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Rexford Assasie Oppong *Editors*

# Sustainable Education and Development – Making Cities and Human Settlements Inclusive, Safe, Resilient, and Sustainable

Proceedings of the Applied Research  
Conference in Africa (ARCA), 2021

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Cities and Human Settlements Inclusive, Safe,  
Resilient, and Sustainable**



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Editors


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 Springer

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# Preface

There is an enormous challenge of the role of research in developing the continent. Africa is a continent where research seems to be not directly related to development. However, the belief is that research could contribute to the socio-economic development of the continent.

Indeed The United Nations explains that the challenges cities face can be overcome in ways that allow them to continue to thrive and grow, while improving resource use and reducing pollution and poverty. The future includes cities of opportunities for all, with access to basic services, energy, housing, transportation and more.

This book has seventy-six peer-reviewed papers relating to Sustainable Development Goal 11 with in-depth focus on the following eight targets, which are i. access for all to adequate, safe and affordable housing and basic services and upgrade slums, ii. access to safe, affordable, accessible and sustainable transport systems for all, iii. enhance inclusive and sustainable urbanisation capacity for participatory and integrated human settlement, iv. safeguarding the world's cultural and natural heritage, v. decreasing the direct economic losses relative to global gross domestic product, vi. Turning the adverse per capita environmental impact of cities to wealth, vii. accessing safe, rural and urban living spaces during COVID-19 pandemic and viii. assessing and encouraging herbal medicine and African response to COVID-19 for inclusive sustainable development.

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# The Impact of Climate Change on Construction Projects in South Africa

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**Abstract. Purpose:** Climate change can be a major concern for the construction industry due to the impact it has on the project life cycle. The construction industry, along with its professional practitioners, has the opportunity to advance and adapt to play a significant part in whether or not the impact of climate change in the years to come will be disastrous or manageable. Future projects can be appropriately safeguarded by applying appropriate risk mitigation techniques. This study's purpose is to investigate the impact climate change has on construction projects in South Africa.

**Research Design:** Through online surveys and semi-structured interviews, the researcher investigated the effect of climate change on construction projects and the role of the construction manager to safeguard the contractor and the best possible methods available for implementation to safeguard a contractor against climate change implications.

**Findings:** However, it remains a concern that construction businesses and firms do not realise the reality and seriousness of climate change and its impact. Regarding the methods available to mitigate the impact of climate change no single solution nor combination of solutions is the perfect solution. It requires an informed and proactive construction manager as they are potentially in a position to mitigate the causes and outcomes of climate change however they are very dependent on the resources available to them as well as the type of construction project underway. From the data collected it is evident that climate change and the impact it has on construction projects is a serious concern for the South African construction industry mainly because of the many different opinions obtained from the participants of the survey and the interviewees regarding the reality and seriousness of climate change.

**Research Implication:** The knowledge gained in this study will create awareness among professionals in the construction industry especially construction managers in terms of the implication of climate change on construction projects. Thorough research should be conducted before the construction phase so that adequate planning can be done to mitigate the effects of climate change. Construction management practitioners need to start applying an informed and proactive approach to prepare as well as they can during the tender phase and have ample information to justify their position.

**Keywords:** Climate change · Contracts · Insurance · Safeguard · Technology

## 1 Introduction

This research investigates the impact of climate change on construction projects and the duty and responsibility of construction management practitioners on construction projects to safeguard contractors against the impacts imposed by climate change. Changes in weather patterns will continue to affect the construction industry and job sites. The role of the construction manager is to manage the physical construction processes of the built environment to safeguard the contractors' companies, workers and job sites from climate change (SACPCMP 2018). This emphasizes the fact that construction managers have a duty and responsibility towards the construction industry to mitigate these impacts by accurately applying their skills and expertise. As the variations in weather patterns become too extreme, their impact becomes magnified. Since the construction industry's profit margins remain one of the lowest compared to other major sectors, slight weather changes could declare construction projects unprofitable (Hegeman 2019). The South African Construction Industry faces challenges due to the ongoing effects of climate change and there may be an increase in the risks during the near future, therefore construction managers must investigate methods to safeguard the contractor against climate change's impact on construction projects.

## 2 Theories Underpinning the Study

Climate change and global warming are two terms that are often used interchangeably, but it is important to realize that climate change is more than just global warming. The increase in global temperatures as a result of a build-up in the concentration of greenhouse gases in the atmosphere can be referred to as "*Global Warming*"; however, the intensifying changes in the measures of climate over a long period can be referred to as "*Climate Change*" (USGS 2020). Since "*Global Warming*" and "*Climate Change*" are frequently used interchangeably yet have different meanings, the terms "*Weather*" and "*Climate*" are sometimes similarly confused. However, they refer to occurrences with mostly different spatial and timescales. "*Weather displays the atmosphere's short-term conditions, whereas climate is the typical daily weather for an extended period at a specific location*" (Shaftel 2020). Climate change can be considered a worldwide weather phenomenon connected to the increase in global average temperatures. Science communicators favour the term climate change as it comprises both an increase in the earth's global average temperature and the climate effects triggered by this increase (WIRED 2018).

Climate change is a growing concern in the construction industry and is an effect of the ongoing effect of industrialisation, increase in population, and the ongoing depletion of resources, which will have devastating impacts on the construction processes due to events such as flooding and storm damage, power outages, drought, loss of biodiversity and changing habitats. Even a 1% increase in the work stoppage due to unexpected weather has a significant impact on the bottom line (Grant 2018).

Climate change can be caused by an assortment of human and natural factors. Anthropogenic (human) causes of climate change include the greenhouse gas emissions that are generated. Even though these gases help keep the planet warm, these gases in our

atmosphere have increased exponentially over the last decades. Natural factors that contribute to climate change are volcanic eruptions, the intensity of the sun and naturally occurring changes in greenhouse gasses concentration. Natural causes of climate change are still occurring today; however, their impact occurs too slowly or is too small to justify the warming experienced during recent decades (Denchak 2017). Climate change results in various challenges such as an increase in annual rainfall, higher temperatures, and other extreme weather events that have major implications affecting a construction project's lifecycle as well as other indirect impacts such as additional construction costs, the safety of labourers, material costs, delivery, and site programming. Climate change is now bringing a whole new, powerful and urgent perspective on how to convey human activities and their impact on our planet, while the challenge is to supply the world's population a standard of living that is socially and environmentally acceptable (Morris 2019).

According to a government report, there is no denying that climate change has an impact in South Africa, and the effects will soon intensify. A rise of up to 6 degrees Celsius and more extreme weather events can be expected throughout the country within the next century. We have already seen droughts that cripple provinces and high-intensity storms in specific regions that often lead to displacements and deaths. Therefore, it can be said that there is enough evidence that South Africa's extreme weather events are undeniably increasing, and that climate zones throughout the country are shifting; this can be seen by the degrading of landscapes and ecosystems, the increased frequency of veld fires, as well as the overused marine and natural terrestrial systems that are placed under stress. The greatest and potentially most destructive "extreme events" are yet to be experienced (Head 2019).

Like most developing countries, South Africa is exceptionally susceptible to climate change and its impacts since South Africa has a duty of balancing the acceleration of economic transformation and growth. In South Africa, the primary medium where the impacts of climate change are mostly experienced is water. The increasing climate change and extremes impact both the availability and quality of water through alterations in rainfall patterns, with intensified storms, droughts, and floods, changes in soil moisture and runoff, and escalating evaporation and changing temperatures of aquatic systems (Affairs 2016). Furthermore, as weather variations are becoming too extreme, their impacts on construction sites are becoming amplified. No projects can be considered risk-free and climate change has a powerful impact on construction projects, and even the smallest impacts might render projects unprofitable.

The safety of regarding worksites is the number one concern regarding climate change. The ever-increasing occurrences of unpredictable rain and flooding result in slippery surfaces and the deterioration of wood, resulting in an increased risk of recordable injuries, thus creating working conditions that are considered unsafe. The rise in temperatures can result in heat exhaustion, heatstroke, and even death (Grant 2018). Other concerns for the industry is that building materials and current structures are affected by climate change as materials such as brick and wood decay and crack faster (Grant 2018). In 2015 CSIRO conducted a case study that found that "*increased concentrations of atmospheric carbon dioxide (due to climate change) – particularly in urban areas – mean greater penetration of carbon dioxide into concrete*" (CSIRO 2015). The

change in construction material composition and manufacturing drive the costs of materials up as the materials required need to be lighter, stronger, and more durable (Hegeman 2019). Lastly, construction companies find themselves confronted by much higher construction costs due to the delays of projects associated with labour risks and extreme weather. This implies that construction companies will either need to stop pursuing specific projects due to their inability to afford insurance or cover the rising costs by increasing the project's costs (Hegeman 2019).

A construction manager must safeguard the contractor against the impact climate change has on the construction process by applying and adapting their experience and expertise to better understand the influences climate change imposes on construction projects. Construction managers should be aware of how they could mitigate climate change's impact on the construction industry and continuously develop and cultivate profitable businesses while simultaneously meeting client needs. Mitigation is concerned with reducing the impact of the risks imposed by climate change, and adaptation being concerned with responding to the risks. Therefore, construction management professionals should operate actively to mitigate climate change's effects and incidences (Morris 2019).

The following objectives are set out to be achieved by this study: i) to determine the most logical approach to mitigate the risks experienced by climate change, ii) to determine the financial implications on construction projects experienced due to climate change, iii) to determine the major concerns raised by climate change in South Africa, iv) to determine the extent to which contractors have implemented methods to adapt to the effects of climate change, v) to determine how does climate change impact the construction project lifecycle and vi) to determine the different methods to safeguard a contractor against the impacts of climate change.

### 3 Methodology

For this research study, a mixed-method approach is adopted. An online questionnaire was developed as part of the quantitative research approach. The questionnaire was made available to a target population within the South African construction industry and consisting of architects, construction managers, contractors, engineers, project managers, and quantity surveyors. The questions are both closed-ended and open-ended. A total of 120 emails with the questionnaire were sent out to a convenient purposive sample. Data collected from the questionnaire were analysed presented logically in tables and figures. Semi-structured interviews formed part of the qualitative approach. The semi-structured interviews were with a selected number of professionals in the construction industry. This convenient and purposive sample included construction managers and contractors to gain a more in-depth view of their thoughts, beliefs, and opinions regarding climate change and its impact on the South African construction industry. Data collected from the semi-structured interviews were recorded and transcribed and grouped thematically.



## **4 Findings and Discussion**

### **4.1 Section 1**

Out of 120 surveys distributed to selected participants, only 27 were returned. The response rate represents a minority of 22.5% out of the 120 surveys. According to surveytown (online) a standard response rate would be between 10–15%. However, it is also mentioned that it is not recommended to run a reliability analysis with less than 30 participants, but the COVID global pandemic response rates were abnormally low.

The majority of the questionnaire respondents were quantity surveyors (48%), followed by 15% construction managers, 15% contractors, 8% project managers, 7% engineers, and 7% architects. This represents a fair distribution of various professional roles in the construction industry. The participants were asked to indicate their work experience in the construction industry 30% of the respondents indicated 0–5 years experience, 26% indicated 6–10 years, 15% indicated 11–15 years, 4% indicated 16–20 years, 7% indicated 21–25 years experience and 18% have more than 25 years of experience in the construction industry. These findings indicate a good balance of respondents when considering their years of experience within the construction industry, allowing for sufficient knowledge to give valuable input in the survey. However, the majority (30%) of the respondents have less than 5 years of experience; this can influence the respondents' knowledge and expertise about climate change and its impact on construction projects.

#### **4.1.1 Are You Aware of Climate Change?**

96% of the respondents were aware of climate change, affirming that climate change is a real-life phenomenon that cannot be overlooked.

#### **4.1.2 Does Climate Change Currently Have an Impact on the South African Construction Industry?**

56% of the respondents believed that climate change does have an impact on the South African construction industry, 22% thought that it does not have an impact on the South African construction industry and 22.2% were unsure as to whether or not climate change has an impact on the South African construction industry.

#### **4.1.3 Have You Witnessed Any Impact on the Safety of Workers On-Site, Weather-Related Delays, a Change in Construction Materials Design and Manufacturing or Increased Insurance Costs Due to the Impact of Climate Change?**

The purpose of this question was to determine the level of awareness on whether or not the impact of climate change on construction projects are noticeable as the safety of workers on-site, weather-related delays, changes in construction materials design and manufacturing, as well as increased insurance costs, are the four primary concerns in terms of the impact of climate change as stated in the literature. The impacts experienced due to climate change is a topic that requires further investigation. This almost perfectly split opinion on the awareness of climate change's impact on construction projects could

be due to the type of construction projects undertaken, lack of adequate experience or possibly due to respondent's working in different geographical locations.

#### **4.1.4 Is It True that Most Financial Implications Experienced on Site Are Due to Weather-Related Delays?**

Only 15% of the respondents agreed that most financial implications experienced on site are due to weather-related delays. 70% of the respondents disagreed with this statement and the other 15% of the respondents were unsure regarding the matter. This illustrates a negative reaction to the literature's statement which mentioned that most financial implications experienced on-site were due to weather-related delays. Do the contractor's out-of-pocket costs rise proportionally to climate change's impact on-site?

#### **4.1.5 Does the contractor's Out-Of-Pocket Costs Rise Proportionally to Climate change's Impact On-Site?**

The purpose of this question is to determine whether the contractor's out-of-pocket costs rise as climate change's impact on site become more extreme, this is important to clarify as "*there is little room for error within a construction site*" as a 1% increase in a construction project's lifecycle could result in major cost overruns. Considering that 48% of the respondents disagreed with this statement and only 30% agreed, it can be assumed that information contained in the literature needs to be revised and further investigation needs to be conducted. This conclusion is based on a substantial array of the respondent's feedback.

#### **4.1.6 Have Previous Projects Experienced Financial Implications Due to Inadequate Implementation of Risk Mitigating Methods for Unforeseen Weather Events?**

The majority (70%) of the respondents agreed that they have experienced financial implications due to inadequate implementation of risk mitigating methods for unforeseen weather events, 26% have not experienced such financial implications and the remaining 4% are unsure regarding the matter.

#### **4.1.7 Are You Aware of Using Contracts to Mitigate the Impacts of Weather Conditions Due to Climate Change on Construction Projects?**

81% of the respondents were aware of using contracts to mitigate the impacts of weather-related conditions, 15% were unaware and 4% of the respondents were unsure. Most respondents would inevitably be aware of using contracts as a risk-mitigating method as most companies that have accounted for extreme weather has done so through additional contract stipulations and indemnifications.

#### **4.1.8 Are You Aware of Using Insurance to Mitigate the Impacts of Weather Conditions Due to Climate Change on Construction Projects?**

56% of the respondents are aware that insurance can be applied with the purpose of mitigating the impact of weather conditions, 37% of the respondents are unaware and

the remaining 7% of the respondents are unsure. According to the results, it can be assumed that insurance as a method of risk mitigation can use some further investigation as only 56% of the respondents were aware of its use.

#### **4.1.9 Are You Aware of the Use of Technology to Deal with the Impacts of Weather Conditions Due to Climate Change on Construction Projects?**

63% of the respondents were aware of applying technology to mitigate the impacts of weather conditions, 26% of the respondents were unaware of applying technology and 11% were unsure whether or not they have applied technology to mitigate adverse weather conditions. The results reflected that the majority of participants reacted positively that they are aware of using technology in the construction industry. As stated in the literature climate change and its adverse weather conditions is an unavoidable factor, therefore the use of technology is important as it allows for some control of certain aspects of the construction process as climate change is considered uncontrollable by many construction companies.

#### **4.1.10 Are You Aware of the Use of Weather Derivatives as a Risk Assessment Tool for Weather Conditions Due to Climate Change on Construction Projects?**

Unlike insurance policies, weather derivatives do not require proof of loss for payment, they only require proof of bad weather, and hence the purpose of this question was to determine the level of awareness amongst the respondents regarding the role that weather derivatives have to mitigate the impacts of weather conditions due to climate change on construction projects (63%) of the respondents were unaware of using weather derivatives to mitigate the risks imposed by climate change, 31% of the respondents were unaware and 6% of the respondents were unsure. As mentioned in the literature the concept of weather derivatives has only been introduced to the construction industry during recent years, however, it is a concept that must not be overlooked as it can aid a construction company in avoiding losses due to bad weather.

#### **4.1.11 What Method is the Most Logical Approach to Mitigate the Risks Imposed by Climate Change?**

This question was aimed at identifying the most logical method, according to the experience and knowledge of the respondents, available that can safeguard the contractor against climate change's impact on construction projects. (59%) of the respondents thought that using contracts to mitigate the risks imposed by climate change is the most logical approach, 19% of the respondents believed technology is the most logical approach, 7% of the respondents believed insurance is the most logical approach and 4% of the respondents believed that through appropriate research accurate planning can be enabled. The remaining 11% of the respondents mentioned that by combining the methods available to mitigate the risks imposed by climate change the most desired results can be achieved. The results obtained from this question indicates that this research topic is still an area with limited knowledge, especially in South Africa.

#### **4.1.12 Do You Think the Construction Manager is in a Position to Safeguard the Contractor Against the Impact of Climate Change on Construction Projects?**

(59%) think that a construction management practitioner is in a position to safeguard the contractor against climate change's impact on construction projects. 33% Of the respondents think that a construction management practitioner is not in a position to safeguard the contractor and the remaining 8% are unsure. As mentioned in the literature not being able to reduce and adapt to climate change will be the highest impactful risk challenging communities.

#### **4.1.13 What Are the Future Methods of Dealing with Risks Imposed by Climate Change?**

Due to the problem of climate change and the implications imposed on the construction industry as well as the contractor, there are serious issues that need to be addressed, therefore the purpose of this question is to explore and identify possible future methods of dealing with the risks imposed by climate change based on the beliefs, experience and knowledge of the respondents. The following suggestions were noted by the respondents:

- i) The risk imposed by adverse weather conditions will always remain a reality, however, climate change only contributes to the intensity of this. To mitigate the impact that climate change might impose on a construction project a contingency amount must be included into the estimated contract value that caters from the possibility of remedial actions required to fix the damages caused by such adverse weather conditions, as well as allow for enough time to be built into the construction schedule to protect the project from suffering delays due to weather. Furthermore, by making use of the force majeure clauses both parties can be protected, to an extent, from suffering losses due to this uncontrollable factor.
- ii) Historical climate data for the specific site's location can be taken into consideration and incorporated into the contract, thereby making allowances for possible loss of manhours due to climatic conditions. This however is becoming more challenging as climate change is causing the weather of different geological locations to change.
- iii) Amending contract documents to cover climate change under unforeseen weather events.
- iv) All-weather data is documented in the contract; therefore, the planner needs to ensure adequate float is allowed in the programme to cover any adverse weather delays.
- v) Collaboration is a must between the employer, engineer, and contractor from the onset of the project to ensure that the risks are logged, assessed, priced and assigned to the correct party to deal with and mitigate if the risk realises.
- vi) With accurate research on climate change and the effects it will have on our weather patterns, planning can be done to mitigate the effects on construction.
- vii) Technology will start to play an increasingly large role on sites as a whole. As the weather becomes more and more unpredictable as the years progress, technology

will allow the construction manager to better predict inclement weather at the tender phase so that sufficient downtime can be allowed in the program. Technology can also allow for early warning of unexpected weather when the project works have already commenced.

- viii) No single solution nor a combination of solutions is the perfect solution. It requires an informed and proactive construction manager to firstly prepare as well as he can during the tender phase and have ample information to justify his position. However, even more time, information and admin will be required during the project to make sure that this security is maintained through remaining informed and vigilant.
- ix) An improvement in building materials and methods of construction is required to deal with adverse weather conditions caused by climate change.

## 4.2 Section 2

Interviews were conducted with 5 participants, who consisted of construction managers and contractors that were purposively sampled. Before the interview the researcher informed the participants about the title of the research study, a brief overview regarding the literature review was given, and the aim and purpose of the research study were highlighted. One of the biggest drawbacks of this study is the limited published information available regarding the safeguarding of contractors against the impacts of climate change in South Africa, hence the interviews can be utilized to represent the viewpoints of all the interviewees who were purposively selected in a summarised approach.

The interviewees who partook in the study has an average of 19 years' experience within the construction industry. All the interviewees are aware of climate change however there are different opinions regarding the impact it has on the construction industry.

### 4.2.1 Based on Your Experience What Are the Major Concerns Raised by Climate Change on Construction Projects?

Various concerns were raised amongst the interviewees regarding the impact climate change has on construction projects. Some of the concerns include a build-up of carbon dioxide within the concrete causing damage and rust to the steel components, a build-up of moisture affecting wooden structures, unpredictable weather patterns are being noticed, delays affecting the approved construction programs, as well as the standing of resources and machinery resulting in additional cost overruns.

### 4.2.2 Have Read in My Literature That Many Construction Projects Suffer Delays and the Main Contributor to Construction Delays and Its Respective Cost Overruns Is the Weather, What Do You Think About It?

This question has received many split opinions regarding the degree of the impact weather has on construction delays and cost overruns. Some of the interviewees believe that the change in seasons and weather patterns is beneficial to the construction industry as there is more time available to construct whereas other interviewees perceive inclement

weather to be one of the biggest contributors to the delays of construction projects and their respective cost overruns.

#### **4.2.3 Have You Noticed Financial Implications on Construction Projects Due to Climate Change?**

Similar to the previous question, this question is divided up into mixed opinions. Most interviewees have experienced financial implications due to inclement weather however some of the interviewees believe that climate change has benefitted them to complete projects ahead of the pre-determined dates.

#### **4.2.4 How Does Climate Change Impact the Construction project's Lifecycle?**

Similar to the questions above, certain interviewees have not yet experienced an alteration to their construction project's lifecycle as climate change aided in the completion of their projects before the predetermined date however the other employees mentioned that adverse weather conditions have brought construction processes to a complete halt resulting in weather-related delays and cost overruns.

#### **4.2.5 Has Your Company Implemented Methods to Adapt to Climate Change? What Are They?**

The majority of construction companies have not implemented methods to adapt to climate change as they either felt that it has not been necessary as of yet or because climate change is unpredictable. Those that implemented the 'bear' minimum did so by closely monitoring the weather patterns by installing weather stations on-site, and by amending the construction programme and setting additional costs aside.

#### **4.2.6 Also Mentioned in the Literature Is That Most Construction Companies Have Not Fully Come To Terms with Climate Change's Impact on the Construction Industry. Those That Have Done So by Adding Additional Contract Stipulations or Increased the Overall Contract Price, What Are Your Thoughts on This?**

Most interviewees mentioned that amending contract stipulations is a good option however increasing the overall contract price could potentially lower the chances of obtaining a tender.

#### **4.2.7 What Are the Future Methods of Dealing with Risks Imposed by Climate Change?**

This question received the least amount of feedback as the interviewees were either unsure of future methods or perceived climate change to only be a serious concern in the years far from now. Some interviewees mentioned that more time will be allowed to complete projects, and workdays might need to be extended to weekends.

#### **4.2.8 Based on Your Experience is the Construction Manager in a Position to Safeguard the Contractor Against the Impact of Climate Change?**

Most interviewees agreed that the construction manager is in a position to safeguard the contractor, however only to an extent as he manages the project based on the circumstances created and the resources available to his disposal.

#### **Summary**

From the data collected it is evident that climate change and the impact it has on construction projects is a serious concern for the South African construction industry mainly because of the many different opinions obtained from the participants of the survey and the interviewees regarding the reality and seriousness of climate change. Construction managers however are potentially in a position to mitigate the causes and outcomes of climate change however they are very dependent on the resources available to them as well as the type of construction project underway.

## **5 Achievements of Research Objectives**

### **5.1 Research Objective 1 – to Determine the Most Logical Approach to Mitigate the Risks Experienced by Climate Change**

No single solution nor a combination of solutions is the perfect solution, the method that will be considered the best option for implementation will depend on the nature and environment of the contract. However, more information and further investigation will be required to discover the best option for implementation as the respondents in this study had a variety of different opinions.

