fig. 8).

vii. **Co-concurrence Analysis -** help researchers identify the key topic and themes within a research field, discover connections between concepts, and highlight emerging trends (Coboet et al., 2011). Using co-occurrence maps inthis study can help gain a deeper understanding of the research landscape related to entrepreneurship education and SDG 1.

The binary counting method, which is one of the two common counting methods, is also known as *presence-absencecounting* (Salton & McGill, 1983). It focused on the presence-absence of a co-occurrence relationship that is used to emphasise the existence of relationships between terms without considering their frequency or intensity.This made it a suitable choice to relate a simplified network that highlight only the existence of connections (Van Eck & Waltman,

2009). Interpreting the co-occurrence findings based on text data involves analysing the frequency of terms and their relevance in relation to the research context (Table 8).

- *United Nations* - with occurrence: 6, relevance: 3.82, had a relatively high relevance source. This suggests that *United Nations* is a significant and relevant concept in this study. This could indicate that possibly it related to entrepreneurship and sustainable development goals, which are central themes in the analysed documents.
- *Sustainable Development Goal* - with occurrence: 17, relevance; 1.34, suggests a strong relation between the concept of sustainable development goals and entrepreneurship education (figure. 7).
- *Entrepreneurial Activity*- with occurrence: 11 relevance: 1.23, represents a moderately frequent concept with above-average relevance. This will be interpreted as *entrepreneurial activity* as a notable aspect of the content under analysis and is relevant to the study.
- *Entrepreneurial Education* - with occurrence: 14, relevance: 1.40, is moderately frequent, and it is relevant above average. This suggested that *entrepreneurial education* is a significant theme in the document and is considered relevant in the context of this study (figure.8).

6. CONCLUSION AND RECOMMENDATIONS

This bibliometric study explored the nexus between entrepreneurship education and sustainable development goal I (SDG I) in Nigeria, as it aligned with the timely theme of the research "A tool for National Development and Innovation in the 21st Century."

The study used a transformative and modern database - Dimensions, and VOSviewer as a software tool. Several critical findings from this study included the thematic clusters and research themes identified through VOSviewer representing countries that contributed to the multifaceted exploration of entrepreneurship education to sustainable development goal I (SDGI).

Citation analysis and bibliographic coupling provided valuable insights into research collaborations and trends. This interconnectedness offers opportunities for shared knowledge while contributing to tackling poverty in Nigeria.

Other findings included key concepts and themes using co-occurrence analysis that suggested key concepts- 'United Nations', 'Sustainable Development Goal', 'Entrepreneurial activity', and 'Entrepreneurial Education' were pivotal in discussions surrounding entrepreneurship education's impact on SDG 1.

Based on this bibliometric study, it is obvious that the bulk of most of the top literature is traced to developed countries, such as the United States and the United Kingdom. Also, the prolific authors are not found in countries where poverty is endemic.

There is a need to foster more international collaboration in advancing research in entrepreneurship education as it impacts sustainable development goal 1 (SDG 1). With research gaps in literature that focused on authors and documents that originate from areas where poverty is at its highest prevalence, there is a need for more inclusion of documents produced by authors from countries with high poverty indicators, such as Nigeria.

Finally, with the robust structure of entrepreneurship education, there is the need to recommend to governments of developing countries to reinforce their strategies and mechanisms in achieving a

robust entrepreneurship education scheme that can provide effective interventions for sustainable development goal 1 (SDG1) in Nigeria.

REFERENCES

[1] Abidemi AA, Adeniyi AO, Oluseye OO, Stephen IA, Idowu FO. Role of learning orientation on SMEs' performance: Empiricalevidence from SMEs in Nigeria. Journal of Entrepreneurship Education. 2018;21(4):1-6.

[2] Acs ZJ. Small business economics: A global perspective. Challenge. 1992 Nov 1;35(6):38-44.

[3] Alberti F, Sciascia S, Poli A. Entrepreneurship education: notes on an ongoing debate. InProceedings of the 14th Annual IntEntConference, University of Napoli Federico II, Italy 2004 Jul (Vol. 4, No. 7).

[4] Austin, J., Steveson, H., & Wei-Skillern, J. (2006). Social and commercial entrepreneurship: Same, different or both?Entrepreneurship Theory and Practice, 30(1), 1-22.

[5] Beynaghi A, Trencher G, Moztarzadeh F, Mozafari M, Maknoon R, Leal Filho W. Future sustainability scenarios for universities:Moving beyond the United Nations Decade of Education for Sustainable Development. Journal of Cleaner Production. 2016 Jan 20; 112:3464-78.

[6] Bode C, Herzog C, Hook D, McGrath R. A guide to the Dimensions data approach. Dimensions Report. Cambridge, MA: DigitalScience. 2018 Jan.

[7] Brock WA, Evans DS. Small business economics. Small business economics. 1989 Mar;1:7-20.

[8] Cobo MJ, Martínez MÁ, Gutiérrez-Salcedo M, Fujita H, Herrera-Viedma E. 25 years at knowledge-based systems: a bibliometricanalysis. Knowledge-based systems. 2015 May 1;80:3-13.

[9] Donthu N, Kumar S, Mukherjee D, Pandey N, Lim WM. How to conduct a bibliometric analysis: An overview and guidelines.Journal of business research. 2021 Sep 1;133:285-96.

[10] Duffy S, Tarabishy A. The State of Entrepreneurship Education In the United States: A Nationwide Survey and Analysis* George

[11] T. Solomon The George Washington University Department of Management Science.

[12] Egeln, J. Die Volkwirtschaftliche Bedeu tung Junger Unternehmen.In Buttler, G.H, et.al (eds) Existenzgrundung. Rahmenbedgungen und strategien. 2000. Heidelberg: Physica verlag.

[13] Fayolle A. Personal views on the future of entrepreneurship education. Entrepreneurship & Regional Development. 2013 Sep1;25(7-8):692-701.

[14] Galvao A, Mascarenhas C, Marques C, Ferreira J, Ratten V. Triple helix and its evolution: a systematic literature review. Journalof Science and Technology Policy Management. 2019 Aug 30;10(3):812-33.

[15] Gibb A. Exploring the synergistic potential in entrepreneurial university development: towards the building of a strategicframework. Annals of Innovation & Entrepreneurship. 2012 Jan 1;3(1):16742.

[16] Global Entrepreneurship Report [Internet]. Gem Consortium; [cited 2023 Oct 13]. Available from: https:// www.gemconsortium.org/report/gem-20202021-global-report

[17] Grant, J. (2015). An introduction to bibliometrics. International School on Research Impact Assessment. http://app.dimensions.ai

[18] Hills GE. Variations in university entrepreneurship education: An empirical study of an evolving field. Journal of businessventuring. 1988 Mar 1;3(2):109-22.

[19] Hook DW, Porter SJ, Herzog C. Dimensions: building context for search and evaluation. Frontiers in Research Metrics andAnalytics. 2018 Aug 23; 3:23.

[20] Hytti U, Kuopusjärvi P. 15 Evaluating entrepreneurship education: play of power between evaluators, programme promoters andpolicy makers. Handbook of Research in Entrepreneurship Education, Volume 2. 2007:244.

[21] Kasgak C, Bahago SB, Gotip NW. Contemporary Entrepreneurship Education for Economic Growth and SustainanbleDevelopment. Journal of African Studies and Sustainable Development. 2022 Dec 30.

[22] Katz JA. The chronology and intellectual trajectory of American entrepreneurship education: 1876–1999. Journal of businessventuring. 2003 Mar 1;18(2):283-300.

[23] Laurie R, Nonoyama-Tarumi Y, Mckeown R, Hopkins C. Contributions of education for sustainable development (ESD) to quality education: A synthesis of research. Journal of Education for Sustainable development. 2016 Sep;10(2):226-42.

[24] López-Fernández MC, Serrano-Bedia AM, Pérez-Pérez M. Entrepreneurship and family firm research: A bibliometric analysis ofan emerging field. Journal of Small Business Management. 2016 Apr 1;54(2):622-39.

[25] Lubna Rashid. (n.d.). Entrepreneurship education and sustainable Development goals: A literature review and closer look atfragile states and Tech enabled.

[26] McClelland DC. The achieving society. New York: Van Nostrand Company, Inc.;1961.

[27] Mongeon, P, Paul-Hus, A. The Journal Coverage of Web of Science and Scopus: a Comparative Analysis. Scientometrics. 2015Oct;106. 10.1007/s11192-015-1765-5.

[28] Mowery D C, Nelson R, Sampat B, Ziedonis, A A. The growth of patenting and licensing by U.S. universities: an assessment of the effects of the Bayh-Dole act of 1980 [Internet]. Research Policy. 2001;30:1, p. 99-119, https://EconPapers.repec.org/ RePEc:eee:respol:v:30:y:2001:i:1:p:99-119.

[29] Mukhtar S, Wardana LW, Wibowo A, Narmaditya BS. Does entrepreneurship education and culture promote students' entrepreneurial intention? The mediating role of entrepreneurial mindset. Cogent Education. 2021 Jan 1;8(1):1918849.

[30] Mwasalwiba ES. Entrepreneurship education: a review of its objectives, teaching methods, and impact indicators. Education+training. 2010 Feb 16;52(1):20-47.

[31] Nabi G, Liñán F, Fayolle A, Krueger N, Walmsley A. The impact of entrepreneurship education in higher education: A systematicreview and research agenda. Academy of management learning & education. 2017 Jun;16(2):277-99.

[32] Nabi G, Liñán F. Graduate entrepreneurship in the developing world: intentions, education and development. Education+training. 2011 Jun 28;53(5):325-34.

[33] Naveen, Satish, K., Mokherjee, D., Pandey, N., & Lim, W. (2021). How to conduct a bibliometric analysis: An overview andguidelines. Journal of Business Research, 133, 285-296.

[34] NIU Qutreach, The role of higher education in economic development. 2005. http //www.hearr.org/pdf/HEARRR white paper.pdf.

[35] Ogedengbe FA, Okhakhu CO, Adekunle SA. Entrepreneurial education for sustainable development. Nigerian Journal ofManagement Sciences. 2015;4(1):78-87.

[36] Orduña-Malea E, Ayllón JM, Martín-Martín A, Delgado López-Cózar E. Methods for estimating the size of Google Scholar.Scientometrics. 2015 Sep;104:931-49.

[37] Piwower, H., Priem, J., Lariviere, V., Alperin, J.P., Mittices, L., Narlander, B., & Haustern, S. (2018). The state of OA: A largescale analysis of the prevalence and impact of open Access of articles. Peer J, 6, e4375.

[38] Sexton DL, Bowman NB. Entrepreneurship education: Suggestions for increasing effectiveness. Journal of Small BusinessManagement (pre-1986). 1984 Apr 1;22(000002):18.

[39] Shapero A. The displaced, uncomfortable entrepreneur. University of Illinois at Urbana-Champaign's Academy for Entrepreneurial Leadership Historical Research Reference in Entrepreneurship. 1975.

[40] Sofoluwe, Shokonbi, Raimi & Ajewole. (n.d.). Entrepreneurship education as a strategy for boosting human capital developmentand employability in Nigeria: issues, prospectus.

[41] Soubbotina TP. Beyond economic growth: An introduction to sustainable development. World Bank Publications;2004.

[42] Studer, S., & Texeire, R. Entrepreneurship and poverty Reduction: An analysis of linkage and issues. World Development. 2020.136,105138.

[43] Trochim WM, Cabrera DA, Milstein B, Gallagher RS, Leischow SJ. Practical challenges of systems thinking and modeling inpublic health. American journal of public health. 2006 Mar;96(3):538-46.

[44] van Eck NJ, Waltman L. Vosviewer: A Computer Program for Bibliometric Mapping. InVosviewer: A Computer Program forBibliometric Mapping: van Eck, Nees Jan| uWaltman, Ludo 2010. [Sl]: SSRN.

[45] Viera, M.R., Lopez, F.M., Pernas, A.M., & Martin, J.L.(2011). Challenging in measuring web impact: The need for recordstandardization Journal of the American Society for Information Science and Technology, 62(4),719-725.

[46] Von Graevenitz G, Harhoff D, Weber R. The effects of entrepreneurship education. Journal of Economic behavior &organization. 2010 Oct 1;76(1):90-112.

[47] VOSviewer version 1.6.19 Copyright 2009-2023 Need Jan van Eek & Ludo Waltman. Universiteit Leiden

[48] Waltman L, Van Eck NJ, Noyons EC. A unified approach to mapping and clustering of bibliometric networks. Journal ofinformetrics. 2010 Oct 1;4(4):629-35.

[49] Watson DM. Pedagogy before technology: Re-thinking the relationship between ICT and teaching. Education and Informationtechnologies. 2001 Dec;6:251-66.

[50] Wiklund J, Davidsson P, Audretsch DB, Karlsson C. The future of entrepreneurship research. Entrepreneurship Theory andPractice. 2011 Jan;35(1):1-9.

[51] Williams, C. (2018). Dimensions from Digital Science. *Insights: The UKSG Journal*, *31*(0), 33.DOI: https://doi.org/10.1629/uksg.420

[52] Sustainable development: World Bank glossary. [Electronic resource]. - Retrieved from: http://www.worldbank.org/depweb/english/beyond/global/glossary.html.

[53] Yatu L, Bell R, Loon M. Entrepreneurship education research in Nigeria: current foci and future research agendas. AfricanJournal of Economic and Management Studies. 2018 Jun 11;9(2):165-77.

[54] Zhao, J., & McShea, W. (2018). Behind eMammal's Success: A Data Curator With A Data Standard. Journal of eScienceLibrarianship, 7, e1154. https://doi.org/10.7191/jeslib.2018.1154

[55] Zupic I, Čater T. Bibliometric methods in management and organization. Organizational research methods. 2015 Jul;18(3):429-72.

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp. 544–560, November 13-16, 2023

The Physical Simulation of Oscillatory Differential Equations of Mass in Motion

Adewale A. James[1], Sabo John[2]
{adewale.james@aun.edu.ng[1], sabojohn21@gmail.com[2]}

Department of Mathematics and Statistics, School of Arts and Sciences, American University of Nigeria, Yola, Nigeria[1], Department of Mathematics, Faculty of Science, Adamawa State University, Mubi, Nigeria[2].

Abstract
This study delved into the practical application and simulation of oscillatory differential equations in the context of objects in motion. The methodology employed power series polynomials, ensuring that the fundamental properties of these functions were met. The new approach was applied to a range of oscillatory differential equations, including those related to harmonic motion, spring motion, dynamic mass motion, Betiss and Stiefel equations, and nonlinear differential equations. It has been shown to be computationally reliable, delivering improved accuracy and quicker convergence compared to the existing methods under consideration.

Keywords: Betiss and Stiefel, harmonic motion, physical application, mass in dynamic motion, spring of motion.

1 Introduction

Many physical problems remain unexplored and not yet fully addressed by researchers. While some problems in the fields of science, social science, and technology have been approached, many others remain uncharted territory. Oscillatory phenomena often play a key role in these areas, and one of the primary tools for modeling such oscillations is through the use of differential equations [1-3].
Researchers have employed oscillatory differential equations to tackle complex systems involving multiple variables [3]. This field of study is of great significance to numerical analysts as it enables the simulation of various phenomena in the realms of science, engineering, and social sciences [4-6]. For instance, it provides solutions for problems related to transportation, mass-spring systems, simple harmonic motion, and dynamic systems of objects, among others [6, 7]. These fields of study are simulated using oscillatory differential equations of the form.

$$\frac{d^2u}{dv^2} = f\left(v, u, \frac{du}{dv}\right),\ u(0) = \delta_0,\ \frac{du}{dv}(0) = \delta_1 \tag{1}$$

Hence, (1) continues to hold great importance for numerical analysts in the fields of science and technology, as it is used to numerically simulate various laws, theorems, and physical relationships [7-9].
In their work, the authors [10-15] attempted to simulate second-order oscillatory differential equation (1). However, the accuracy of their methods in terms of error was found to be notably low and not particularly encouraging.
The force governing the motion is consistently directed towards the equilibrium position and is directly proportional to the distance from it. In other words,

$$F = -kv \tag{2}$$

In this context, "F" represents the force, "v" denotes the displacement, and "k" is a constant—a relationship commonly referred to as Hooke's law. In simple terms, a spring-mass system involves a block attached to the free end of a spring. Typically, this system is employed to determine the period of an object undergoing simple harmonic motion [7, 8]. Moreover, it finds applications in a wide range of scenarios.
For example, a spring-mass system can be utilized to model (1). One of the most challenging aspects in the numerical solution of differential equations pertains to handling highly oscillatory systems. The

primary goal of this research is to develop a method for simulating second-order oscillatory differential equations associated with objects in motion.

2 Methodology

The power series polynomial was used to develop the new method, for simulation of (1).
Let the approximate solution of

$$\gamma(\tau) = \sum_{j=0}^{\psi+\varsigma-1} \varpi_j \tau^j \tag{3}$$

be the expected solution of (3) where $\tau \in [0, 1]$ and the number of interpolating and collocating points are ψ and ς. Differentiating (3) twice, yield

$$\gamma''(\tau) = \sum_{j=0}^{\psi+\varsigma-1} \tau(\tau-1)\varpi_j \tau^{j-2} \tag{4}$$

Substituting (3) into (1) yield

$$\sum_{j=0}^{\psi+\varsigma-1} \tau(\tau-1)\varpi_j \tau^{j-2} = f(\tau, \gamma, \gamma') \tag{5}$$

equation (3) is interpolated at $\psi = \frac{1}{6}, \frac{1}{4}$ while equation (5) is collocated at

$\varsigma = 0, \frac{1}{6}, \frac{1}{4}, \frac{1}{3}, \frac{1}{2}, \frac{2}{3}, \frac{3}{4}, \frac{5}{6}, 1$ which lead to

$$AX = U \tag{6}$$

where

$$A = \begin{bmatrix}
1 & \frac{1}{6} & \frac{1}{36} & \frac{1}{216} & \frac{1}{1296} & \frac{1}{7776} & \frac{1}{46656} & \frac{1}{279936} & \frac{1}{1679616} & \frac{1}{10077696} & \frac{1}{60466176} \\
1 & \frac{1}{4} & \frac{1}{16} & \frac{1}{64} & \frac{1}{256} & \frac{1}{1024} & \frac{1}{4096} & \frac{1}{16384} & \frac{1}{65536} & \frac{1}{262144} & \frac{1}{1048576} \\
0 & 0 & \frac{2}{h^2} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & \frac{2}{h^2} & \frac{1}{h^2} & \frac{1}{3h^2} & \frac{5}{54h^2} & \frac{5}{216h^2} & \frac{7}{1296h^2} & \frac{7}{5832h^2} & \frac{1}{3888h^2} & \frac{5}{93312h^2} \\
0 & 0 & \frac{2}{h^2} & \frac{3}{2h^2} & \frac{3}{4h^2} & \frac{5}{16h^2} & \frac{15}{128h^2} & \frac{21}{512h^2} & \frac{7}{512h^2} & \frac{9}{2048h^2} & \frac{45}{32768h^2} \\
0 & 0 & \frac{2}{h^2} & \frac{3}{h^2} & \frac{4}{3h^2} & \frac{20}{27h^2} & \frac{10}{27h^2} & \frac{14}{81h^2} & \frac{56}{729h^2} & \frac{8}{243h^2} & \frac{10}{729h^2} \\
0 & 0 & \frac{2}{h^2} & \frac{3}{h^2} & \frac{3}{h^2} & \frac{5}{2h^2} & \frac{15}{8h^2} & \frac{21}{16h^2} & \frac{7}{8h^2} & \frac{9}{16h^2} & \frac{45}{128h^2} \\
0 & 0 & \frac{2}{h^2} & \frac{4}{h^2} & \frac{16}{3h^2} & \frac{160}{27h^2} & \frac{160}{27h^2} & \frac{448}{81h^2} & \frac{3584}{729h^2} & \frac{1024}{243h^2} & \frac{2560}{729h^2} \\
0 & 0 & \frac{2}{h^2} & \frac{9}{2h^2} & \frac{27}{4h^2} & \frac{135}{16h^2} & \frac{1215}{128h^2} & \frac{5103}{512h^2} & \frac{5103}{512h^2} & \frac{19683}{2048h^2} & \frac{295245}{32768h^2} \\
0 & 0 & \frac{2}{h^2} & \frac{5}{h^2} & \frac{25}{3h^2} & \frac{625}{54h^2} & \frac{3125}{216h^2} & \frac{21875}{1296h^2} & \frac{109375}{5832h^2} & \frac{78125}{3888h^2} & \frac{1953125}{93312h^2} \\
0 & 0 & \frac{2}{h^2} & \frac{6}{h^2} & \frac{12}{h^2} & \frac{20}{h^2} & \frac{30}{h^2} & \frac{42}{h^2} & \frac{56}{h^2} & \frac{72}{h^2} & \frac{90}{h^2}
\end{bmatrix}$$

$$X = \begin{bmatrix} a_0 & a_1 & a_2 & a_2 & a_3 & a_4 & a_5 & a_6 & a_7 & a_8 & a_9 \end{bmatrix}^T$$

$$U = \begin{bmatrix} y_{n+\frac{1}{6}} & y_{n+\frac{1}{4}} & f_n & f_{n+\frac{1}{6}} & f_{n+\frac{1}{4}} & f_{n+\frac{1}{3}} & f_{n+\frac{1}{2}} & f_{n+\frac{2}{3}} & f_{n+\frac{3}{4}} & f_{n+\frac{5}{6}} & f_{n+1} \end{bmatrix}^T$$