### **5.2 Research Objective 2 – to Determine the Financial Implications on Construction Projects Experienced Due to Climate Change?**

Most respondents who partook in the study have experienced financial implications due to inclement weather however some of the interviewees believe that climate change has benefitted them to complete projects ahead of their pre-determined dates. Those that have experienced financial implications were mostly due to weather-related delays that allowed for the extension of time but without the compensation for cost. As mentioned in the literature even a 1% increase in work stoppage due to unexpected weather has a major impact on the bottom line, however, depending on the structure being erected and the geographical location of the site certain projects will experience more severe impacts.

### **5.3 Research Objective 3 – to Determine the Major Concerns Raised by Climate Change in South Africa?**

As stated in the literature review, the four (4) major concerns within the construction industry that gets impacted by climate change include the safety of workers, weather-related delays, the design and manufacturing of construction materials as well as insurance costs. The empirical study supported the findings of the literature review as various

concerns were raised amongst the respondents regarding the impact climate change has on construction projects. Some of the concerns include a build-up of carbon dioxide within the concrete causing damage and rust to the steel components, a build-up of moisture affecting wooden structures, unpredictable weather patterns are being noticed, delays affecting the approved construction programs, as well as the standing of resources and machinery resulting in additional cost overruns.

#### **5.4 Research Objective 4 – to Determine the Extent to Which Contractors Have Implemented Methods to Adapt to the Effects of Climate Change?**

As mentioned in the literature it is crucial to be aware of the implication's climate change has on construction projects because awareness of such implications will determine whether climate change's impact on construction projects will be disastrous or manageable. The majority of construction companies have not implemented methods to adapt to climate change as they either felt that it has not been necessary as of yet or because climate change is unpredictable. Those that implemented the 'bear' minimum did so by closely monitoring the weather patterns by installing weather stations on-site, and by amending the construction programme and setting additional costs aside. However, setting aside additional costs will have an impact on the contractor's competitive advantage. Therefore, it can be assumed that the majority of the construction businesses and firms have not yet realised the reality and seriousness of climate change and its impact.

#### **5.5 Research Objective 5 – to Determine How Does Climate Change Impact the Construction Project Lifecycle?**

Many respondents have not yet experienced alterations to their construction project's lifecycle as climate change aided in the completion of their projects before the predetermined date however other respondents mentioned that adverse weather conditions have brought construction processes to a complete halt resulting in weather-related delays and cost overruns. Once the project's lifecycle becomes altered it has a direct impact on on-site programming, delays, additional expenses, material costs and the labourers' safety as they will have to increase their productivity and efficiency levels to complete the project on time or with minimal delay.

#### **5.6 Research Objective 6 – to Determine the Different Methods to Safeguard a Contractor Against the Impacts of Climate Change?**

Many professionals in the construction industry are either unsure of the methods available or perceive climate change to only be a serious concern in the years far from now. However based on the information captured in the literature review adverse weather conditions are expected to worsen in the years to come and it is therefore important for construction companies to think out the box to mitigate construction delays and their respective cost overruns. Currently, the different methods available to safeguard a contractor against the impacts of climate change include adequate research, construction



contracts, construction insurance, construction technology as well as weather derivatives which is a new concept that must not be overlooked. Future methods of dealing with risks that were identified include improved collaboration between the employer and employee, improved building materials and methods of construction as well as extending workdays into weekends.

## 6 Conclusion and Recommendations

The problem statement highlighted that the South African construction industry faces various challenges due to the ongoing effects of climate change, and there may be an increase in the risks shortly; therefore, construction managers must apply methods to safeguard the contractor against climate change's impact on construction projects. Some of the findings do not correlate with the literature review, one of the prime examples is where 70% of the respondents disagreed with the statement that most financial implications experienced on site are due to weather-related delays, climate change is, therefore, a topic that still requires further investigation. Regarding the methods available to mitigate the impact of climate change no single solution nor combination of solutions is the perfect solution. It requires an informed and proactive construction manager to firstly prepare as well as he can during the tender phase and have ample information to justify his position. Construction managers however are potentially in a position to mitigate the causes and outcomes of climate change however they are very dependent on the resources available to them as well as the type of construction project underway.

Based on the results of the study, the following recommendations can be made:

- i) Unlike insurance policies, weather derivatives do not require proof of loss for payment, they only require proof of bad weather. A majority (63%) of the respondents were unaware of using weather derivatives to mitigate the risks imposed by climate change however it is a concept that must not be overlooked and further investigation can be done as it can aid a construction company in avoiding losses due to bad weather.
- ii) Thorough research should be conducted before the construction phase so that adequate planning can be done to mitigate the effects climate change could potentially have on construction.
- iii) Construction management practitioners need to start applying an informed and proactive approach to prepare as well as they can during the tender phase and have ample information to justify their position.
- iv) Professionals in the construction industry need to be made aware of the implication's climate change has on construction projects because awareness of such implications will determine whether climate change's impact on construction projects will be disastrous or manageable.
- v) Even though the construction industry's professional practitioners have the opportunity to mitigate the impact climate change has on construction projects more awareness needs to spread as the majority of the construction businesses and firms have not yet realised the reality and seriousness of climate change and its impact.

- vi) Climate change and the impact it has on construction projects is an area that requires further investigation and research as many answers received from the respondents were of different opinions.

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# Students Housing Occupancy Satisfaction: Perception of Tertiary Students in Bloemfontein

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**Abstract. Purpose:** Student housings provide a setting for students learning and living experience. Thus, these facilities ought to be well-resourced to support the needs of students. This paper explores the perceptions of tertiary students about their off-campus student housing in Bloemfontein.

**Design/Methodology/Approach:** The study adopted both qualitative and quantitative approaches. Convenient sampling technique guided the distribution of the sets of the questionnaire. Descriptive statistics were used to analyse the quantitative data whilst content analysis was used to analyse the qualitative data.

**Findings:** The findings revealed that students had both positive and negative sentiments about their student housing. On the one hand, seven main themes (i.e., safety, lack of basic facilities and services, off-campus housings are too expensive, lack of privacy, poor housing conditions, need for government funding/support, proximity, and personal development) emerged as the negative sentiments. On the other hand, three themes - services are provided, freedom, cheaper to share – emerged as the positive sentiments.

**Practical Implication:** The study provides invaluable information on the concerns that off-campus students have about their housing facilities. With this information, hostel developers would be able to ensure that all basic facilities are incorporated in the development of off-campus private hostels. Moreover, owners of private student housing could improve the quality of student housing by incorporating essential facilities identified by students. Also, university authorities could use the findings as a guide when assessing and approving off-campus student housing.

**Research Limitations:** The study focused on one location in Bloemfontein. To offer a broader perspective, further study should expand the number of participants/student housing.

**Keywords:** Measures · Safety · Satisfaction · Security · Student housing

## 1 Introduction

Housing is one of the basic needs and fundamental rights of man. Housing is perceived as a shelter that consists of the physical structure, neighbourhood, environmental factors as well as facilities, and services required for the well-being of the occupants. Thus, student

housing should be perceived as a fundamental student's need (Simpheh and Shakantu 2018). This explains why university authorities and governments take a keen interest in the provision of student housing. Student housing is perceived as an accommodation built to create an environment that supports students' living and learning experience while pursuing their education (Fields 2011). Thus, the student housing environment must be able to promote student's living and learning requirements. Residing in student housing as a student endangers positive outcomes and values. For example, Too and Bajracharya (2015) stipulated that positive education outcomes can be stimulated in students staying in student housing. Furthermore, student housing makes students see education as their main occupation; promotes the integration of students into a new academic environment; promotes unity; allow students to have quick access to learning facilities (Hassanain 2008; Department of Higher Education and Training 2011; Addai 2013; Oladokun and Ajayi 2019).

Notwithstanding, student's enrolment in higher education institutions in many countries, including South Africa, outstrip the volume that universities can hold and can thus not provide satisfactory and affordable accommodation for all university students (Ackermann and Visser 2016). Due to the increase in students' enrolment in tertiary education internationally, student housing has become one of the most significant problems universities face (Spio-Kwofie et al. 2016). Just like most developing countries, South Africa has a deficiency of affordable student housing due to the rapid expansion of universities, the increase in enrolment of students from all backgrounds in the universities, as well as the funding restrictions for the development and maintenance (renovation) of university-owned (on-campus) student accommodation (Department of Higher Education and Training 2011). Donaldson et al. (2014) revealed that two of the reasons students choose to stay in off-campus accommodations in Bloemfontein are that they prefer not to be part of the culture of campus hostel accommodation and also because on-campus accommodation is not enough to cater for all students. As a result, most students are left with no choice; but to stay off-campus in private housings. Unfortunately, most off-campus private student housing does not provide students with all the basic facilities required to promote their living and learning experience. It is on this premise that this paper explores the perceptions of tertiary students about their off-campus student housing in Bloemfontein.

## 2 Theories Underpinning the Study

### 2.1 Student Housing Satisfaction

The concept of satisfaction is widely used in evaluating the performance of living environments. Satisfaction relates to the ability of an individual to appraise his/her expectation with what he/she receives or experiences after a product is used or service is provided. Two general perspectives of satisfaction theories are the process and outcome approaches (Parker and Mathews 2001; Yang and Zhu 2006). Although the satisfaction concept is mostly applied in marketing research, it is considered a very useful norm in evaluating housing. Amole (2009) believes that housing satisfaction helps to determine a housing's success, points out the aspects of the housing that is underperforming,

and measures the user's emotional and cognitive responses. Thus, assessing the living environment helps to determine areas where improvements are required.

## 2.2 Empirical Evidence of Student Housing Perception/Satisfaction

According to Ghani and Suleiman (2016), many students believe that student housing must contain essential facilities such as the supply of running water, a bathroom, sewerage, electricity, kitchenette, and toilet that leads to adequate and gratifying comfort, safety as well as convenience, which in combination lead to a rewarding life. Khozaei et al. (2010) revealed that convenience, i.e., walking distance to lecture halls is a key factor affecting student housing selection. Simpeh and Shakantu (2020) also found that students expect their student housing to be resourced with several facility services and spaces. The authors conducted ten focus group discussions where students listed a total of 38 spaces and 41 services. Spaces mentioned by the majority of the groups were washroom, sleeping space, kitchen, study area, laundry area, visitors lounge, outdoor field, library, mini-mart, cafeteria, sickbay, Television room, gym area, recreation room, swimming pool, car park, prayer room, and computer room. Additionally, services including water, electricity, internet, security, cleaning, catering, maintenance service, shuttle, generator, laundry service, ATM/bank, health service, and vendor dominated the list of at least 4 groups (Simpeh and Shakantu 2020). Besides, students want to reside in a neighbourhood that is conducive for effective learning and in residences close to school/campus (Kobue et al. 2017). Gbadegesin et al. (2021) indicated that student housing satisfaction is influenced by the context of the country and the institution where the study is done. Thus, studies conducted in different parts of the world and/or institutions provide varying results. For example, Najib et al. (2011) conducted a study on student residential satisfaction in Malaysia; the authors found that students were satisfied with the provided housing facilities with a student residential satisfaction index of 2.96. Hassanain (2008) also revealed that students expressed dissatisfaction with specific elements such as noise level, control of artificial light, quality of air, the capacity of wardrobe, adequacy of personal storage, and type of chairs.

In the African context, a study conducted by Gbadegesin et al. (2021) in the off-campus accommodation in Nigeria revealed that students were generally dissatisfied with their student housing. The authors classified the elements into 4 broad features and found that students were dissatisfied with the standard of kitchen facilities, accommodation layout, outdoor and indoor noise, hostel design, common areas, heating, insulation and ventilation systems, pest control, facilities in common areas, quality of electricity installations (under physical elements); closeness to major city areas, reputation on the level of crime, closeness to academic facilities, car parking provision, quality of community infrastructure, fire, safety and emergency service in the community, closeness to sports and recreation & religious facilities, transportation links to market and major

city areas, transportation links to university (under community-related elements); routine maintenance, the safety of lives and properties, waste management and quality of water (under contract-related elements); and easy access to quality entertainment (under academic and social elements). On the other hand, the study revealed that students were satisfied with local amenities access (local shops, bars, restaurants), closeness to university, communication lines regarding events and university news, academic and social environment, academic goals achievement, conduciveness for study, student privacy, socialization opportunities, freedom of choice of hostel mates, room size, the standard of toilet and bathroom facilities, size of indoor space, security facilities and features (gates, fence, doors) (Gbadegesin et al. 2021). Another study conducted in Nigeria revealed that students residing in the polytechnics hostel facilities were generally dissatisfied with the hostel facilities. Moreover, it became evident that basic facilities such as laundry, kitchen, ceiling fan, and internet facilities were not provided in some of the student housing (Sawyer and Yusof 2013). Studies conducted in Ghana also present varying satisfaction ratings. On one hand, Danso and Hammond (2017) revealed that, except for the commitment of the hostel operators towards maintenance needs, students residing in the private hostels around Kwame Nkrumah University of Science and Technology campus were satisfied with several aspects of the student housing. On the other hand, Simpeh and Shakantu (2018) revealed that students residing in on-campus student housing in selected universities in the southern part of Ghana had complaints such as the poor condition of bathrooms facilities, absence of study areas, poor standard of cleaning, lack of kitchens, and slow response to maintenance requirements. However, the study also revealed that the students were pleased with the proximity of the student housing to the lecture theatres, the provision of mini-mart, and the washrooms provided inside the bedrooms.

In the South African context, a case study conducted by Simpeh and Adisa (2020) on student housing facilities security and safety performance in a university in the Western Cape revealed that students were generally satisfied with the security and safety measures provided in the student housing. However, the students expressed dissatisfaction with measures including weapon detectors, sprinkler systems, CCTV, smoke detectors, burglar bars of doors, ventilation, disabled toilet facility, and lifts for disabled students. Gopal and Niekerk (2018) revealed gaps in the measures instituted to promote students' safety in student housing. The ministerial committee's report for the review of the provision of student accommodations in South African universities supports Gopal and Niekerk's assertion (Department of Higher Education and Training 2011). Oke et al. (2017) also revealed that factors such as the enforcement of rules, the effectiveness of the lift system, provision of laundry service in the residence, numbers of electrical sockets, the size of wardrobe and closet, and window quality contribute to student dissatisfaction.

### 3 Research Methodology

This paper explores the perceptions of tertiary students with their off-campus student housing in Bloemfontein. Thus, qualitative and quantitative approaches were deemed appropriate. Qualitative research focuses on describing and sometimes explaining social, particular, or complex phenomena within their natural occurring context to develop an understanding of the meaning(s) imparted by the respondents (Gibbs 2007; Leedy and Ormrod 2015). The initial plan was to conduct interviews. However, due to the lockdown restriction at the time of data collection, an open-ended questionnaire was adopted. Quantitative data (close-ended) was also sought to supplement the qualitative data. Subsequently, both closed-ended and open-ended questions were asked. The closed-ended questions related to demographic features and the satisfaction ratings (Tables 1 and 2), whereas the open-ended question, seeking the reasons behind student's satisfaction or dissatisfaction (Tables 3 and 4). The survey monkey platform was used to distribute the questionnaire; respondents were then sent a link to the questionnaire through WhatsApp or email.

The target population of the study comprised of University of the Free State students staying in off-campus student housing in Bloemfontein. The sampling technique is generally applied due to the limitation of time to analyse an entire population (Taherdoost 2016). Sampling is the process where few events, individuals, or objects get identified, chosen, and examined to determine the population from which it was chosen (Salaria 2012). Sampling helps with the selection of a subset of a population to represent the entire population of interest. Convenient sampling technique guided the distribution of the sets of the questionnaire. Thus, any off-campus student staying in a hostel (within the selected location) and was willing and readily available to answer the questionnaire was included in the study. A total of 150 set questionnaire were distributed, of which 98 well-completed questionnaire were received back and analysed. This indicates a response rate of 65%. The quantitative data was analysed descriptively (i.e., Mean Item score) while the qualitative data was analysed thematically (i.e., using themes).

## 4 Findings and Discussion

### 4.1 Demographic Information

The respondents' demographic features, as shown in Table 1 shows that there were more female respondents than male; 65% against 35%. Additionally, the majority were full-time and unemployed. It can also be inferred that 77% were either in the third or fourth year; thus, by the years they have been studying and staying in the student residence would be able to rate the satisfaction of their student housing better.

**Table 1.** Demographic features of respondents

Nature of respondents	Frequency	Percentage
<b>Gender</b>		
Male	34	35%
Female	64	65%
	<b>98</b>	<b>100%</b>
<b>Age</b>		
18–25	87	89%
26–30	11	11%
31–40	0	0%
40 and over	0	0%
	<b>98</b>	<b>100%</b>
<b>Level of studies</b>		
First year	9	9%
Second year	8	8%
Third year	46	47%
Honours	29	30%
Masters	0	0%
PhD	0	0%
Other	6	6%
	<b>98</b>	<b>100%</b>
<b>Employment Status</b>		
Unemployed	72	73%
Employed	21	21%
	<b>98</b>	<b>100%</b>
<b>Type of student</b>		
Full time	94	96%
Part time	4	4%
	<b>98</b>	<b>100%</b>

Source: Own construction



#### 4.1.1 Respondents' Satisfaction Level of Their Off-Campus Housing

This question aimed to determine the satisfaction level of respondents in terms of the flat and/or room they were residing in. The aim was to determine how satisfied students were with 6 aspects of student housing. Table 2 shows that most of the respondents were satisfied with all 6 aspects of student housing. The parameters that students were most satisfied with were 'safety' followed by 'neatness', 'available facilities', and 'quality of structure'. Although the overall satisfaction rate of the student housing looks good, not all respondents are satisfied, which implies that there is a need to address the few lapses which affect student satisfaction.

**Table 2.** Respondents' satisfaction level of off-campus housing

Aspects	Satisfied	Not satisfied	MIS
Safety	86 (88%)	12 (12%)	86.24
Neatness	85 (87%)	13 (13%)	85.27
Available Facilities	80 (82%)	18 (18%)	80.37
Quality of the structure	80 (82%)	18 (18%)	80.37
Quality of the bathrooms	78 (80%)	20 (20%)	78.41
Privacy	74 (76%)	24 (24%)	74.49

*Source: Own construction*

#### 4.1.2 Respondents Opinion Regarding Their Off-Campus Accommodation

The purpose of this part was to allow respondents to express why they are satisfied or dissatisfied with their off-campus student housing. Both positive and negative sentiments were provided. The concerns or negative sentiments raised by students could be classified into seven main themes (i.e., safety, lack of basic facilities and services, off-campus housings are too expensive, lack of privacy, poor housing condition, need for government funding/support, proximity issues, and personal development). Safety, lack of basic facilities and services, unaffordability of off-campus housing, and poor housing conditions were the predominant concerns of students (see Table 3). Conversely, it can be inferred from Table 4 that participants had few positive opinions about their off-campus housing. Few respondents were pleased that Wi-Fi facilities were provided and cleaning services were made available. Some also indicated that off-campus housing offers freedom and could also afford students the opportunity to share rooms, thereby reducing cost. Thus, three themes - services are provided, freedom, cheaper to share - could be drawn from the positive comments.

**Table 3.** Respondents' opinion about their student housing (negative)

	Main theme	Sub themes	Frequency	Total
1	Safety	Better safety must be provided	13	<b>13</b>
2	Lack of basic facilities and services	Basic facilities are not provided	6	<b>12</b>
		Study areas must be made available	3	
		There is a need for transport to and from campus on an hourly basis	3	
3	Off-campus housing is too expensive	Off-campus housing is not regulated; therefore, it opens for exploiting students financially	5	<b>12</b>
		The accommodation should be more affordable	5	
		Off-campus housing should not be overpriced	1	
		Off-campus accommodation close to campus is usually scarce or too expensive	1	
4	Privacy	Lack of privacy	4	<b>7</b>
		There are too many shared facilities	3	
5	Housing condition	Student accommodations must be renovated	5	<b>6</b>
		Parking can be better arranged to avoid damage to property and theft	1	
6	Government funding	Government funding is required due to the high rental values of student accommodation	1	<b>2</b>
		NSFAS accredited accommodations should not require deposits due to a lack of funds by students	1	
7	Proximity	The accommodation should be close to campus	1	<b>1</b>
8	Personal development	Student accommodation should not just be a space where you eat, sleep, study, but a place where you can develop as a person, develop skills and relationships	1	<b>1</b>

(Source: Own Construction)

**Table 4.** Respondents' opinion about their student housing (positive)

	Main theme	Sub themes	Frequency	Total
1	Services are provided	Wi-Fi Facilities are included and available	4	7
		Cleaning services are made available	3	
2	Freedom	Off-campus accommodation has the advantage of being on your own, and no one is controlling you, unlike on-campus, where there are time constraints and security monitors	2	3
		Off-campus can fit your custom individual preferences and lifestyle much better	1	
3	Cheaper to share	It is cheaper to share accommodation than to get a single unit	1	1

(Source: Own Construction)

#### 4.1.3 Discussion of the Findings

Studies carried out in different parts of the world demonstrate that students housing safety is very important (Najib et al. 2011; Oke et al. 2017; Simpeh and Shakantu 2020). Notwithstanding, safety is identified as the number one student's concern in this study. As many as 13 respondents had issues with the safety of the student housing. This does not relate to the satisfaction ratings, which demonstrate that students are satisfied with safety (see Table 2). Perhaps, students feel satisfied because some of the concerns raised do not positively influence satisfaction. This finding correlates with Gopal and Niekerk (2018), who indicated that student housing in South Africa has some form of safety lapses. The finding is also in agreement with the report on the ministerial committee for the review of the provision of student accommodations in South African universities. The report revealed that some student housing had poor access control and a lack of security guards at the entrance (Department of Higher Education and Training 2011). Poor safety could be catastrophic; therefore, any safety concerns need to be prioritised. The lack of basic facilities and services is the second concern. Although it appears that most of the respondents were satisfied with the available facilities, few were dissatisfied (see Table 2). The lack of study area and shuttle services were pointed out in this study. These are very important facilities/services. Kobue et al. (2017) indicated that students prefer to reside in student housing that is conducive to effective learning. Students need a study room to promote learning whilst the shuttle is required to transport students to campuses. Studies conducted in Nigeria (e.g., Sawyerr and Yusof 2013; Gbadegesin et al. 2021) and Ghana (e.g., Simpeh and Shakantu 2018) also reveal that some of the student housings lack basic facilities such as laundry, kitchen, ceiling fan, study areas, and adequate kitchens. The high cost of off-campus student housing was mentioned by 12 participants. Ackermann and Visser (2016) revealed that affordability of student housing is a challenge due to student's enrolment surpassing the volume that universities can hold.

As a result of this problem, students are forced to stay in off-campus housings. The fact that some off-campus student housings are not regulated results in the exploitation of students; thus, affecting affordability. The sentiment regarding the need for government intervention has a relation with the ‘high cost of off-campus student housing’. If students on the list of NSFAS can occupy off-campus housing without paying the deposit, then the burden of upfront payment would be eliminated.

There was also an indication of a lack of privacy. A total of 7 respondents had privacy issues. Although most of the respondents were satisfied with privacy, there was quite a number (i.e., 24%) who were dissatisfied (see Table 2). The lack of privacy could be related to other issues such as “too many shared facilities”. For example, too many students using washrooms could affect privacy. The lack of facilities also aggravates the issue of privacy. Poor housing conditions can be partly attributed to neglect and poor maintenance practices. Issues related to maintenance could escalate to the point where renovations become inevitable. Some respondents indicated that the student housings need renovations. It can be deduced from the satisfaction rating the 18% of the respondents are not satisfied with the quality of the structure, and another 20% are dissatisfied with the quality of the bathroom (see Table 2). Studies conducted in Ghana (e.g., Danso and Hammond 2017; Simpeh and Shakantu 2018) and Nigeria (e.g., Sawyerr and Yusof 2013) also demonstrate that hostel managers do not prioritise the maintenance needs of students. Moreover, the report on the ministerial committee for the review of the provision of student accommodations in South African universities revealed 7 out of 15 universities student housing-related protest actions were due to poor maintenance/facilities (Department of Higher Education and Training 2011). The issue of building condition is very important as the poor condition could result in safety and health risk. Only one respondent mentioned proximity. The lack of basic facilities/services such as study areas and shuttle services makes proximity a serious one. Kobue et al. (2017) stated that students want to reside in a residence that is close to school. For example, students may need to walk to campus to study if the student housing is un conducive for studying. Where there is no shuttle, students need to stay in student housings that are a walking distance to campus. Convenience in terms of walking distance to lecture halls is a key factor that influences student housing selection (Khozaei et al. 2010). Student housings ought to create an atmosphere that promotes socialization and personal development. This idea is shared by the Department of Higher Education and Training (2011), who expressed that the set-up of student housing should enhance the integration of students and provides a community setting for the students. However, the expression of the respondent ‘*student housing should promote personal development and help students to develop skills and relationships*’ suggest the opposite.