The unknown values of $a'_j s, j = 0(1)9$ are obtained by applying Gaussian elimination method and substituted into (3) to produce a continuous scheme with its derivatives of the form:

$$\gamma(\tau) = \sum_{j=\eta} \alpha_j^i(\tau) y_{n+j} + \sum_{j=0}^{1} \beta_j(\tau) f_{n+j} + \sum_{\varsigma \in \frac{1}{6}, \frac{1}{4}, \frac{1}{3}, \frac{1}{2}, \frac{2}{3}, \frac{3}{4}, \frac{5}{6}} \beta_\varsigma^i(\tau) f_{n+j}, \eta = \frac{1}{6}, \frac{1}{4}, \varsigma = \frac{1}{6}, \frac{1}{4}, \frac{1}{3}, \frac{1}{2}, \frac{2}{3}, \frac{3}{4}, \frac{5}{6} \quad (7)$$

Where the values of α_j, $j = \eta$ and $\beta_\varsigma, \varsigma \in \frac{1}{6}, \frac{1}{4}, \frac{1}{3}, \frac{1}{2}, \frac{2}{3}, \frac{3}{4}, \frac{5}{6}$ in equation (7) are

$$\alpha_{\frac{1}{6}} = 3 - 12\tau$$

$$\alpha_{\frac{1}{4}} = -2 + 12\tau$$

$$\beta_0 = \frac{109198219}{75246796800} - \frac{1562744609}{37623398400}\tau - \frac{1}{2}\tau^2 + \frac{601}{180}\tau^3 + \frac{1237}{90}\tau^4 - \frac{21959}{600}\tau^5 + \frac{28861}{450}\tau^6 - \frac{367}{5}\tau^7 + \frac{3693}{70}\tau^8 + \frac{108}{5}\tau^9 + \frac{95}{25}\tau^{10}$$

$$\beta_{\frac{1}{6}} = \frac{5336531}{154828800} - \frac{31769593}{7741400}\tau + \frac{162}{7}\tau^3 - \frac{11367}{70}\tau^4 + \frac{14013}{25}\tau^5 - \frac{28647}{25}\tau^6 + \frac{10152}{7}\tau^7 - \frac{5589}{5}\tau^8 + \frac{16848}{35}\tau^9 - \frac{15552}{175}\tau^{10}$$

$$\beta_{\frac{1}{4}} = -\frac{733019}{20995200} + \frac{41105527}{73483200}\tau - \frac{1024}{21}\tau^3 + \frac{123136}{315}\tau^4 - \frac{36864}{25}\tau^5 + \frac{721408}{225}\tau^6 - \frac{29696}{25}\tau^7 + \frac{16896}{5}\tau^8 - \frac{52224}{35}\tau^9 + \frac{49152}{175}\tau^{10}$$

$$\beta_{\frac{1}{3}} = \frac{25067281}{928972800} - \frac{40128343}{92897280}\tau + \frac{81}{2}\tau^3 - \frac{13797}{40}\tau^4 + \frac{55323}{40}\tau^5 - \frac{158139}{50}\tau^6 + \frac{30483}{7}\tau^7 - \frac{250533}{70}\tau^8 + 1620\tau^9 - \frac{7776}{25}\tau^{10}$$

$$\beta_{\frac{1}{2}} = -\frac{3043807}{250822656} + \frac{124090512}{627056640}\tau - 20\tau^3 + \frac{541}{3}\tau^4 - \frac{3866}{5}\tau^5 + \frac{28454}{15}\tau^6 - \frac{19512}{7}\tau^7 + \frac{16974}{7}\tau^8 - 1152\tau^9 + \frac{1152}{5}\tau^{10}$$

$$\beta_{\frac{2}{3}} = \frac{1213349}{103219200} - \frac{9986671}{51609600}\tau + \frac{81}{4}\tau^3 - \frac{1353}{20}\tau^4 + \frac{166617}{200}\tau^5 - \frac{106569}{50}\tau^6 + \frac{22977}{7}\tau^7 - \frac{209709}{70}\tau^8 + \frac{7452}{5}\tau^9 - \frac{7776}{25}\tau^{10}$$

$$\beta_{\frac{3}{4}} = -\frac{1367003}{146966400} + \frac{2257181}{14696640}\tau - \frac{1048}{3}\tau^3 + \frac{47872}{315}\tau^4 - \frac{2048}{3}\tau^5 + \frac{398848}{225}\tau^6 - \frac{19456}{7}\tau^7 + \frac{90624}{35}\tau^8 - \frac{92116}{7}\tau^9 + \frac{49152}{175}\tau^{10}$$

$$\beta_{\frac{5}{6}} = \frac{1216513}{464486400} - \frac{10067843}{232243200}\tau + \frac{162}{35}\tau^3 - \frac{3051}{70}\tau^4 + \frac{4941}{25}\tau^5 - \frac{12987}{25}\tau^6 + \frac{28944}{35}\tau^7 - \frac{27459}{35}\tau^8 + \frac{14256}{35}\tau^9 - \frac{15552}{175}\tau^{10}$$

$$\beta_1 = -\frac{6979241}{75246796800} + \frac{8281069}{5374771200}\tau - \frac{1}{6}\tau^3 + \frac{571}{360}\tau^4 - \frac{1459}{200}\tau^5 + \frac{8791}{450}\tau^6 - \frac{223}{7}\tau^7 + \frac{2181}{70}\tau^8 - \frac{84}{5}\tau^9 + \frac{96}{25}\tau^{10}$$

For $j = 0$, equation (7) is evaluated at the non-interpolating point $x_{n+\kappa}, \kappa = 0, \frac{1}{3}, \frac{1}{2}, \frac{2}{3}, \frac{3}{4}, \frac{5}{6}, 1$

For $j = \frac{1}{6}, \frac{1}{4}$ equation (7) are evaluated to produce the discreet schemes with its derivatives. The discreet scheme and its derivatives are combined in a block form as

$$\mathrm{AY}_m = Z\mathrm{N}_1 + h^2\left[\Omega\mathrm{N}_2 + B\mathrm{N}_3\right] \quad (8)$$

$$A=\begin{pmatrix}
1 & 0 & 0 & -2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 4 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 6 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 7 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 8 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 10 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & \frac{12}{h} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & \frac{12}{h} & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & \frac{12}{h} & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & \frac{12}{h} & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & \frac{12}{h} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & \frac{12}{h} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & \frac{12}{h} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & \frac{12}{h} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1
\end{pmatrix}, \mathrm{Y}_m=\begin{pmatrix}
y_{n+\frac{1}{6}} \\ y_{n+\frac{1}{4}} \\ y_{n+\frac{1}{3}} \\ y_{n+\frac{1}{2}} \\ y_{n+\frac{2}{3}} \\ y_{n+\frac{3}{4}} \\ y_{n+\frac{5}{6}} \\ y_{n+1}
\end{pmatrix}, Z=\begin{pmatrix}
3 & 0 \\ -1 & 0 \\ -3 & 0 \\ -5 & 0 \\ -6 & 0 \\ -7 & 0 \\ -9 & 0 \\ -\frac{12}{h} & -1 \\ -\frac{12}{h} & 0 \\ -\frac{12}{h} & 0 \\ -\frac{12}{h} & 0 \\ -\frac{12}{h} & 0 \\ -\frac{12}{h} & 0 \\ -\frac{12}{h} & 0 \\ -\frac{12}{h} & 0
\end{pmatrix}, N_1=\begin{pmatrix} y_n \\ y'_n \end{pmatrix}, \Omega=\begin{pmatrix}
\frac{109198219}{75246796800h^2} \\
-\frac{695202}{225740390400h^2} \\
\frac{852491}{37623398400h^2} \\
-\frac{77509}{1672151040h^2} \\
\frac{571181}{10749542400h^2} \\
-\frac{478871}{8062156800h^2} \\
-\frac{826073}{5016453120h^2} \\
-\frac{1562744609}{37623398400h} \\
-\frac{126905078873}{4180377600h} \\
-\frac{1694300961851}{37623398400h} \\
-\frac{441985204589}{7524679680h} \\
-\frac{30120945190783}{37623398400h} \\
-\frac{358877107289}{4180377600h} \\
\frac{597039207199}{7524679680h} \\
\frac{2417108191009}{37623398400h} \\
\frac{8684951}{5374771200h}
\end{pmatrix}, N_2=\begin{bmatrix} f_n \end{bmatrix}, N_3=\begin{pmatrix}
f_{n+\frac{1}{6}} \\ f_{n+\frac{1}{4}} \\ f_{n+\frac{1}{3}} \\ f_{n+\frac{1}{2}} \\ f_{n+\frac{2}{3}} \\ f_{n+\frac{3}{4}} \\ f_{n+\frac{5}{6}} \\ f_{n+1}
\end{pmatrix}$$

and

$$B=\begin{pmatrix}
\frac{109198219h^2}{75246796800} & \frac{5336531h^2}{154828800} & -\frac{733019h^2}{20995200} & \frac{25067281h^2}{928972800} & -\frac{1213349h^2}{103219200} & -\frac{1367003h^2}{146966400} & \frac{1216513h^2}{464486400} & \frac{6979241h^2}{75246796800}\\
-\frac{820373h^2}{1393459200} & \frac{2559607h^2}{440899200} & \frac{1467341h^2}{2786918400} & \frac{39581h^2}{752467968} & -\frac{174439h^2}{2786918400} & \frac{22417h^2}{440899200} & -\frac{20227h^2}{1393459200} & \frac{117499h^2}{22740390400}\\
\frac{173741}{77414400h^2} & \frac{1191037}{73483200h^2} & \frac{8930671}{464486400h^2} & \frac{632159}{125411328h^2} & -\frac{109861}{51609600h^2} & \frac{107227}{73483200h^2} & -\frac{86657h^2}{232243200} & \frac{439849h^2}{37623398400}\\
\frac{383057}{92897280h^2} & \frac{247577}{9797760h^2} & \frac{7878697}{185794560h^2} & \frac{2599903}{83607552h^2} & \frac{52613}{185794560h^2} & \frac{4981}{3265920h^2} & -\frac{47207}{92897280h^2} & \frac{94037}{5016453120h^2}\\
\frac{108341}{22118400h^2} & \frac{79919}{2624400h^2} & \frac{7036861}{132710400h^2} & \frac{1668539}{35831808h^2} & \frac{152069}{14745600h^2} & \frac{313}{328050h^2} & -\frac{22337}{66355200h^2} & \frac{167299}{10749542400h^2}\\
\frac{281603}{49766400h^2} & \frac{561937}{15746400h^2} & \frac{6328331}{99532800h^2} & \frac{1668539}{26873856h^2} & \frac{2077151}{99532800h^2} & \frac{97447}{15746400h^2} & \frac{21083}{22249766400h^2} & \frac{74989}{8062156800h^2}\\
\frac{20227}{206434h^2} & \frac{361087}{9797760h^2} & \frac{5973157}{61931520h^2} & \frac{6771913}{83607552h^2} & \frac{474569}{6881280h^2} & \frac{25553}{1399680h^2} & \frac{1127509}{30965760h^2} & \frac{1452743}{1003290624h^2}\\
-\frac{31769593h}{77414400} & \frac{41105527h}{73483200} & \frac{40128343h}{92897280} & \frac{124090513h}{627056640} & -\frac{9986671h}{51609600} & \frac{2257181h}{14696640} & -\frac{10067843h}{232243200} & \frac{8281069h}{5374771200}\\
\frac{21594670289h}{46448640} & -\frac{4280007077h}{3499200} & \frac{532876014413h}{464486400} & -\frac{134055047461h}{209018880} & \frac{320972388889h}{464486400} & -\frac{462338871h}{8164800} & \frac{5439073883h}{33177600} & -\frac{15177389611h}{2508226560}\\
\frac{7627652837h}{11059200} & -\frac{16665615493h}{91185400} & \frac{790472698507h}{464486400} & -\frac{596578867391h}{627056640} & \frac{52904100707h}{51609600} & -\frac{137780687h}{164025} & \frac{56479066153h}{232243200} & -\frac{337717095179h}{37623398400}\\
\frac{208927290389h}{2322243200} & -\frac{1738975333321h}{73483200} & \frac{343686903407h}{154828800} & -\frac{778139715439h}{627056640} & \frac{88720288991h}{66355200} & -\frac{80511027823h}{73483200} & \frac{327411485h}{1032192} & -\frac{440495877253h}{37623398400}\\
\frac{94921775111h}{77414400} & -\frac{47404837813h}{14696640} & \frac{1405364732749h}{464486400} & -\frac{30300843589h}{17915904} & \frac{18810099997h}{10321920} & -\frac{109733517167h}{73483200} & \frac{100406334589h}{232243200} & -\frac{600381611141h}{37623398400}\\
\frac{305355437077h}{232243200} & -\frac{84720763523h}{24494400} & \frac{215281194251h}{66355200} & -\frac{379053845797h}{209018880} & \frac{907717913113h}{464486400} & -\frac{13074605239h}{8164800} & \frac{107668758653h}{232243200} & -\frac{214601277143}{12541132800}\\
\frac{94073939363h}{77414400} & -\frac{4194761041h}{1312200} & \frac{1392805460971h}{464486400} & -\frac{10510034318 39h}{627056640} & \frac{93219247043h}{51609600} & -\frac{6797094653h}{4592700} & \frac{568634503h}{1327104} & -\frac{595026871403h}{37623398400}\\
\frac{32644966403h}{33177600} & -\frac{190202395273h}{73483200} & \frac{75184098019h}{30965760} & -\frac{850970104687h}{627056640} & \frac{679318145561h}{464486400} & -\frac{2515778117h}{2099520} & \frac{89534648373h}{25804800} & -\frac{481798339717h}{37623398400}\\
\frac{812443h}{15482880} & -\frac{6670217h}{73483200} & \frac{148718413h}{464486400} & -\frac{7292783h}{627056640} & \frac{28831121h}{51609600} & -\frac{36489839h}{73483200} & \frac{97427581h}{232243200} & -\frac{311983487h}{7524679680}
\end{pmatrix}$$

equation (8) is multiplied by the inverse of A to have a hybrid block method of the form

$$A^{(0)}\mathrm{Y}_m = A^{-1}ZN_1 + h^2\left[A^{-1}\Omega N_2 + A^{-1}BN_3\right] \quad (9)$$

Equation (9) can be written as follows

$$y_{n+\frac{1}{6}} = y_n + \frac{hy'_n}{6} + h^2\left[\frac{9649609}{1763596800}f_n + \frac{4925}{145152}f_{n+\frac{1}{6}} - \frac{200876}{3444525}f_{n+\frac{1}{4}} + \frac{979999}{21772800}f_{n+\frac{1}{3}} - \frac{612761}{29393280}f_{n+\frac{3}{4}} + \frac{49583}{2419200}f_{n+\frac{2}{3}} - \frac{56132}{3444525}f_{n+\frac{3}{4}} + \frac{50143}{10886400}f_{n+\frac{5}{6}} - \frac{57859}{352719360}f_{n+1}\right]$$

$$y_{n+\frac{1}{4}} = y_n + \frac{hy'_n}{4} + h^2\left[\frac{1844099}{206438400}f_n + \frac{781353}{11468800}f_{n+\frac{1}{6}} - \frac{4701}{44800}f_{n+\frac{1}{4}} + \frac{1858113}{22937600}f_{n+\frac{1}{3}} - \frac{128467}{3440640}f_{n+\frac{3}{4}} + \frac{839997}{22937600}f_{n+\frac{2}{3}} - \frac{11731}{403200}f_{n+\frac{3}{4}} + \frac{94257}{11468800}f_{n+\frac{5}{6}} - \frac{20123}{68812800}f_{n+1}\right]$$

$$y_{n+\frac{1}{3}} = y_n + \frac{hy'_n}{3} + h^2\left[\frac{68291}{5511240}f_n + \frac{8753}{85050}f_{n+\frac{1}{6}} - \frac{502016}{3444525}f_{n+\frac{1}{4}} + \frac{238}{2025}f_{n+\frac{1}{3}} - \frac{12349}{229635}f_{n+\frac{3}{4}} + \frac{17923}{340200}f_{n+\frac{2}{3}} - \frac{144128}{3444525}f_{n+\frac{3}{4}} + \frac{67}{5670}f_{n+\frac{5}{6}} - \frac{5791}{13778100}f_{n+1}\right]$$

$$y_{n+\frac{2}{3}} = y_n + \frac{2hy'_n}{3} + h^2\left[\frac{90224}{3444525}f_n + \frac{3448}{14175}f_{n+\frac{1}{6}} - \frac{1077248}{3444525}f_{n+\frac{1}{4}} + \frac{12902}{42525}f_{n+\frac{1}{3}} - \frac{20368}{229635}f_{n+\frac{3}{4}} + \frac{238}{2025}f_{n+\frac{2}{3}} - \frac{45056}{492075}f_{n+\frac{3}{4}} + \frac{1096}{42525}f_{n+\frac{5}{6}} - \frac{3154}{3444525}f_{n+1}\right]$$

$$y_{n+\frac{3}{4}} = y_n + \frac{3hy'_n}{4} + h^2\left[\frac{136011}{4587520}f_n + \frac{3190833}{11468800}f_{n+\frac{1}{6}} - \frac{15867}{15867}f_{n+\frac{1}{4}} + \frac{8028477}{22937600}f_{n+\frac{1}{3}} - \frac{102897}{1146880}f_{n+\frac{3}{4}} + \frac{3295809}{22937600}f_{n+\frac{2}{3}} - \frac{4701}{44800}f_{n+\frac{3}{4}} + \frac{67797}{2293760}f_{n+\frac{5}{6}} - \frac{24021}{22937600}f_{n+1}\right]$$

$$y_{n+\frac{5}{6}} = y_n + \frac{5hy'_n}{6} + h^2\left[\frac{2335225}{70543872}f_n + \frac{136375}{435456}f_{n+\frac{1}{6}} - \frac{54500}{137781}f_{n+\frac{1}{4}} + \frac{38375}{96768}f_{n+\frac{1}{3}} - \frac{533125}{5878656}f_{n+\frac{3}{4}} + \frac{148375}{870912}f_{n+\frac{2}{3}} - \frac{15500}{137781}f_{n+\frac{3}{4}} + \frac{4925}{145152}f_{n+\frac{5}{6}} - \frac{83375}{70543872}f_{n+1}\right]$$