The positive sentiments suggest that not all the student housings are performing poorly. Some students believe that their student housings were resourced with the required facilities. Some commended the cleaning services whilst others were pleased that Wi-Fi facilities are available. The second positive sentiment relates to the freedom students enjoy in off-campus housings. The freedom from the strict on-campus rules and regulation, the freedom to choose who to stay with and where to stay, and the freedom to choose a student housing that fit individual preferences and lifestyle are all reasons why students prefer to stay off-campus. This view correlates with the findings of

Donaldson et al. (2014), who revealed that some students choose to stay in off-campus accommodations in Bloemfontein because they prefer not to be part of the culture of the campus hostel. Finally, one respondent highlighted that sharing accommodation could be cheaper as the rental cost and other costs associated with staying in the house could be shared.

## 5 Conclusion

Student housings provide a setting that promotes students learning and living experience. Consequently, it becomes imperative that student housings are well-resourced with all the necessary facilities and services required to promote student's living and learning requirements. Unfortunately, most of the off-campus privately-owned student housing does not provide students with all the basic facilities and services required to promote their living and learning experience. This paper explored the perceptions that tertiary students in Bloemfontein have about their off-campus student housing. The findings indicate that as much as students are generally satisfied with their off-campus housing, several issues need improvement. The perceptions that students have about student housing are more negative than positive. Safety, lack of basic facilities and services, off-campus housings being too expensive, lack of privacy, poor housing condition, need for government funding/support, proximity, and personal development emerged as the negative sentiments, whereas provision of services, freedom, and cheaper to share emerged as the positive sentiments. This implies that hostel owners need to take cognizance of the student's sentiments and incorporate them when maintaining and/or renovating their student housings. Also, private developers need to undertake research among students to ascertain their needs and requirements before embarking on new students' accommodation development. Moreover, university authorities would have to prioritise students' needs when assessing and approving off-campus student housing. A study that expands the number of participating off-campus housing is recommended since the data for this study was collected from only one location in Bloemfontein.

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# Architect's Awareness, Knowledge and Usage of Sustainable Architecture in Nigeria

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**Abstract. Purpose:** This paper assesses the status of sustainable architecture in Nigeria. The specific objective is to assess the level of awareness, knowledge, and usage of sustainable architecture in Nigeria.

**Design/Methodology/Approach:** The survey research was used. A close-ended structured questionnaire was designed and distributed face-to-face and through email to collect data. A total of 160 questionnaires were randomly distributed to architects in Kaduna, Abuja and Lagos, Nigeria. 136 questionnaires were returned (with a response rate of 85%). The data collected from the questionnaires were then collated in Microsoft Excel spreadsheets and presented using infographics.

**Findings:** Findings revealed that the majority of Nigerian architects are just aware of the concept of sustainable architecture. However, very few have excellent knowledge to adopt and use it. In addition, the majority are only planning to use it in the next three years. The government of Nigeria was identified as a major driver of sustainable architecture.

**Research Limitation/Implications:** The study focused on sustainable architecture awareness, knowledge, and usage level among architects only. The study only concentrated on Kaduna Metropolis, FCT Abuja and Lagos, Nigeria where there is a high percentage of practising architects.

**Practical Implication:** The findings of this study will further the need for the adoption of sustainable architectural practice in Nigeria to have an inclusive, safe, resilient and sustainable environment in keeping the sustainable development goals, SDGs 11.

**Social Implication:** The knowledge advanced by this study will help policy-makers to reassess the existing roadmap and realign with the present realities in the construction industry for achieving the SDGs, especially goal 11.

**Originality/Value:** This study reveals the present awareness, knowledge, and usage level on sustainable architectural practice in Nigeria.

**Keywords:** Architects · Built environment · Industry · Practice · Sustainable architecture

## 1 Introduction

Third world nations are faced with climatic conditions such as intense solar radiation, high humidity, and condensation, dust and sandstorms, and flood which affects the comfort of man and the safety of the built environment (Elimisiemon et al. 2016). The effect



of climate change on the built environment will depend on the sensitivity and adaptability of the systems (US EPA, 2011 in University of Michigan and US Green Building Council 2011). These challenges on the environment and emerging technological innovations had given rise to new approaches such as sustainable architecture in architectural practices and the tools been used.

Sustainable architecture is a practice in architecture that minimizes the negative impact of building in the environment through efficient use of materials, energy, development space, and ecosystem. The built environment is designed to deliberately conserve energy and the ecosystem (Dublin Institute of Technology 2013).

A concept of philosophy of green design also known as sustainable building or high-performance building U.S. Environment Protection Authority (EPA 2016). It involves making and utilizing structures and processes that are responsible to the environment and efficient in the use of resources from the siting, design, construction, maintenance, renovation, and deconstruction (U.S. EPA 2016).

The U.S. Green Building Council (USGBC) (2015) identified five fundamental principles of green building and sustainable site design: sustainable site design-minimize urban sprawl and needless destruction of valuable land, habitat and green space, which results from inefficient low-density development; water quality and conservation-preserve the existing natural water cycle and design site and building improvements such that they closely emulate the site's natural "pre-development" hydrological systems; energy and environment-minimize adverse impacts on the environment (air, water, land, natural resources) through optimized building siting, optimized building design, material selection, and aggressive use of energy conservation measures; indoor environmental quality-provide a healthy, comfortable and productive indoor environment for building occupants and visitors and material and resources-maximize the use of recycled content materials, modern resource-efficient engineered materials, and composite type structural systems.

However, despite the importance of sustainable architecture in preserving the environment against the devastating effect of traditional construction practices, very few engineers, architects, and other professionals in the sector practice it. More so, empirical evidence shows that very few studies have been carried out in this area. This is attributed to the low awareness level, lack of will, and strategy to it in construction practices desire.

Other barriers that have been identified by other researchers include lack of design and construction team; lack of building codes and regulation, lack of public awareness, lack of demand, lack of strategy for promotion, lack of expertise, lack of database and information, resistance to change, lack of government support, lack of a measurement tool, lack of incentives, higher investment cost, lack of cooperation, lack of training, lack of technology, increased capital cost, the attitude of professionals (Bash and Halkkinen 2015 cited in Ayarkwa et al. 2017; Djokoto et al. 2014; Ahmed and Opoku 2014; Bangdome-Dery and Kootin-Sanwu 2013). Architects and clients are the most important players in sustainable development (Abidin 2010), this study focus on the perspective of architects on awareness, knowledge, and usage of sustainable architecture in Nigeria.

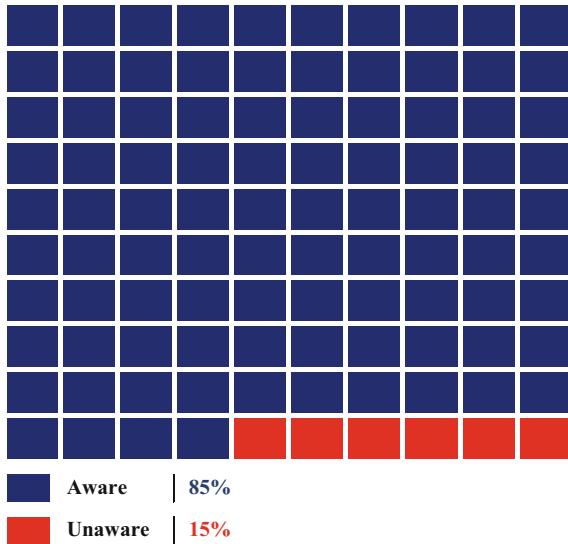
This study aims to assess the status of sustainable architecture in Nigeria. The specific objective is to assess the architects’ level of awareness, knowledge and usage of sustainable architecture in Nigeria.

## 2 Methodology

This is an explorative study. The survey research was used. A close-ended structured questionnaire was designed and distributed face-to-face and through email. The population of the study is made up of architects in Kaduna, FCT Abuja and Lagos, Nigeria. A total of 160 questionnaires were randomly distributed to architects in Kaduna, Abuja and Lagos Nigeria, and 136 questionnaires were collected (with a response rate of 85%). The data collected were analyzed using SPSS and presented using tables and infographics.

## 3 Findings

Table 1 and Fig. 1 show that almost all respondents (85%) are aware of sustainable architecture, only 15% said that they were not aware of it.



**Fig. 1.** Sustainable architecture awareness

**Table 1.** Sustainable architecture awareness

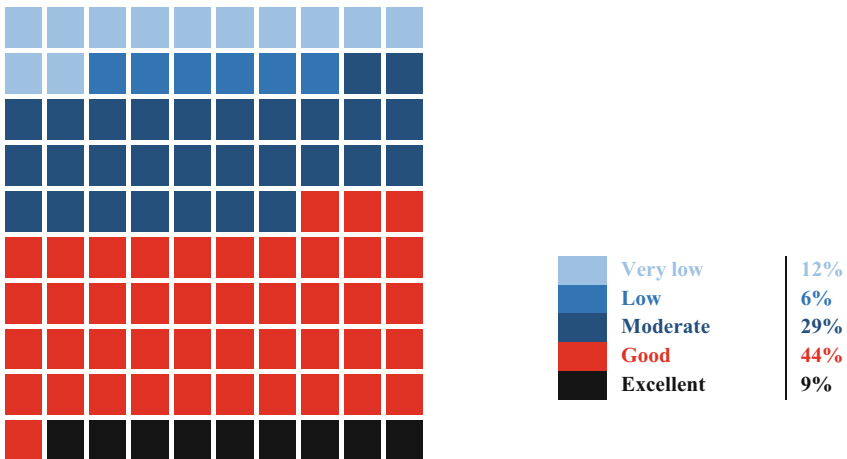
Item	Frequency	Percentage (%)
Aware	116	85.29
Unaware	20	14.71
<b>Total</b>	136	100

### 3.1 Level of Knowledge and Understanding

Table 2 and Fig. 2 below show that of the 85% of respondents that were aware of the concept of sustainable architecture, only 8% have excellent knowledge, while 44% have a good knowledge of it, 29% have moderate knowledge with 12% having very low knowledge.

**Table 2.** Level of knowledge and understanding of sustainable architecture

Item	Frequency	Percentage (%)
Very low	16	11.76
Low	8	5.88
moderate	40	29.41
Good	60	44.12
Excellent	12	8.82
<b>Total</b>	<b>136</b>	<b>100</b>



**Fig. 2.** Level of knowledge and understanding of sustainable architecture

### 3.2 Awareness, Knowledge, and Usage

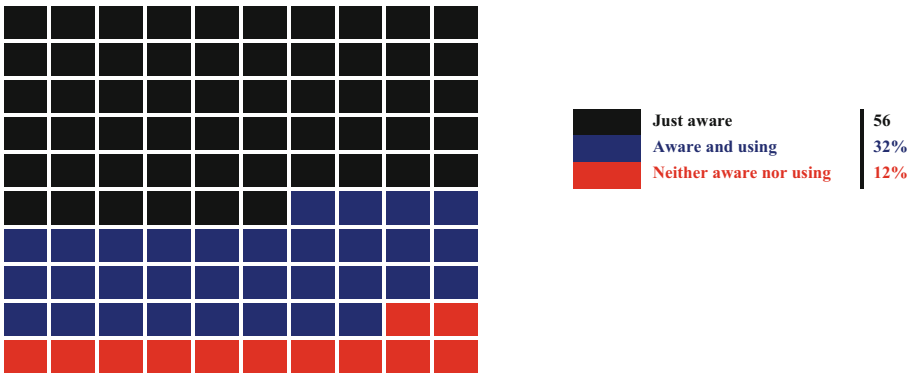
About awareness, knowledge and usage, Table 3, Figs. 3 and 4 show from the 85% of respondents who are aware of sustainable architecture, 56% of the respondents are just aware but are not using it in architectural practice, only 29% of the respondents are aware and using it in it in practice, while the remaining 15% are neither aware nor using it.

In addition, in terms of awareness, knowledge and usage, 6% have excellent knowledge and are using it, 47% are aware and have good knowledge but only 21% are using

it, a further 26% are aware with moderate knowledge with only 9% using it; 6% have low knowledge and an additional 15% have very low knowledge with neither using it. This suggests that a substantial majority of respondents are just aware but not using sustainable architectural practice.

**Table 3.** Awareness and usage

Item	Frequency	Percentage (%)
Aware and currently using	40	29.41
Just aware	76	55.88
Neither aware nor using	20	14.71
<b>Total</b>	<b>136</b>	<b>100</b>



**Fig. 3.** Awareness and usage

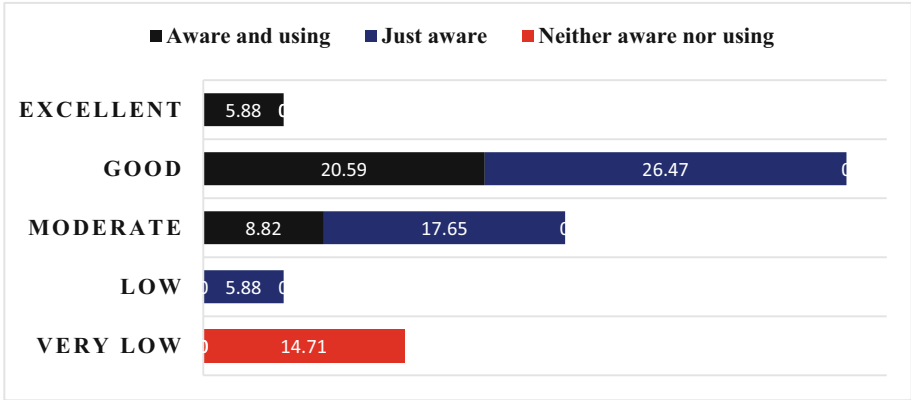


Fig. 4. Knowledge and usage

### 3.3 Willingness to Use Sustainable Architecture in the Future

Looking ahead, the intent is to adopt sustainable architecture. Among both current users (35% of respondents) of sustainable architecture and those yet to adopt it, 24% plan to use it within the next three years as seen in Table 4 and Fig. 5.

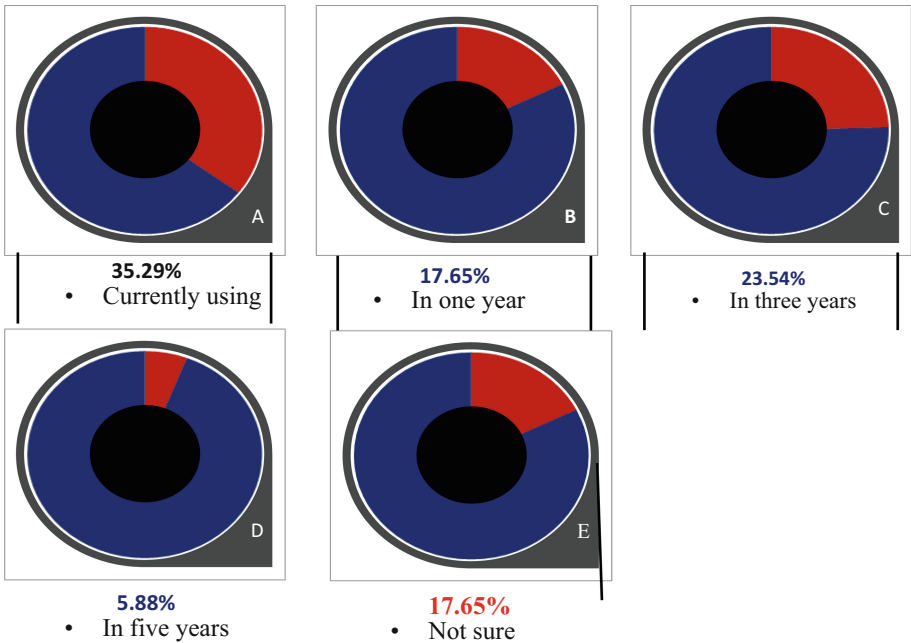


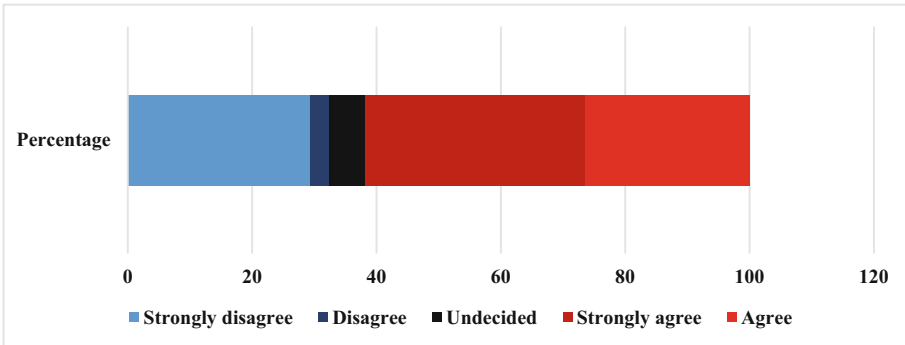
Fig. 5. Intention to use sustainable architecture in the future

**Table 4.** Intention to use sustainable architecture in the future

Item	Frequency	Percentage (%)
Currently using	48	35.29
In one year	24	17.65
In three years	32	23.53
In five years	8	5.88
Not sure	24	17.65
<b>Total</b>	<b>136</b>	<b>100</b>

### 3.4 Role of Nigeria Government in the Adoption of Sustainable Architecture

The Government has been identified as a major driver of innovation especially in the construction industry in terms of standards and regulations required. The respondents were asked whether Nigeria required regulation by the government to enforce the practice of sustainable architecture. The findings in Table 5, Fig. 6 shows that 62% of respondents agree that there is need for government in Nigeria to provide standard and guides in sustainable architecture and also ensure that professionals adopt and adheres to what is required in practice.



**Fig. 6.** Role of Nigeria government in the adoption of sustainable architecture

**Table 5.** Role of Nigeria government in the adoption of sustainable architecture

Item	Frequency	Percentage (%)
Strongly disagree	40	29.42
Disagree	4	2.94
Undecided	8	5.88
Strongly agree	48	35.29
Agree	36	26.47
<b>Total</b>	<b>136</b>	<b>100</b>

## 4 Discussion

There is a high-level awareness of the concept of sustainable architecture in Nigeria. This finding agrees with the studies of Ade-Ojo and Awodele (2020), Nduka and Ogansanmi (2015), Waniko (2014), Abolore (2012), and Otegbulu (2011). However, it disagrees with the study carried out by Amuda-Yusuf et al. (2020), Abisuga and Oyekanmi (2014), and Oliyide (2014) that there is a low level of awareness on sustainability among construction professionals in Nigeria.

There is a low level of knowledge and understanding necessary for adoption and usage. This study reveals that a substantial number of architects do not have sufficient knowledge and understanding to used sustainable architectural practices. This study agrees with the study carried out by Koku and Bello (2020), Ade-Ojo and Awodele (2020) and Obot and Obia (2016).

However, a majority of respondents are willing to use it within the next three years if they have the basic knowledge and understanding that will enable adoption and usage.

The government was identified as the major driver of innovation in the construction industry in Nigeria in terms of standard and regulation policy formulation. This further buttress what studies carried by Dahiru et al. (2014) and Oliyide (2014) revealed. One of the major barriers to the adoption and usage of sustainable architectural practice is the lack of government policy and guidelines on sustainable architectural practice.

## 5 Conclusion

This study reveals that there is a high level of awareness of sustainable architecture among architects. However, there is a low level of adoption and usage. Finally, the government is identified as the major driver of sustainable architectural practice.

The above findings imply that Nigeria's aim of achieving Sustainable Development Goal 11 may not be achieved by 2030 if the present trend continues. The social implication is that Nigeria cities and communities will remain unsustainable. The pressure from the high cost of imported building materials may continue to rise. Empirical evidence shows that energy consumption will continue to rise. Therefore, the government

needs to act now by collaborating with stakeholders in the construction industry to create awareness, training/education, make policies and also provide standards and guidelines on sustainable architecture to enable adoption and usage.

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# Heritage Impact Assessment: A Sustainable Tool for Historic Buildings and Sites Preservation in Ghana

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**Abstract. Purpose:** Historic buildings and sites are easily demolished for redevelopment without recourse to their importance and preservation.

**Design/Methodology/Approach:** This study reviewed the literature to assess laws, policies and tools governing Historic Buildings and Sites Preservation (HBSP) and Town Planning policies in Ghana for sustainable cultural heritage preservation in the country.

**Findings:** The study realised lack of tools for HBSP and apparent disconnection between the Ghana Museums and Monuments Board (GMMB) and the District Planning Authority (DPA).

**Research Limitation/Implications:** The study focused on historic buildings and sites preservation in Ghana.

**Practical Implication:** Recommends that Heritage Impact Assessment (HIA) be adopted to the Ghanaian situation as the requirement for a permit with certification by Ghana Museums and Monuments Board (GMMB).

**Originality/Value:** This study developed the legal framework for Heritage Impact Assessment, Ghana Museums and Monuments Board and District Planning Authority indicating their roles that affect Historic Buildings and Sites Preservation in Ghana.

**Keywords:** Cultural heritage · Heritage impact assessment · Historic buildings and sites · Preservation · Sustainability

## 1 Introduction

Ghana has a rich and diversified culture, with different ethnic groups upholding different beliefs and values. Ghana's historic buildings and sites are manifested in three distinct eras namely, pre-colonial, colonial and post-colonial. It is becoming much easier to demolish these architectural heritage properties to be replaced by other redevelopments without options for preservation. For instance, many pre-colonial earth circular traditional buildings in the northern sector of Ghana are gradually being replaced with rectangular shaped buildings with totally different construction materials. Colonial buildings such as the Kumasihene's Palace at Adum, the ridge stilt and compound

houses are demolished with ease, especially in urban areas. These historic buildings and sites form part of Ghana's cultural heritage and a sustainable preservation mechanism is imminent. A sustainable tool for Historic Buildings and Sites Preservation (HBSP) is important in the achievement of Sustainable Development Goal (SDG) 11 as efforts to protect and safeguard the world's cultural and natural heritage is strengthened through enhanced inclusive, participatory and integrated settlement planning and management (UN 2015). The UNESCO (United Nations Educational, Scientific and Cultural Organisation) under Article 1 of the 1972 convention, defines cultural heritage as "architectural works, element or structures of an archaeological nature, monumental sculpture and painting, inscriptions, cave dwellings and combination of features, archaeological elements or constructions which are of outstanding universal worth from the perspectives of history, art, and science" (UNESCO General Conference 1972). If development is considered as an improvement in living conditions, then efforts to achieve long-term development must take into account the realm of culture (Sadowski 2017). HBSP promotes societal, environmental and economic development as it gives identity to towns and boosts tourism. Therefore, it requires policies and development models capable of sustainable preservation and respect for distinctiveness (UNESCO 2014). Over the past years, culture has evolved into diverse forms. This diversity is strongly influenced by the nature of the groups that encompass humans (Dragana 2009).

The notion of heritage is important for culture and development in so far as it contributes to the continual revalorization of cultures and identities and a pertinent drive for the transmission of expertise, skills and knowledge between generations (UNESCO 2014). Change in the surroundings or built environment is probably inevitable but it should not damage the Outstanding Universal Values of the heritage places, especially those on the World Heritage List. However, HBSP including the World Heritage Sites in Ghana leaves much to be desired since it is only a short-term reactive project-based initiative by site managers within communities (Fredholm 2016). This is because there is no clear management plan or tool, in addition to a lack of integration of heritage preservation, development planning and design.

In Sub-Saharan Africa, Ghana was the first nation to establish a Committee of the International Council on Monuments and Sites (ICOMOS) and sanctioned the UNESCO Convention on the Protection of the World Cultural and Natural Heritage in 1975. Ghana possesses several historic buildings and sites including, pre-colonial traditional buildings, colonial buildings and post-colonial buildings (10 years after independence). Ghana became a "State Party" after approving the World Heritage Convention (UNESCO, 1972), agreeing to ensure appropriate conservation, identification and protection of the heritage of the world (UNESCO 2011). UNESCO issues operational guidelines (OGs) to state parties, which state explicitly in paragraph 53 that the implementation of efficient control measures (scientific, legal, financial, policy, administrative) towards the management of World Heritage properties is the responsibility of the States Parties. These actions were adopted to protect and improve the integrity and/or authenticity of the property at the time of inscription in future items of Outstanding Universal Value (OUV). Ghana faces obstacles such as lack of protection, management programs and legislative control measure. It also lacks adequately trained personnel and research on preservation tools for sustainable HBSP. Proper management and development of heritage require

a tool that focuses on the right balance for the preservation of architectural properties. Whereas the Ghana Museums and Monuments Board (GMMB) is in charge of HBSP, the Planning Authority (PA) of the various Metropolitan, Municipal and District Assemblies (MMDAs) is in charge of development through the issuance of permits for new projects. A sustainable tool and collaboration between these entities would reduce the threat to historic buildings and sites in Ghana. Therefore, the present study attempts to review statutes enacted to sustain historic buildings and sites and identify the extent to which Ghana, as a State Party, has fulfilled its duty to domesticate the World Heritage Convention (1972) for sustainable HBSP.

## 2 Methods

In order to synthesize a holistic perspective for Ghana's sustainable development, this study reviews literature to assess tools, legislation, and policies guiding HBSP and town planning policies. The study attempts to answer the question: why is it easy to demolish architectural heritage property in Ghana? Therefore, the study reviews literature on preservation and management tool - Heritage Impact Assessment (HIA), legislation and administrative systems of bodies concerned with HBSP and town planning such as GMMB and PA of the MMDAs respectively. This article assesses the functions of GMMB, legal documents and development planning guidelines from 1960 to 2021.

### 2.1 Heritage Impact Assessment (HIA)

Sustainable preservation and management of architectural heritage properties including historic buildings and sites require assessment tools to identify and document threats and potentials for development. Historic Impact Assessments (HIA), which are applied to architectural heritage assets at the project or higher strategic levels, have become increasingly popular in recent years (HIA) (Pereira Roders and Hudson 2011, Pereira Roders et al. 2013, Rogers 2017). ICOMOS (2005) mission report indicates that management deficiencies and aggressive development form a significant part of threats to cultural heritage and recommended measures for effective management and preservation of such properties including HIA. Although the ICOMOS mission focused on threats to listed cultural world heritage properties, HIA could be useful for new developments too. UNESCO (2011) suggested HIA as a tool to support sustainable and continuous planning and design. HIA is a procedure that could be used for determining, communicating, forecasting and assessing the possible consequences of an ongoing or planned developmental policy on the community's heritage values, cultural life, institutions and resources. The HIA process' findings and conclusions are subsequently added to the overall planning and decision-making process, to minimize the unwanted consequences and boost positive outcomes (WHITRAP 2012). HIA emphasizes strategies that may change a specific cultural value or asset, and the study is limited to the cultural implications. Therefore, HIA serves as a sustainable tool to manage changes in historic buildings and sites as it identifies threats to heritage and recommends solutions for its preservation (Rogers 2017). HIA has a sequential flow (Fig. 1) used to maintain a high-level HBSP.

According to Rogers (2017), the HIA process begins with the identification of a potential threat or impact of a proposed development on heritage before data collection



**Fig. 1.** The HIA process is depicted in a flow chart. (Source: Rogers 2017)

to create a baseline against which findings may be monitored and compared before the project begins. This is followed by defining the significance of the property and identifying the physical attributes that embody the heritage value of the property. Subsequently, specific threats are identified to ascertain the direction of impacts to the development. Combining the detected threats with an assessment of the severity of expected repercussions can be used to determine the degree of impact. This is followed by designing a means of preserving the property which requires stakeholder inputs and feedbacks. Finally, a report is produced as a public document. It is interesting to note that Ghana does not have a standard practice for impact assessment of historic buildings and sites for development planning. However, there are laws and policies with regards to architectural heritage preservation as discussed in the next section.

## 2.2 Policy and Legislation Concerning the Preservation and Management of Architectural Heritage in Ghana

Cultural treasures especially historic buildings and sites in Ghana are being destroyed without considering their values to the society. The historic buildings, sites and monuments are representations of the past lessons and serve as examples for the present-day quality. Being mindful of the importance of cultural heritage, lawmakers in Ghana have enacted laws and policies for its preservation and management. This section (Table 1) presents some laws and policies in Ghana enacted from 1960 to 2021 on the preservation of the nation's cultural heritage.

The NLCD (387) National Museums Decree was revised by the Departments, Ministries, and Agencies (Funds Retention) Act, 2007 (Act 735). This act generally deals with the control of antiquities; duties and powers of the GMMB; meetings proceedings and remuneration; members of the board; officers and employees; accounts and audit. In detail, this decree spells out the procedure for the excavation and export of antiquities and seem more silent on HBSP. However, only Article 39 (4) of the 1992 Constitution

**Table 1.** Ghanaian legislation and strategies that take heritage preservation into account.

Item	Year	Legal document	Regulation/Law
1	1969	National Liberation Council Decree (NLCD) 387 National Museums Act	a. To preserve, equip, and run the National Museum; b. To maintain, create, equip and manage any other museums it deems appropriate; c. To conserve, repair, or restore any antiquity deemed to be of national importance; d. To examine and report on any issues on antiquity when requested by the Commissioner; e. To keep records of any antiquities it acquires or that come to its attention
2	1972	Executive Instrument (EI) 42	To protect European forts and castles along the coast
3	1992	Constitution	Article 39 (4) The state will make every effort to conserve and protect historical sites and artefacts

Source: Authors (2021)

spells out legislation that the state will make every effort to conserve and protect historical sites and artefacts. The rest are policies as outlined by Fredholm (2016) in Table 2 which consider issues on heritage in Ghana.

**Table 2.** Heritage concerns are addressed in Ghanaian policies and initiatives.

Entity	Year	Policy document about cultural heritage
National Development Planning Committee (NDPC): Socio-Economic Development	1996–2000	Coordinated Program of Economic and Social Development Policies Vision 2020
	2003–2012	The Coordinated Program for the Economic and Social Development of Ghana
	2006 – 2009	Growth and Poverty Reduction Strategy (GPRS II)
	2010–2013	Medium-term National Development Policy Framework

(continued)

**Table 2.** (continued)

Entity	Year	Policy document about cultural heritage
	2010–2016	The Coordinated Program of Economic and Social Development Policies Ghana Shared Growth and Development Agenda
National Commission On Culture (NCC): Development of Culture	2004	The Cultural Policy of Ghana. For the Promotion of Unity in Diversity
Ministry of Tourism (MoT): Development of Tourism	1996–2010	The 15-Year Tourism Development Plan
	2006–2010	National Tourism Policy, Seventh Draft
	2009–2012	National Tourism Marketing Strategy
	2013–2027	National Tourism Development Plan

Source: Fredholm (2016)

The common feature of these policies is mainly the diverse nature of Ghanaian festivals, traditions and culture, while HBSP is not mentioned. These policies demonstrate a lack of consistency across various development planning views. Historic buildings are a part of a country's cultural legacy and their preservation cannot be overemphasised as the next section looks at the history and legal framework.

### 2.3 History and Legal Framework of Cultural Heritage Preservation in Ghana

The quest to preserve her cultural heritage saw pre-independence efforts by the Gold Coast government to appoint a part-time curator (Thurstan Shaw) in 1937 to manage the nation's heritage at Achimota College (Kense 1990). Shaw's mandate expanded from collections of amateur archaeologists in the colonial era to broader conservation of antiquities and the restoration of architectural monuments which resulted in the establishment of the Monuments and Relics Commission (MRC) eleven years later (Myles 1989). The commission ensured that the forts and castles, together with some traditional buildings, were scheduled for preservation with some restoration works already started on the decaying Elmina and other castles along the coast. The increasing edge to preserve heritage by the Gold Coast government further resulted in the establishment of the Ancient Monuments and Historic Buildings Division (AMHBD) under the leadership of A.W. Lawrence (Director of the MRC) in 1952 (Hyland 1995, Addo 2013). After being appointed as the director in 1951, Lawrence (an Archaeologist) was given the responsibility to set up the National, Regional Museums and the Archaeology departments (Currey 1990). The National Museum (NM) was then established to exhibit objects from diverse ethnic groups in Ghana and beyond to capture Ghana's first President, Dr. Kwame Nkrumah's motto "unity in diversity", before independence (Kankpeyeng

and DeCorse 2004). Ghee (2015) recalls the establishment of the National Museum, beginning with the arrival of a British museum ethnographer, Harmann Justus Braunholtz, on the west coast of Africa in 1947. Braunholtz was on a two-month mission to survey the British colonies namely the Gold Coast, Sierra Leone, the Gambia and Nigeria to advise the governments regarding the heritage “preservation of West African antiquities”. His recommendation realized the construction of the National Museum (NM) building in Accra, which was commissioned on 5th March 1957. It was not until 1957 when the Gold Coast ordinance 20 merged with the MRC and the NM to form the Ghana Museums and Monument Board (GMMB) (Kankpeyeng and DeCorse 2004, Gavua 2015) under the National Museums Ordinance of 1957 with the organogram in Fig. 2. In 1969, the 1957 Ordinance was revoked and supplanted by the National Liberation Council Decree, (NLCD 387). The GMMB now operates offices in seven of Ghana’s sixteen regions (Volta, Greater Accra, Central, Western, Upper West, Ashanti and Upper East regions).

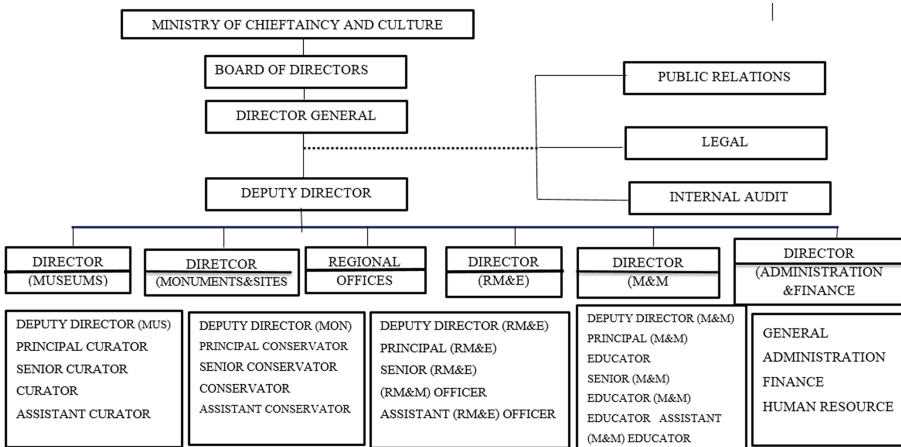


Fig. 2. Ghana Museums and Monuments Board Organogram. (Source: Ordinance 1957)

The GMMB, to date, is mandated to preserve and restore heritage sites in Ghana. GMMB currently has its head office in Accra (Kuntaa 2012) making it more centralized in all its endeavours. The GMMB is a statutory body, is empowered by the NLCD (387) and Executive instruments 118 of 1969, 42 of 1972 and 29 of 1973. The board is made up of two major divisions namely: the Monuments and Sites Division (MSD) and the Museum’s Division (MD). The MSD is of utmost interest in this study due to its responsibility of identification, listing, protection, preservation and management of Ghana’s historic buildings and sites. Additionally, the MSD division employs professionals including conservators and inspectors who interpret and exhibit historical monuments and places to tourists around the country (domestic and international). The MSD also has the responsibility of creating a full national register that contains the cultural inventory and heritage of national historic structures and sites, as well as the enactment of programs on buildings, assessing the state of dilapidation and applying restoration, preservation,



and renovation programs (Amekudi 2009). Unfortunately, historic buildings and sites are under threat due to neglect or demolishing for new development. Nevertheless, a permit for demolishing these properties to be replaced by new development is granted by Town and Country Planning Authority and not the GMMB as discussed in the next sections.

## 2.4 Development Planning in Ghana

There have been numerous calls for the Land Use and Spatial Planning Authority to ensure sustainable planning in Ghana due to the unnecessary sprawl and disordered growth (Botchway et al. 2014, Adarkwa 2012, Cobbinah and Amoako 2012, Yeboah and Obeng-Odoom 2010). As a result of the sprawl and chaotic growth, old buildings and places have been demolished for new development with little regard for preservation (Adarkwa and Oppong 2005, Twumasi-Ampofo and Oppong 2016). The Local Government Act 462 (1993) and the Local Governance Act 936 (2016) have been established to regulate the local government system as stated in the 1992 constitution of Ghana. Act 462 (1993) created the Metropolis, Municipalities and Districts Assemblies (MMDAs). Each MMDA is led by a CEO who is appointed by the President to steer the affairs of the assembly through the executive committee. Act 936 (2016) also created a Planning Authority within the MMDAs, which creates district development plans with the National Development Planning Commission's approval. The person, body, or organ in the district responsible for or involved with the implementation of the plans follows the authorized district development plan. Physical development may not be carried out in a district without prior clearance from the District Planning Authority (DPA) in the form of a written permit. The procedure and manner for securing a permit is prescribed by the Ghana National Building Regulations (GNBR) established in 1996 by Legislative Instrument (LI 1630). This regulation is divided into 19 sections, including regulations and building plans, site preparation and landscaping, building materials, thermal insulation, heat-producing appliances, hearths, chimneys, access accommodations, plot development, pest control and decay protection, air movement and ventilation, drainage, sound insulation, lighting and electrical installations, structural stability, sanitary conveniences, refuse disposal, water supply, structural fire precautions, special requirements for rural buildings and miscellaneous provisions.

The Ghana National Building Regulations (GNBR) does not feature HBSP. The DPA is represented by a board composed of 17 members. These members include; (a) a chairperson; (b) one representative each of: the Ministry of Local Government and Rural Development; the Ministry of Environment, Science, Technology and Innovation; the Ministry of Lands and Natural Resources; the Ministry of Roads and Highways; the Ministry of Water Resources, Works and Housing; the Ministry of Food and Agriculture; (all of whom should not be below the rank of a director (c) the Chief Executive Officer of the MMDA; (d) Executive Director, Environmental Protection Agency (EPA); (e) the Executive Secretary, Lands Commission; (f) the Stool Lands Administrator; (g) National Development Planning Commission (NDPC) representative not below the rank of a Director; (h) National House of Chiefs (traditional authority) representative; (i) a representative of the Ghana Institute of Planners; and (j) three private built environment professionals one of whom is a woman nominated by the Ghana Institute of Architects,

Ghana Institution of Engineers and the Ghana Institution of Surveyors. The chairperson should have considerable knowledge in human settlement, town planning and built environment or spatial planning related issues and not employed as a public servant in a full-time capacity. Section 4 provides that the function of the board is to “ensure the control of physical development in uncontrolled or less controlled but sensitive areas like forest reserves, nature reserves, wildlife sanctuaries, green belts, wetlands along the coast, rivers, lakes, mine sites, and public parks including open spaces for sustainable development of land and human settlements through a decentralised planning system (LUSP Act 2016, Act 925).

The Development Permitting Guidelines (2015:2.2.3) lists other subsidiary requirements (certified reports/permits) from Ghana National Fire Service and Environmental Protection Authority, depending on the type, scope and complexity of the development with an apparent exclusion of heritage impact. The board composition does not have a representative from the GMMB to enforce its mandate.

### 3 Conclusion and Recommendations

This study brings to fore, the legal framework for HIA, GMMB and DPA indicating their roles that affect HBSP in Ghana. The study shows that, even though the various constitutions mention the need to protect cultural heritage, (NLCD 387, 1969, EI 1972, Constitution, 1992) there is no clear policy document and tools for sustainable HBSP. Apart from the NLCD 387 (1969), not much has been achieved in terms of act enactments about functions of the GMMB. The available policies and legislation do not seem to be coherent as the Land Use and Spatial Planning Act 2016 (Act 925) which spells out the composition and functions of the DPA, to grant demolishing and development permit at the various MMDAs do not consider membership from MSD of GMMB, neither does it require certified reports or permits as spelt out in the Development Permitting Guidelines (2015). Apparently, there is no connection between HBSP and town planning in Ghana. The current rampant demolishing of historic buildings and sites call for effective collaboration between GMMB and the MMDAs through the utilisation of HIA (certified report) as a tool to connect the two entities. This HIA report should be submitted by prospective developers on special projects involving historic buildings and sites, as part of the permit requirement to indicate how the cultural heritage values of the property will be preserved and managed either partial or whole. It is also recommended that, the local government Act, Act 462 (1993) and Land Use and Spatial Planning Act Act 925 (2016) on the development planning authority’s board at the MMDA be amended to include representatives of GMMB, which has the mandate to preserve and manage historic buildings and sites. Furthermore, amendments to the Development Permitting Guidelines (2015) should be geared toward the additional requirement for a permit from GMMB through certified HIA reports by DPAs for sustainable HBSP in Ghana.

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# Overcoming Challenges Associated with Circular Economy in Real Estate Development

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**Abstract. Purpose:** This paper recommends a strategy for the application of circular economy (CE) in Africa's real estate sector. The objective identified the factors that impede the application of CE in the real estate sector and characterised the factors based on their nature to the African context.

**Design/Methodology:** The study adopts a qualitative exploratory design. Data were derived via a systemic review of literature of articles obtained from the Scopus database within 10 years (2012 to 2021). Analysis was done through content analysis.

**Findings:** Findings indicated that hesitancy to change, low level of knowledge, high investment price, unavailability of incentives, dearth of awareness, non-existent favourable policies are challenges of CE adoption. The paper recommends strategies such as clear policies on CE, financial incentives, tax reduction on CE initiatives and increased education on CE.

**Research Limitation/Implications:** The study focused on challenges impeding CE in Africa's building sector, therefore the recommendations are specifically tailored to the African context.

**Practical Implication:** The study responded to the "sustainable development goal (SDG)11 for sustainable cities and communities". It contributes to the education of team members in the built environment on the significance of transitioning to CE for a sustainable built environment.

**Social Implication:** This study is valuable and has a bearing on the policy-makers in the building and construction sector to make innovative policies favourable in the direction of CE in real estate developments.

**Originality/Value:** The study demonstrates novelty as the discussion on transitioning into the circular economy (CE) gradually take roots in the building sector globally, the African continent is challenged to apply the concept, hence, the need for studies tailored to suit the African environment.

**Keyword:** Circular economy · Developing countries · Real estate · Sustainability

## 1 Introduction

Industries globally are expressing increasing apprehension about environmental subjects. In this setting, the real estate industry, which is considered an enormous consumer of

resources and generator of waste (Esa et al. 2017), has a high responsibility to take in lowering the ecological footprint and the sustainable use of resources. The depletion of existing resources and waste generated in construction projects represents the major causes of the real estate sector's environmental footprint, and these are increasing at an alarming rate (Lo Presti 2013). Waste from construction and demolition, signifying the termination of a structure, accounts for about 50% of the waste from the industry (Akanbi et al. 2017). This has been a challenging trend because the construction industry for a long time practices a "linear economy system", on the principle of "take, use and, throw-away (Ellen Mc Arthur Foundation (EMF) 2015). In this system, the idea is to extract virgin materials from the environment, which undergo processes to be used as construction materials and assembled, such that they cannot be disassembled on the site, and this ends up in the landfills or being incinerated (Mangialardo and Micelli 2018).

In contrast, an alternative system referred to as the Circular Economy (CE), is rapidly gaining attention within the past 10 years, advocating the principle of efficient and sustainable use of resources (EMF 2015). The CE is defined by EMF (2013) as "an eco-industrial system which by design restores and regenerates, to keep products, mechanisms, and materials in a state of highest utility and value always, distinctive between mechanical and organic sequences". The circular-economy system is grounded from the principle of reusing and recycling building constituents and their parts which serves as a bank of material for new building projects (Hopkinson et al. 2018). The concept, however, requires advancement of know-how and strategies for better adoption (Lacy and Rutqvist 2015), particularly for the real estate sector, noted for adopting innovation slowly for practicality and implementation (Pomponi and Moncaster 2017).

Currently, after over a decade of research, the circular economy is gaining global spread in research, not excluding diverse industries with policymakers (Winans et al. 2017). However, challenges exist in the implementation of circularity in the real estate and building sector that requires to be examined to develop strategies to overcome them. Thus, this paper contributes as a recommendation of a circular economy strategy specifically designed for construction projects in the African context.

## **2 Overview of Circular Economy Concept for the Real Estate Sector**

Circular Economy (CE) as terminology is receiving widespread contemplation. Nations like China and Germany have utilised it as part of their legislature, while the emphasis can vary from country to country (Benton et al. 2015). Eliminating waste and circular recycling represents the major mechanisms in the German regulation (Bilitewski 2012); however, the terminology in China's legislation, is focused on eco-conception, clean production, and ecological industrial parks to make a society that is circular-oriented. As reported by Ellen McArthur (EMF 2013), CE idea is founded on the ideologies of "cradle to cradle", biomimicry (McDonough and Braungart 2002), with industrial ecology. Currently, the most well-known definition of CE is the one provided by the EMF (Bressaneli et al. 2018), which defines the CE as an "economic system that is restorative and renewable by the concept" and which "purposes for the eradication of waste".

Although many professionals in the sphere of economy and policy have declared their interest in the circular economy (Lacy and Rutqvist 2015), their operation seems to be still at infancy (Ghisellini et al. 2016). China appears to be outstanding as the country in 2009 implemented a ‘CE Promotion law’ in 2009 which has set the country at the lead of circularity operation all the way (Geissdoerfer et al. 2017) although it is arguably still some miles from achieving complete circularity. Some researchers have ascribed the restricted growth in circular executions to several CE challenges owing to some research focused on the circular economy bottlenecks recently (Rizos et al. 2016, Pomponi and Moncaster 2017).

The all-encompassing appraisal of the circular economy concept and challenges is necessary for its application. Given the circular economy is a rather novel idea to emerging economies, specifically the economies with low-income conditions (Ferronato et al. 2019), and possess a high prospect and the ability for fiscal development, knowledge on the practicability and viability of operating circularly in emerging economies are of importance (Fig. 1).

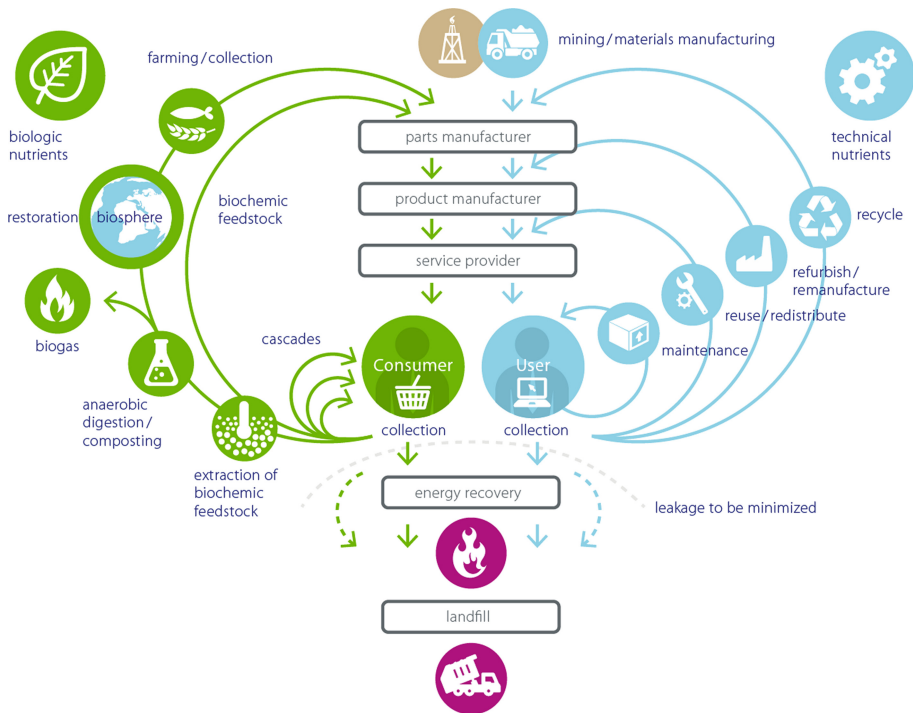


Fig. 1. The circular economy system (EMF 2013)

## 2.1 Circular Economy and Real Estate Development in Africa

The “African Circular Economy Alliance (ACEA)” was founded in 2017 to promote Africa’s shift to a circular economy (CE). This is expected to bring fiscal development,



job opportunities, and constructive ecological outcomes. This alliance was launched in response to the critical global resource depletion and constraint on the planet and is mostly germane to Africa (Circularity Gap Report 2020). Growth in Africa's urban population expands the built environment, causing increased resource consumption and pollution. It is projected that Africa's urban population will triple by 2050, thereby skyrocketing the need for construction and its materials, and the production of which gives rise to more than 10 percent of overall releases of carbon dioxide from the building sector (Hajjar 2020). This increased urbanization implies an increased burden on existing resources and Africa's susceptibility to climate issues (World Bank 2015). Although the African continent is rich in opportunities in terms of population and resources to integrate the circular economy approach into real estate developments if well harnessed, there are challenges that slow and hamper the transition process. The cost of construction material is a major challenge in implementing sustainability in Africa real estate for instance, in some places in Africa, construction material takes about forty percent of the overall cost of the building which is even difficult in nations that are into importation of construction material from abroad. For example, cement and sand in Rwanda are costlier relative to Germany (Bah et al. 2018). Further, considering the evolving context of circular economy inventions and the informal nature of several SMEs across Africa, the availability of financial facilities (loans and mortgage) is a contest. This is informed by the risk-phobic characteristic of monetary organisations in Africa that are mostly uninformed of CE business models (World Bank 2015). Therefore, there is a need to proffer strategies in which African countries can overcome these challenges for a sustainable evolution to a circularity. A review of the literature reveals significant opportunities to achieve circularity. however, strategies must be in response to the traditional setting for success.