$$y_{n+1} = y_n + hy'_n + h^2\left[\frac{503}{12600}f_n + \frac{27}{70}f_{n+\frac{1}{6}} - \frac{256}{525}f_{n+\frac{1}{4}} + \frac{351}{700}f_{n+\frac{1}{3}} - \frac{11}{105}f_{n+\frac{3}{4}} + \frac{351}{1400}f_{n+\frac{2}{3}} - \frac{256}{1575}f_{n+\frac{3}{4}} + \frac{27}{350}f_{n+\frac{5}{6}}\right]$$

$$y'_{n+\frac{1}{6}} = y_n + h\left[\frac{6117617}{146966400} f_n + \frac{1571}{4050} f_{n+\frac{1}{6}} - \frac{673996}{1148175} f_{n+\frac{1}{4}} + \frac{802813}{1814400} f_{n+\frac{1}{3}} - \frac{15413}{76545} f_{n+\frac{3}{4}} + \frac{356563}{1814400} f_{n+\frac{2}{3}} - \frac{178996}{1148175} f_{n+\frac{3}{4}} + \frac{1247}{28350} f_{n+\frac{5}{6}} - \frac{229633}{146966400} f_{n+1}\right]$$

$$y'_{n+\frac{1}{4}} = y_n + h\left[\frac{1070131}{25804800} f_n + \frac{300429}{716800} f_{n+\frac{1}{6}} - \frac{52279}{100800} f_{n+\frac{1}{4}} + \frac{1211031}{1814400} f_{n+\frac{1}{3}} - \frac{10481}{53760} f_{n+\frac{3}{4}} + \frac{547641}{2867200} f_{n+\frac{2}{3}} - \frac{15289}{100800} f_{n+\frac{3}{4}} + \frac{30699}{716800} f_{n+\frac{5}{6}} - \frac{39299}{25804800} f_{n+1}\right]$$

$$y'_{n+\frac{1}{3}} = y_n + h\left[\frac{381439}{9185400} f_n + \frac{5897}{14175} f_{n+\frac{1}{6}} - \frac{545792}{1148175} f_{n+\frac{1}{4}} + \frac{53141}{113400} f_{n+\frac{1}{3}} - \frac{15286}{76545} f_{n+\frac{3}{4}} + \frac{22061}{113400} f_{n+\frac{2}{3}} - \frac{177152}{1148175} f_{n+\frac{3}{4}} + \frac{617}{14175} f_{n+\frac{5}{6}} - \frac{14201}{9185400} f_{n+1}\right]$$

$$y'_{n+\frac{1}{2}} = y_n + h\left[\frac{8329}{201600} f_n + \frac{297}{700} f_{n+\frac{1}{6}} - \frac{116}{225} f_{n+\frac{1}{4}} + \frac{13149}{22400} f_{n+\frac{1}{3}} - \frac{11}{105} f_{n+\frac{3}{4}} + \frac{3699}{22400} f_{n+\frac{2}{3}} - \frac{212}{1575} f_{n+\frac{3}{4}} + \frac{21}{700} f_{n+\frac{5}{6}} - \frac{281}{201600} f_{n+1}\right]$$

$$y'_{n+\frac{2}{3}} = y_n + h\left[\frac{47611}{1148175} f_n + \frac{5944}{14175} f_{n+\frac{1}{6}} - \frac{569344}{1148175} f_{n+\frac{1}{4}} + \frac{7904}{14175} f_{n+\frac{1}{3}} - \frac{752}{76545} f_{n+\frac{3}{4}} + \frac{4019}{14175} f_{n+\frac{2}{3}} - \frac{28672}{164025} f_{n+\frac{3}{4}} + \frac{664}{14175} f_{n+\frac{5}{6}} - \frac{1844}{1148175} f_{n+1}\right]$$

$$y'_{n+\frac{3}{4}} = y_n + h\left[\frac{118827}{2867200} f_n + \frac{43011}{102400} f_{n+\frac{1}{6}} - \frac{5583}{11200} f_{n+\frac{1}{4}} + \frac{1608903}{2867200} f_{n+\frac{1}{3}} - \frac{261}{17920} f_{n+\frac{3}{4}} + \frac{945513}{2867200} f_{n+\frac{2}{3}} - \frac{1473}{11200} f_{n+\frac{3}{4}} + \frac{31347}{716800} f_{n+\frac{5}{6}} - \frac{4443}{2867200} f_{n+1}\right]$$

$$y'_{n+\frac{5}{6}} = y_n + h\left[\frac{243865}{5878656} f_n + \frac{475}{1134} f_{n+\frac{1}{6}} - \frac{22700}{45927} f_{n+\frac{1}{4}} + \frac{40325}{72576} f_{n+\frac{1}{3}} - \frac{125}{15309} f_{n+\frac{3}{4}} + \frac{22475}{72576} f_{n+\frac{2}{3}} - \frac{2900}{45927} f_{n+\frac{3}{4}} + \frac{85}{1134} f_{n+\frac{5}{6}} - \frac{10025}{5878656} f_{n+1}\right]$$

$$y'_{n+1} = y_n + h\left[\frac{503}{12600} f_n + \frac{81}{175} f_{n+\frac{1}{6}} - \frac{1024}{1575} f_{n+\frac{1}{4}} + \frac{1053}{1400} f_{n+\frac{1}{3}} - \frac{22}{105} f_{n+\frac{3}{4}} + \frac{1053}{1400} f_{n+\frac{2}{3}} - \frac{1024}{1575} f_{n+\frac{3}{4}} + \frac{81}{175} f_{n+\frac{5}{6}} - \frac{503}{12600} f_{n+1}\right]$$

3 Basic Properties of the new Method

We will scrutinize the assessment of the novel approach, encompassing various properties such as order, error constant, consistency, convergence, zero-stability, and stability region [16, 17], among others.

3.1 Order and Error constant of the Method

In determining the order and error constant of the new method (9), we define the linear difference operator L associated with equation (9) as

$$L[y(x); h] = Y_m - A^{-1}ZN_1 - h^2\left[A^{-1}\Omega N_2 + A^{-1}BN_3\right] \tag{10}$$

Corollary 1 [17]
Compare the linear operator (10) with the truncation error $C_{09}h^{09}y^{09}(x_n)+0(h^{10})$.

Proof

The linear difference operators (10) is compared with the new method (9) as

$$\left.\begin{aligned}
l_{\frac{1}{6}}[y(x_n);h] &= y\left(x_n+\frac{1}{6}h\right)-\left(\alpha_{\frac{1}{6}}\left(x_n+\frac{1}{6}h\right)+\alpha_{\frac{1}{4}}\left(x_n+\frac{1}{4}h\right)+h^2\sum_{j=0}^{1}\left(\beta_\varsigma(x)f_{n+\varsigma}+\beta_\varsigma(x)f_{n+\varsigma}\right)\right)\\
l_{\frac{1}{4}}[y(x_n);h] &= y\left(x_n+\frac{1}{4}h\right)-\left(\alpha_{\frac{1}{6}}\left(x_n+\frac{1}{6}h\right)+\alpha_{\frac{1}{4}}\left(x_n+\frac{1}{4}h\right)+h^2\sum_{j=0}^{1}\left(\beta_\varsigma(x)f_{n+\varsigma}+\beta_\varsigma(x)f_{n+\varsigma}\right)\right)\\
l_{\frac{1}{3}}[y(x_n);h] &= y\left(x_n+\frac{1}{3}h\right)-\left(\alpha_{\frac{1}{6}}\left(x_n+\frac{1}{6}h\right)+\alpha_{\frac{1}{4}}\left(x_n+\frac{1}{4}h\right)+h^2\sum_{j=0}^{1}\left(\beta_\varsigma(x)f_{n+\varsigma}+\beta_\varsigma(x)f_{n+\varsigma}\right)\right)\\
l_{\frac{1}{2}}[y(x_n);h] &= y\left(x_n+\frac{1}{2}h\right)-\left(\alpha_{\frac{1}{6}}\left(x_n+\frac{1}{6}h\right)+\alpha_{\frac{1}{4}}\left(x_n+\frac{1}{4}h\right)+h^2\sum_{j=0}^{1}\left(\beta_\varsigma(x)f_{n+\varsigma}+\beta_\varsigma(x)f_{n+\varsigma}\right)\right)\\
l_{\frac{2}{3}}[y(x_n);h] &= y\left(x_n+\frac{2}{3}h\right)-\left(\alpha_{\frac{1}{6}}\left(x_n+\frac{1}{6}h\right)+\alpha_{\frac{1}{4}}\left(x_n+\frac{1}{4}h\right)+h^2\sum_{j=0}^{1}\left(\beta_\varsigma(x)f_{n+\varsigma}+\beta_\varsigma(x)f_{n+\varsigma}\right)\right)\\
l_{\frac{3}{4}}[y(x_n);h] &= y\left(x_n+\frac{3}{4}h\right)-\left(\alpha_{\frac{1}{6}}\left(x_n+\frac{1}{6}h\right)+\alpha_{\frac{1}{4}}\left(x_n+\frac{1}{4}h\right)+h^2\sum_{j=0}^{1}\left(\beta_\varsigma(x)f_{n+\varsigma}+\beta_\varsigma(x)f_{n+\varsigma}\right)\right)\\
l_{\frac{5}{6}}[y(x_n);h] &= y\left(x_n+\frac{5}{6}h\right)-\left(\alpha_{\frac{1}{6}}\left(x_n+\frac{1}{6}h\right)+\alpha_{\frac{1}{4}}\left(x_n+\frac{1}{4}h\right)+h^2\sum_{j=0}^{1}\left(\beta_\varsigma(x)f_{n+\varsigma}+\beta_\varsigma(x)f_{n+\varsigma}\right)\right)\\
l_1[y(x_n);h] &= y(x_n+h)-\left(\alpha_{\frac{1}{6}}\left(x_n+\frac{1}{6}h\right)+\alpha_{\frac{1}{4}}\left(x_n+\frac{1}{4}h\right)+h^2\sum_{j=0}^{1}\left(\beta_\varsigma(x)f_{n+\varsigma}+\beta_\varsigma(x)f_{n+\varsigma}\right)\right)
\end{aligned}\right\} \quad (11)$$

Corollary 2 [17]
The local truncation error of (9) is assume $y(x)$ to be sufficiently differentiable and expanding $y(x_n+qh)$ and $y(x_n+jh)$ about x_n using Taylor series to have

$l_{\frac{1}{6}}[y(x_n);h]=(1.2415\times10^{-12}),\ l_{\frac{1}{4}}[y(x_n);h]=(2.2041\times10^{-12}),\ l_{\frac{1}{3}}[y(x_n);h]=(3.1629\times10^{-12}),$
$l_{\frac{1}{2}}[y(x_n);h]=(5.0339\times10^{-12}),\ l_{\frac{2}{3}}[y(x_n);h]=(6.9050\times10^{-12}),\ l_{\frac{3}{4}}[y(x_n);h]=(7.8638\times10^{-12}),$
$l_{\frac{5}{6}}[y(x_n);h]=(8.8264\times10^{-12}),\ l_1[y(x_n);h]=(1.0068\times10^{-11})$

Proof
Expanding the term Y_m and N_3 using a Taylor series about x_n respectively and then collecting their like elements to the power of h gives

$$l_{\frac{1}{6}}[y(x_n);h] = (1.2415\times10^{-12})h^9 y^{(9)}(x_n) + 0(h^{10})$$
$$l_{\frac{1}{4}}[y(x_n);h] = (2.2041\times10^{-12})h^9 y^{(9)}(x_n) + 0(h^{10})$$
$$l_{\frac{1}{3}}[y(x_n);h] = (3.1629\times10^{-12})h^9 y^{(9)}(x_n) + 0(h^{10})$$
$$l_{\frac{1}{2}}[y(x_n);h] = (5.0339\times10^{-12})h^9 y^{(9)}(x_n) + 0(h^{10})$$
$$l_{\frac{2}{3}}[y(x_n);h] = (6.9050\times10^{-12})h^9 y^{(9)}(x_n) + 0(h^{10})$$
$$l_{\frac{3}{4}}[y(x_n);h] = (7.8638\times10^{-12})h^9 y^{(9)}(x_n) + 0(h^{10})$$
$$l_{\frac{5}{6}}[y(x_n);h] = (8.8264\times10^{-12})h^9 y^{(9)}(x_n) + 0(h^{10})$$
$$l_1[y(x_n);h] = (1.0068\times10^{-11})h^9 y^{(9)}(x_n) + 0(h^{10})$$

Hence, from the above results, the order of the new method (9) is 9, and the error constants is

$$C = \begin{pmatrix} 1.2415\times10^{-12}, 2.2041\times10^{-12}, 3.1629\times10^{-12}, 5.0339\times10^{-12}, \\ 6.9050\times10^{-12}, 7.8638\times10^{-12}, 8.8264\times10^{-12}, 1.0068\times10^{-11} \end{pmatrix}^T.$$

3.2 Consistency

Definition 1 [17]

The new method (9) is consistent because it is of order 9.

3.3 Zero-stability of the Method

For zero stability, we consider the characteristic function of the equation below:

$$\left\|\left[\lambda B^{(0)} - B^i\right]\right\| = \left| \lambda \begin{pmatrix} 1&0&0&0&0&0&0&0\\ 0&1&0&0&0&0&0&0\\ 0&0&1&0&0&0&0&0\\ 0&0&0&1&0&0&0&0\\ 0&0&0&0&1&0&0&0\\ 0&0&0&0&0&1&0&0\\ 0&0&0&0&0&0&1&0\\ 0&0&0&0&0&0&0&1 \end{pmatrix} - \begin{pmatrix} 0&0&0&0&0&0&0&1\\ 0&0&0&0&0&0&0&1\\ 0&0&0&0&0&0&0&1\\ 0&0&0&0&0&0&0&1\\ 0&0&0&0&0&0&0&1\\ 0&0&0&0&0&0&0&1\\ 0&0&0&0&0&0&0&1\\ 0&0&0&0&0&0&0&1 \end{pmatrix} \right| = 0$$

$\lambda^8 - \lambda^7 = 0, 0, 0, 0, 0, 0, 0, 1$

Since the roots of the equations lies between 0 and 1, hence the new method is zero stable see [16].

3.3 Convergent

Theorem 1 [17]

According to Dalquist theorem, the new method is convergent since it is consistence and zero-stable see [16].

3.5 Linear Stability

Definition 3 [18]
The stability region of a new method is the set of complex values λh for which all solutions of the test problem $y''=-\lambda^2 y$ remain bounded as $n\to\infty$.
The concept of A-stability according to [18] is discussed by applying the test equation

$$y^{(k)}=\lambda^{(k)}y \tag{12}$$

To yield

$$Y_m=\mu(z)Y_{m-1},\ z=\lambda h \tag{13}$$

Where $\mu(z)$ is the amplification matrix of the form

$$\mu(z)=\left(\xi^0-z\eta^{(0)}-z^2\eta^{(0)}\right)^{-1}\left(\xi^1-z\eta^{(1)}-z^2\eta^{(1)}\right) \tag{14}$$

The matrix $\mu(z)$ has Eigen values $(0, 0, \cdots, \xi_k)$ where ξ_k is called the stability function.
Thus, the stability function of new method (9) is given as

$$\zeta=-\frac{\left(\begin{array}{l}24799949\,719675695z^8-1167073163\,739266043z^7+27\,128030061143833235z^6-\\515\,556735008\,654413944z^5+6539\,326196102\,856181344z^4-65866\,416469167\,064393152z^3\\+430104\,648937877\,518309632z^2-1874456\,030584895\,333990400z+366902\,8117771997\,675520000\end{array}\right)}{\begin{array}{l}29255954\,595840000z^8-1172188580\,806656000z^7+28\,951692668\,043264000z^6-\\513\,945205576\,040448000z^5+6754\,848844724\,305920000z^4-64936\,984916199\,997440000z^3\\+435626\,312980066\,467840000z^2-1834514\,058885998\,837760000z+366902\,8117771997\,675520000\end{array}}$$

4 Mathematical Illustration

The new method was employed for simulating various types of oscillatory differential equations. Firstly, we conducted a numerical simulation of oscillatory differential equation (1) in a motion to identify the characteristics of mass in a spring, dynamic mass, and equilibrium in harmonic form. Secondly, we simulated oscillatory differential equation (1) with an external force "F" to examine its impact on the system's behavior. Lastly, we conducted oscillatory simulations of (1) in both linear and nonlinear forms.

The notations below are used in the results
ES: Exact Solution
CS: Computed Solution
NM: New Method
ENM: Error in New Method
E[19]: Error in [19]
E[12]: Error in [12]
E[13]: Error in [13]
E[20]: Error in [20]
E[21]: Error in [21]
E[22]: Error in [22]
E[23]: Error in [23]

Example 1
Consider the mechanical oscillatory differential equation in harmonic motion, of an object which stretches a spring 6 inches in equilibrium.

i. Set up the equation of motion and find its general solution.

ii. Find the displacement of the object for $t > 0$, if it's initially displaced 18 inches above equilibrium and given a downward velocity of $3\frac{ft}{s}$.

From Newton's second law of motion, we have

$$mu''+cu'+ku = F \tag{15}$$

By setting $c = 0$ and $F = 0$, we get

$$mu''+ku = 0 \Rightarrow u''+\frac{k}{m}u = 0 \tag{16}$$

The equation of the weight of the object is given as follow:

$$mg = k\Delta l \Rightarrow \frac{k}{m} = \frac{g}{\Delta l} \tag{17}$$

Substituting $g = 32\frac{ft}{s^2}$, $\Delta l = \frac{6}{12}\,ft$ into (17) we obtain

$$\frac{k}{m} = \frac{32}{\frac{6}{12}} = 64 \tag{17}$$

Substituting equation (18) into the equation (16) we get

$$u''+64u = 0 \tag{18}$$

The initial upward displacement of 18 inches is positive and must be expressed in feet. The initial downward velocity is negative; thus, $u(0) = \frac{3}{2}, u'(0) = -3$ and $h = 0.1$. We make use of (18) as

$$dsolver\left(\left\{u''(v)+64u(v) = 0, u(0) = \frac{3}{2}, u'(0) = -3\right\}\right) \tag{20}$$

We obtain the exact solution (20) as

$$u(v) = -\frac{3}{8}\sin(8v)+\frac{3}{2}\cos(8v) \tag{21}$$

Source: [19].

Example 2

The second order mechanical oscillatory differential equation in a spring of motion is consider. A $128lb$ weight is attached to a spring having a spring constant of $64lb/\,ft$. The weight is started in motion with no initial velocity by displacing it $6inches$ above the equilibrium position and by simultaneously applying to the weight an external force $F_4(v) = 8\sin 4v$. Assuming no air resistance, compute the subsequent motion of the weight at $t: 0.01 \le v \le 0.10$.

Now, we model this problem into a mathematical model and then apply our method to compute the motion on the weight attached to the spring. Here,

$$m = 4, k = 64, b = 0, and\ F_4(v) = 8\sin 4v$$

Thus, problem 3 boils down to

$$\frac{d^2u}{dv^2}+16u = 2\sin 4v, u(0) = -\frac{1}{2}, u'(0) = 0 \tag{22}$$

with the exact solution of (22) is given by,

$$u(v) = -\frac{1}{2}\cos 4v+\frac{1}{16}\sin 4v-\frac{1}{4}v\cos 4v \tag{23}$$

Source: [12, 13].

Example 3

Consider the mass in a dynamic motion that is coined into linear oscillatory form of differential equation (1).
A mass of $10\,kg$ is attached to a spring having a constant spring of $140\ N/M$. The mass is started in motion from the equilibrium position with an initial velocity of 1 m/sec in the upward direction and with an applied external force $F(v)=5\sin v$. Find the subsequent motion of the mass $(v:0.10\le v\le 1.00)$ if the force due to air resistance is $90\left(\frac{du}{dv}\right)N$.

We apply the same procedure, where $m=10,\ k=140,\ a=90\ and\ F(v)=5\sin v$ example 3 reduces to

$$dsolver\left(\left\{\frac{d^2u}{dv^2}+9\frac{du}{dv}+14y(u)=\frac{1}{2}\sin(v),\ u(0)=0,\ u'(0)=-1\right\}\right) \tag{24}$$

with the exact solution of (24) is given by,

$$u(v)=\frac{1}{500}\left(-90\exp(-2v)+99\exp(-7v)+13\sin v-9\cos v\right) \tag{25}$$

Source [12, 13, 20].