### 3 Materials and Methods

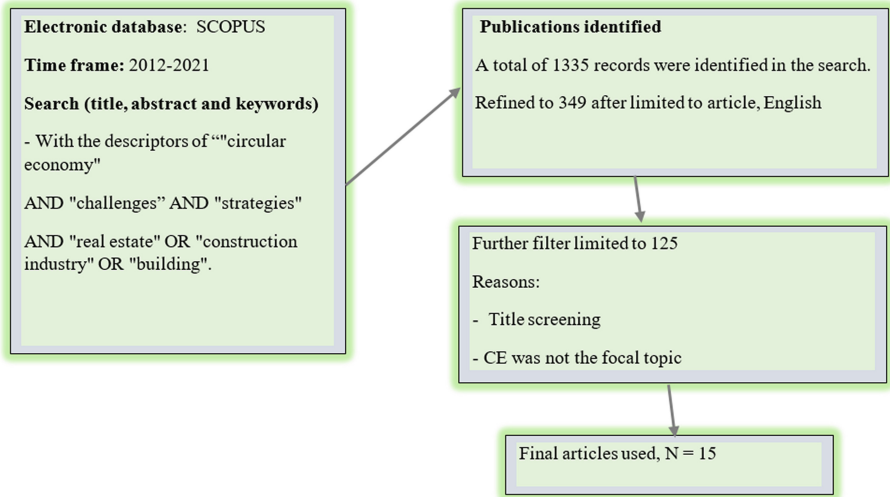
The selected methodology for this study was a systematic review. This review technique runs an overview of past research to establish the research gap from the documented studies on the subject. Denyer and Tranfield (2009) proposed a five-step process to systematically reviewing the literature. This process involves formulating questions on the research, selecting appropriate studies, assessment of the selected studies, analysing, and writing results. The process according to Denyer and Tranfield (2009) was followed in this study.

To reach a reasonable depth of the study on CE challenges in real estate development, a systematic review was carried out using of appropriate academic research published from 2012 to 2021 from the Scopus database. Scopus is a highly reputable bibliographic database noted for distinct features for searching reputable materials. The year 2012 is justified due to its status in promoting the concept of CE succeeding the research output of EMF dated 2012.

A thorough exploration was conducted on the search engine of Scopus using the "title-abstract-keyword" section. The keywords for the search comprised "circular economy", "challenges", "strategies", "real estate", "construction industry", and "building". The search produced 1335 documents. These were further screened using the following keywords: "sustainability, sustainable development, construction, built environment,



building, resource efficiency, circular economy. These produced a result of 125 documents. Furthermore, restrictions were made to include only subject areas of “environmental sciences”, “social sciences”, “energy”, “engineering”, with specifically the document type of “article”. Titles were further screened producing 33 publications, from which abstracts were screened to determine inclusion. Figure 2 describes in detail the procedure for the research.



**Fig. 2.** Systematic review search procedure and criteria adopted.

Overall, 15 articles were selected from the process indicated in Fig. 2 for review and analysed using thematic analysis. The broad themes included the challenges and strategies. The challenges were further coded as intrinsic and extrinsic factors. The outcomes are provided in the next section.

## 4 Results

The literature review revealed the challenges associated with the application of circular economy in the real estate development sector as well as possible strategies to nullify the challenges. These were analysed and deliberated in this segment.

### 4.1 Challenges to Implementing Circular Economy in Real Estate Development

The identified challenges were categorised into intrinsic and extrinsic factors. The intrinsic aspects to CE implementation are the market, cultural and attitudinal, and technological challenges. The extrinsic challenges are the political, economic, social, and policy challenges. The challenges are summarised in Table 1.

#### 4.1.1 Intrinsic Factors

The Intrinsic challenges are the market, cultural and attitudinal, and technological, which deeply impedes the real estate development sector in implementing the CE. In terms of the market, investors are not certain about the marketplace and their own profitability and seek survival (Govindan and Hasanagic 2018). The review found that doubt about the marketplace, such as economic depressions, might hinder CE schemes (Rios and Charnley 2016). Furthermore, lower market demand for secondary materials and low prices of recycled materials constrain their collection and availability, which impede CE schemes (Liu and Bai 2014).

Regarding cultural and attitudinal, first, most RED's in emerging economies do not possess the know-how or inventiveness in structural values owing to their complicated administrative structure. Consequently, numerous developers are ignorant of the significance, nor understand the core and idea of circular economy implementation (Min et al. 2021). In particular, many developers only support and participate in CE to receive grants from the programs (Adams et al. 2017).

#### 4.1.2 Extrinsic Factors

These are the political, economic, social and policy factors. This section largely explores external factors that impede the RED's implementation of CE. Starting with the political perspective, these are challenges associated with contextual political conditions, such as political uncertainty and exploitation, which may inhibit law enforcement. Some authors have also linked acts of corruption to a decrease in the trust among actors in a network as a serious challenge for RED's CE adoption (Rizos et al. 2016, Ritzen and Sandström 2017).

Touching on the economic standpoint, the process of RED's and choices to execute circularity is a function of the state fiscal system and nationwide support instrument (Mochkabadi and Vokman 2020). The profit-motivated nature of the present economy makes it difficult for the traditional economy to be radically changed, especially among RED's (Veleva and Bodkin 2018). The prevailing market system is not encouraging to RED's in Africa that lack adequate finance to implement CE into their businesses (Mc Arthur 2013). Further, referring to the social perspective, community education and awareness is relatively weak to inspire RED's to fulfill government or market conditions (Kirchherr et al. 2018). Lastly, from policy perspective, a significant challenge to circularity application can be tracked to the regulation from the constitutional level. Garces-Ayerbe et al. (2019) emphasised that regulations on circular economy are technically cumbersome and uneasily comprehended by all to implement. The review shows that barriers such as lack of law enforcement, low monitoring capacity, can hinder CE implementation (Ferronato et al. 2019, Garces-Ayerbe et al. 2019).

**Table 1.** Challenges and strategies for implementing circular economy as identified from the literature

Theme	Factors	Description key actors (challenges)	Strategies
<b>Intrinsic factors</b>	Market	<ul style="list-style-type: none"> <li>- Doubt about the marketplace (e.g., economic depression).</li> <li>- Low market demand for circular products.</li> <li>- Low prices of recycled materials</li> <li>- Unavailability of secondary market mechanisms</li> <li>- Absence of operative quality assurance for recycled materials</li> </ul>	<ul style="list-style-type: none"> <li>- Access to financial resources through collaboration with firms, NGOs</li> <li>- Increased security of the marketplace</li> <li>- Public-private partnership to invest in circular projects</li> <li>- Incentives for demand in circular products-leveraging the E-market through online platforms</li> </ul>
	Cultural and Attitudinal	<ul style="list-style-type: none"> <li>- Lack of interest</li> <li>- Linear system culture</li> <li>- Negative attitudes and behaviours of stakeholders</li> </ul>	<ul style="list-style-type: none"> <li>- Educating and sensitizing the various professionals in RED's</li> <li>- Change of attitude through educating the society of advantages of recycling, reuse, and remanufacturing</li> </ul>
	Technological	<ul style="list-style-type: none"> <li>- Changes in specifications and technology over time</li> <li>- Lack of technology and the know-how</li> <li>- Limited circular design</li> </ul>	<ul style="list-style-type: none"> <li>- Development of enabling technologies</li> <li>- Training in relevant technologies</li> </ul>
<b>Extrinsic factors</b>	Political	<ul style="list-style-type: none"> <li>- Lack of support from government</li> <li>- Absence of incentive and bureaucratic difficulty</li> <li>- Absence of training developments for professionals</li> </ul>	<ul style="list-style-type: none"> <li>- Executing model schemes that can be of guide to others</li> <li>- Providing tax benefits for firms implementing CE can increase the willingness to participate</li> <li>- Reduce complexity and make the subject of circularity accessible and understandable</li> </ul>

*(continued)*

**Table 1.** (continued)

Theme	Factors	Description key actors (challenges)	Strategies
	Economic	<ul style="list-style-type: none"> <li>- Limited funding for circular initiatives</li> <li>- High investment costs</li> </ul>	<ul style="list-style-type: none"> <li>- Financial support for development companies to lessen the risk associated with an initial cost of investment</li> </ul>
	Social	<ul style="list-style-type: none"> <li>- Limited awareness among key actors across the supply cycle</li> <li>- Absence of motivations in the designing of CE products</li> <li>- Lack of perception and understanding</li> </ul>	<ul style="list-style-type: none"> <li>- Increased alertness on CE making it more enticing to real estate investors and the users</li> <li>- Media exposure for education and awareness</li> </ul>
	Policy or legal	<ul style="list-style-type: none"> <li>- Lack of regulations and policy</li> <li>- Unclear information on CE guidelines, performance indicators, and reference points</li> <li>- Having no CE-specific legislation in place</li> <li>- Restricted scope in current sustainable commercial models and frameworks (non-replicable frameworks in another context)</li> </ul>	<ul style="list-style-type: none"> <li>- Innovation policies should be developed</li> <li>- Incentivizing as a means to jack up the rate of employment for a circular economy</li> <li>- Legislations and bye-laws should be enacted in the direction of CE in real estate developments</li> </ul>

## 4.2 Towards Circular Economy Implementation

The factors (intrinsic and extrinsic) responsible for the operation of CE were market, cultural and attitudinal, technological, political, economic, social, and policy or legal challenges. It is, therefore, crucial to develop strategies to alleviate these factors if circularity is to be successfully implemented in Africa's real estate sector. These strategies as identified from literature are discussed hereunder and the recommended action plan for implementation of the strategies in the African context is presented in Table 2.

### 4.2.1 Intrinsic Factors

Drawing from the market challenges, investors are hesitant to embark on circular projects, considering the high investment cost associated with building projects (Adams et al. 2017) and this significantly hinders CE schemes. Therefore, increased security of the marketplace and easy access to financial resources is pivotal (Ritzen and Sandstrom 2017, Min et al. 2021). Furthermore, government initiatives such as incentives can be useful in overcoming investors' hesitance to investing in CE (Park and Tucker 2017, Sandoval et al. 2018).

From the cultural and attitudinal challenges, owing to the societal culture and age-long practice of linear systems, investors and developers are reluctant to adapt and transition to sustainable and circular initiatives (McArthur 2013). There is a need for a shift in thinking and re-orientation by creating publicity on the benefits of CE among the actors involved in real estate development by leveraging sustainable education (Min et al. 2021).

Lastly, in terms of the technological challenge, literature identified the lack of technology and the relevant know-how to implement circular projects (Govindan and Hasanagic 2018). Thus, the development of enabling technologies to develop circular projects in the built environment is highly important (Su et al. 2013). There is also a need for training in relevant technologies to drive innovation (McArthur 2013).

### 4.2.2 Extrinsic Factors

Based on the political challenges, the prevailing political climate often characterised by the absence of assistance, capital and incentives from the government, and bureaucratic difficulty, presents a strong challenge to implementing CE in Africa. Therefore, support from the government in implementing pilot projects, incentives, cut in taxes, grants, and rewards, represent major strategies identified through literature (Sandoval et al. 2018, Geissdoerfer et al. 2017, Min et al. 2021). From the economic perspective, the challenges of limited funding for circular initiatives and high investment costs impedes CE (Mochkabadi et al. 2020). Therefore, economic initiatives and incentives to reduce investment costs and risks for enterprises are critical.

Concerning the social factors, given limited awareness among key actors across the sector and the lack of incentives to design for CE products, it is important to increase awareness to make it attractive. Leveraging on social media, and thus using media exposure as a tool can contribute to increased awareness (Govindan and Hasanagic 2018). From the policy stance, unclear information on CE guidelines, and lack of CE-specific legislation in place pose major challenges (Garces-Ayerbe et al. 2019). Therefore, enacting of a clear and concise circular economy policy represents a critical implementation strategy (Ghissellini et al. 2016, Min et al. 2021). Table 2 recommends an action plan for the implementation of the strategies in the African context.

**Table 2.** An action plan for implementation of strategy in the African context

Theme	Factors	Key action for circularity in Africa real estate development
Intrinsic factors	Market	<ul style="list-style-type: none"> <li>- The real estate sector needs to rely on local resources that would push people to look for more efficient alternatives. Africa can benefit from the available labour force (high unemployability)</li> <li>- Local and traditional construction practices should be explored and developed as they are likely to be more context-appropriate</li> <li>- Governments as the largest developers in Africa, must implement sustainable building and construction practices and adopt circular practices in the procurement, construction, maintenance, and finance of their projects</li> <li>- There is a need for African governments to collaborate with the local private sector</li> <li>- The Government needs to incentivise the RED's to transition to CE and activate SMEs to develop</li> </ul>
	Cultural and Attitudinal	<ul style="list-style-type: none"> <li>- Educate and train all players including government, stakeholders, architects, contractors, and builders, among others as part of community engagement programs and curricula</li> </ul>
	Technological	<ul style="list-style-type: none"> <li>- Leverage the large young population in African cities as an opportunity to develop local human-capital skills and invention with evolving green technologies</li> <li>- Reduction of resources and technology importation by developing and growing local building and construction materials and technology (this will enhance local economies as well as businesses)</li> </ul>
Extrinsic factors	Political	<ul style="list-style-type: none"> <li>- Africa needs to implement green building regulations and laws to direct the building sector</li> </ul>
	Economic	<ul style="list-style-type: none"> <li>- SMEs must be supported to align with the circularity strategy</li> <li>- SMEs should be connected with formal players to enable skill transfers and allow SMEs to get into larger markets</li> <li>- Merge SMEs in informal groups to create a cycle of value supply and boost the efficiency of current circular operations</li> </ul>
	Social	<ul style="list-style-type: none"> <li>- Collaboration is required for a circular economy approach among stakeholders in Africa</li> <li>- Collaboration for circular Africa is required within regions and outside the countries</li> <li>- Learn best practices from other case studies, to improve collaboration for Africa</li> </ul>

*(continued)*

**Table 2.** (continued)

Theme	Factors	Key action for circularity in Africa real estate development
	Policy or legal	<ul style="list-style-type: none"> <li>- Stringent construction management regulations and standards must be implemented</li> <li>- Training for contractors and built environment professionals on circular processes must be mandatory</li> </ul>

## 5 Conclusion

The study was conducted to recognise the obstacles to enacting circularity in real estate development and suggest strategies for enhanced application and ways of subjugating the challenges. From a systematic review, the intrinsic and extrinsic factors were identified and the challenges they pose were highlighted. Strategies to aid the application of CE were identified and a corresponding implementation plan applicable to the African context was recommended. The review revealed that the part of the government concerning the application of the CE in real estate projects is critical based on the associated huge investment capital. Moreover, given the value-oriented nature of firms, financial returns are much prioritised before due consideration is given to the environment. Thus, the government must enact laws and policies that facilitate the implementation of a circular economy, which firms could easily follow. The review also highlighted the need for financial incentives to stimulate circular projects and reduction in tax for circular-related developments. There is also a need for increased education and awareness to foster a change in attitude from the linear system and practices for sustainability.

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# Housing Policy and Well-Being of Civil Servants in Calabar Municipality, Cross River State, Nigeria

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**Abstract. Purpose:** This paper investigates the housing policy and well-being of civil servants in Calabar Municipality, Cross River State, Nigeria. It examined the influence of location of housing; type/quality of housing on the well-being of civil servants.

**Design/Methodology/Approach:** Survey research design was used in collecting, analysing, and interpreting data based on the sociological nature of the study. A multi-stage sampling technique was used based on segments of the population. Stratified and random sampling procedures were used to select 10 Ministries, Departments and Agencies, representing 10 strata. Four hundred (400) respondents (40 per stratum) were sampled for the study. The data obtained were analysed and presented in tables and diagrams. Descriptive statistics and independent t-Test inferential statistics were used.

**Findings:** Findings revealed that housing policy on location, type/quality of housing influences well-being of civil servants in terms of improvement in quality of fundamental needs, economic progress and higher self-esteem for both individuals and communities.

**Research Limitation/Implications:** This research focused on housing policy and wellbeing of civil servants in Calabar Municipality of Cross River State, Nigeria.

**Practical Implication:** The knowledge from this study will assist individuals, families, agencies and stakeholders in housing projects to comprehend and address the intervening and mediating factors essential in the housing-wellbeing equation.

**Social Implication:** This study will assist development policy-makers in adopting a well-functioning environment that promotes socio-economic well-being in line with the targets of SDG 11.

**Originality/Value:** This study is based on a housing adjustment behaviour framework; it analysis the dynamics of satisfying housing needs and the ways society decides how individuals and households are sheltered.

**Keyword:** Adjustment behaviour · Affordable · Civil servants · Housing policy · Well-being

## 1 Introduction

Housing development in nation-building has been one of the paramount concerns of policymakers in recent times. Despite all efforts coupled with articulated, well-planned and excellent housing policies over the years, the housing delivery system paints a picture of a dismal future. The need for housing policy is underscored by the fact that housing is a basic requirement for human beings and it is of great importance that citizens should have basic knowledge, information and understanding of what the government is doing to facilitate access to adequate and affordable housing by the citizenry (Housing Today 2000). More so, housing policies ultimately seeks to improve human wellbeing which is the essential goal of all developmental efforts.

The United Nations (2017) indicates that for housing to contribute to national socio-economic development and the achievement of the Sustainable Development Goals (SDGs), housing policies must include a ‘project strategy’, poverty, health and employment. “The housing needs of the poorest and most vulnerable people, especially women, youth and those living in slums, should be a priority on the development agenda” (UN 2017). Housing is one of the best indices of an individual’s living standard and status in the community of society. The essential functions of housing policy are determining housing availability, adequacy, location, housing quality and housing cost especially as these variables influence the status and welfare of an individual in the society (Oluwole 2011; Jiboye 2011).

Festus and Amos (2015), argued that housing is crucial to the existence of mankind. Housing policy is important because it paves way for people to obtain land with ease; as well as determines housing affordability and availability of thus making housing functionally convenient and aesthetically satisfying family wellbeing. All families require a secured, firm and dependable healthy place to live. Housing insecurity and unrelenting financial challenges are harmful to households’ physical, economic and emotional wellbeing (Schuetz 2018). Aribigbola (2008), also observes that, although Nigeria has a well-articulated housing policy document, the government’s well-meaning intentions have not been transformed into concrete reality for the ordinary citizen. The concern has rather been on the delivery of expensive (luxury) accommodation instead of low-cost living ones to cater for the less privileged. Thus, housing policies must be tailored towards enhancing the well-being of all categories of the citizenry.

Housing delivery system is still fraught with serious challenges such as inadequacy, inconsistency housing policy, housing deficit, infrastructural deficit, poor housing location, high cost of building materials and construction, etc. Today, Nigerians are still wallowing in quantitative and qualitative housing poverty and the “poorest of the poor” is yet to get a house in line with the objectives of our policies (Housing Today 2000; Adeshina and Idaeho 2019). Between 1981/1982 and 2012, the government formulated several housing policies all of which promised to revolutionize the housing sector and give Nigerians succour through access to decent, affordable and quality housing, but unfortunately, they could not deliver on their promises. Even the 2012 “National Housing Policy that promised to provide Nigerians real mass housing which the country has been dreaming of” has failed to address the huge housing challenge in the country.

The Land Use Act/policy of 1978 constitutes a clog in the wheel of progress of all land-related issues in Nigeria because all lands are vested in the government. The

problems associated with Nigeria's housing policy include poor planning, poor policy formulation and implementation, policy inconsistency, and poor monitoring and evaluation, among others. These have serious implications for the well-being of the citizens (Olawale et al. 2015; Agbola 1998; Jiboye 2011). The research questions answered in the study were: How do housing policy and location of housing influence the well-being of civil servants? Do housing policy and type/quality of housing correlate with the well-being of civil servants? The study investigated housing policy and well-being of civil servants in Calabar Municipality, Cross River State, Nigeria. Specifically: to ascertain housing policy influence of location on the well-being of civil servants. To determine housing policy influence of type/quality on the well-being of civil servants. The **hypotheses include:** Housing policy influence of location of housing has no significant influence on the well-being of civil servants. And Housing policy influence of type/quality of housing has no significant influence on the well-being of civil servants.

## 2 Theories Underpinning the Study

Housing is articulated in Goal 11 of the Sustainable Development Goals (SDGs), which is seen as a key component of sustainable development across all Goals, improving access to basic services, promoting inclusive growth and supporting future development with direct impact on factors that contribute to or mediate the impacts of climate change. Housing availability and affordability have a direct and profound impact on at least 14 SDGs: access to adequate, safe and affordable housing and basic services; and improved slum conditions for all by 2030.

The importance of housing in sustainable development is very high, housing has a huge impact on the health and well-being of low-income families, and urban and family farming is the foundation for achieving food security and access to quality education. Water and sanitation are provided for families through the provision of good and affordable housing. Expanding access to affordable housing finance and building social and economic infrastructure to support an efficient housing market for all.

The need for housing to achieve the Sustainable Development Goals was highlighted by the UN (2017). It promotes inclusive growth, creates wealth, fosters job creation, improves economic development, and promotes financial intermediation. Housing management regulatory frameworks support gender quality and reduce inequalities. Housing is a high-yield investment that can redirect consumer lending, increasing income-earning potential.

The housing development is thus guided by housing policy. Housing policy provides the framework upon which actions in the housing sector are based (Schaefer 1990). Typically, housing policy describes government actions inclusive of legislation and programme delivery that have direct/indirect bearing on housing provision and accessibility, housing location, housing cost, housing quality, urban planning and development, as well as housing finance or credit (Olowale et al. 2015). Housing policy is also a key determinant of how resources are allocated in the sector, rents, as well as tax policies (Festus and Amo 2015). Human wellbeing is the basic goal of all development efforts. Housing policy is the framework for actualizing housing development is critical to human well-being. This underpins the prominence and relevance of housing policy and housing

to human wellbeing. It has been asserted by housing experts that at the moment, about 1000,000,000 people globally live in shanty houses or grossly inadequate shelters; and approximately 100,000,000 are homeless due to lack of priority attention to housing development (Jiboye 2011).

## **2.1 Integrating Housing Adjustment and Abraham Maslow Need Theories**

The theory of housing adjustment behaviour was first put forward in 1975 by Earl W. Morris and Mary Winter and further expounded by Bruin (1995) respectively. Housing adjustment theory is considered suitable for the study because it is appropriate in analysing the elaborate procedure by which households make decisions about their housing needs and how societies decide how individuals and households are housed. From this theoretical perspective, it is assumed that inadequate housing is a result of defective housing policies.