Example 4

Consider the linear oscillatory differential equation in Betiss and Stiefel form

$$\frac{d^2u_1}{dv^2}+\frac{du_1}{dv}=0.001\cos(v),\ u_1(0)=1,\ \frac{du_1}{dv}=0 \tag{26}$$

$$\frac{d^2u_2}{dv^2}+\frac{du_2}{dv}=0.001\sin(v),\ u_1(0)=0,\ \frac{du_1}{dv}=0.9995 \tag{27}$$

With exact solution of (26) and (27) as

$$u_1(v)=\cos(v)+0.0005v\sin(v) \tag{28}$$

$$u_2(v)=\sin(v)-0.0005v\cos(v) \tag{29}$$

Source [21, 22]

Example 5:

Consider the nonlinear oscillatory differential equation

$$\frac{d^2u}{dv^2}-4yu'+8u=v^3,\ u(0)=2,u'(0)=4, \tag{30}$$

Whose exact solution is

$$y(v)=\exp(2v)\left(2\cos(2v)-\frac{3}{64}\sin(2v)\right)+\frac{3v}{32}+\frac{3v^2}{16}+\frac{v^2}{8} \tag{31}$$

Source: [22, 23].

5 Results and Discussion

Table 1: Computation of NM with [19] when solving example 1

v	ES	CS	ENM	E[19]
0.1	0.77605152993342709579	0.77605152993274408426	6.8301(-13)	3.3496(-07)
0.2	- 0.41863938459249752594	-0.41863938459387367324	1.3762(-12)	1.6371(-06)
0.3	- 1.35938926601855498469	-1.35938926601955541960	1.0056(-12)	3.2716(-06)
0.4	- 1.47555185990678711611	-1.47555185990606872960	7.1843(-13)	3.5979(-06)
0.5	- 0.69666449555494477770	-0.69666449555213113975	2.8136(-12)	1.3589(-06)
0.6	0.50481020347261010590	0.50481020347619324768	3.5831(-12)	2.9143(-06)

0.7	1.4000738069674951883	1.40007380696939826270	1.9031(-12)	6.7226(-06)
0.8	1.4460714263183540043	1.44607142631665691830	1.6971(-12)	7.0589(-06)
0.9	0.61490152285494961183	0.6149015228498909249 9	5.0587(-12)	2.6543(-06)
1.0	- 0.58925939319668845548	0.58925939320237650700	5.6881(-12)	4.6056(-06)

See [22, 23].

Table 2: Computation of NM with [12, 13] when solving example 2

v	ES	CS	ENM	E[12]	E[13]
0.1	- 0.49959872021047678004	- 0.49959872021047678004	0.0000(00)	1.6621(-09)	1.0000(-19)
0.2	- 0.49839019330974949646	- 0.49839019330974949646	0.0000(00)	1.1586(-08)	4.1000(-19)
0.3	- 0.49636836974027966301	- 0.49636836974027966301	0.0000(00)	2.9743(-08)	9.1000(-19)
0.4	- 0.49352852660817937130	- 0.49352852660817937130	0.0000(00)	5.6076(-08)	1.6600(-18)
0.5	- 0.48986728796894500998	- 0.48986728796894500998	0.0000(00)	9.0504(-08)	2.6200(-18)
0.6	- 0.48538264289709933476	- 0.48538264289709933476	0.0000(00)	1.3291(-07)	3.8000(-18)
0.7	- 0.48007396129056685722	- 0.48007396129056685722	0.0000(00)	1.8317(-07)	5.2000(-18)
0.8	- 0.47394200736436189072	- 0.47394200736436189072	0.0000(00)	2.4110(-07)	6.8500(-18)
0.9	- 0.46698895079202783994	- 0.46698895079202783994	0.0000(00)	3.0653(-07)	8.7500(-18)
1.0	- 0.45921837545722401274	- 0.45921837545722401274	0.0000(00)	3.7922(-07)	1.0850(-17)

See [12, 13].

Table 3: Computation of NM with [12, 13, 20] when solving example 3

V	ES	CS	ENM	E[12]	E[13]	E[20]
0.1	-0.06436205154552458248	- 0.06436205154550692713	1.7655(-14)	1.2744(-08)	2.0453(-10)	4.4268(-09)
0.2	-0.08430720522644774945	- 0.08430720522643379455	1.3955(-14)	3.0442(-08)	4.8485(-10)	2.2383(-08)
0.3	-0.08405225313390041905	- 0.08405225313389384414	6.5749(-15)	4.1501(-08)	6.6174(-10)	3.5865(-08)
0.4	-0.07529304213333374810	- 0.07529304213333305897	6.8913(-16)	4.5385(-08)	7.2649(-10)	4.2157(-08)
0.5	-0.06357063960355798563	-0.06357063960356088722	2.9016(-15)	4.4298(-08)	7.1295(-10)	4.2895(-08)
0.6	-0.05142117069384508163	- 0.05142117069384974188	4.6603(-15)	4.0466(-08)	6.5550(-10)	4.0288(-08)
0.7	-0.03993052956438697070	- 0.03993052956439220056	5.2299(-15)	3.5475(-08)	5.7884(-10)	3.6051(-08)
0.8	-0.02949865862803573900	- 0.02949865862804086216	5.1232(-15)	3.0285(-08)	4.9808(-10)	3.1287(-08)
0.9	-0.02021269131259124546	- 0.02021269131259391333	2.6679(-15)	2.5408(-08)	4.2140(-10)	2.6618(-08)
1.0	-0.01202699425403169607	- 0.01202699425403402038	2.3243(-15)	2.1071(-08)	3.5257(-10)	2.2352(-08)

See [12, 13, 20].

Table 4: Computation of NM with [21, 22] when solving (26)

V	ES	CS	ENM	E[21]	E[22]
0.1	0.09978366643856425102	0.09978366643856425102	0.0000(00)	1.2567(-12)	1.0170(-12)
0.2	0.19857132413727709130	0.19857132413727709130	0.0000(00)	2.1140(-12)	1.4285(-11)
0.3	0.29537690618797073421	0.29537690618797073421	0.0000(00)	2.3764(-12)	4.9557(-11)
0.4	0.38923413010984991465	0.38923413010984991465	0.0000(00)	3.4242(-12)	1.0161(-10)
0.5	0.47920614296373040709	0.47920614296373040709	0.0000(00)	3.3944(-12)	1.7416(-10)
0.6	0.56439487271056245371	0.56439487271056245371	0.0000(00)	3.3436(-12)	2.6425(-10)
0.7	0.64394999247214148272	0.64394999247214148272	0.0000(00)	4.2949(-12)	3.7579(-10)
0.8	0.71707740821578389546	0.71707740821578389546	0.0000(00)	4.2574(-12)	5.0602(-10)
0.9	0.78304718514176158945	0.78304718514176158945	0.0000(00)	5.2344(-12)	6.5904(-10)
1.0	0.84120083365496243679	0.84120083365496243679	0.0000(00)	6.2265(-12)	8.3225(-10)

See [21, 22].

Table 5: Computation of NM with [21, 22] when solving (27)

V	ES	CS	ENM	E[21]	E[22]
0.1	0.99500915694885810751	0.99500915694885810750	0.0000(00)	2.8269(-12)	1.0169(-11)
0.2	0.98008644477432113724	0.98008644477432113723	0.0000(00)	5.8994(-12)	2.0390(-11)
0.3	0.95538081715660522058	0.95538081715660522057	0.0000(00)	6.8309(-12)	1.5451(-13)

0.4	0.92113887767134681290	0.92113887767134681288	0.0000(00)	1.4991(-12)	8.1063(-11)
0.5	0.87770241827502376687	0.87770241827502376685	0.0000(00)	1.8395(-12)	2.5377(-10)
0.6	0.82550500765169680785	0.82550500765169680783	0.0000(00)	1.6559(-11)	5.4848(-10)
0.7	0.76506766347502161813	0.76506766347502161811	0.0000(00)	1.2970(-11)	9.9571(-10)
0.8	0.69699365178352523002	0.69699365178352523001	0.0000(00)	8.4312(-11)	1.6260(-10)
0.9	0.62196246537999682400	0.62196246537999682400	0.0000(00)	5.3240(-11)	2.4697(-10)
1.0	0.54072304136054366565	0.54072304136054366565	0.0000(00)	3.2126(-11)	3.5575(-10)

See [21, 22].

Table 6: Computation of NM with [22, 23] when solving example 5

V	ES	CS	ENM	E[22]	E[23]
0.1	2.3941125769963956181	2.39411257699639563790	1.9800(-17)	7.1426(-08)	5.1070(-06)
0.2	2.7481413324264235256	2.74814133242642358080	5.5200(-17)	1.7491(-07)	1.4959(-05)
0.3	3.0078669405110678859	3.00786694051106799770	1.1180(-16)	3.6449(-07)	2.7853(-05)
0.4	3.1017624057742078185	3.10176240577420801430	1.9580(-16)	6.1898(-07)	4.2891(-05)
0.5	2.9395431007452620774	2.93954310074526238920	3.1180(-16)	6.9889(-07)	6.7031(-05)
0.6	2.4118365344157147255	2.41183653441571519130	4.6580(-16)	1.4794(-06)	1.0264(-04)
0.7	1.3915548304898433104	1.39155483048984396930	6.5890(-16)	2.1022(-06)	1.4491(-04)
0.8	-0.262326758334357631	- 0.26232675833435674263	8.8837(-16)	2.8409(-06)	1.9091(-04)
0.9	-2.697771160773070925	- 2.69777116077306977980	1.1452(-15)	3.6689(-06)	2.3973(-04)
1.0	-6.058560720845666951	- 6.05856072084566553990	1.4111(-15)	4.5617(-06)	2.9467(-04)

See [22, 23]

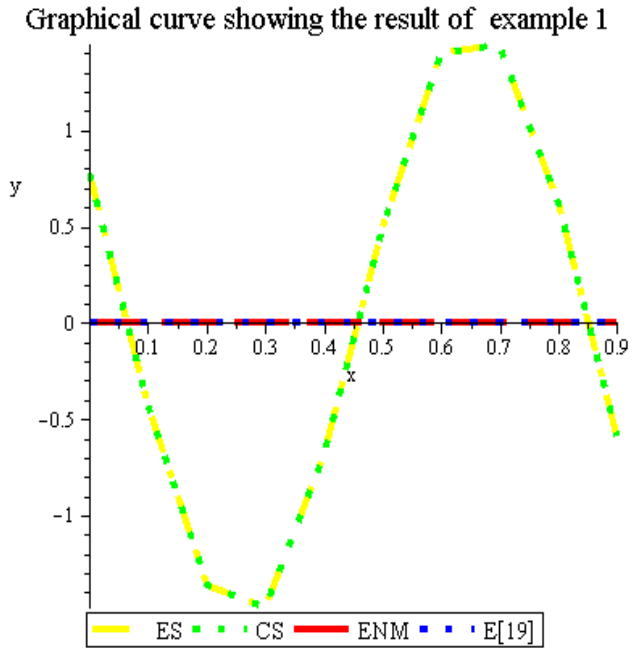


Figure 1: Textual graph of table 1

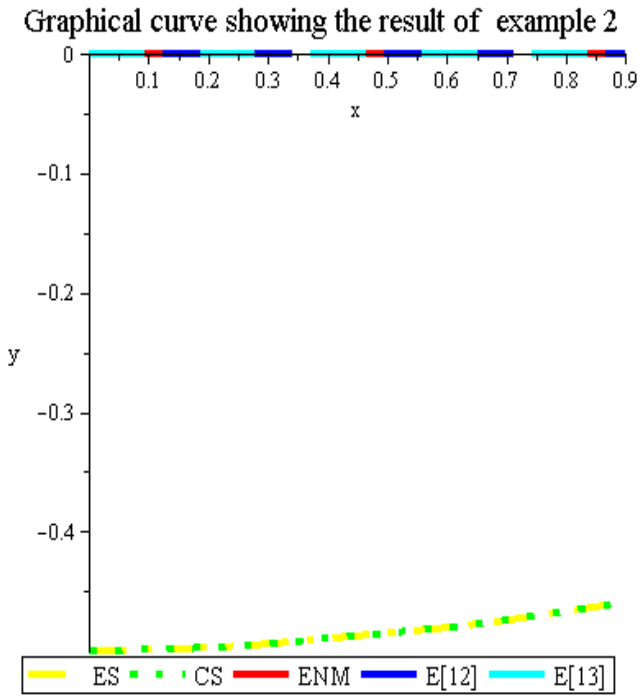


Figure 2: Textual graph of table 2

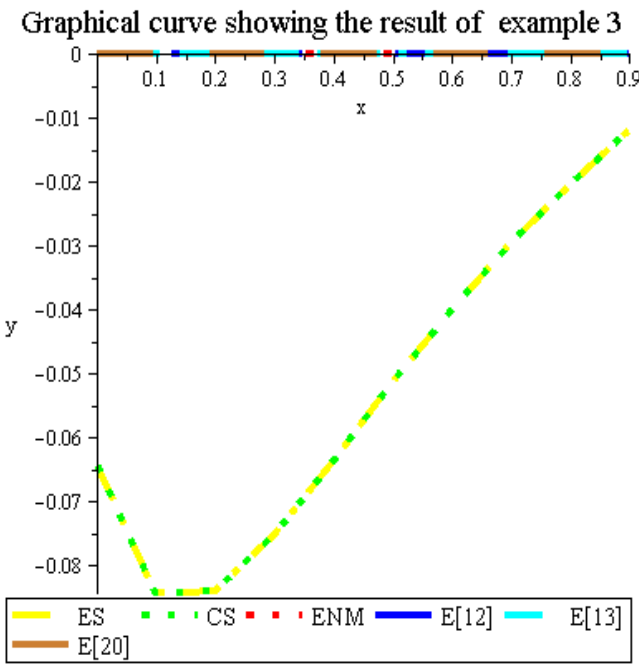


Figure 3: Textual graph of table 3

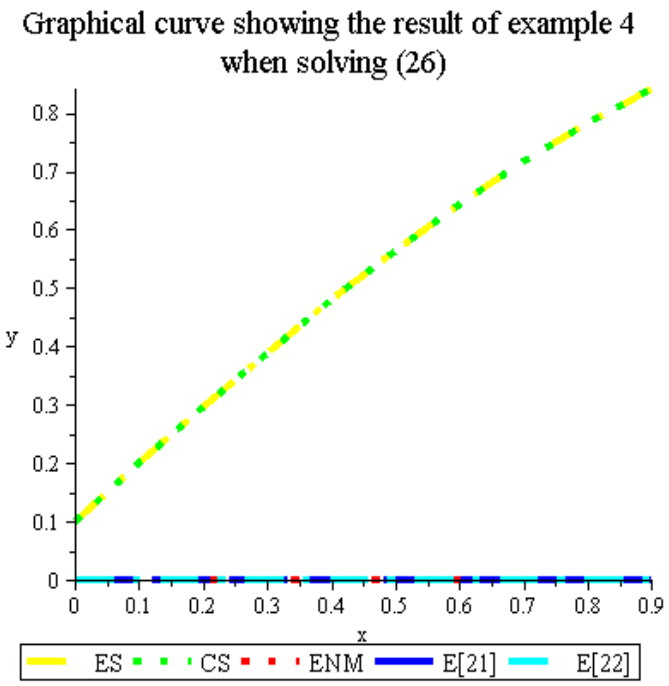


Figure 4: Textual graph of table 4

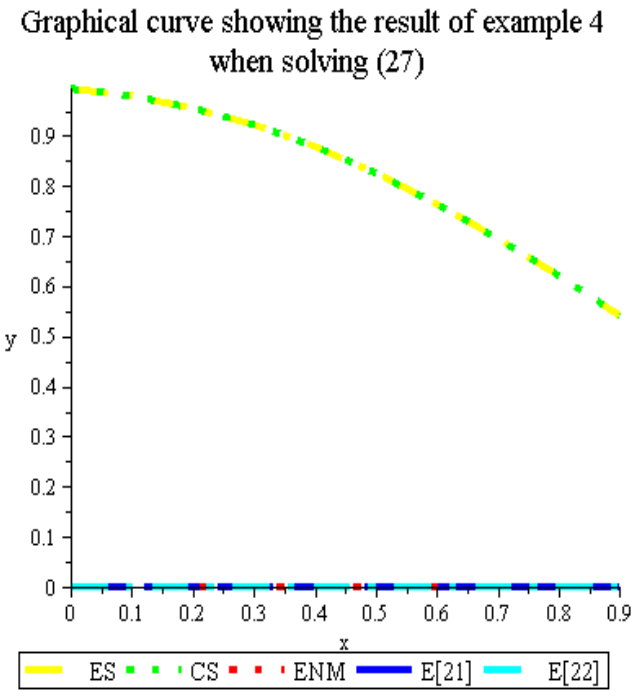


Figure 4: Textual graph of table 5

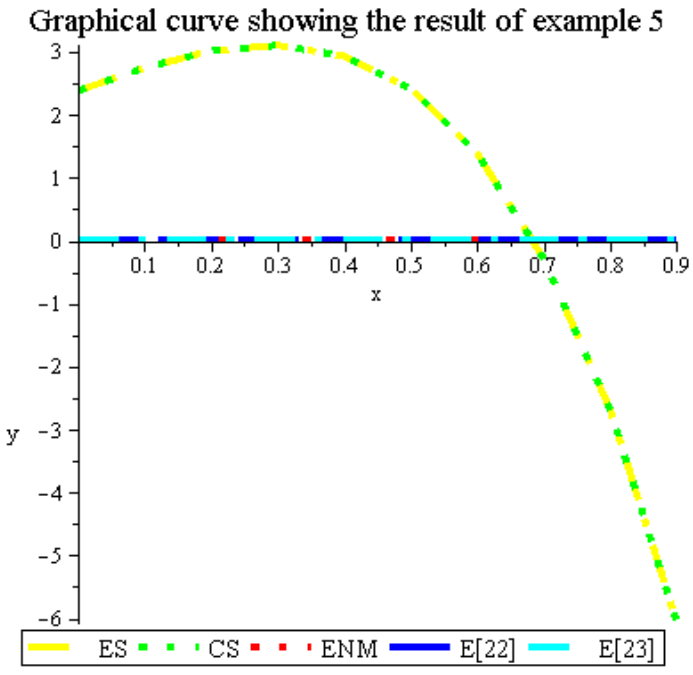


Figure 4: Textual graph of table 6

The new method was employed to simulate five different oscillatory differential equations. The results, as presented in Tables 1 to 6, clearly demonstrate that the new method outperforms the ones it was compared with.

Furthermore, the simulation results depicted in Figures 1 to 6 confirm the effectiveness of the new method in simulating oscillatory differential equations.
The application of the new method to simulate oscillatory differential equations in harmonic motion revealed superior convergence compared to the method described in reference [19], as evident in Table 1 and Figure 1.

Table 2 provides a comparison of the new method with references [12, 13] when solving oscillatory differential equations in spring motion. This comparison sheds light on the influence of external force "F" on the system's behavior.
Similarly, the new method was applied to simulate second-order oscillatory differential equations in mass dynamic motion, Betiss and Stiefel equations, and nonlinear oscillatory differential equations (examples 3 to 5). The results in Tables 3 to 6 and Figures 3 to 6 unequivocally demonstrate that the new method surpasses the methods described in references [12, 13, 20-23].
Conclusively, both the tabulated results in Tables 1 to 6 and the graphical representations in Figures 1 to 6 validate the efficiency and effectiveness of the new method in handling second-order oscillatory differential equations.

6 Conclusion

This research delved into the numerical approximation and practical application of oscillations in a moving mass. The new method was developed based on power series polynomials, and its properties were rigorously analyzed. It has been found that the new method exhibits computational reliability superior to the methods considered for solving similar oscillatory differential equations.