Abraham Maslow's hierarchy of needs theory has been extensively applied to employees' roles in the organization and human resource management in enhancing the well-being, productivity/performance of employees. It is a truism that having one's basic needs such as food, housing, health, water, etc. satisfied enhances well-being (Ayambem 2013). The shelter is a fundamental need of man next to food and clothing and belongs to the lower level needs which must be satisfied first to enhance well-being. This harmonizes with SDG 11. The goal seeks to make cities and human settlements inclusive, safe, resilient and sustainable (UN 2017). Making cities safe and resilient means ensuring access to safe and affordable housing and improving living conditions in slums. Previous studies neglected the crucial role of housing adjustment behaviour and its linkage to individual wellbeing. This study was meant to bridge this knowledge gap.

## **3 Materials and Methods**

The study used a descriptive design and was conducted in Calabar Municipal, Cross River State, Nigeria. Calabar Municipal is a local government area in the state of Cross River, Nigeria. It covers an area of 331,551 square kilometres with a total population of 183,681 people. According to the 2006 census, the Municipality of Calabar is made up of ten (10) central municipalities (districts 1–10). Lives in space Efix and Kvass (Abasiattai 1987).

### **3.1 The Population of the Study**

The population of this study consisted of civil servants and employees of selected ministries, departments, and agencies (MDAs), in Calabar Municipality of Cross River State. The total population of the study was 1,846 civil servants.

### 3.2 Sampling Technique

Ten ministries, departments and agencies constituted the ten strata of the study. Forty respondents were selected from each strata using a simple random sampling procedure. A total of 400 respondents participated in the study. The main instrument employed to elicit facts or data for this study was the questionnaire.

**Table 1.** Sample distribution of civil servants according to the selected MDAs in Calabar Municipality, Cross River State

S/N	MDA	Population	Sample
1	Civil Service Commission	91	40
2	Ministry of Lands and Housing	400	40
3	Ministry of Education	250	40
4	Ministry of Local Government Affairs	60	40
5	Ministry of Works	400	40
6	Ministry of Health	150	40
7	State Universal Basic Edu. Board	300	40
8	State Planning Commission	90	40
9	Ministry of Women Affairs/Social Dev	105	40
10	Cross River State Internal Revenue Service	97	40
	Total	1943	400

Source: *Civil Service Commission, 2019*

### 3.3 Data Analysis

#### 3.3.1 Presentation of Socio-demographic Data

The social demographic data of the respondents are presented in Table 1. Results based on the age of the respondents show that the majority of the respondents were within the age bracket of 25–44 years with 155(38.75). The responses on the sex of the respondents indicated that 218(54.5%) were males while 182(45.5%) were females out of the 400 respondents that were sampled. The result on the marital status of the respondents disclosed that the majority of the respondents were married with 204(51.0%). The occupation had civil servants as the highest with 374(93.5%). For educational qualification, respondents with the highest qualification were HND/B.Sc. holders 154(38.5%) (Table 2).

**Table 2.** Results of demographic data

S/N	Variables	Responses	Percentage (%)
1	Age (Years)		
	18–24	14	3.5
	25–34	87	21.75
	35–44	155	38.75
	45–54	106	26.5
	55 and above	48	9.5
	Total	400	100
2	Sex		
	Male	218	54.5
	Female	182	45.5
	Total	400	100
3	Marital status		
	Married	204	51.0
	Single	134	33.5
	Divorced	26	6.5
	Separated	19	4.75
	Widowed	17	4.25
	Total	400	100
4	Occupation		
	Civil servant	374	93.5
	Self-employed	11	2.75
	Unemployed	15	3.75
	Total	400	100
5	Educational qualification		
	FSLC	31	7.75
	SSCE	88	22.0
	NCE/OND	68	17.0
	HND/B.Sc	154	38.5
	Others	59	14.75
	Total	400	100

Source: Researcher's Fieldwork, 2019

### 3.4 Data Analysis

**Hypothesis One:** Housing policy on the location of housing has no significant influence on well-being of civil servants. The results are presented in Tables 3 and 4 and Fig. 1.

**Table 3.** Responses to housing policy/location of housing and well-being of civil servants

S/N	Items	Responses				Total
		Agree		Disagree		
		Freq	%	Freq	%	
7	The location of a house or housing estate can improve/undermine the safety of families	259	64.75	141	35.25	400
9	A residential area that is furnished with schools and recreational facilities improves the lifestyle/quality of life of the people	364	91.0	36	9	400
10	The proximity of a house to a workplace, marketplace, worship place and medical or pharmaceutical services eases movement and enhances the overall well-being of the people	338	84.5	62	15.5	400
11	Houses with pipe-borne water, constant power supply, and good waste disposal facilities are most preferable	295	73.75	105	26.25	400

Source: *Researcher’s Fieldwork, 2019*

**Table 4.** Independent t-test analysis of the influence of housing policy on the location of housing on well-being of civil servants (n = 400)

Housing policy/location	N	$\bar{x}$	SD	t-cal	Sign
Good	283	9.879	2.341	5.171	.000
Poor	117	9.017	2.284		

$P < .05$ ,  $df = 398$ , Critical  $t = 1.960$  (Source: *Researcher’s Field work, 2019*)

The results in Table 3 show that the calculated t-value of 5.171 is greater than the critical t-value of 1.960 tested at 0.05 level of significance and 398 degrees of freedom. This means policies that encourage the location of houses or estates in good neighbourhoods are most welcomed and houses located in high opportunity neighbourhoods have a way of bringing joy, happiness, and fulfilment to the residents owing to proximity to workplace, worship place, market place and other services.

Figure 1 shows that most people would prefer houses located close to the source of power and as such a house with no power supply is discouraging. Again, it can be deduced from Fig. 1 that proximity to the place of worship is another major factor for preference of a house, followed by constant water supply. Proximity to the place of work is another



determinant of residential choice. The least factor influencing the choice of residence is the availability of proper waste disposal facilities. The results show the importance of power supply to the well-being of civil servants. It also implies that housing policies should give top priority to the provision of infrastructures such as power supply, potable water, and sewage disposal facilities, among others influence on the well-being of civil servants. This hypothesis was analyzed using independent t-test analysis.

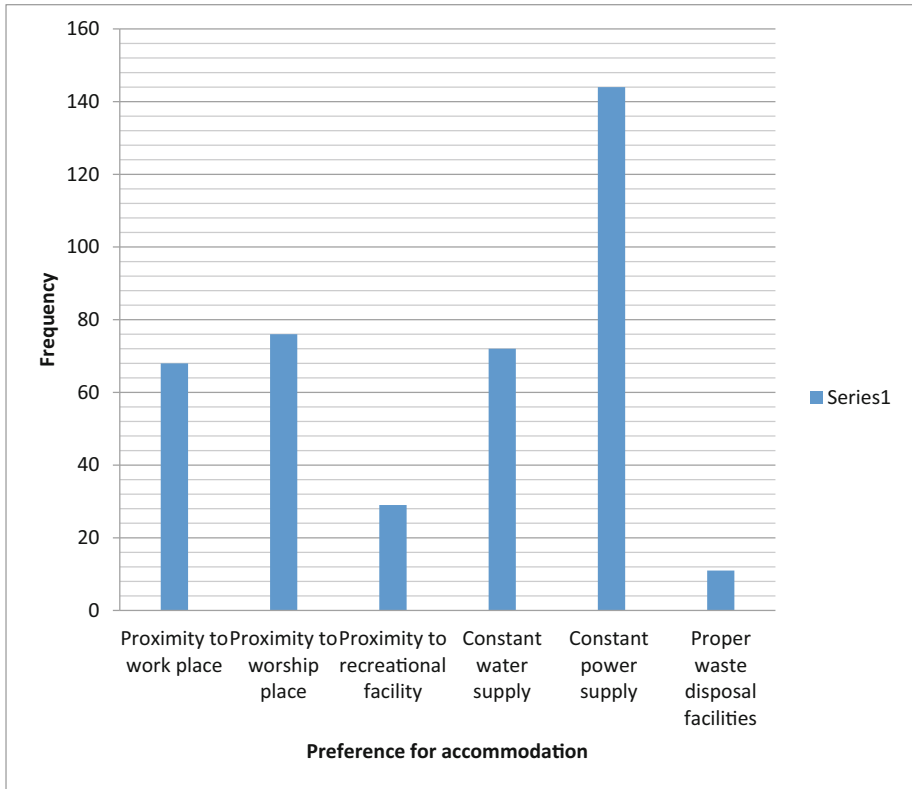


Fig. 1. Preference for housing location.

**Hypothesis Two:** Housing policy on type/quality has no significance The results are presented in Tables 5 and 6, and Figures 2 and 3 below.

Type/quality	N	$\bar{x}$	SD	t-cal	Sign
Good	222	10.764	2.527	7.855	.001
Poor	178	9.528	2.381		

P < .05, df = 398, Critical t = 1.960

**Table 5.** Responses on housing policy type/quality of housing and well-being of civil servants.

S/N	Items	Responses				Total
		Agree		Disagree		
		Freq	%	Freq	%	
12	A residential neighbourhood or area with basic facilities such as potable water, electricity, sewage disposal, etc. contributes/promotes workers' well-being	288	72	112	28	400
14	A house with poor roof structure and leakages affects the comfort and overall happiness and satisfaction of its residents	127	31.75	273	68.2	400
16	Inadequate space, poor ventilation, pollution, presence of lead found in paints, rusted water pipes, defective plumbing, mold growth and asbestos in a home are harmful to the health/well-being of residents	203	50.75	197	49.2	400
17	Policy that advocates good housing quality can improve not only the well-being and health of the residents but also that of the community as a whole	185	46.25	215	53.7	400

Source: *Researcher's Fieldwork, 2019*

Figure 2 indicates that among the components influencing the quality of a house, the inadequate ventilation system is a major factor, followed by pollution of the environment. Leaking roof is another factor that negatively influences the quality of a house. The last factor considered by the respondents is the design of a house and a poor waste disposal system. Figure 3 indicates what constitutes quality housing, availability of potable water was highest, followed by availability of electricity. Good roads, a good transport system, and a good communication network were other variables that define quality housing. The least variable or determinant of quality housing was sewage disposal facilities.

The result in Table 6 reveals that the calculated t-value of 7.855 is greater than the critical t-value of 1.960 tested at 0.05 level of significance and 398 degrees of freedom. Hence type/quality of housing affects the well-being of civil servants. This implies that

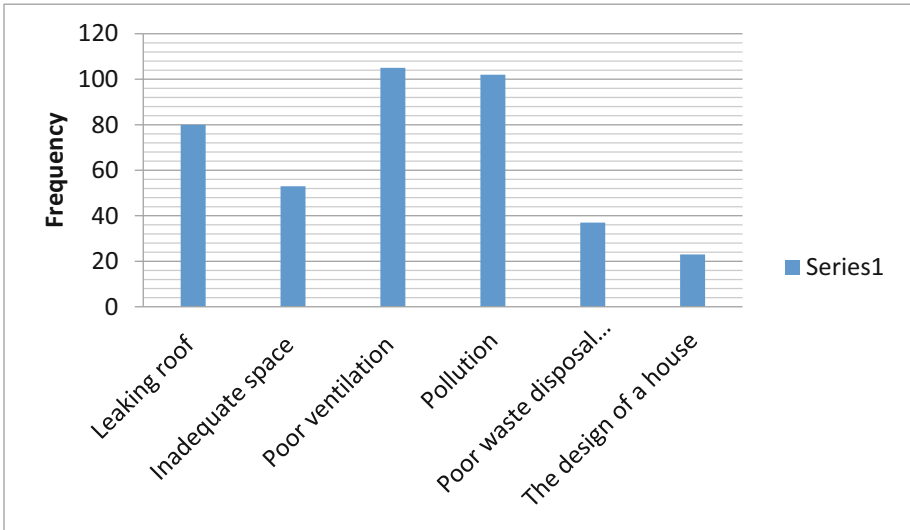


Fig. 2. Factors affecting the quality of housing

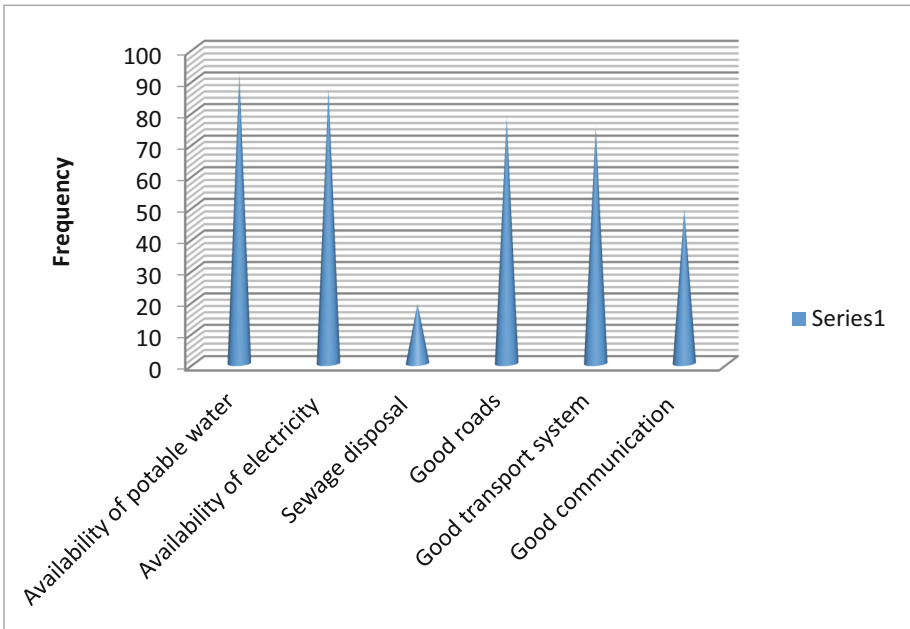


Fig. 3. Quality of housing

**Table 6.** Independent t-test analysis of the influence of housing policy and quality of housing on well-being of civil servants.

Type/quality	N	$\bar{x}$	SD	t-cal	Sign
Good	222	10.764	2.527		
				7.855	.001
Poor	178	9.528	2.381		

$P < .05$ ,  $df = 398$ , Critical  $t = 1.960$  (Source: Researcher's Field work, 2019)

the overall well-being of occupants is dependent upon housing policy and quality of housing.

## 4 Discussion

**Housing Policy on the Location of Housing and Well-Being of Civil Servants** The result of the testing of this hypothesis discloses that a significant relationship exists between housing policy and the location of housing and the well-being of civil servants. This result agrees with the findings of Ariyawansa (2010), in an “empirical study of consumer behaviour in the housing market.” The number of characteristics of the housing market is in line with the views of the potential buyer concerning the buying decision of a home or house. The study found that thirty-five percent (35%) of the respondents indicated among other things that the location of a house is the most significant determining factor of the decision to buy in addition to other considerations such as quality, price, legality, availability of basic facilities, and neighbourhood.

### **Housing Policy and Type/Quality of Housing and Well-Being of Civil Servants**

The result of the testing of this hypothesis indicates that a significant correlation exists between housing policy and type/quality of housing and well-being of civil servants. In other words, housing policy and the quality/type of housing significantly influence workers' well-being. Accordingly, this result agrees with the finding of Olotuah (2006), in an empirical study of “housing quality in sub-urban areas (Oba-Ile, Nigeria).” Olotuah's study found that the provision of sanitary facilities and other basic services/amenities in the study area was in a deplorable state and impacted severely on the housing quality. According to the study, the quality of homes in the study area will be significantly improved with a corresponding increase in wastewater treatment capacity and other basic services such as water supply, electricity, etc. and the frequency of waste collection. A 100% improvement in the provision and use of medical services will significantly affect the change in the quality of housing by 52.4% and will have a positive impact on people's lives.

## 5 Conclusion and Recommendations

Housing policies are meant to ensure access to safe and affordable housing services with the overall goal of improving human wellbeing. Government intervention determines

housing location, quality, cost, finance, also the extent to which housing is sufficient to disallow slums settlements. Housing policy on the location of housing, as well as type/quality of housing, significantly affect the wellbeing of civil servants. Government should redirect and redefine existing housing policy frameworks to ensure accessibility and availability to reduce incidences of slum settlements. Government should ensure that the formulation of housing policies takes into cognizance the location of housing and/or encourage housing that provides residents with economic opportunities for advancement at low costs.

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# Creating Sustainable Cities: The Viability of Urban Regeneration in Bloemfontein, South Africa

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**Abstract. Purpose:** Central business districts within South African cities are experiencing rapid deterioration, ultimately leading to decay and decentralisation. The study will aim to identify the necessity and viability of urban regeneration in South Africa. Shared thinking is that Bloemfontein can be a successful candidate for urban regeneration for one primary reason as it is South Africa's juridical capital.

**Design/Methodology/Approach:** This study's approach to gain insight into urban regeneration is qualitative of nature. The empirical study involved document analysis, case studies, and semi-structured interviews regarding the feasibility of urban regeneration in South African but more specifically the inner-city of Bloemfontein and how regeneration strategies and frameworks can be implemented.

**Findings:** Throughout the study, it is clear that regeneration is necessary for economic and social growth within the inner city. The recommendations above will not ensure complete and successful regeneration but will serve as a basis to confront inner-city decay.

**Practical Implication:** The viability of urban regeneration is possible with the municipality/local authorities' involvement and public-private partnerships, thus creating a safe and sustainable city. The suggestions will prove more valuable than current policies initiated by the local municipality.

**Research Limitation/Implications:** This research focused on the viability of urban regeneration of the inner-city in Bloemfontein.

**Originality/Value:** The successful and effective approaches, policies and frameworks adopted in Port Elizabeth, Cape Town and Johannesburg will be applied to current challenges in terms of inner-city decay in Bloemfontein.

**Keywords:** Feasibility · Public-private partnerships · Regeneration · Sustainable · Urban

## 1 Introduction

According to Eren (2014), regeneration is known worldwide as a process of creating and utilizing new methods and techniques to address deterioration issues in urban areas

through the redevelopment and development of the property. Tsenkova (2002) states that urban regeneration is an imperative approach to confront inner-city decay and deterioration. Regeneration offers a framework to influence, monitor, and improve the built and natural environment within a city centre, significantly affecting economic and cultural restoration, leading to developing a dynamic and thriving city centre (Derby City Council 2012). This research aims to provide a framework to inspire, encourage, and drive the urban centre's feasible urban regeneration with a vision to recognise the economic and social potential of a city. Furthermore, the study will aim to identify the necessity and viability of urban regeneration in South Africa, more specifically in Bloemfontein, through a case study approach.

## 2 Theories Underpinning the Study

Inner-city degeneration and decay is a universal occurrence within the socio-economic development cycle of cities. Migration from the inner city area to suburban areas are common in the western part of the world. This was done to enhance occupant's lives socially or economically (Galster 2012).

Urban decay can be a product of one significant factor or a series of contributing factors. As one of the factors, crime impacts the potential investor negatively; poor living conditions which included the scarcity of facilities, inadequate living spaces, lack of basic services or poor housing, violence, diseases and the age of buildings, and the transformations in the area. Mismanagement and the shortage of maintenance could be the cause of decay as well (Ndlebe 2017). Furthermore, urban decay influence city planning and restructuring, as well as development. Globally most cities are affected by urban decay and it could have serious implications on town planning strategies and on land usage that can presently be found within a city.

The world is experiencing greater urbanization and changing demographics. It is predicted that 66% of the world's population will live in cities by the year 2050, which is an increase of 12% of the present population of the world living in cities (Cook and Porter 2015). South Africa is not an exception to this, as it is noted that about 60% of South Africans live in urban areas (The Department of Co-operative Governance and Traditional Affairs 2016). It is projected that in 2030 71% will live in urban areas and by 2050 it might increase even more to about 80%. According to Healey (2013) "*cities are the central point of social, economic, and environmental interest to form a connected framework cooperating in a specific area*". Urban regeneration is recognized as a solution for urban decay and a way to upgrade a sector's current features by capitalising and transforming these renovated parts into a more sustainable environment that is more profitable and aesthetically attractive (Santhurie 2003). The core driving force behind regeneration strategies is economic renewal and property redevelopment (Couch and Dennemann 2000). The urban regeneration process is mutually multifaceted and comprehensive, with extensive funding essential to redevelop (McGreal and Deddiss 1993). NASHO (2013) recommends that municipalities in cooperation with both provincial and national public agencies need to develop firmer systematised interactions with regards to the funding and execution of urban regeneration The NASHO (2013) specifies that no robust strategic framework for urban regeneration in South Africa existed.



Keeping and Shiers (2004) mentions that it is crucial for public and private sectors to operate cooperatively to ensure effective regeneration implementation. The most essential component in rejuvenating decaying urban areas is through private sector participation (Creamer 2016). Furthermore, it is stated by the authors of the report that the involvement of both public and private sectors and community shareholders reached a reduction in vacant property rates from 40% in 2003 to 17% in 2008 and a parallel increase in property transactions. According to Macdonald & Cheong (2014), the main aim of PPP's is to merge both partners' resources and skills to create goods or public service for the public. The resources provided by both partners are reciprocal, where the private sector generally offers investment or fund-raising assistance, technical knowledge, and effective execution of the strategy. In addition, the public sector generally offers resources, a regulatory outline and financial incentives. The incentives commonly comprise a subsidy, grant or tax inducements that allures private investors. Property development is crucial in urban regeneration projects attempted by public-private partnerships, as Pacione (2009) suggested. Public-private partnerships, which are collectively referred to as PPPs, Triple P's and PFIs (private finance initiatives in the UK), are expanding quickly as procurement vehicles for the development of buildings, infrastructure and service delivery, mainly in the built environment (Hauptfleisch and Verster 2017). Altenburg (2005) mentions that risks, limitations and additional costs are involved when entering public-private alliances. The first major risk is the consequence of misuse and corruption of public resources when subsidies are involved. To limit public resources' wastage, the agreements between the parties should specify performance or outputs where each partner can be held responsible. The second major risk involved is that a PPP requires additional processes that translate into increased transaction costs, such as assigning projects, negotiating services, performance indicators and tariffs, commanding partnership agreements, and monitoring the projects' performance. Managing the latter risk ensures that both participating parties keep transaction costs as low as possible by defining contractual relationships that include the services, prices, and distribution of risks.

### 3 Methodology

The empirical study involved document analysis, case studies and semi-structured interviews to discuss the feasibility of urban regeneration of Bloemfontein's inner city and how regeneration strategies and frameworks can be implemented which will result from a qualitative approach. Case studies of urban regeneration strategies used in Port Elizabeth, Cape Town, and Johannesburg CBD are studied and presented. Semi-structured interviews are conducted with professionals and academics in quantity surveying, urban and town planning, and architecture. The semi-structured interviews aimed to gain input on urban regeneration within Bloemfontein CBD and its feasibility. The sampling technique for the semi-structured data collection was purposive and the sample of twelve included: four quantity surveying professionals and one academic in the quantity surveying industry; two town and regional planning professionals and two academics in the town and regional planning industry; and two architectural professionals and one academic within architecture. The data analysis method for the qualitative data collection was to record

and transcribe the interviewee's responses to semi-structured questions. The data collection's ethical consideration was to ensure the protection of the interviewee's rights and privacy. This included but was not limited to consent from the interviewee, voluntary participation, the anonymity of the participants, and no remuneration.

## 4 Case Studies

The following three case studies were studied and are presented to gather data on urban regeneration strategies and frameworks. These studies include Nelson Mandela Bay, Cape Town's Safmarine House and Jewel city in Johannesburg.

### 4.1 Nelson Mandela Bay: Port Elizabeth (2004 – 2008, R800 Million)

The Nelson Mandela Bay project in Port Elizabeth started in 2004 and was completed in 2008. The project was worth R800 million. The Industrial Development Corporation (IDC) and the Nelson Mandela Bay Municipality (NMBM) established the Mandela Bay Development Agency (MBDA) in 2003 and began with ventures in 2004 (Voges 2013). The MBDA, with a team that consisted of architects, urban economists, consulting engineers, and quantity surveyors, created a 'Master Plan', with various projects to be executed over fifteen years. Feasibility studies were conducted from a political, market-demand, and social perspective and with great awareness of financial concerns (Voges 2013). Stopping urban decay and embarking on capital projects were the key objectives for establishing the agency. These objectives are used to bring back investments to the demarcated 'Mandate Area' in the CBD of Port Elizabeth and the other nodes in the metro. Sustainability was a vital consideration when it came to selecting infrastructure projects, the prime philosophy being that "*if a public investment does not lead to downstream private sector investment, to sustain and deepen its role in the economic and social life of the area/city, then one cannot call it a successful public sector investment*" (Voges 2013). The various regeneration projects that were planned included: i) The revamp of Govan Mbeki Avenue, ii) The redevelopment of Jetty street; iii) Redevelopment of Parliament street and iv) Donkin Reserve; v) Upgrading Strand street; vi) Redevelopment of Kings Beach, vii) Athenaeum redevelopment; and viii) The redevelopment of Tramways building forming part of the broader Baakens Valley redevelopment initiative. An economic impact evaluation of three different MBDA projects, including the Govan Mbeki Avenue, Parliament Street, and Donkin Reserve, was done in 2013 by the MBDA and showed that these improvements had generated the following advantages for the CBD/Central area and the greater NMBM. i) New business sales worth R185.2 million; ii) 825 new employment opportunities, iii) additional GGP worth R61.5 million (Voges 2013). These business sales, employment opportunities, and increased GGP were generated as a result of direct, indirect, as well as forced effects of the improvements. The impact of private-sector investment, in terms of the reaction to the public-sector investment, was noteworthy as well. The fundamental urban renewal method of the MBDA is still similar throughout all of the above-mentioned projects: i) to detect dormant properties of the municipality that have potential and ii) to allocate them to the MBDA's list. Afterwards, they focus on planning, investments, and initiation

of private-sector development on these specific properties upon the grounds of a lease contract, guaranteeing that the renovation of urban areas is initiated, businesses exceptionally succeed, and employment opportunities are generated and a greater group of rates and taxes is produced. Therefore, the MBDA approaches the activity of redeveloping and leasing dormant properties that are owned by the municipality, which creates revenue streams to add to urban renovation, and also to act as an initiator and assist future private-sector investment on land that's owned privately, such as acting as an initiator for procreative factor producing. This example of '*product development in urban space*' is recognized as a fundamental part of all that the MBDA executes (Oranje and Voges 2014). The belief that '*public-sector investment has to be followed by private-sector investment*' was implemented as a guideline. The MBDA helped to create a variety of interests in a framework of collaboration among the political system, the governmental functions, as well as companies with associated productional systems.

#### **4.2 Radisson Blu Hotel and Residence: Cape Town (2015 – 2018, R1 Billion)**

The 23-storey Safmarine House with its unique rooftop design is amongst the city's most iconic buildings. It is located on the corner of Long street and Riebeeck street in Cape Town. With a height of over 100 m, it was regarded as Cape Town's tallest residential building (Lewis 2015). It was designed by Louis Karol Architects and constructed in the 1990s. The Multi-storey building was previously used as offices but the building has been converted into high-class apartment units. The lower floors (from one to eleven) were redeveloped into the Radisson Blu hotel and from level twelve to twenty-three is home to hundred-and-seventy sectional title, one/two bedroom (40-88 m<sup>2</sup>) apartments. It involves seven exceptional 97-214 m<sup>2</sup> penthouses and three three-bedroom penthouses with sizes ranging up to 290 m<sup>2</sup>. The Stonehill Property Fund took over Safmarine House from Old Mutual in July 2014. Previously known as the Safmarine House, the award-winning office building in the middle of the city is simply recognizable through its flamed and polished granite facade. Originally at a cost of US \$6-million to construct the unique glass, granite and modern concrete high-rise, the present investment will be estimated at a total of R1-billion (Radisson Blu Hotel and Residence Cape Town on track for take-off - eProperty News 2016). The development was divided into three individual parts – the Radisson Blu hotel, residential apartments and penthouses. Every part was managed by a team of specialists, providing their special professional touch to the project and giving every aspect of the development its unique appeal and at the same time guaranteeing that it operates within the vision as an entire project. It was a speed-driven programme and needed smooth management between the professional team and contractors. The incredible success of the redevelopment of Old Mutual's Safmarine House by Signatura into a Radisson Blu and The Radisson Residences has uplifted the market. Additionally, there are also several other CBD suggested redevelopment projects in progress.

They involve:

- i) Ingenuity's 117 on Strand (a combined-use office, retail and residential plan that is presently under construction),

- ii) ii) The Onyx (previous Nedbank House – a joint venture between Signatura and Nedbank Property partners – 18,000 m<sup>2</sup> combined-use hotel apartment and residential units with ancillary ground-floor retail),
- iii) iii) 16 on Bree (FWJK's 350 residential units with construction beginning in the second quarter of 2018),
- iv) iv) Harbour Arch (Amdec owned the Culemborg site and over 200,000 m<sup>2</sup> of permissible bulk which will be reconstructed into two Marriott hotels/residential, retail and showroom space with Phase One anticipated to begin during the first quarter of 2018) (Tracey 2017)

### 4.3 Jewel City: Johannesburg (2019 – Present, R1,2 Billion)

In Johannesburg, the Jewel City project worth R1.2 billion commenced in 2019. Jewel City is an immense urban redevelopment project on the Maboneng Precinct's outskirts in Johannesburg's eastern Central Business District (CBD). The iconic Jewel City is one of Diversity Urban Property Fund's R1.2 billion projects. The formerly isolated ex-centre of the diamond and valuable metals trade in Johannesburg had been excluded from the public during the mid-'90s and remained a remote and overlooked node for tens of years (Rajgopaul 2019). Jewel City project includes the remodelling of this prior industrial complex as an exposed, lively combined-use zone that will be more socially and economically sustainable (Leading Architecture and Design 2019). The developers regard Jewel City as a development that's enhancing the eastern CBD's urban potential, presenting essential services that involve new reasonably priced residential areas, schools, healthcare services and retail outlets like pharmaceutical outlets and supermarkets, a fitness centre as well as other recreational facilities that assist the sustainability of a comprehensive, flourishing and wholesome urban social, economic and cultural life within the city centre (Robertson 2019). The vision of Jewel City was seen as a chance to reverse apartheid-era dimensional divisions and change the city centre to focus on the needed access to resources and economic opportunities while addressing the serious need for housing (Leading Architecture and Design 2019). The redevelopment initiative is an important venture in the South African city by Diversity. This new investment fund is reintroducing and revitalizing South Africa's urban centres by implementing unique inner-city zone development. The development is also focused on creating significant employment opportunities in the city with a projected 1 279 impermanent employment opportunities and 1 384 permanent employment opportunities. Additionally, it will add to the municipal and national tax base (Robertson 2019). Jewel City will consist of 20 000 m<sup>2</sup> commercial office space, 7000 m<sup>2</sup> retail space at completion, 1 550 new residential apartments, and 40 000 m<sup>2</sup> brand new buildings. This recent redevelopment and development will be a safe pedestrian urban precinct with vibrant living, shopping, and six city blocks' office environment. A school, clinic, gym, ample parking, convenience retail, and fast food outlets and restaurants will be present on completion of Jewel City (Atterbury 2019).

## 5 Findings and Discussion

Ten questions were formulated for the semi-structured interviews with quantity surveyors, town and regional planners and architects. The main objective was to establish the viability of urban regeneration of Bloemfontein's CBD.

### 5.1 What is Your Opinion of Urban Regeneration in General but More Specifically in Bloemfontein?

In answer to the question, "*What is your opinion of urban regeneration in general but more specifically in Bloemfontein?*" the following responses were received:

- i) Urban regeneration and the revival of the inner city focus on the physical, economic and environmental conservation, infrastructure development, financial benefits, accessibility and historical and emotional significance.
- ii) Throughout the world, urban regeneration assists in and fights against urban growth, handling natural urban constraints.
- iii) If implemented correctly, with the correct stakeholders, planning, capital and investors, the rejuvenation of a city's inner-city areas can offer constructive socio-economic benefits, providing a sustainable lifestyle for its inhabitants, providing closer access to employment opportunities. However, if there is a lack of involvement, it will only remain a good initiative with no action being taken.
- iv) It is economically viable in terms of significant cost saving when restoring existing dilapidated buildings and environments, compared to constructing entirely new buildings or installing bulk services on a property that lacks these services. Servicing and rezoning are time-consuming and expensive procedures that can require two to four years to be completed.
- v) It can utilize formerly uninhabited buildings/areas and rejuvenate the area at a fraction of the cost of constructing an entirely new building, leading to increased property prices and persuading people to return to formerly undesirable areas which reciprocally add value to neighbouring areas/buildings.

### 5.2 In Your Opinion, What Are the Barriers to Urban Regeneration, and How Can They Be Overcome?

The barriers mentioned mainly by the respondents are political and municipal barriers and economic activities and security. One respondent indicated that the political barrier can be overcome with strong political determination to ensure equal opportunities. Another respondent mentioned that pressure on the government and municipalities by the public can help to overcome these barriers. Another respondent said implementing practical urban design and a brand new approach towards urban planning can help overcome barriers. Responses also complement research conducted by NASHO (2013), which determined that the "*concept of urban regeneration is an effective approach to restructure cities in South Africa*".

### 5.3 In Your Opinion, What Makes Urban Regeneration Feasible and Viable? Will Urban Regeneration Be Possible in Bloemfontein?

One respondent said a sustainable way of living and economic motives for citizens and developers makes Urban Regeneration feasible and viable. Bloemfontein can be feasible and viable; however, local authorities would need to learn from various cities across the globe regarding what has been done to obtain the specific lifestyle of its citizens. Another respondent replied that economic advantages in the light of return on investment and allurements for possible investment and usage would make Urban Regeneration feasible and viable and in Bloemfontein, it would be possible, but authorities would have to assist the change. Respondent two argues that infrastructure is the single greatest benefit that should cause urban regeneration to be feasible and viable. In Bloemfontein, there are various infrastructures available and would be possible for Urban Regeneration. Respondent four states that to make Urban Regeneration feasible, there has to be a cost-saving of up to 25% compared to new buildings in most instances. And viable that the majority of infrastructure, as well as zonings, are already in a position which, in many instances, guarantees quicker inception to completion period. CBD's are based in central areas of cities and therefore potentially attract a lot of people as well as a business towards these areas. In Bloemfontein it will be possible, there is a lot of rundown buildings in the Bloemfontein CBD that possess the potential of turning into modern apartment buildings, office blocks, student housing. Respondent five responded that aspects such as the correct stakeholders, great leaders, professionals, developers, as well as investors have to be engaged in the project from inception to completion and with these, it would be possible in Bloemfontein. Urban regeneration, according to respondent six, is made viable through the maintenance of present buildings. Every city requires a good urban area. It is the centre where everything occurs as well as where everything is cultivated from. That's why it is extremely important to have an urban area that operates well and supports the remainder of the city. With that being said, it would be possible in Bloemfontein. According to respondent seven, other than the political determination, the economic mechanisms includes investment capital. There has to be a possibility of connecting a definite identity to an area that has been reserved for development. Considering the present extent of mismanagement concerning the delivery of basic services and the extent of corruption within the metro, it would be exceptionally challenging to make it possible in Bloemfontein. Respondent eight suggests that Urban Regeneration is a more cost-effective way to upgrade current buildings than constructing entirely new buildings since all of the infrastructures within the area is already in place and the building's structural elements would be costly to construct. Furthermore, it would most certainly be a possibility in Bloemfontein.

The most common answer among the respondents for the feasibility of urban regeneration is the economic objective and for the viability of urban regeneration is the magnitude of infrastructure readily available. All the respondents agree that Urban Regeneration will be feasible and viable in Bloemfontein. As Graaskamp (1970:4) defines feasibility as "*a real estate project is 'feasible' when the real estate analyst determines that there is a reasonable likelihood of satisfying explicit objectives when a selected course of action is tested for fit to a context of specific constraints and limited resources*". The

objectives of a feasibility study may involve economic and social or other objectives (Cloete 2006).

#### **5.4 In Your Opinion, Which Sites in Bloemfontein Will Be Most Suitable for Urban Regeneration?**

5 Respondents agreed and mentioned the same areas as potential urban regeneration locations. The locations mentioned are all around the Loch Logan Waterfront area. The areas include the Zoo, Park West, Old Grey's sports fields, Stadia and the Spruit. Another location mentioned which is common among the other respondents is Hoffman Square which is in the CBD of Bloemfontein.

#### **5.5 Do You Think that Urban Regeneration Promotes Economic Growth? Will This Be Possible in Bloemfontein?**

8 Respondents replied that there is a possibility; however, it depends on how it is executed and the factors that influence the way it is done. As for Bloemfontein, it could encourage development, however, it will be completely dependent on the creation of a practical, sustainable business environment with an appealing human environment. Urban Regeneration promotes economic growth as it assists specific properties in areas to increase in value at a minimum cost. Economic growth in Bloemfontein is possible if implemented in the right manner. There is a well-founded agreement between the respondents that Urban Regeneration promotes economic growth if implemented right. Respondents seven and four believe through employment with Urban Regeneration, and there will be economic growth. Respondent one suggests that by creating a practical, sustainable business environment with an appealing human climate, there can be economic growth in Bloemfontein through Urban Regeneration. The regeneration of city centres can generate value-added economic interests, employment and empowerment prospects, accelerate public unity and safety, and aid in energy efficiency and environmental sustainability (Department of Transport and Public Works 2012).

#### **5.6 How Would You Implement Urban Regeneration in Bloemfontein so that It Would Be Viable?**

Respondents three, four and five argue that starting with the municipality and local authorities are needed to successfully implement Urban Regeneration. Public-Private Partnership is also essential for success as mentioned by respondent five. This reaction confirms Keeping and Shiers (2004) statement that: "*public and private sectors function collectively through a public-private partnership to guarantee successful regeneration implementation*". Location identified by MMM must be promoted as sites that are detected for possible future rejuvenation with incentives for developers, as stated by respondent four, it is needed. Respondents one, two, six, seven and eight suggest a plan needs to be in place to successfully implement Urban Regeneration. The newly released IUDF is the South African Government's policy and framework for the urbanisation process (COGTA 2016). The framework will be utilised to prevent further decay within the South African CBDs.

### **5.7 Would You Say that Bloemfontein Can Be a Candidate for Successful Urban Regeneration, and Why?**

Respondents one and two replied, yes. Bloemfontein is a city with areas and locations that would enrich urban regeneration in architecture, open areas, old buildings, etc. It is situated in central South Africa, which is the juridical capital of South Africa, with incredible educational institutions such as schools and universities. It provides a pleasantly reliable and foreseeable environment. Respondent three mentions, it is the centre of a large location in the central part of South Africa. It should be a very appealing area for economic interchange and activities and a place to assist economically operative people. Respondents four, five, and eight respond that yes, many rundown buildings in the Bloemfontein CBD possess the potential of being turned into modern apartment buildings, office blocks, student housing, etc. There is a lack of zoned and serviced unoccupied land. This is made clear by all the issues developing regarding business, such as in Westdene, Preller etc. Respondent six says that Bloemfontein has a delightful city centre that's falling apart due to the lack of maintenance in the area and the lack of crime prevention pushing everyone out of the area making it a candidate for Urban Regeneration. Respondent seven mentions that there are specific areas in Bloemfontein that would meet the standard for regeneration. Nevertheless, it would need a great extent of cooperation throughout every sector of the city.

There is shared thinking amongst all of the respondents that Bloemfontein can be a successful candidate for Urban Regeneration. A common reason between the majority of the respondents is that Bloemfontein is the central part of South Africa, it's the juridical capital of South Africa as mentioned by respondent two.

### **5.8 What Possible Changes in Bloemfontein Inner-City/CBD Would Need to Be Considered to Increase the Functionality of an Urban Regeneration Project?**

Respondents, one and two indicated that changes include re-planning, brand new urban design ideas, more walkways, increased diversity, blended use of old buildings, and creating more open green areas. Respondent seven says that possibly one of the principal considerations would be to obtain an achievable solution for informal traders, which doesn't completely remove them from the CBD but also creates an area where they could still carry out their trade. The other respondents mention safety and security that require change. Other changes mentioned are public transportation and the closing of roads to accommodate walkways and ease of access to buildings. Furthermore, upgrading and renewing existing buildings while persuading large and significant businesses to return to the inner-city area.

### **5.9 Can You Think of Buildings in Bloemfontein Inner-City/CBD that Would Be Viable to Regenerate? and Why Specifically Those?**

Respondent one replied that these buildings include the old Volkskas building, Barclays Bank in St Andrews Street, the stadia-area, the old zoo, as well as the Bloemspruit channel. These specifically as recycling these areas is a necessity otherwise decay and



empty spaces will characterize these areas. Respondent two mentioned that most buildings require attention as a very small amount of capital was used on buildings in the CBD of Bloemfontein during the past 25 years compared to other new developments within the city. According to respondent three, a new perspective of old buildings such as the station, old shopping malls, bank buildings, parking lots, and public transportation are buildings that would be viable to generate. Respondent four explains that buildings that would be viable would include any rundown apartment buildings as well as office blocks close to main routes. Any rundown building possesses the potential of having value added to it through the process of regeneration. Respondent five indicated that several consecutive buildings on First Avenue could be regenerated into residential and commercial buildings. These buildings are in close range of a lot of existing facilities such as the Loch Logan Waterfront and educational institutions such as the Central University of Technology (CUT) and the Zoo area that holds potential for new developments in the future. According to respondent six, there are possible buildings. The majority of buildings. We have very pleasant timeworn buildings in the inner city that could be upgraded and put to use again. Our city is filled with history that could be brought back once again. Respondent seven says remote office blocks and high-rise apartments with Bloemfontein CBD, as a result of their lifespan, these buildings have come to their maximum age and need a lot of maintenance. Respondent eight replied the buildings that would be viable to regenerate would be all the outdated apartment buildings in the Bloemfontein CBD along the Spruit. These areas have been chosen because they still possess a lot of potential for being turned into upgraded areas since they haven't been ultimately rundown yet. By elevating those areas, it could steadily begin to permeate deeper into the CBD where the areas will steadily become safer and more secure.

### **5.10 Do You Know of Any Other Urban Regeneration Projects in South Africa, and What is Your Opinion?**

Respondents one and two responded briefly that two projects including Cape Town and the Durban harbour area. It is an ongoing process that requires time but it reflects possibilities of a new way of living for its citizens. Respondent three, four and five says locations such as Cape Town centre and Cape Town areas. There are grand initiatives to take older, abnormally planned buildings in an insecure areas to create space for new modern skyscrapers, which adds to neighbouring areas' value. Respondents six, seven and eight indicated that the inner-city project in Johannesburg. It has contributed to a revitalized city centre where many people have settled in their living situations and their jobs. It has been extremely successful when it comes to establishing the economic rhythm of Africa.

It could be said that professionals within the construction industry are aware of urban regeneration projects in urban areas in South Africa. The lack of understanding is evident in how these projects are implemented. The case studies identify and assess how urban regeneration is approached by each city and the success of the projects are evident. This study's purpose involved the identification of effective regeneration framework strategies within South African cities to assist professionals and authorities in comprehending and understanding urban regeneration.

## 6 Conclusion and Recommendations

This research aimed to provide a framework to inspire, encourage, and drive the urban centre's feasible urban regeneration with a vision to recognise the economic and social potential of a city. Also, to identify the necessity and viability of urban regeneration in South Africa. It was evident that the CBDs in South African cities experienced rapid deterioration and degeneration, which ultimately led to the decays and decentralisation. The key findings were based on reliable publications, journals and relevant academic papers. Urban regeneration can only be achieved through public and private sector entrepreneurship by evaluating, promoting and implementing rigorous redevelopment and regeneration framework strategies within South African cities to prevent further decay of city centres. The facilities and quality of life in the inner city must continuously evolve for the changing environment. The success of regeneration is subjected to effective partnerships between the private and public sectors. Throughout the research, it is evident that regeneration is an essential part of cities' continuing growth. Lastly, the successful and effective approaches, policies and frameworks adopted in Port Elizabeth, Cape Town and Johannesburg will be applied to current challenges in terms of inner-city decay in Bloemfontein. The following suggestions will prove valuable to the successful implementation of urban regeneration policies in the CBD of Bloemfontein. By evaluating the approaches, policies and frameworks adopted in Port Elizabeth, Cape Town and Johannesburg; the current challenges in Bloemfontein will be addressed.

The recommendations are as follow:

- i) The infrastructure improvements and upgrades will ensure the inflow of private investments
- ii) Fraud and corruption in the public sector will be curbed by the strong political leadership.
- iii) Through the establishment of an independent agency, the various plans and strategies will be effective and collaboration will be established between local, provincial and national governments.
- iv) The encouragement of private investors and collaborations such as PPP.
- v) Collaboration between the local municipality and the private sector to encourage property development and redevelopment in the inner city.

Throughout the study, it is clear that regeneration is necessary for economic and social growth within the inner city. The recommendations above will not ensure complete and successful regeneration but will serve as a basis to confront inner-city decay. The suggestions will prove more valuable than current policies initiated by the MMM.

## 7 Areas for Future Research

In order to improve the study, the following suggestions can be used for future research:

- i) Interviewing a more comprehensive range of professionals and a bigger sample size of professionals,

- ii) Determine the willingness of businesses to return to CBD of Bloemfontein after an urban regeneration development,
- iii) Determine potential investors for an urban regeneration development in CBD in Bloemfontein,
- iv) Determine a specific area within Bloemfontein CBD for an urban regeneration project.

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# A Qualitative Inquiry into the Drivers of Sustainable Competitive Advantage in the Construction Industry: The Example of Ghana

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**Abstract. Purpose:** This study identifies the drivers of sustainable competitive advantage and determines the relative influence of each of the drivers by providing an example from the construction industry in Ghana.

**Design/Methodology/Approach:** The study employed the Delphi Method. A structured questionnaire was used to collect data from the experts (respondents) via e-mail. Fifteen (15) experts completed a three-round Delphi process. Data were analysed using the median, mean, standard deviation, interquartile deviation, and percentile.

**Findings:** A strong consensus was reached on thirteen (13) drivers of sustainable competitive advantage. Knowledge management culture, continual staff development, and sustaining cost leadership in the industry recorded a mean score of 8.20 each and jointly emerged first among the 13 drivers.

**Research Limitation/Implications:** This study is geographically limited to Ghana. The findings only reflect the view of the Delphi panellists thus validating this study quantitatively will be a novelty.

**Practical Implication:** This study unravels the drivers of sustainable competitive advantage in the Ghanaian construction industry.

**Social Implication:** It will inform governments in formulating policies geared towards the sustainable competitive advantage of indigenous construction firms. This tends to reduce overreliance on foreign firms in infrastructure delivery and its associated economic losses relative to global gross domestic product.

**Originality/Value:** It is the only study that has employed a Delphi technique in identifying the drivers of sustainable competitive advantage in the construction industry in Ghana.

**Keyword:** Competitive advantage · Construction · Strategic management · Sustainability

## 1 Introduction

Globalization coupled with the increasing embracement of the tenets of free trade among nations across the globe, as well as internationalization of businesses have heightened

competition in many industries and the construction industry is not exceptional (Somiah 2018). According to Porter (2004) and Somiah (2018) competition is a zero-sum game: a gain in market share by a nation, industry, or a firm is as a result of another country, industry, or firm losing its market share(s) and risking being marginalized (Porter 2004, Somiah 2018). Therefore, the survival and growth of firms in competition is dependent on firms' ability to obtain a competitive advantage and sustain it for a long period. Thus, there is the need for construction entrepreneurs and researchers alike to give attention equally to sustainable competitive advantage. More so, whereas competitive advantage studies in the past have explored the attributes of firms' competitive advantage and constraints to obtain a competitive advantage (see Lu 2006, Wang 2014, Somiah 2018), among others, little is known of studies that explore the drivers of sustainable competitive advantage in the construction industry. It is against this backdrop that this current study aims at identifying the drivers of sustainable competitive advantage and determine the relative influence of each of the drivers by providing an example from the construction industry in Ghana. The specific objectives governing this current study were: to identify the drivers of sustainable competitive advantage in the Ghanaian construction industry; and to determine the relative influence of each of the drivers of sustainable competitive advantage in the Ghanaian construction industry.