References

[1] Blanka B. (2019). Oscillation of second-order nonlinear non-canonical differential equations with deviating argument. *Applied Mathematics Letters, 91,* 68–75.

[2] Kusano, T., & Naito, Y. (1997). Oscillation and nonoscillation criteria for second order quasilinear differential equations. *Acta Math. Hungar, 76,* 81–99.

[3] Agarwal, R.P., Grace, S.R., & O'Regan, D. (2003). *Oscillation Theory for Second Order Dynamic Equations.* Taylor & Francis.

[4] Bainov, D.D., & Mishev, D.P. (1991). *Oscillation Theory for Neutral Differential Equations with Delay.* Adam Hilger.

[5] Agarwal, R.P., Bohner, M., Li, T., & Zhang, C. (2013). A new approach in the study of oscillatory behavior of even-order neutral delay differential equations. *Appl. Math. Comput, 225,* 787–794.

[6] Triana, C.A., & Fajardo, F. (2013). Experimental study of simple harmonic motion of a spring-mass system as a function of spring diameter. *Revista Brasileira de Ensino de Física, 35*(4), 4305.

[7] Saker, S. (2010). *Oscillation Theory of Delay Differential and Difference Equations: Second and Third Orders.* LAP Lambert Academic Publishing.

[8] Triana, C.A., & Fajardo, F. (2013). Experimental study of simple harmonic motion of a spring-mass system as a function of spring diameter. *Revista Brasileira de Ensino de Física, 35*(4), 4305.

[9] French, A.P. (1964). *Vibrations and Waves.* Norton.

[10] Donald, J. Z., Skwame, Y., Sabo, J., & Ayinde, A. M. (2021). The use of linear multistep method on implicit one-step second derivative block method for direct solution of higher order initial value problems. *Abacus (Mathematics Science Series), 48*(2), 224-237.

[11] Fatunla, S.O. (1980). Numerical integrators for stiff and highly oscillatory differential equations. *Math Comput., 34,* 373-390.

[12] Skwame, Y., Bakari, A. I., & Sunday, J. (2017). Computational method for the determination of forced motions in mass-spring systems. *Asian Research Journal of Mathematics, 3*(1), 1-12.

[13] Sabo, J., Kyagya, T. Y., & Vashawa, W. J. (2021). Numerical simulation of one step block method for treatment of second order forced motions in mass spring systems. *Asian Journal of Research and Reviews in Physics, 5*(2), 1-11.

[14] Omole, E. A., & Ogunware, B. G. (2018). 3-point single hybrid block method (3PSHBM) for direct solution of general second order initial value problem of ordinary differential equations. *Journal of Scientific Research & Reports, 20*(3), 1-11.

[15] Olanegan, O. O., Ogunware, B. G., & Alakofa, C. O. (2018). Implicit hybrid points approach for solving general second order ordinary differential equations with initial values. *Journal of Advances in Mathematics and Computer Science, 27*(3), 1-14.

[16] Kwari, L. J., Sunday, J., Ndam, J. N., Shokri, A., & Wang, Y. (2023). On the simulations of second-order oscillatory problems with applications to physical systems. *Axioms, 12,* 9, 10. https://doi.org/10.3390/axioms12030282

[17] Arevalo, C., Soderlind, G., Hadjimichael, Y., & Fekete, I. (2021). Local error estimation and step size control in adaptative linear multistep methods. *Numer. Algorithms, 86,* 537-563.

[18] Sabo, J. (2021). Single step block hybrid methods for direct solution of higher order initial value problems. *M.Sc. Thesis, Adamawa State University, Mubi-Nigeria.* (Unpublished), 5-11.

[19] Areo, E. A., & Rufai, M. A. (2016). An efficient one-eight step hybrid block method for solving second order initial value problems of ODEs. *International Journal of Differential Equation and Application, 15*(2), 117-139.

[20] Skwame, Y., Donald, J. Z., Kyagya, T. Y., Sabo, J., & Bambur, A. A. (2020). The numerical applications of implicit second derivative on second order initial value problems of ordinary differential equations. *Dutse Journal of Pure and Applied Sciences, 6*(4), 1-14.

[21] Lydia, J. K., Joshua S. Ndam J. N., & James, A. A. (2021). On the numerical approximations and simulations of damped and undamped duffing oscillators. *Science Forum (Journal of Pure and Applied Science), 21,* 503-515.

[22] Olabode, B. T., & Momoh, A. L. (2016). Continuous hybrid multistep methods with Legendre basic function for treatment of second order stiff ODEs. *American Journal of Computational and Applied Mathematics, 6*(2), 38-49.

[23] Jator, S. N., & Li. (2009). A self-starting linear multistep method for the direct solution of a general second order initial value problem. *International Journal of Computer Math, 86*(5), 817-836.

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp. 561–575, November 13-16, 2023

A Continuous Hybrid Scheme for Initial Value Problem of Third Order Ordinary Differential Equations.

F. L. Joseph[1] and SAMUEL, Busayo Oluwafemi[2]
{folakelois@gmail.com, samuel.busayo@uniabuja.edu.ng}
Department of Mathematical Sciences, Bingham University, Karu,
Nasarawa State[1], Nigeria and University of Abuja, Abuja, Nigeria[2]

Abstract
In this work, we focus on development of solution for initial value problems of third order ordinary differential equations using a new class of constructed orthogonal polynomial of weight function $w(x) = x$ valid in the interval [0,1],as basis function for the development of continuous hybrid scheme in a collocation and interpolation technique. The method was analyzed to investigate the basic properties, from the findings it shows that the method is accurate and convergent. Three examples were solved, the results obtained when compared with existing method are favourable.

Keyword: Orthogonal polynomial, Hybrid, Interpolation, Collocation, Block Method

1 Introduction

Initial Value Problems (IVPs) of third order ordinary differential equations (ODEs) of the form

$$y''' = f(x, y, y', y''); y(a) = \alpha, y'(a) = \beta, y''(a) = \gamma \quad (1)$$

where f is continuous in $[a, b]$ arises in many area of physical problems.
Some of these problems have no analytical solution, thereby numerical schemes are developed to solve the problems. Milne (1953), proposed Block method for ODEs. Many researchers used different orthogonal polynomials as the basis function to solve the problems numerically. Chebyshev orthogonal polynomial was used by Lancsos(1983)also Tanner (1979) and Dahlguist (1979). Adeniyi, Alabi and Folaranmi (2008), Adeyefa, Akinola, Folaranmi and Owolabi (2016), Joseph, Adeniyi and Adeyefa(2018), all of these researchers constructed orthogonal polynomials in certain interval for different weight functions. In this work, an orthogonal polynomial constructed for the interval [0,1] with respect to the weight function $w(x) = x$ is adopted to solve third order ODEs for the Initial Value Problem (1).

2 Construction of Orthogonal Polynomials

Let $\{\phi_n(x)\}$ be a class of orthogonal polynomials defined by

$$\phi_n(x) = \sum_{r=0}^{n} C_r^{(n)} x^r \quad (2)$$

The required conditions are as follows:

$$\phi_n(1) = 1 \quad (3)$$

$$< \phi_m(x), \phi_n(x) > = 0, \; m \neq n \quad (4)$$

This class of orthogonal polynomials valid in the interval [0,1] and weight function

$$w(x) = x.$$

Let $w(x) = x$ and $[a, b] = [0,1]$ in (2) - (4).
when $n = 0$, we have

$\phi_0(x) = C_0^{(0)}$ and
$\phi_0(1) = 1 = C_0^{(0)}$ giving $\phi_0(x) = 1$
For $n = 1$, we have

$$\phi_1(x) = C_0^{(1)} + C_1^{(1)}x$$
$$\therefore\ \phi_1(1) = C_0^{(1)} + C_1^{(1)} = 1 \tag{5}$$
$$\langle \phi_0(x), \phi_1(x) \rangle = \int_0^1 x\left(C_0^{(1)} + C_1^{(1)}x\right)dx = 0$$

That is,

$$\frac{1}{2}C_0^{(1)} + \frac{1}{3}C_1^{(1)} = 0 \tag{6}$$

The solution of (5)-(6) yields

$$C_0^{(1)} = -2,\ C_1^{(1)} = 3$$

Hence,
$\phi_1(x) = -2 + 3x$ or $\phi_1(x) = 3x - 2$
For $n = 2$, we have

$$\phi_2(x) = C_0^{(2)} + C_1^{(2)}x + C_2^{(2)}x^2$$
$$\therefore\ \phi_2(1) = C_0^{(2)} + C_1^{(2)} + C_2^{(2)} = 1 \tag{7}$$
$$< \phi_0(x), \phi_2(x) >= \frac{1}{2}C_0^{(2)} + \frac{1}{3}C_1^{(2)} + \frac{1}{4}C_2^{(2)} = 0 \tag{8}$$
$$< \phi_0(x), \phi_2(x) >= \frac{1}{12}C_1^{(2)} + \frac{1}{10}C_2^{(2)} = 0 \tag{9}$$

From these equations, we get

$$C_0^{(2)} = 3,\ C_1^{(2)} = -12,\ C_2^{(2)} = 10$$

Hence,

$$\phi_2(x) = 3 - 12x + 10x^2$$

Similarly, we obtain more polynomials to give the following collection:

$$\begin{aligned}
\phi_0(x) &= 1 \\
\phi_1(x) &= 3x - 2 \\
\phi_2(x) &= 10x^2 - 12x + 3 \\
\phi_3(x) &= 35x^3 - 60x^2 + 30x - 4 \\
\phi_4(x) &= 126x^4 - 280x^3 + 210x^2 - 60x + 5 \\
\phi_5(x) &= 462x^5 - 1260x^4 + 1260x^3 - 560x^2 + 105x - 6 \\
\phi_6(x) &= 1716x^6 - 5544x^5 + 6930x^4 - 4200x^3 + 1260x^2 - 168x + 7 \\
\phi_7(x) &= 6435x^7 - 24024x^6 + 36036x^5 + 27720x^4 + 11550x^3 - 2520x^2 + 252
\end{aligned} \tag{10}$$

2.1 Two-step Method with $x_{n+\frac{2}{3}}$ as the Off-step Point

The analytical solution of (1) is approximated via experimental solution of the form:

$$Y(x) = \sum_{j=0}^{r+s-1} a_j \phi_j(x) \tag{11}$$

where $x \in [a, b], r$ and s are the number of collocation and interpolation points respectively. The function $\phi_j(x)$ is the j^{th} degree orthogonal polynomial valid in the range of integration of $[a, b]$. The third derivative of (11) is given by

$$y'''(x) = \sum_{j=0}^{r+s-1} a_j \phi_j'''(x) = f(x, y, y', y'') \tag{12}$$

To estimate the solution of problem (1), we interpolation at least three times. Equation (11) is interpolated at $(xn + s)$ points, and equation (12) is collocated at $(xn + r)$ points, yielding a system of equations to be solved using the Gaussian elimination method.

We will use hybrid approach to apply this concept.

Here, let $x_{n+\frac{2}{3}}$ be the off-step point. Equation (11) is interpolated at $x = x_{n+s}, s = 0, \frac{2}{3}$ and 1; (12) is collocated at $x = x_{n+r}, r = 0, \frac{2}{3} 1$ and 2. This leads to the system of equations:

$$\begin{bmatrix} 1 & -5 & 25 & -129 & 681 & -3653 & 19825 \\ 1 & -3 & \frac{73}{9} & \frac{-593}{27} & \frac{1627}{27} & \frac{-13555}{81} & \frac{11732}{25} \\ 1 & -2 & 3 & -4 & 5 & -6 & 7 \\ 0 & 0 & 0 & 210 & -4704 & 65520 & -730080 \\ 0 & 0 & 0 & 210 & -2688 & 20720 & \frac{-375680}{3} \\ 0 & 0 & 0 & 210 & -1680 & 7560 & -25200 \\ 0 & 0 & 0 & 210 & 1344 & 5040 & 14400 \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \\ a_5 \\ a_6 \\ a_7 \end{bmatrix} = \begin{bmatrix} y_n \\ y_{n+\frac{2}{3}} \\ y_{n+1} \\ h^3 f_n \\ h^3 f_{n+\frac{2}{3}} \\ h^3 f_{n+1} \\ h^3 f_{n+2} \end{bmatrix} \tag{13}$$

Solving system (12) to obtain the values of the unknown parameters $a_j, j = 0(1)6$ yielded:

$$\begin{aligned}
a_0 &= \frac{13}{12} y_n - \frac{21}{4} y_{n+\frac{2}{3}} + \frac{31}{6} y_{n+1} + \frac{56h^3}{6051} f_n + \frac{173h^3}{2366} f_{n+\frac{2}{3}} + \frac{593h^3}{4656} f_{n+1} + \frac{35h^3}{6892} f \\
a_1 &= \frac{23}{30} y_n - \frac{33}{10} y_{n+\frac{2}{3}} + \frac{38}{15} y_{n+1} + \frac{27h^3}{3238} f_n + \frac{173h^3}{4746} f_{n+\frac{2}{3}} + \frac{227h^3}{1843} f_{n+1} + \frac{53h^3}{8667} f \\
a_2 &= \frac{3}{20} y_n - \frac{9}{20} y_{n+\frac{2}{3}} + \frac{3}{10} y_{n+1} + \frac{110h^3}{33159} f_n - \frac{34h^3}{4863} f_{n+\frac{2}{3}} + \frac{31h^3}{613} f_{n+1} + \frac{13h^3}{3336} f_n \\
a_3 &= h^3 \left(\frac{29}{41580} f_n - \frac{17}{3080} f_{n+\frac{2}{3}} + \frac{4}{495} f_{n+1} + \frac{25}{16632} f_{n+2} \right) \\
a_4 &= h^3 \left(\frac{1}{38016} f_n - \frac{1}{19712} f_{n+\frac{2}{3}} - \frac{1}{3168} f_{n+1} + \frac{13}{38226} f_{n+2} \right) \\
a_5 &= -h^3 \left(\frac{6}{23374} f_n - \frac{9}{45760} f_{n+\frac{2}{3}} + \frac{19}{90090} f_{n+1} - \frac{1}{250685} f_{n+2} \right) \\
a_6 &= -h^3 \left(\frac{1}{274560} f_n - \frac{3}{183040} f_{n+\frac{2}{3}} + \frac{1}{68640} f_{n+1} - \frac{1}{549120} f_{n+2} \right)
\end{aligned} \tag{14}$$

Substituting (14) in (11) gives a continuous implicit two-step method in the form

$$\bar{y}(x) = \sum_{j=0}^{1} \alpha_j(x) y_{n+j} + \alpha_{\frac{2}{3}}(x) y_{n+\frac{2}{3}} + h^3 \left(\sum_{j=0}^{2} \beta_j(x) f_{n+j} + \beta_{\frac{2}{3}}(x) f_{n+\frac{2}{3}} \right) \tag{15}$$

where $\alpha_j(x)$ and $\beta_j(x)$ are continuous coefficients. From (15) the parameters $\alpha_j(x)$ and $\beta_j(x)$ are given by:

$$
\begin{aligned}
\alpha_0(t) &= \frac{3}{2}t^2+\frac{t}{2}\\
\alpha_{\frac{2}{3}}(t) &= -\frac{9t^2}{2}-\frac{9t}{2}\\
\alpha_1(t) &= 3t^2+4t+1\\
\beta_0(t) &= -h^3\left(\frac{t^6}{160}-\frac{t^5}{120}-\frac{t^4}{96}+\frac{t^3}{235058424339189180}\right.\\
&\quad \left.-\frac{43t^2}{6480}-\frac{2260t}{915301}+\frac{1}{300349807825007740}\right)\\
\beta_{\frac{2}{3}}(t) &= h^3\left(\frac{9t^6}{320}+\frac{t^5}{12688236664456307}-\frac{9t^4}{64}+\frac{16748472397082323}{163}+\frac{29t^2}{180}-\right.\\
&\quad \left.+\frac{11866908084007885}{14}\right)\\
\beta_1(t) &= -h^3\left(\frac{t^6}{40}-\frac{t^5}{60}-\frac{t^4}{8}+\frac{t^3}{6}-\frac{22t^2}{405}-\frac{247t}{57163}+\frac{t^3}{30264189495929732}\right)\\
\beta_2(t) &= h^3\left(\frac{t^6}{320}+\frac{t^5}{120}+\frac{t^4}{192}-\frac{1}{3695570313586332200}\right.\\
&\quad \left.+\frac{18t^2}{116639}+\frac{18t}{116639}-\frac{1}{373665233501228290}\right)
\end{aligned}
\tag{16}
$$

By evaluating (15) at x_{n+2}, the main method is obtained as

$$
\begin{aligned}
y_{n+2} &= 2y_n-9y_{n+\frac{2}{3}}+8y_{n+1}\\
&\quad +h^3\left(\frac{7}{324}f_n+\frac{7}{72}f_{n+\frac{2}{3}}+\frac{25}{81}f_{n+1}+\frac{11}{648}f_{n+2}\right)
\end{aligned}
\tag{17}
$$

Differentiate (15), to get the continuous coefficients:

$$
\left.
\begin{aligned}
\alpha_0'(t) &= \frac{3t+\frac{1}{2}}{h}\\
\alpha_{\frac{2}{3}}(t) &= \frac{-\left(9t+\frac{9}{2}\right)}{h}\\
\alpha_1'(t) &= \frac{(6t+4)}{h}\\
\beta_0'(t) &= -h^2\left(\frac{3t^5}{80}-\frac{t^4}{24}-\frac{t^3}{24}+\frac{t^2}{78352808113063056}-\frac{43t}{3240}-\frac{2260}{9153301}\right)\\
\beta_{\frac{2}{3}}'(t) &= h^2\left(\frac{27t^5}{760}+\frac{t^4}{24}-\frac{9t^3}{16}+\frac{29t}{558282412360774700}+\frac{7}{90}+\frac{7}{144}\right)\\
\beta_1'(t) &= h^2\left(\frac{-(3t^5)}{20}-\frac{t^4}{12}+\frac{t^3}{2}+\frac{t^2}{2}+\frac{2201759380413025t}{20266198323167232}+\frac{9121851463349}{9153301}\right)\\
\beta_2'(t) &= h^2\left(\frac{3t^5}{160}+\frac{t^4}{24}+\frac{t^3}{48}-\frac{t^2}{1231856771195444}+\frac{35t}{113399}+\frac{18}{116639}\right)
\end{aligned}
\right\}
\tag{18}
$$

The second derivatives of continuous functions (15) yield the following coefficient

$$\begin{aligned}
\alpha_0''(t) &= \frac{3}{h^2} \\
\alpha_{\frac{2}{3}}''(t) &= \frac{-9}{h^2} \\
\alpha_1''(t) &= \frac{6}{h^2} \\
\beta_0''(t) &= -h\left(\frac{3t^4}{16} - \frac{t^3}{6} - \frac{t^2}{8} + \frac{t}{39176404056531528} - \frac{43}{3240}\right) \\
\beta_{\frac{2}{3}}''(t) &= h\left(\frac{27t^4}{32} + \frac{t^3}{634411833222815230} - \frac{27t^2}{16} + \frac{t}{2791412066180387300} + \frac{2}{9}\right. \\
\beta_1''(t) &= -h\left(\frac{3t^4}{4} - \frac{t^3}{3} + \frac{3t^2}{2} + t + \frac{44}{405}\right) \\
\beta_2''(t) &= h\left(\frac{3t^4}{32} + \frac{t^3}{6} + \frac{t^2}{16} - \frac{t}{615928385597721980} + \frac{35}{113399}\right)
\end{aligned} \tag{19}$$

The additional methods to be coupled with the main method (17) are obtained by evaluating the first and second derivatives of (15) at x_n, $x_{n+\frac{2}{3}}$, x_{n+1} and x_{n+2} respectively to obtain:

$$\begin{aligned}
&hy_n' + \frac{5}{2}y_n - \frac{9}{2}y_{n+\frac{2}{3}} + 2y_{n+1} \\
&\qquad = h^3\left(\frac{173f_n}{6480} + \frac{173f_{n+\frac{2}{3}}}{1440} - \frac{61f_{n+1}}{1620} + \frac{5f_{n+2}}{2592}\right)
\end{aligned} \tag{20}$$

$$\begin{aligned}
&hy'_{n+\frac{2}{3}} + \frac{y_n}{2} + \frac{3}{2}y_{n+\frac{2}{3}} - 2y_{n+1} \\
&\qquad = h^3\left(\frac{-11f_n}{3888} - \frac{167f_{n+\frac{2}{3}}}{4320} - \frac{23f_{n+1}}{4860} - \frac{29f_{n+2}}{102502}\right)
\end{aligned} \tag{21}$$

$$\begin{aligned}
&hy'_{n+1} - \frac{y_n}{2} + \frac{9}{2}y_{n+\frac{2}{3}} - 4y_{n+1} \\
&\qquad = h^3\left(\frac{2260f_n}{915301} + \frac{7f_{n+\frac{2}{3}}}{144} + \frac{247f_{n+1}}{57163} + \frac{18f_{n+2}}{116639}\right)
\end{aligned} \tag{22}$$

$$\begin{aligned}
&hy'_{n+2} - \frac{7}{2}y_n + \frac{27}{2}y_{n+\frac{2}{3}} - 10y_{n+1} \\
&\qquad = h^3\left(\frac{133f_n}{2160} - \frac{1312f_{n+\frac{2}{3}}}{57251} + \frac{95f_{n+1}}{108} + \frac{353f_{n+2}}{4320}\right)
\end{aligned} \tag{23}$$

$$\begin{aligned}
&h^2y_n'' - 3y_n + 9y_{n+\frac{2}{3}} - 6y_{n+1} \\
&\qquad = h^3\left(-\frac{527f_n}{2441} - \frac{751f_{n+\frac{2}{3}}}{1440} + \frac{311f_{n+1}}{1620} - \frac{131f_{n+2}}{12960}\right)
\end{aligned} \tag{24}$$

$$h^2 y''_{n+\frac{2}{3}} - 3y_n + 9y_{n+\frac{2}{3}} - 6y_{n+1} = h^3\left(\frac{121f_n}{6480} + \frac{209f_{n+\frac{2}{3}}}{1440} - \frac{89f_{n+1}}{1620} + \frac{77f_{n+2}}{34411}\right) \quad (25)$$

$$h^2 y''_{n+1} - 3y_n + 9y_{n+\frac{2}{3}} - 6y_{n+1} = h^3\left(\frac{43f_n}{3240} + \frac{29f_{n+\frac{2}{3}}}{90} + \frac{44f_{n+1}}{405} + \frac{35f_{n+2}}{113399}\right) \quad (26)$$

$$h^2 y''_{n+2} - 3y_n + 9y_{n+\frac{2}{3}} - 6y_{n+1} = h^3\left(\frac{761f_n}{6480} - \frac{751f_{n+\frac{2}{3}}}{1440} - \frac{1115f_{n+1}}{731} + \frac{469f_{n+2}}{1451}\right) \quad (27)$$

Equations (17) and (20) - (27) are solved using Shampine and Watts (1969) block formula defined as

$$Ay_m = hBF(y_m) + E_{y_n} + hDf_n \quad (28)$$

$$A = \begin{pmatrix} 9 & -8 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ -\frac{9}{2} & 2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \frac{3}{2} & -2 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ \frac{9}{2} & -4 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ \frac{27}{2} & -10 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 9 & -6 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 9 & -6 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 9 & -6 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 9 & -6 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix} B$$

$$= \begin{pmatrix} 7/72 & 25/81 & 11/648 \\ 173/1440 & -61/1620 & 5/2592 \\ -167/4320 & 23/4860 & -29/102502 \\ 7/144 & 247/57163 & 18/116639 \\ -1312/57251 & 95/108 & 353/4320 \\ -751/1440 & 311/1620 & -131/12960 \\ 209/1440 & -89/1620 & 77/34411 \\ 29/90 & 44/405 & 35/113399 \\ -751/1440 & 1115/731 & 469/1451 \end{pmatrix}$$

$$D = \begin{pmatrix} 7/324 \\ 173/6480 \\ -11/3888 \\ 2260/915301 \\ 133/2160 \\ -527/2441 \\ 121/6480 \\ 43/3240 \\ 761/6480 \end{pmatrix} \quad E = \begin{pmatrix} 2 & 0 & 0 \\ -5/2 & -1 & 0 \\ -1/2 & 0 & 0 \\ 1/2 & 0 & 0 \\ 7/2 & 0 & 0 \\ 3 & 0 & -1 \\ 3 & 0 & 0 \\ 3 & 0 & 0 \\ 3 & 0 & 0 \end{pmatrix}$$

Substituting A, B, D and E into equation (28) the following equations are obtained:

$$y_{n+\frac{2}{3}} = y_n + \frac{2}{3}y'_n + \frac{2}{9}y''_n + \frac{22}{729}f_n + \frac{29}{810}f_{n+\frac{2}{3}} - \frac{64}{3645}f_{n+1} + \frac{7}{7290}f_{n+2} \quad (29)$$

$$y_{n+1} = y_n + y'_n + \frac{1}{2}y''_n + \frac{13}{160}f_n + \frac{9}{64}f_{n+\frac{2}{3}} - \frac{7}{120}f_{n+1} + \frac{1}{320}f_{n+2} \quad (30)$$

$$y_{n+2} = y_n + 2y'_n + 2y''_n + \frac{2}{5}f_n + \frac{9}{10}f_{n+\frac{2}{3}} + \frac{1}{30}f_{n+2} \quad (31)$$

$$y'_{n+\frac{2}{3}} = y'_n + \frac{2}{3}y''_n + \frac{139}{1215}f_n + \frac{17}{90}f_{n+\frac{2}{3}} - \frac{104}{1215}f_{n+1} + \frac{11}{2430}f_{n+2} \quad (32)$$

$$y'_{n+1} = y'_n + y''_n + \frac{23}{120}f_n + \frac{9}{20}f_{n+\frac{2}{3}} - \frac{3}{20}f_{n+1} + \frac{1}{120}f_{n+2} \quad (33)$$

$$y'_{n+2} = y'_n + 2y''_n + \frac{7}{15}f_n + \frac{9}{10}f_{n+\frac{2}{3}} + \frac{8}{15}f_{n+1} + \frac{1}{10}f_{n+2} \quad (34)$$

$$y''_{n+\frac{2}{3}} = y''_n + \frac{19}{81}f_n + \frac{2}{3}f_{n+\frac{2}{3}} - \frac{20}{81}f_{n+1} + \frac{1}{81}f_{n+2} \quad (35)$$

$$y''_{n+1} = y''_n + \frac{11}{48}f_n + \frac{27}{32}f_{n+\frac{2}{3}} - \frac{1}{12}f_{n+1} + \frac{1}{96}f_{n+2} \quad (36)$$

$$y''_{n+2} = y''_n + \frac{1}{3}f_n + \frac{4}{3}f_{n+1} + \frac{1}{3}f_{n+2} \quad (37)$$

2.2 Analysis of the Methods

The basic properties are order, error constant, zero stability and consistency.

The main methods derived are discrete schemes belonging to the class of LMMs of the form:

$$\sum_{j=0}^{k} \alpha_j y_{n+j} = h^3 \sum_{j=0}^{k} \beta_j f_{n+j} \quad (38)$$

Following Futunla (1988) and Lambert (1973), we define the Local Truncation Error (LTE) associated with (38) by difference operator;

$$L[y(x):h] = \sum_{j=0}^{k} \left[\alpha_j y(x_n + jh) - h^3 \beta_j f(x_n + jh)\right] \quad (39)$$

where $y(x)$ is an arbitrary function, continuously differentiable on $[a, b]$. Expanding (3) in Taylor's Series about the point x, we obtain the expression

$$L[y(x):h] = c_o y(x) + c_1 h y'(x) + \cdots c_{p+3} h^{p+3} y^{p+3}(x) \quad (40)$$

where the $c_o, c_1, c_2 \ldots c_p \ldots c_{p+3}$ are obtained

$$c_0 = \sum_{j=0}^{k} \alpha_j \tag{41}$$

$$c_1 = \sum_{j=1}^{k} j\alpha_j \tag{42}$$

$$c_3 = \frac{1}{3!}\sum_{j=1}^{k} j^3\alpha_j \tag{43}$$

$$c_q = \frac{1}{q!}\left[\sum_{j=1}^{k} j^q\alpha_j - q(q-1)(q-2)(q-3)\sum_{j=1}^{k} \beta_j j^{q-3}\right] \tag{44}$$

In the sense of Lambert (1973), equation (38) is of order p if $c_o = c_1 = c_2 = c_2 = \cdots c_p = c_{p+1} = c_{p+2} = 0$ and $c_{p+3} \neq 0$. The $c_{p+3} \neq 0$ is called the error constant and $c_{\mathrm{p+3}}h^{\mathrm{p+3}}y^{\mathrm{p+3}}(x_n)$ is the Principal Local truncation error at the point x_n. The equation (17) is of order $\mathrm{p} = 4$ and error constants $C_{p+3} = -\frac{31}{29160}$

2.2.1 Zero stability

The LMM (1) is said to be Zero-stable if no root of the first characteristic polynomial $\rho(R)$ has modulus greater than one and if and only if every root of modulus one has multiplicity not greater than the order of the differential equation.

2.2.2 Consistency

The LMM is said to be consistent if it has order $p \geq 1$ and the first and second characteristic polynomials which are defined respectively, as

$$\rho(z) = \sum_{j=0}^{k} \alpha_j z^j \tag{45}$$

and

$$\sigma(z) = \sum_{j=0}^{k} \beta_j z^j \tag{46}$$

where z is the principal root, satisfy the following conditions:

$$\sum_{j=0}^{k} \alpha_j = 0 \tag{47}$$

$$\rho(1) = \rho'(1) = 0 \tag{48}$$

And

$$\rho'''(1) = 3 \cdot \sigma(1) \tag{49}$$

(Henrichi, 1962)

The scheme (18) is of order $\rho = 4 > 1$ and they have been investigated to satisfy conditions (I)-(III) of Definition (47) -(49). Hence, the scheme is consistent.

2.2.3 Convergence

According to the theorem of Dahlguist, the necessary and sufficient condition for an LMM to be convergent, is that, it is consistent and zero-stable.
The methods satisfy the two conditions stated in Definition (47) $-(49)$ and hence the method is convergent.

2.2.4 Zero stability of the Method.

To analyze the Zero-stability of the method, equations (29)-(37) is represented in block form below:

$$A^0 y_m = hBF(y_m) + A' y_n hDf_n$$

where h is a fixed mesh size within a block.
The zero stability of equations (29)-(37) gives

$$A^0 = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$A^r = \begin{bmatrix} 0 & 0 & 1 \\ 0 & 0 & 1 \\ 0 & 0 & 1 \end{bmatrix}$$

$$B = \begin{bmatrix} 29/810 & -64/3645 & 7/7290 \\ 9/64 & -7/120 & 1/320 \\ 9/10 & 0 & 1/30 \end{bmatrix}$$

$$D = \begin{bmatrix} 0 & 0 & 22/729 \\ 0 & 0 & 13/160 \\ 0 & 0 & 2/5 \end{bmatrix}$$

The first characteristic polynomial of the block hybrid method is given by

$$\rho(R) = \det\left(RA^0 - A'\right) \tag{50}$$

Substituting A^0 and A' in equation (50) and solving for R, the values of R are obtained as 0 and 1.
According to Fatunla (1988,1991), the block method equations (29)-(37) are zero-stable, since from (50), $\rho(R) = 0$, satisfy $|R_j| \leq 1, j = 1$ and for those roots with $|R_j| = 1$, the multiplicity does not exceed three.

2.3 Region of Absolute Stability (RAS)

For the Two-step with Off-step Point $\frac{2}{3}$, we have

$$y_{n+2} + 9y_{n+\frac{2}{3}} - 8y_{n+1} - 2y_n = \frac{h^3}{648}\left(14f_n + 63f_{n+\frac{3}{3}} + 200f_{n+1} + 11f_{n+2}\right)$$

$$\bar{h}(z) = \frac{648\left(z^2 + 9z^{\frac{2}{3}} - 8z - 2\right)}{63z^{\frac{2}{3}} + 200z + 11z^2 + 14}$$

$$\bar{h}(\theta) = \frac{648e^{i2\theta} + 9e^{i\frac{2}{3}\theta} - 8e^{i\theta} - 2}{11e^{i2\theta} + 63e^{i\frac{2}{3}\theta} + 200e^{i\theta} + 14}$$

The RAS is shown in the figure below

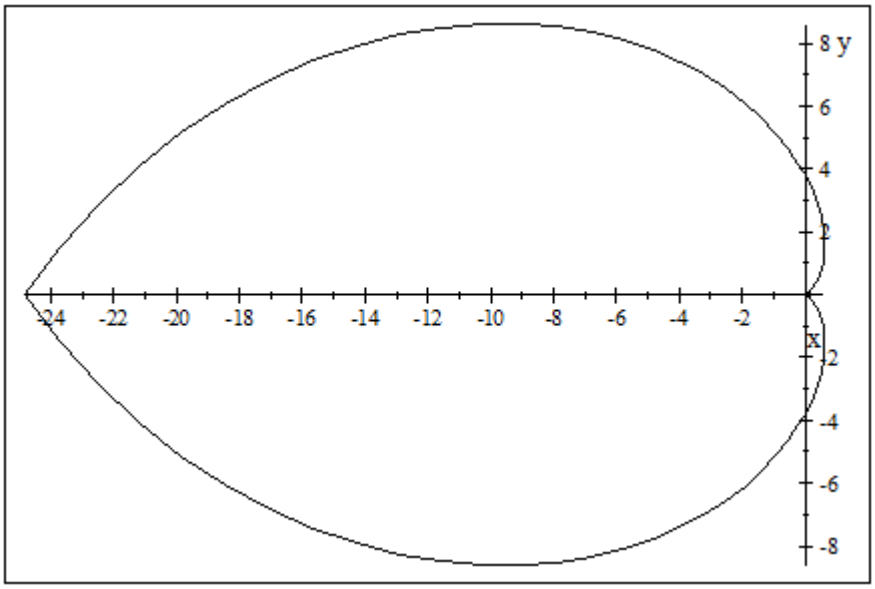


Figure 1: Region of Absolute Stability for Two-step with Off-step Point $\frac{2}{3}$

3 Application of the Method

Three problems characterized by different features will be considered in this section.

Problem 1
The highly nonlinear problem

$$y''' + e^{-y} - 3e^{-2y} + 2e^{-3y} = 0$$
$$y(0) = \ln\ 2, y'(0) = \frac{1}{2}, y''(0) = \frac{1}{4}$$

sourced from Muhammed (2016) whose analytic solution is

$$y(x) = \ln\ (e^x + 1)$$

was considered with $h = 0.1$,

Problem 2
The nonlinear application problem called Blasius Equation

$$2y''' + yy'' = 0$$
$$y(0) = 0,\ y'(0) = 0,\ y''(0) = 1$$

and sourced from Adesanya et al (2014) was solved here with $h = 0.1$.

Problem 3
An Application Problem (Nonlinear Genesio Equation)
Considered, the nonlinear chaotic system from Genesio and Tesi (1992)

$$x''''(t) + Ax''(t) + Bx'(t) = x^2(t) - Cx(t)$$
$$x(0) = 0.2,\ x'(0) = -0.3,\ x^n(0) = 0.1,\ t \in [0,1]$$

where $A = 1.2, B = 2.29$ and $C = 6$ are positive constants that satisfied $AB < C$ for the existence of the solution.

3 Tables of Results

Table 1: Results for Problem 1

x	Exact solution	Two-steps with $v = \frac{2}{3}$
0.1	0.744396660073572	0.744396660068558
0.2	0.798138869381592	0.798138869344556
0.3	0.854355244468526	0.854355244286741
0.4	0.913015252399952	0.913015251874836
0.5	0.974076984180107	0.974076982907236
0.6	1.037487950485890	1.037487947917230
0.7	1.103186048885460	1.103186044201130
0.8	1.171100665947780	1.171100658162400
0.9	1.241153874732090	1.241153862586050
1.0	1.313261686336555	1.313261669600100

Table 2: Results for Problem 2

x	Analytical solution	two-step method with $v = \frac{2}{3}$
0.1	0.0049999551874560	0.004999958347116
0.2	0.0199986590802381	0.019998666938153
0.3	0.04498987410259470	0.044989879952218
0.4	0.0799573773516761	0.079957379380653
0.5	0.1248700476465370	0.124870060961250
0.6	0.179677126361217	0.179677148374987
0.7	0.2443036129003850	0.244303630177998
0.8	0.3186459794646740	0.318646031552947
0.9	0.4025686062131340	0.402568655792802
10	0.4959003376293370	0.495900435482723

Table 3: Results for Problem 3

X	Analytical solution	two-step method with $v = \frac{2}{3}$ as the Off-step point
0.1	0.170440346269364	0.170440346869070
0.2	0.141582173138664	0.141582171130925
0.3	0.113282963581607	0.113282958227538
0.4	0.085554524922736	0.085554520377859
0.5	0.058543682864593	0.058543674213629
0.6	0.032510877478247	0.032510862344549
0.7	0.007806854082744	0.007806836744866
0.8	−0.015152336804258	−0.015152348568936
0.9	−0.035911645118586	−0.035911639463907
10	−0.054004107797261	−0.054004072464382

4 Tables of Errors

Table 4: Error for Problem 1

x	Error in Anake (2013)	Two-steps $v = \frac{2}{3}$
0.1	1.608800×10^{-9}	5.014000×10^{-12}
0.2	1.038700×10^{-8}	3.703600×10^{-11}
0.3	2.957200×10^{-8}	1.817850×10^{-10}
0.4	2.314700×10^{-7}	5.251160×10^{-10}
0.5	4.542000×10^{-7}	1.272871×10^{-9}
0.6	1.474600×10^{-6}	2.568660×10^{-9}
0.7	2.873400×10^{-6}	4.684330×10^{-9}
0.8	4.682600×10^{-6}	7.785380×10^{-9}
0.9	6.921700×10^{-6}	1.214604×10^{-8}
1.0	9.597400×10^{-6}	1.673646×10^{-8}

Tables of Errors

Table 5: Error for Problem 2

X	Two-steps with $v = \frac{2}{3}$	Error in Anake Block Algorithm
0.1	$3.159660000 \times 10^{-9}$	4.2730000×10^{-8}
0.2	$7.8579149000 \times 10^{-9}$	1.2075900×10^{-6}
0.3	$5.849623300 \times 10^{-9}$	8.6071900×10^{-6}
0.4	$2.028976900 \times 10^{-9}$	$3.40900400 \times 10^{-5}$
0.5	$1.331471300 \times 10^{-8}$	9.7406800×10^{-5}
0.6	$2.201377000 \times 10^{-8}$	2.2571100×10^{-4}
0.7	$1.727761300 \times 10^{-8}$	4.5145470×10^{-4}
0.8	$5.208827300 \times 10^{-8}$	8.084729×10^{-4}
0.9	$4.9579668000 \times 10^{-8}$	1.3262207×10^{-3}
1.0	$9.785338600 \times 10^{-8}$	2.0220546×10^{-3}

Table 6: Error for Problem 3

x	Two-steps with $v = \frac{2}{3}$
0.1	$5.99706000 \times 10^{-10}$
0.2	$2.007739000 \times 10^{-9}$
0.3	$5.35406900 \times 10^{-9}$
0.4	$4.544877000 \times 10^{-9}$
0.5	$8.650964000 \times 10^{-9}$
0.6	$1.513369800 \times 10^{-8}$
0.7	$1.7337878000 \times 10^{-8}$
0.8	$1.176467800 \times 10^{-8}$

0.9	$5.654679000 \times 10^{-9}$
1.0	$3.533287900 \times 10^{-8}$

4 Conclusion

Continuous hybrid scheme with off point was used with constructed orthogonal polynomials as basis function, developed through a collocation and interpolation technique. These method by analysis, were shown to be consistent and zero stable and hence convergent. Three selected problems have been considered to test the effectiveness and accuracy of the method. It is obvious from our table of results that the method is accurate and effective since the approximation closely estimate the analytic solution.

References

[1] Adeniyi, R. B., Alabi, M. O., Folaranmi, R. O. (2008). A Chebyshev Collocation Approach for a Continuous Formulation of Hybrid Methods for Initial Value Problems in Ordinary Differential Equations. Journal of Nigerian Association of Mathematical Physics, 12(1), 369-398.

[2] Adesanya, A. O., Anake, T. A., Oghoyon, G. J. (2009). Continuous Implicit Method for the solution of General Second Ordinary Differential Equations. Journal of Nigerian Association of Mathematical Physics, 15(1), 71-78.

[3] Adeyefa, E. O. (2014). A Collocation Approach for Continuous Hybrid Block Methods for Second Order Ordinary Differential Equations with Chebyshev Basis Function. Unpublished doctoral dissertation, University of Ilorin, Ilorin.

[4] Anake, T. A. (2011). Continuous Implicit Hybrid One-step methods for the Solution of Initial Value Problems of General Second Order Ordinary Differential Equations. Unpublished doctoral dissertation, Covenant University, Ota, Nigeria.

[5] Areo, E. A. (2013). A Self-Starting Linear Multistep Method for Direct Solution of Initial Value Problem of Second Order Ordinary Differential Equations. International Journal of Pure and Applied Mathematics, 85, 345-364.

[6] Awari, Y. S. (2013). Derivation and Application of Six Point Linear Multistep Numerical Methods for Solution of Second Order Initial Value Problems. ISOR Journal of Mathematics, 7, 23-29.

[7] Awoyemi, D. O., Kayode, S. J. (2008). A Minimal Order Collocation Method for Direct Solution of Initial Value Problems of General Second Order Ordinary Differential Equations. In Proceedings of the conference organized by National Mathematical Centre, Abuja, Nigeria.

[8] Awoyemi, D. O., Anake, T. A., Adesanya, A. O. (2012). A One Step Method for Solution of General Second Ordinary Differential Equations, 2, 159-163.

[9] Bamgbola, M. O., Adeniyi, R. B. (Accepted). Formulation of Discrete and Continuous Hybrid Method, Using Orthogonal Polynomials as Basis Function. Journal of Nigerian Association of Mathematical Physics.

[10] Bun, R. A., Vsilyev, Y. D. (1992). A Numerical Method for Solving Differential Equations of any orders. Computational Mathematics and Physics, 32, 317-330.

[11] Dahlquist, G. (1979). Some Properties of Linear Multistep and One Leg Method for Ordinary Differential Equations. Department of Computer Science, Royal Institute of Technology, Stockholm.

[12] Dahlquist, G. (1983). On One-leg Multistep Method. SIAM Journal on Numerical Analysis, 20, 1130-1146.

[13] Ekundayo, F., Adeniyi, R. B. (2014). An Orthogonal Collocation Approach for Continuous Formulation of Hybrid Methods for Initial Value Problems in Ordinary Differential Equations. Journal of Nigerian Association of Mathematical Physics (Accepted).

[14] Fatunla, S. O. (1988). Numerical Methods for Initial Value Problems in Ordinary Differential Equations. Academic Press Inc.

[15] Fatunla, S. O. (1991). Block Methods for Second Order Initial Value Problem (IVP). International Journal of Computer Mathematics, 41, 55-63.

[16] Haruna, Y., Adeniyi, R. B. (Accepted). A Collocation Technique Based on Orthogonal Polynomial for Construction of Continuous Hybrid Methods. Ilorin Journal of Science.

[17] Lambert, J. D. (1973). Computational Methods in Ordinary Differential System. John Wiley and Sons.

[18] Milne, W. E. (1953). Numerical Solution of Differential Equations. John Wiley and Sons.
[19] Mohammad, U., Yahaya, Y. A. (2010). Fully Implicit Four Point Block Backward Differentiation Formula for Solution of First Order Initial Value Problems. Leonardo Journal of Sciences, 16, 21-30.
[20] Onumanyi, P., Sirisena, W. V., Jator, S. N. (1999). Continuous Finite Difference Approximations for solving differential equations. International Journal of Computer and Mathematics, 72, 15-21.
[21] Owolabi, K. M. (2012). A Family of Implicit Higher Order Methods for the Numerical Integration of Second Order Differential Equations. Journal of Mathematical Theory and Modeling, 2, 67-76.
[22] Rosser, J. B. (1967). A Runge-Kutta for all Seasons. SIAM Review, 9, 417-452.
[23] Yusuf, Y., Onumanyi, P. (2005). New Multiple FDMs through Multistep collocation for y^n=f(x). In Proceedings of the seminar organized by the National Mathematical Center, Abuja, Nigeria.

e-ISSN: 3027-0650
Vol. 1, Issue 1, pp. 576–587, November 13-16, 2023

A Geographic Information System Base Spatial Decision Support Systems for Poverty Analysis and Management in Adamawa State, Nigeria

Geoffrey Naphtali[1], Samuel Chinedu Utulu[2], Hamira Joila[3]
{geoffrey.naphtali@aun.edu.ng[1], samuel.utulu@aun.edu.ng[2], hamirayoila80@gmail.com [3]}

Adamawa State University Mubi, Geography Department[1], School of Information and Technology Communication American University of Nigeria[2], Adamawa State University, Mubi[3]

Abstract
Poverty is a multidimensional, multifaceted, and complex, poverty can manifest in the social, political, economic, environmental and any sector of human existence. In Nigeria pervious government and present administration have adopted many poverty alleviations programs but most of them did not yield any positive result due to lack of spatial Geodatabase. Therefore, this article uses the concept of spatial decision support system and Geographic Information System in assessing the spatial distribution of poverty in Adamawa State as a model for decision making. Spatial decision making are multi-facetted challenges that needs technical requirement because they contain economic, social, environmental, and political dimension. Solving theses complex issues requires integrating and using information systems such as Geographic Information System and Spatial Decision Support Systems. The pragmatic approach was used as the methodology for collecting spatial information and for making inquiries into the complex phenomena. The geographic disparities theory was used as a lens to provide answers to the research questions. The Poverty situation in Adamawa State was measured using the Fosre, Greer and Thorbecke (FGT) index to determine the incidence of poverty in the state. A GIS base spatial decision support system model was design for decision making on how to alleviate poverty in disadvantage areas of the state.

Keywords: Geographic Information System (GIS), Poverty, Spatial Decision Support System, Geodatabase, decision making.

1 Introduction

Poverty is a threat to humanity all over the world. Poverty is multidimensional, multifaceted, and complex, poverty can manifest in the social, political, economic, environmental and any sector of human existence [18] Poverty in a nutshell referred to as the pronounced deprivation of individuals' economic and social wellbeing and has become a global problem that attracted renewed interests by governments and international agencies [4]. The components of wellbeing of individuals are measured in terms of income and consumption, access to health care, nutrition, education, good sanitation; others are access to good drinking water, quality housing and capability to function in a society among others [34].

Several poverty reductions programs have been adopted to alleviate or reduce poverty in Nigeria [27], notable poverty reduction programs pursued by previous administration in Nigeria include; operation feed the nation, free and compulsory primary education, green revolution, low-cost housing, river basin development authority, national agricultural land development etc.[2],[7],[18],[20] gave many reasons why poverty alleviation programs and initiatives in Nigeria failed. Some of the reasons given are poor design and implementation, poor funding and corruption, policy inconsistencies and discontinuity, political differences, lack of comprehensive Geodatabase and use of information system for planning, design, implementation, and monitoring. Almost all these programs happen somewhere on a spatial location in Nigeria and all these programs need spatial decision making for them to be effective.

Spatial decision making is a routine activity that is common to individuals and to organizations [32]. Spatial decision making are multi-facetted challenges that needs technical requirement because they contain economic, social, environmental, and political dimension. Solving these complex issues requires integrating and using information systems such as geographic information system and spatial decision support systems.

Geographic information system (GIS) is one of the most widely used decision aids, especially for solving complex spatial problems [30]. [13] define Geographic information system (GIS) as a computer-based information system that enable capture, modelling, storage, retrieval, sharing, manipulating, analysis and presentation of geographically referenced data. Spatial decision support system in the other hand is an interactive computer-based system designed to support a user or group of users in achieving highest effectiveness of decision making while solving a semi- structured spatial decision problem [33].

Geographic information system Poverty mapping is a relatively new concept. It describes the methodology for providing a detailed description of the spatial distribution of poverty and inequality within a state, region, or country [5], she further state that, it combines individual and household (micro) survey data and population (macro) census data with the objective of estimating welfare indicators for specific geographic area as small as a village or hamlet.

There is no consensus in the definition of poverty; poverty definition varies from place to place. But there are four major classes of poverty assessment measures identified based on data sources, assumptions, and the statistical routine utilized [4]. These are econometric, social, demographic, and vulnerability-based measures [7].

Econometrics poverty indicators are current consumption expenditures, income and wealth, social indicators are nutrition, water, health and education, demographic measures use gender, health, and household age structure indicators while vulnerability measures are level of household exposure to shocks, environmental challenges, physical insecurity, political changes etc.

Geographic Information System Poverty maps are useful in devising policy for tackling poverty [31]. These maps show the spatial distribution of poverty, which can be used to quantify regional disparities in living standards and identify areas falling behind in economic development [22]. Geographic Information System Poverty maps are used for various purposes, ranging from identifying and understanding the causes of poverty, assisting in program development and policy formulation, guiding allocation of anti-poverty investments and expenditures to areas of greatest need.

Geographic Information System maps are needed to show that certain areas are disadvantaged and to rapidly assess options for emergency interventions and for better decision making for poverty alleviation. Geographic Information System poverty mapping techniques use composite indexes as the poverty measure rely on the direct aggregation of census data to display the poverty indicator for the chosen geographic area. Composite indexes used for this spatial decision support system and Geographic Information System poverty mapping include United Nations Development Program's well-known Human Development Index (HDI) and various basic needs measures. These include life expectancy, education (literacy), income, access to water, access to sanitation, access to health services and quality of housing. All these components are weighted equally.[34]

Choosing an indicator or indicators of poverty is a very important step in developing spatial decision support systems and Geographic Information System poverty map model production. The selected indicator may be a monetary or non-monetary variable. For example, the proportion of households below a certain income level etc.

Recent advances in Geographic Information System (GIS), data base and computer aided software engineering has made Geographic Information System poverty mapping possible, where data can be presented in the form of maps and overlaying interfaces for cross-comparisons as spatial decision support system for decision making by relevant organizations. Geographic Information System Poverty maps are not a panacea for understanding or solving poverty problems; they are only one tool among many for investigating the complex phenomenon of poverty. They should be used in conjunction with other information such as spatial decision support (SDSS) and analysis that provide context and ground trotting within communities.

Despite all the poverty alleviation and reduction programs embark by previous and present governments in Nigeria, most of the populations are still under the poverty line. Adamawa state as one the state in Nigeria is not exempted from this problem. Therefore, this paper is aimed at using

Geographic Information System mapping techniques in assessing the geospatial poverty spread in the state to design a spatial decision support system model for better decision making on poverty reduction and management.
This paper contributes to knowledge by providing geospatial information on the geographical distribution of poverty in Adamawa State.
The paper seeks to answer the following research question. RQ1. What are the main courses of poverty in Adamawa State? RQ2 what is the geographical spread of poverty in Adamawa state? RQ3. How can GIS and spatial decision support system be integrated to a model for decision making?
To explore or rather answer these questions, we use a pragmatic approach which draws heavily on the inductive and deductive reasoning [28]. This is because, to fully analyse a phenomenon, it is vital and necessary to support the inductive approach with deductive thinking to enable it to tackle a real-world problem such as in the case of this article [33]
The pragmatic approach provides for the use of both qualitative and quantitative research methodology to collect information and make inquiry into complex phenomenon of social and natural context [16], [24]. Therefore, the pragmatic research philosophy provides for the adoption of mixed methods as the data collection method which opens the opportunity to be objective and subjective in analysing the points of view of the participants.
The pragmatic approach helps to provide a grounding where the research avoids engaging in issues of insignificance rather than issues of truth and reality and as such is intuitively appealing [16],[23].

2 The Concept of Poverty

[26] affirmed that there is no standard definition of poverty despite enormous literatures on poverty and its universality. But distinctions have been made by scholars between absolute and relative poverty [30]. Absolute poverty is a situation where household are unable to meet its basic needs such as shelter, food, clothing, transportation, and education [25]. Absolute poverty is also viewed as a situation of low income and consumption which are the parameters and yard stick for measuring the minimum and maximum standard of living. While relative poverty, is a situation where an individual or household income falls below the average income of the population of the society being considered.
The World Bank adopted that people are considered poor if they earn less than $1 per day [34]. This paper adopts the later concept in mapping and assessing poverty spread in Adamawa state. Other methods that are also used by scholars and researchers in measuring poverty are head count/incidence of poverty, poverty gap/income shortfall, disparity of income distribution, composite poverty measures, physical quality of life index (PQLI), augmented physical quality of life index (APQLI), and the human development index.[3]

2.1 Poverty Theories

Poverty has attracted the interest of many scholars and researchers all over the world. Poverty reduction programmes are normally designed based on theories that justify such interventions. There are many poverty theories that can be use or applied in different poverty research and alleviation programmes such as the culture of poverty theory developed by Oscar Lewis an American anthropologist, others are the individual deficiency theory, the progressive social theory, the geographical disparities theory, the cyclical interdependence theory, poverty individualization theory and the theory of social exclusion/cumulative disadvantage [26].
This paper adopts the geographical disparities theory as the research lens. This theory focuses on poverty in geographical perspective such as ghetto poverty, rural poverty, southern or northern poverty, third world poverty etc. The theory emphasis that people in certain geographical areas lack basic to wealth creation opportunities [5]. This theory is adopted in this paper because it is applicable

in the Nigerian context whereby poverty is prevalent in some geographical locations for example rural areas, slums areas prone to floods, draught, desert encroachment and disasters. Mostly economic activities in those areas are very low leading to unemployment and poverty. The theory also indicates that the neglect of government in the provision of social amenities and empowerment opportunities are the causes of these imbalance in most of these areas that are geographically disadvantaged.

3 Literature Review

Many studies have been carried out by researchers on poverty and its effects on human bean. [6] relate poverty to social exclusion in both developed and developing countries,[13] discuss and analyses children poverty and its effects on children wellbeing. [30] also analyses the effects of poverty in most advanced countries in Europe.

Poverty is a very significant topic of discuss and research in Africa, researchers such as [11] have also contributed on the effects of poverty in Africa. Other topics of discuss on poverty are the link of poverty to climate vulnerability [24], poverty and social protection [9]. Poverty and gender issue [12]. [29] listed poverty as one of the risk factors in health challenges. Combining poverty indicators with geo-spatial referenced datasets help to highlight where poverty overlaps with socio-economic and environmental challenges [10]. Geographic information system and spatial decision system are important tools and technology in combining and analysing poverty indicators and geo-spatial referenced dataset [3]. She also acknowledged the role Geographic Information System plays in poverty assessment and mapping which has increased in importance, as a means of explaining variables because of its data integration and spatial analysis capabilities.

As spatial determinants are increasingly important in understanding poverty, the consistent use of spatial datasets in developing poverty reduction strategies is a growing requirement [5]. Data modelling is required to better convey the components, processes and meaning of poverty assessment as with other geographic phenomenon and translating the knowledge into a geographic information system [23]. [23] emphasized that spatial decision support modelling is also another means of poverty assessment for making decision on poverty reduction and alleviation.[23] and [19] identify four classes of Geographic Information System poverty mapping measures based on data sources, assumptions, and statistical routine utilization. These are econometrics, social, demographic, and vulnerability-based measures, and therefore this paper based its assessment on econometric poverty indicators which are current consumption, expenditure, income, and wealth of the people in Adamawa state.

4 Study Site

Adamawa state is located at the north-eastern part of Nigeria, it lies between latitude 7º and 11º N of the equator and between longitude 11º and 14º E of the Greenwich meridian. It shares boundary with Taraba state in the south and west, Gombe State in its Northwest and Borno state to the north. Adamawa state has an international boundary with the Cameroon republic along its eastern border. The state covers a land area of about 38,741 km with a population of 3,675,750 People according to the 2006 census and a population density 115.1km2. Adamawa state is divided into 21 local government areas. This article covers 20 local government areas out of the 21 local government areas of Adamawa State,

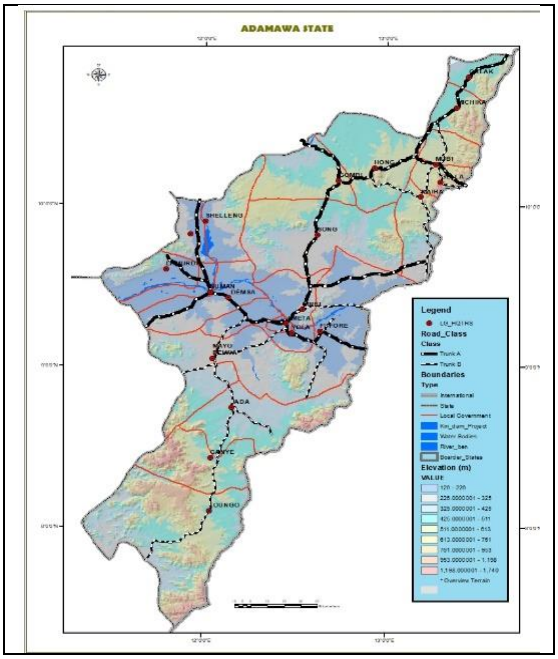


Fig.1. Study Area

5 Research Design

There are many research design alternatives that can be applied in research study such as experiments, survey, case study, action research, grounded theory, ethnography, and archival research. Therefore, we combine both case study and survey research. Case study is an empirical inquiry that investigates a contemporary phenomenon within its real –life context especially when the boundaries between the phenomenon and context are not clear [28].
Case study research according to [29] are analysis of a person, event, decision, periods, projects, policies, institution, or other systems that are studied holistically by one or more method. While survey research is the collection of information's from a sample of individuals through their responses to question (check & Schutt, 2012, p. 160). They further added that "this type of research allows for a variety of methods to recruit participants, collect data and utilize various methods of instrumentation".

6 Methodology

This paper adopts the mixed method research methodology which combines the quantitative and qualitative research methods which is underpin by the pragmatic research philosophy. A quantitative research approach is an investigation based on testing a theory composed of variables, measured with numbers and analysis with numerical procedures, to determine whether the prognostic generalization of the hypothesis holds true [16]. For the mixed method approach, it employs both quantitative and qualitative approaches in a research work for the purpose of breadth and depth of understanding and partnership [17]. They added that the use of both quantitative and qualitative in mixed method design would provide better understanding of the research problem than the use of either one method along in a study.

6.1 Method

In this article we used the concept of geographic information system poverty mapping to produce a poverty map of Adamawa state. Community and household data from twenty (20) out of twenty-one (21) Local Government Areas of Adamawa State cutting across the 226 political wards both in the

urban, semi-urban and rural communities with their geographical positioning obtained from the baseline information were used in constructing the poverty map of the State. Data were then aggregated to derive estimates at both the community and Local Government levels. The sample size was 10 household questionnaires and 1 community-based questionnaire in each sampled community. The communities were randomly and purposively selected for inclusion in the survey from each of the 20 LGAs covered.

The overall objective of the model is to provide a detailed description of the spatial distribution of poverty and inequality in all the communities in 20 LGAs of the State. It combines individual and household (micro) survey data and population (macro) data with the objective of estimating welfare indicators for specific geographic area as small as village or hamlet. It is thus, a very good tool of targeting mechanisms.

The traditional approach of a poverty index is based on headcount of poor individuals below the specified cut-off point, i.e., the proportion of the population whose standard of living is less than the poverty line to the number of individual or households [35]. The poverty line is the level of welfare that distinguishes poor households from the non-poor households.

For the purpose of this study, the poverty line was determined by categorizing households with less than $1.00 per capita income or consumption to current naira value purchasing power parity (i.e., ≤ ₦750) per day as poor and households with $1.00 and above per capita income or consumption to current naira value purchasing power parity (> ₦750) per day as non-poor. This was used to categorize the households into poor or non-poor. Household income was divided by the number of people in the household to establish income per person.

The poverty situation in Adamawa state was measured using Foster, Greer and Thorbecke (FGT) Index [21] to determine the incidence and depth of poverty in the State. This method subsumes the Headcount Ratio and the poverty gap measurements [6]. It also allows for the decomposition of poverty levels among the various categories of a population. It is generally given as:

$$P\alpha = \frac{1}{} \Sigma \frac{Z}{} \left[\frac{-Yi}{N} \right]^{\alpha}_{Z} \qquad (1)$$

Where:

α = Foster, Greer and Thorbecke Index

$(0 \leq P \geq 1)$

N = Total number of respondents

Z = Poverty line

Yi = Income of the respondents (The sum is taken only on the poor)

q = Number of respondents below the poverty line

α = FGT ≥ 0. The 'α' takes a value of 0, 1, and 2 with different implications:

'P_0'= When $\alpha = 0$; it measures poverty incidence (the index of people that are impoverished).

'P_1' = When $\alpha = 1$; it measures poverty depth or gap, that is, the proportion of the poverty line that the average poor will require to attain to poverty line. That is, the value obtained will give an indication of the amount of money that would make the poor people to cross the threshold of poverty [2].

'P_2' = When $\alpha = 2$; it measures the severity of poverty, giving more weight to the poorest.

The closer the FGT index is to 1, the greater the poverty level. The FGT index had been widely used to determine the level of poverty by various studies [35], [8].

The Headcount Ratio (HR) measures the percentage of the population below the poverty line. It is given as:

$$HR = q / N \qquad (2)$$

Where:

HR = Headcount Ratio with value ranging from 0 to 1. The higher and closer the value is to 1, the higher the proportion of people below the poverty line [1].

q = Number of households below the poverty line

N = Total number of households in the population

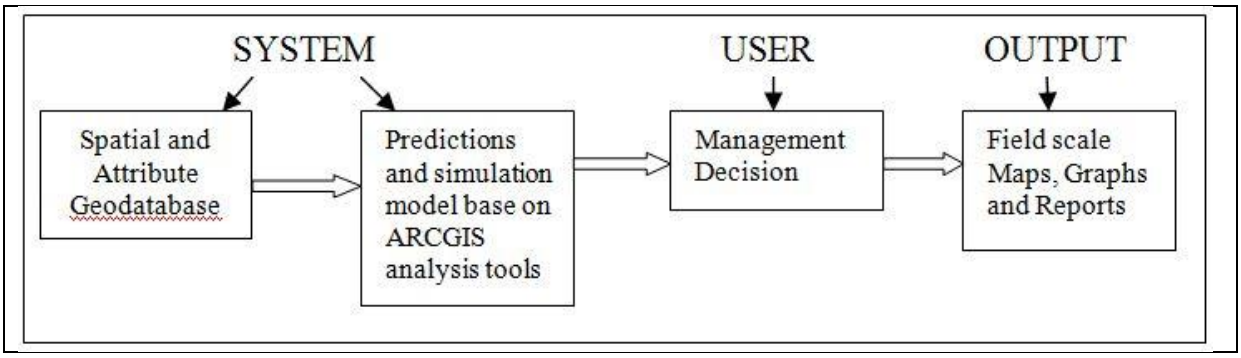


Fig. 2. Schematic model of the GIS based spatial decision support system for poverty assessment

7 Description of the Model

System: the system section is divided into two sub sections the first sub section is the spatial data collected from the field such as the geographical coordinate of communities, names of communities and location of the 21 local government areas of the state, other data in the first sub-section are attribute data such as numbers of household, total number of respondents, income of respondents, population of the communities, poverty line and head count ratio. The second sub- section is where predictions and simulation of the model based of ARCGIS, and analysis tools are stored; this sub-section helps in the production of different types of models and database management system that can be used for decision making.

User: the user section is linked to the system section where information (data) and models in the system section can be used by the management for decision making.

Output: this section of the model can also be referred to as the graphic user interface (GUI) where tables, maps and reports are presented in for of graphic for easy analysis and decision making. The model is a conceptual model of the GIS base spatial decision support system for poverty mapping, it can be expanded and be used for real situation and decision making by the government of Adamawa State for poverty assessment and alleviation.

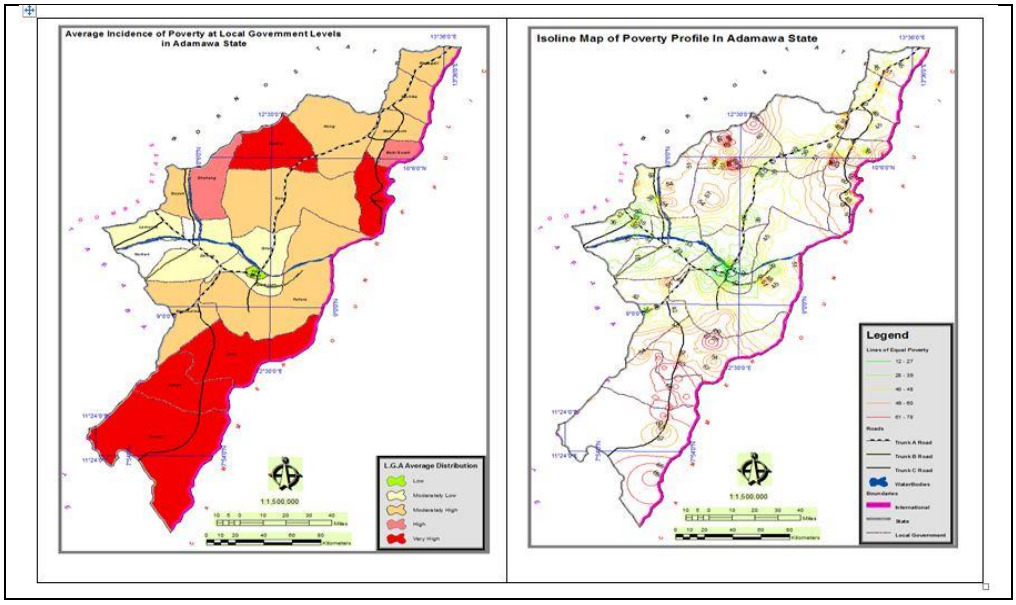


Fig.3. Average incidence of poverty. **Fig.4**. Isoline map of poverty profile

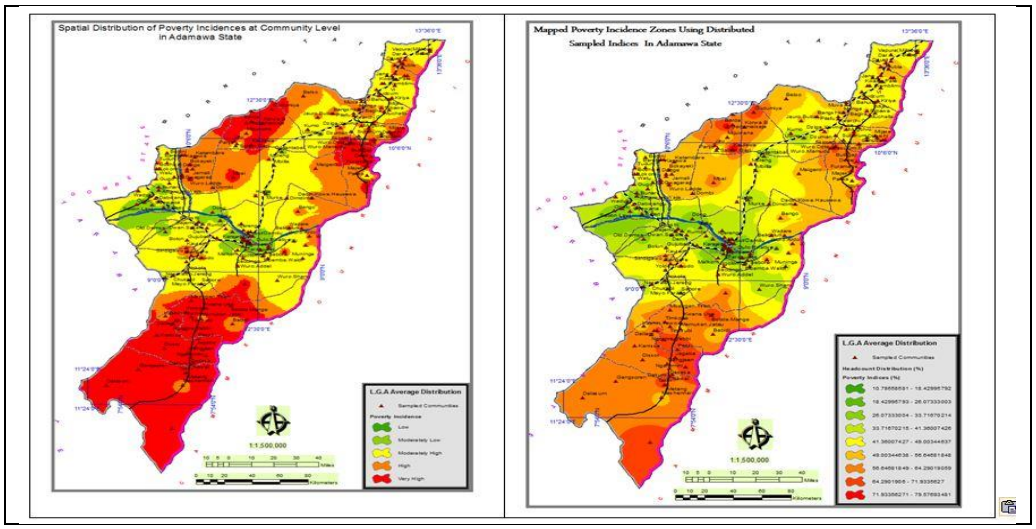


Fig. 5. poverty incidence at community level zones **Fig. 6**. poverty incidence zones

8 Results and Discussion

The different colours on the maps signify the spatial heterogeneity of poverty across the state. The Local Government areas and communities coloured green indicates low incidences of poverty with poverty rate of 11-26%. Lemon and yellow colours indicate moderately high incidences of poverty with poverty rate of 34-49%. The brown and red colours indicate high to very high incidences of poverty with poverty rate of 49-80%. It is evident from the map that many communities in the southern part of the state, particularly around Toungo and Ganye local government areas have fallen within the brown and red colours indicating that the poverty level is high in those local government areas. Also, communities around Maiha, Mubi south and Gombi local government areas falls within the zone of high poverty level. These communities are disadvantaged in the provision of basic social amenities. However, communities within the central and northern parts of the state appear to have low to

moderately high incidences of poverty. The isocline map tries to link communities with equal levels of poverty.

The characteristic feature of most of the communities in the state, particularly those that have fallen within the moderately high and very high incidences of poverty is the near complete absence of basic amenities especially good quality drinking water, road network, health facilities, electricity, and educational facilities. In places where some of these facilities exist, they are either in complete state of dilapidation or are not easily accessible. People had to trek long distances to access some of these facilities. Additionally, there are many cases of water borne diseases, high maternal and infant mortality, high school drop-out among children and loss of self-esteem among community members.

The poverty indicators in the state are presented in Table 1. It shows that poverty in the rural areas of the state is higher than that in the semi-urban and urban areas of the state. About 66% of the population in the rural areas of the state lives below the poverty line. This is as opposed to 52.78% and 31.27% in the semi-urban and urban communities respectively. This is an indication that poverty incidence in Adamawa state is high despite the many interventions by government and the private sector.

On poverty gap as shown in the table, rural income must increase by 44% to get the population to poverty line. Consequently, incomes must increase by 37% and 24% to get the semi-urban and urban communities respectively to poverty line. Alternatively, the expenditure pattern of the rural, semi-urban and urban population must increase by 44%, 37% and 24% respectively to move them to the line of poverty threshold. This indicates that the poverty gap in the state is large. The population must be able to engage in other income generating activities outside their primary occupation to sufficiently move them to the line of poverty so as not to be classified as poor in the context of incidence of poverty.

On the severity of poverty, the table also shows that, of the people classified as poor in the rural communities, 26% are severely affected by poverty. This also applies to semi-urban and urban communities where 15% and 12% respectively are severely affected by poverty. These analyses show that poverty is a serious problem in the State. The places that may be seen as having low incidences of poverty are in the real sense also poor if other indicators outside income and expenditure are considered.

Table 1: Poverty Indicators in Adamawa state

Poverty incidence (%)			**Poverty depth**			**Poverty**		
Urban	Semi-Urban	Rural	Urban	Semi-Urban	Rural	Urban	Semi-Urban	Rural
31.27	52.78	66.23	0.25	0.37	0.44	0.12	0.15	0.26

Source: field survey 2021-2023

9 Summary

The concept of GIS-base spatial decision support system for poverty assessment is very significant in poverty reduction and alleviation. Several poverty reduction and programs have been adopted in Nigeria over the years, but most of these programs lack a comprehensive geo-database such as the one design in this article. GIS mapping helps in visualizing the impact of poverty in communities affected. Poverty maps are useful in devising policy for tackling poverty [31]. These maps show the spatial distribution of poverty, which can be used to quantify regional disparities in living standards and identify areas falling behind in economic development [22] Poverty maps are used for various purposes, ranging from identifying and understanding the causes of poverty, to assisting in program development and policy formulation, to guiding allocation of anti-poverty investments and expenditures to areas of greatest need. Maps may be needed to show that certain areas are disadvantaged and to rapidly assess options for emergency interventions.

10 Conclusion and Further Research

Geographic Information System Poverty mapping is a relatively new concept. It describes the methodology for providing a detailed description of the spatial distribution of poverty and inequality within a state, region, or country. Three research question RQ1. What are the main courses of poverty in Adamawa State? RQ2 what is the geographical spread of poverty in Adamawa State, RQ3 how can GIS and spatial decision support system be integrated to a model for decision making by the government. The questions were answered using the geographical disparities theory that was adopted as the lens to guide the paper findings. The main courses of poverty in Adamawa State are that; communities are disadvantaged in the provision of basic social amenities. The characteristic feature of most of the communities in the state, particularly those that have fallen within the moderately high and very high incidences of poverty is the near complete absence of basic amenities especially good quality drinking water, road network, health facilities, electricity, and educational facilities due to their geographical nearness to the centre of administration. In places where some of these facilities exist, they are either in complete state of dilapidation or are not easily accessible. People had to trek long distances to access some of these facilities. Additionally, there are many cases of water borne diseases, high maternal and infant mortality, high school drop-out among children and loss of self-esteem among community members. On what is the geographical spread of poverty in Adamawa State, the communities in the semi-urban and urban areas of the state have lower incidence of poverty compared to communities that are in rural area with high incidence of poverty. The government can use the GIS base spatial decision support system model as a lens that will guide its decision making on poverty alleviation, distribution of social amenities etc.

References

[1] Aigbokhan, B. E. Spatial Analysis of Hotspots and Coldspots of Poverty in Nigeria. *Journal of Geographic Information System.* 2000, *8*(2).

[2] Aigbokhan, B. E. Growth, inequality, and poverty in Nigeria. Prepared for United Nations Economic Commission for Africa (UNECA), Addis Ababa, Ethiopia. 2016

[3] Akinyemi, F. O. Database design and development for census mapping in Nigeria. In O.Y. Balogun & A.S.O. Soneye (Eds.), *Cartography in the Service of Government.* Lagos, Nigerian Cartographic Association. 1999. (pp. 191–202).

[4] Akinyemi, F. O. Geographic targeting for poverty alleviation in Nigeria: A GIS approach. In *Proceedings of the Twenty-first International Cartographic Association Conference on Mapping the Twenty-first Century (ICC)* Beijing, China. 2001, *Vol. 2)* (pp. 1259–1270),

[5] Akinyemi, F. O. Spatial data needs for poverty management. In H. J. Onsrud (Ed.), *Research and Theory in Advancing Spatial Data Infrastructure Concepts*, Redlands, CA: ESRI Press. 2012. (pp. 262–277).

[6] Anyanwu, J. D. (1997). Poverty in Nigeria: Concepts, Measurements, and Determinants. In P. J. Obaseki (Ed.), *Poverty Alleviation in Nigeria*, Nigeria Economic Society (NES). 1997. (pp. 93–120),

[7] Arise-Nwugballa, E. A., Elom, M. E., & Onyeizugbe, C. U. Evaluating the relevance of Entrepreneurial Orientation to the Performance of Micro, Small and Medium Enterprises in Ebonyi State, Nigeria. *International Journal of Academic Research in Accounting, Finance, and Management Science*. 2016, *6*(3), 221-230.

[8] Atobatele, J. T., & Amudipe, I. Poverty Profile of Working Women in Akure North and South Local Governments of Ondo State. In Y. L. Fabiyi & E. O. Idowu (Eds.), *Poverty Alleviation and Food Security in Nigeria*, Nigerian Association of Agricultural Economists (NAAE). 1999, (pp. 127–131),

[9] Barrientos, A., & Hulme, D. Social protection for the poor and poorest: concepts, policies, and politics. Springer. 2016.

[10] Bedi, T., Coudouel, A., & Simler, K. (Eds.). More Than a Pretty Picture: Using Poverty Maps to Design Better Policies and Interventions. Washington, DC: World Bank. 2007

[11] Beegle, K., Christiaensen, L., Dabalen, A., & Gaddis, I. Poverty in a rising Africa. World Bank publication. 2016. https://doi.org/10.1596/978-1-4648-0723-7.
[12] Bhalla, A. S., & Lapeyre, F. Poverty and exclusion in a global world. Springer. 2016.
[13] Bradshaw, J., & Main, G. Child poverty and deprivation. In *The Wellbeing of Children in the UK*. 2016 pp31.
[14] Chang, K. *Introduction to Geographic Information System* (7th ed.). Singapore: McGraw-Hill. 2013
[15] Chen, S., & Ravallion, M. Absolute poverty measures for the developing world 1981-2004. *Proceedings of the National Academy of Sciences*, 104(43), 2007. 16757-16762. https://doi.org/10.1073/pnas.
[16] Creswell, J. W. *Research Design: Quantitative and Qualitative Approaches* (3rd ed.). London: SAGE Publications. 2009.
[17] Creswell, J. W., & Plano, C. V. L. *Designing and Conducting Mixed Methods Research* (2nd ed.). London: SAGE Publications. 2011
[18] Dauda, R. S. Poverty and economic growth in Nigeria: issues and policies. *Journal of Poverty*, *21*(1), 2017. 61-79. https://doi.org/10.1080/10875549.2016.1141383.
[19] Davis, B. Choosing a Method for Poverty Mapping. Rome: FAO. 2003.
[20] Elumilade, D., Asaolu, T., & Adereti, S. Appraising the institutional framework for poverty alleviation programs in Nigeria. *International Research Journal for Finance and Economics*, *3*(9), 2006. 66.
[21] Foster, J., Greer, J., & Thorbecke, E. A Class of Decomposable Poverty Measures. *Econometrica*, *52*(1), 1984. 761-766.
[22] Gauci, A., & Steinmayer, V. Poverty maps: A useful tool for policy design to reduce poverty. Poverty and Social Policy Team, ESPD, UN Economic Commission for Africa working paper. 2005
[23] Glennon, A. Creating and validating object-oriented geographic data models: Modeling flow within GIS. *Transactions in GIS*, *14*, 2010. 23–42.
[24] Grootaert, C. Structural change and poverty in Africa: A decomposition analysis for Cote d'Ivoire. *Journal of Development Economics*, *47*(2), 1995. 375-401. https://doi.org/10.1016/0304-3878(95)00018-L.
[25] Hope Sr, K. R. Corruption in Nigeria corruption and governance in Africa Springer. 2017. (pp. 125-162). https://doi.org/10.1016/0305-750X (93)90142-V.
[26] Laderchi, C. R., Saith, R., & Stewart, F. Does the definition of poverty matter? Comparing four approaches. *Poverty in Focus*, 2006.*10-11*.
[27] Oshewolo, S. Galloping poverty in Nigeria: an appraisal of government interventionist policies. *Journal of Sustainable Development in Africa*, *12*(6), 2010. 264-274.
[28] Paulinus, W. I., & David, E. Pragmatic research: a framework for sustainable management of public housing estate in Nigeria. *Journal of US-China Public Administration*, *10*(10), 2013. 933-944.
[29] Pearson, T. Poverty: The Other Risk Factor for Diabetes and Its Complications. *AADE in Practice*, *3*(2), 2015. 8-10. https://doi.org/10.1177/2325160315572597.
[30] Room, G. New poverty in the European community. Springer. 2016
[31] Sachs, J. *The End of Poverty: Economic Possibilities for Our Time*. New York: Penguin Press. 2005
[32] Shah, M. K.The Myth of Community: Gender Issues in Participatory Development. ITGD Publishing.2016.
[33] Sugumaran, R., Degroote, J., & Sugumaran, V. *Principles and Practices*. ISBN 10: 1420062093, CRC Press. 2010.
[34] World Bank. *World Development Report 1990: Poverty*. New York: Oxford University Press. 1990.
[35] World Bank. *Nigeria: Poverty in the Midst of Plenty - The Challenge of Growth with Inclusion*. A World Bank Poverty Assessment. 1996.129 pp.

1ST AUN INTERNATIONAL

Research: A Tool For National Development And Innovation In The 21st Century

14th – 15th November, 2023

PUBLISHED BY:
AMERICAN UNIVERSITY OF NIGERIA

ADDRESS:
98 Lamido Zubairu Way, Yola
Township bypass, PMB 2250, Yola,
Adamawa State, Nigeria

WEBSITE:
www.aun.edu.ng
@AUNigeria