This current study like many competitive advantage studies adopted the industry or country-specific approach in studying competitive advantage (Flanagan et al. 2005, Lu 2006). In this study, drivers of sustainable competitive advantage refer to the set of abilities, assets, and/or conditions that enable firms to continue to outperform their competitors and maintain their edge for the longer term (Wang 2014, Krishnaswamy 2017, Peskett 2018, Somiah 2018). Ghana was chosen for the study because the construction industry in Ghana shares common characteristics with many countries across the globe thus making the findings of the study being of inuring benefit to all the countries across the globe that share several resemblances with Ghana such as Nigeria, Malaysia, Hong Kong, and Singapore.

## 2 Drivers of Sustainable Competitive Advantage

In an attempt to sustain competitive advantage, several views have been advanced in literature since competitive advantage studies gain prominence and took the centre stage of strategic management studies in the 1990s. Wenger (1998) identified a well-functioning community of practice to be a driver of sustainable competitive advantage (Wenger 1998) in addition to focus and differentiation strategy, and cost leadership (Porter 1985, Porter 1990, Krishnaswamy 2017).

Krishnaswamy (2017) further argued that quality, knowledge management, and low-cost leadership are drivers of sustainable competitive advantage. Whereas some earlier literature attributed sustainable competitive advantage to political stability, functioning competition law, and enforcement of local content policies (Njuko 2012). Kaming et al. (1994) and Rao (2013) informed that technological sufficiency and continuous human resource development were drivers of sustainable competitive advantage. Further, Nigam (2011) identified corporate reputation, brand image, brand strength, motivation for innovation, improved shareholders' value, operational efficiency, improved human

and intellectual capital to be drivers of sustainable competitive advantage (Nigam 2011). In addition, Flanagan et al. (2005) posited that improved client satisfaction, shareholders' satisfaction, and society's satisfaction, among others, were drivers of sustainable competitive advantage (Flanagan et al. 2005), while Deng et al. (2013) asserted that political stability is an essential driver of sustainable competitive advantage.

### 3 Theory Underpinning the Study

This current study had its theoretical basis in the Industrial Organization theory (IOT), also known as a structure-conduct-performance theory by Mason (1939) and Bain (1959). The theory opines that sustainable competitive advantage is dependent on the influence of the industry structure, and firms' competencies, strategies and resources. This opinion contrasts the argument of the resource-based theory that sustainable competitive advantage is only influenced by the resources of the firm (Barney 2001). Also, IOT encapsulates Porter's five competitive forces model, which had become the bedrock for a plethora of competitive advantage studies. Additionally, it shares close resemblances with Porter's competitive strategy and competitive advantage theory. Thus, the IOT offers a more comprehensive approach to studying sustainable competitive advantage at the firm level. The industry-related factors include concentration (Metaxas and Economou 2012, Somiah 2018), political stability, barriers to entry, barriers to exit, the relative size of competing firms, economic stability (Porter 2000), trusted legal systems, and economies of scale (Mason 1939, Depperu and Cerrato 2005, Oyewobi et al. 2014, Somiah 2018). These factors usually lie outside the remit of the firm, unlike competencies, strategies and resources which are under the direct control of the firm.

According to Parnell (2013), profitability which had been a dominant measure of competitive advantage at the firm level is closely associated with the industry structure. In consonance, Porter (1981) conceived that the positive structures of industries drive firms to multiply their profitability. Thus, for sustainable competitive advantage firm's industry structure play a pivotal role in addition to firms' resources, competencies and strategies. The IOT assumes that sustainable competitive advantage is derived from firms' competencies, strategies and resources which are influenced by the structure of the industry (Somiah 2018).

Hence, since no single study is holistically sufficient in containing all the drivers of sustainable competitive advantage, organizing the several drivers in a single study to empirically ascertain whether or not they are drivers of sustainable competitive advantage, as well as their relative contribution in the construction industry, will be a novel and comprehensive approach in determining the drivers of sustainable competitive advantage. To this end, this current study carried out a qualitative inquiry into the drivers of sustainable competitive advantage in the Ghanaian construction industry as well as empirically ascertaining the relative influence of the drivers of sustainable competitive advantage in the Ghanaian construction industry. Grounded in the IOT, it considered drivers relating to industry structure, firms' competencies, strategies and resources.

## 4 Methodology

This study employed a two-stage approach to research. Firstly, literature was reviewed which aided in identifying the drivers of sustainable competitive advantage in some industries and national settings as well as the operational definition of sustainable competitive advantage to place the study in context. Secondly, the Delphi method (a qualitative instrument) was used to solicit the views of experts as to the extent that the identified drivers of sustainable competitive advantage influence sustainable competitive advantage in the Ghanaian construction industry. In all, 15 experts drawn from academia and industry completed a three-round Delphi process. This sample size of 15 experts was consistent with that of similar studies in engineering and management which employed the Delphi method (see Ameyaw et al. 2016). According to McKenna (1994), the panel of experts is a panel of informed individuals.

The Delphi method operates on the assumption that a decision from a structured group is more accurate than a decision from an unstructured group of persons (Rowe and Wright 2001, Tilakasiri 2015, Ameyaw et al. 2016). Additionally, it is suitable for studies that seek to solicit views from a group of experts in an attempt to build consensus in the experts' views and to predict the likelihood of a future event (Lang 1995). It is regarded as a qualitative methodology. It establishes consensus in the views of experts through rounds of survey (Miller 1993, Hanson et al. 2005, Loo 2002). The method employs a structured questionnaire in data collection (Ameyaw et al. 2016). Concerning this study, the common criteria for selecting the experts was that an expert should have had both theoretical and practical knowledge about sustainable competitive advantage. The experts were selected to embody a broad range of opinions on the issue under investigation (see Aigbavboa 2014, Somiah 2018). Subsequently, after each round of the Delphi survey, a statistical estimate of the experts' views was computed and analysed using the interquartile deviation, median, standard deviation, and mean. In measuring consensus in the views of the Delphi panellists:

1. A strong consensus - mean 8–10, median 9–10, interquartile deviation (IQD)  $\leq 1$  and  $\geq 80\%$  (8–10);
2. A good consensus - mean 6–7.99, median 7–8.99,  $1.1 \leq \text{IQD} \leq 2$  and  $\geq 60\% \leq 79\%$  (6–7.99); and
3. A weak consensus - mean  $\leq 5.99$ , median  $\leq 6.99$ , and  $2.1 \leq \text{IQD} \leq 3$  and  $\leq 59\%$  (5.99).

The scale was based on a 10-point influence scale where 1 and 2 represent no influence; 3 and 4 represent low influence; 5 and 6 represent medium influence; 7 and 8 represent high influence; 9 and 10 represent very high influence (see Somiah 2018). Ethically, the identity of the experts was kept confidential in this study.

## 5 Findings and Discussion

### 5.1 Respondents' Demographics

To situate the findings of the study, the demographics characteristics of the panel of experts were solicited (Table 1).



**Table 1.** Respondents' demographic characteristics

Respondents' demographics characteristics	Frequency (n = 15)	Percentage (%)
<i>Gender</i>		
Male	13	86.7
Female	2	13.3
<i>Level of Education</i>		
Bachelor's Degree	2	13.3
Master's Degree	10	66.7
Ph.D.	3	20
<i>Profession</i>		
Lecturer	3	20
Research institute	2	13.3
Chief Executive Officer of Construction firm	2	13.3
Quantity surveyor	2	13.3
Contract Manager	1	6.7
Civil Engineer	1	6.7
Construction Engineer	1	6.7
Procurement manager	1	6.7
Non-governmental organization	2	13.3
<i>Work experience</i>		
5 years or less	2	13.3
6–10 years	3	20
11–15 years	5	33.4
16–20 years	3	20
Over 21 years	2	13.3

In this study, male respondents dominated with an 86.7% score whereas female respondents accounted for 13.3%. The gender distribution affirms the fact that the construction industry across the globe has been a male-dominated sector. More so, the rich academic qualification of the respondents evidenced the education level of the respondents. 66.7% of the respondents had a master's degree, 13.3% had a bachelor's degree, while the 20% had a doctorate (Ph.D.). In addition, the respondents of the study were carefully selected to represent a broad spectrum of opinions on the issue being investigated. The demographics also revealed that 20% of respondents were lecturers, whereas 13.3% were chief executive officers with construction firms. All the demographic characteristics of the respondents suggest that the respondents have knowledge and experience about the subject under investigation.

**Table 2.** Drivers of sustainable competitive advantage in the Ghanaian construction industry

SN.	Drivers	Median (M)	Mean ( $\bar{x}$ )	Standard deviation ( $\sigma_x$ )	Interquartile deviation (IQD)	Mean scores ranking (R)
1	Knowledge management culture	8	8.20	0.41	0.00	1 <sup>st</sup>
2	Continual staff development	8	8.20	0.41	0.00	1 <sup>st</sup>
3	Sustaining cost leadership in the industry	8	8.20	0.41	0.00	1 <sup>st</sup>
4	Consistency in quality performance	8	8.13	0.35	0.00	4 <sup>th</sup>
5	Having economies of scale	8	8.13	0.35	0.00	4 <sup>th</sup>
6	Political stability	8	8.00	0.00	0.00	5 <sup>th</sup>
7	The use of efficient technology	8	8.00	0.38	0.00	6 <sup>th</sup>
8	Economic stability	8	8.00	0.38	0.00	6 <sup>th</sup>
9	Trusted legal systems	8	8.00	0.38	0.00	6 <sup>th</sup>
10	Well-functioning competition law	8	8.00	0.38	0.00	6 <sup>th</sup>
11	Continual shareholders' satisfaction	8	8.00	0.38	0.00	6 <sup>th</sup>
12	Brand loyalty	8	8.00	0.65	0.00	7 <sup>th</sup>
13	Consistency in time performance	8	8.00	0.65	0.00	7 <sup>th</sup>

**Objective One:** To identify the drivers of sustainable competitive advantage in the Ghanaian construction industry;

Concerning objective one, literature was reviewed and some drivers likely to sustain firms' competitive advantage were identified. Subsequently, experts' views were sought on whether or not the identified drivers influence the sustainability of a firm's competitive advantage in the Ghanaian construction industry and the analysis was presented in a form of a table (Table 2).

A strong consensus was reached by the experts on (13) drivers of sustainable competitive advantage to have had a high influence. Each of the 13 drivers of sustainable

competitive advantage attained a group median of eight (8). Moreover, the values of IQD showed a strong consensus in the views of the expert panellists as all the IQD values were less than one (1). The values of standard deviation affirmed a high degree of consistency and non-variability in the views of the experts. Respectively, all the values of standard deviation were less than one (1). Thus, based on the strong consensus in the views expressed by the experts in the Delphi study, this study advances that 13 drivers influence sustainable competitive advantage in the Ghanaian construction industry. The 13 drivers are brand loyalty, political stability, economic stability, trusted legal systems, well-functioning competition law, continual shareholders' satisfaction, consistency in quality performance, having economies of scale, consistency in time performance, knowledge management culture, continual staff development, sustaining cost leadership in the industry, and the use of efficient technology.

**Objective Two:** To determine the relative influence of each of the drivers of sustainable competitive advantage in the Ghanaian construction industry.

In achieving objective two, the mean scores of the 13 drivers of sustainable competitive advantage were ranked. Relatively, knowledge management culture, continual staff development, and sustaining cost leadership in the industry recorded a mean score of 8.20 each and jointly emerged first. According to Krishnaswamy (2017), knowledge management and sustaining cost leadership are drivers of sustainable competitive advantage whereas Kaming et al. (1994) and Rao (2013) found continuous development of human resources of a firm to be an essential driver of sustainable competitive advantage. Also, the drivers consistency in quality performance and having economies of scale both recorded a mean score of 8.13 and ranked 4<sup>th</sup> among the drivers that influence sustainable competitive advantage in the Ghanaian construction industry. Subsequently, brand loyalty, political stability, trusted legal systems, well-functioning competition law, continual shareholders' satisfaction, consistency in time performance, and the use of efficient technology recorded a mean score of (8.0) each and jointly emerged the 6<sup>th</sup> among the influential drivers of sustainable competitive advantage. According to Nigam (2011), brand loyalty ought to be sought by firms that are desirous of sustaining competitive advantage. In addition, the political stability driver affirms the study by Deng et al. (2013) that sustainable competitive advantage could be achieved where there is political stability. More so, well-functioning competition law affirms the findings of the studies by Wenger (1998) and Njuko (2012). The authors opined that sustainable competitive advantage takes place in an environment where well-functioning competition law exists. Similarly, continual shareholders' satisfaction supports the study by Flanagan et al. (2005). According to Flanagan et al. (2005), shareholders' satisfaction is an essential driver of sustainable competitive advantage. In support of the study by Rao (2013), the use of efficient technology was found to be an essential driver of sustainable competitive advantage.

## 6 Conclusion

This study aims at identifying the drivers of sustainable competitive advantage and determine the relative influence of each of the drivers by providing an example from

the construction industry in Ghana. The study employed the Delphi Method and concluded that thirteen drivers are influential in sustaining the competitive advantage of a construction firm in Ghana. The thirteen drivers were brand loyalty, political stability, economic stability, trusted legal systems, well-functioning competition law, continual shareholders' satisfaction, consistency in quality performance, having economies of scale, consistency in time performance, knowledge management culture, continual staff development, sustaining cost leadership in the industry, and the use of efficient technology. Ranking the drivers by their respective mean score, three drivers jointly emerged first with an individual mean score of 8.20. These drivers were knowledge management culture, continual staff development, and sustaining cost leadership in the industry. Whereas the least ranked drivers of sustainable competitive advantage included brand loyalty, political stability, economic stability, trusted legal systems, well-functioning competition law, and continual shareholders' satisfaction.

The practical value of this study is that it identifies the set of abilities, assets and/or conditions that will aid construction firms to sustain competitive advantage in the Ghanaian construction industry. In addition, the study applies the Delphi method in identifying the drivers of sustainable competitive advantage, a methodology no existing study had applied in identifying the drivers of sustainable competitive advantage in the Ghanaian construction industry. Theoretically, it advances that sustainable competitive advantage drivers in the Ghanaian construction industry are embodied in thirteen elements: brand loyalty, political stability, economic stability, trusted legal systems, well-functioning competition law, continual shareholders' satisfaction, consistency in quality performance, consistency in health and safety performance, consistency in time performance, knowledge management culture, continual staff development, continual staff retraining, the use of efficient technology and regarding mean scores ranking priority should be given to knowledge management culture, continual staff development, and sustaining cost leadership in the industry. Among others, the study addresses the lack of literature that determines the drivers of sustainable competitive advantage in the Ghanaian construction industry. Whiles also serving as the reference literature for future studies. It also informs stakeholders and policymakers in policy formulation geared towards the sustainability of competitiveness of construction firms, especially indigenous construction firms. When indigenous firms sustain their competitiveness in the delivery of infrastructure, it tends to reduce the overreliance on foreign firms in infrastructure delivery and its associated economic losses relative to global gross domestic product. It is recommended that for a firm to sustain competitive advantage attention should be paid to the thirteen drivers especially knowledge management culture, continual staff development, and sustaining cost leadership. The findings of the study will inform governments and industry stakeholders in developing policies aim at sustaining the competitiveness of indigenous construction firms. This tends to reduce overreliance on foreign firms in infrastructure delivery and its associated economic losses.

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# Towards Accessing Safe Affordable Housing for Artisans in Osogbo, Nigeria

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**Abstract. Purpose:** Housing is living spaces to shelter people. Housing is a necessity for human beings like food and clothing. Having a place to live boost the economy of a country. Hence, this study examines the factors limiting artisans from affording to build a safe house; what the social welfare agencies can do to alleviate the sufferings of artisans from building a house and investigate if there is any significant relationship between factors limiting artisans from accessing safe affordable housing and their living in Osogbo.

**Methodology:** The study adopted a survey approach with a questionnaire as the major instrument of data collection. Artisans numbering 150 were randomly selected to administer the questionnaire. In analysing the data, the study employed research questions using frequency counts and percentages, while the statistic was tested using chi-square.

**Findings:** Findings revealed that fear of falling into the hands of dubious land sellers and the high cost of land limit artisans from having personal buildings; also, social welfare agencies could assist by counselling, and helping artisans to get housing loans and cheap building materials. Findings also revealed there is a significant relationship between factors limiting artisans from accessing safe affordable housing and their living in Osogbo.

**Research Limitation:** The research centered on artisans' affordability of housing in Osogbo, thus the research work focused on one city out of ten cities where artisans could be found in large numbers in the state.

**Practical Implication:** Through this study, members of the society will be able to understand the reasons many artisans are finding it difficult to access good housing to live in or acquire personal ones.

**Social Implications:** Through this study, Non-governmental organisations will find means of assisting artisans in getting loans, and policy on housing loans by the federal government should be reviewed to be enjoyed by every member of the society to afford to house.

**Originality:** The main focus of this research was on factors limiting artisans, and efforts of social welfare agencies at alleviating the sufferings of artisans from accessing and building a personal house.

**Keyword:** Accessing · Affordable · Artisans · Housing scheme · Sustainability

## 1 Introduction

As the population of Nigeria is increasing every day so also the inflow to towns by dwellers from remote areas, with the belief that jobs are available in cities especially the

state capital. This contributed to the increasing demand for housing in our cities. Many of the houses could not be termed houses because many are lacking all the necessary amenities like water, toiletries and electricity.

Many of the houses in Nigerian cities experience overcrowding with additional challenges of being in slums and even expensive to bear for a low-income earner. Some buildings are old and some are poorly built without complying with the laid down quality standard and building regulations (Adenuga 2013), and that is why we are having cases of houses collapsing and killing many occupants. If a middle or low-income earner finds it difficult to rent a small apartment to accommodate him/her and family members, how will the person find it convenient to access building a safe and comfortable house? This is why it is difficult for an average income earner today in Nigeria to afford accommodation or buy land and own a building.

According to the report of Saturday 11<sup>th</sup> September 2021, Nigeria population was estimated to be 212,206,996 taking 7<sup>th</sup> position on population all over the world (United Nations Data Worldometer 2021). Osogbo City, being the capital of Osun State in Nigeria is populated with 731,000 citizens (macrotrends net). There is a daily increase in population in cities. Thus getting good accommodation accompanied with finding it unpleasant to enjoy infrastructure like electricity, water supply, transportation, health services, security and many others are common problems in many towns, and mostly in cities (Enisan 2017).

In Nigeria, the major state capitals and cities are overcrowded. Many houses are surrounded by bad drainages, slum housing and are still expensive to afford (Akinyode 2017). Many houses are lent out by expecting tenants to pay yearly. On many occasions, tenants pack in before realising housing problems like roof leakage, bad toilet facilities and erosion disturbing in times of rain. Artisans residing in Osogbo are the major focus of this research because they are skilled workers who contribute in different ways to the development of Nigeria. Their areas of specialisation have been of great importance to the extent that the Nigerian government is making sure the learning of different skills is being introduced to the Secondary School system in the country. These artisans are self-employed, they are daily earners and always find it difficult to save or access money easily compared with government workers who can have the opportunity of getting a loan in their places of work.

Some artisans to save money and discharge their responsibilities within their family and the society at large, forced themselves to do daily, weekly or monthly contributions. These contributions could be with micro-finance banks, some do their savings with individuals going round to collect money and keep till the end of the month. Some artisans may be fortunate to get their share at the end of the month after the collector might have deducted his/her percentage for the services rendered, or the person runs away with the artisans' contributions. In some cases, some artisans associate themselves with cooperative societies to afford to build a house. As a member, some associations give out loans but not in cash. They operate by granting a member loan, he/she will tell the committee what he intends to buy for the building, whether he wants to use the loan to buy cement, wood, iron sheets or any building materials. This will be bought by members of the committee and deliver the goods at the site where he/she wants to use it. They are doing this to guide the borrower from diverting the loan to something else, instead of spending it in starting or progressing on building a house. Gradually, each member will become a landlord with the help of the cooperative society.



Today, the cost of housing is beyond the reach of many people to the extent that many artisan tenants are being ejected after finding it difficult to pay their rent age for years, and affording packing to the new apartment also become a big problem in cities, especially Osogbo City. More-also, affording a house or accessing a personal building is becoming more complicated with the outbreak of the Covid-19 Pandemic.

Therefore, it is necessary to develop means by which affording safe housing and being able to build personal ones to improve the standard of living of artisans in the society. It would be of great benefit if the provision of the housing unit is facilitated at a reasonable cost, and this could be achieved by understanding the factors that are not making accessing affordable housing to be possible (Akinyode 2017).

## 2 Theories Underpinning the Study

Acquiring a house is an expensive investment for social-economic development in society (Makinde 2014). Different reform programmes have been formulated by the Nigerian government to overcome the problem of housing, an example of this is the Central Bank. It could be asked, to what extent are these organisations been able to meet the needs of the targeted clients? are they given free hands to operate? Or are they transparent enough to alleviate the sufferings of Nigerians? Some non-governmental organisations like Shelter for Comfort embarked on the supply of housing for Nigerians (Makinde 2014).

### 2.1 Current Housing Problem in Osogbo City Osun State, Nigeria

There are two local government areas within Osogbo City. Before 1991, Osun State was part of the old Oyo State. A city accommodating railway lines linking the Southwest to the Northern part of Nigeria, thus making it a commercial City. Osogbo City being a state capital is surrounded by many towns without a glaring demarcation. Accompanied with the problem of unemployment, many people resulted in learning different skills by preferring settling in Osogbo City, eventually in need of affordable houses. Accessing affordable houses will depend on their level of income, prices, standard of houses and where the houses are located (Forsyth 2003).

### 2.2 Artisans Accessing Safe Affordable Housing in Osogbo City, Osun State

Artisans could be found in cities and towns to work and make their living. An artisan could be seen as people working with their hands, requiring manual skills and decorate items using traditional techniques.

They work by depending on the resources in their surroundings to create different items like clothes, tools, ceramics and pottery; textiles, wood, metalwork, goldsmith, natural fibres, furniture and sculpture (Libi 2020). Artisans could pass their knowledge to families, but today, Nigerians learn the skill not basing it on family traits. Someone somewhere (2020) opined an artisan could learn from their community or family, thus making an artisan having many apprenticeships who will also need accommodation.

Artisans at times depend on local and foreign raw materials to produce their goods. It might be difficult for them to have money if they could not get adequate and regular

raw materials for their productions, or when members of the society do not require their services. This is in agreement with National Herald (2020) that during the COVID-19 lockdown, artisans could not get raw materials to work which prevented money from coming in for them. Artisans found it difficult to get money for two meals a day and feed their families. Olatubara (2007) opined being able to afford a house and meeting other responsibilities in the family will be determined by the income of the household and the price of the houses. The price of a house and the income of the household will determine how an individual will be able to afford to rent a house and meeting other responsibilities in the family. Makinde (2017) also reiterated prices of renting a house are higher in urban areas, like Osogbo than the rural settlement.

According to Onu and Onu (2012) being able to rent a house will be determined by the level of rent, eligibility for housing benefits and the income of the household, as renting a house depends on the payment one has to make to be given the apartment for rent age (Bramley 2011). The price of any house being given out will be determined by the rate of increasing demands for it (Lee and Ong 2005). It means any artisan with low income from his products will not be able to access and afford a house, as people's income is low to acquire land in areas of their choice. It could be observed almost half of the people in Nigeria settle in towns, but a large number of them are in overcrowding places without adequate social amenities (Ogunwale 2016) (Fig. 1).



**Fig. 1.** An example of a building in Nigeria where some people are living. Source: The researcher, March 26, 2021

### 2.3 Effects of Nigerian Economic Situations on Building a House

Ogunwale (2016) referring to the writings of Nelson Mandela (Quotes by Nelson Mandela) that acquisition of a house is necessary before someone could be referred to as a man. This view is always in the head of every Nigerian as individuals struggle to have affordable buildings. Among the revised housing policy objectives is that the Nigerian government sees the delivery of housing opportunity is rendered by their three tiers of government (Emedate 2019). Mortgage lending has been difficult indicating a decrease in the activities to accessing housing (Igbinoba 2009). He further reiterated cost attached to a plot of land in cities is always making it difficult for artisans to acquire. According to Oluwatayo et al. (2019) apart from delays in administrative work, there has been uneasy land registration and inadequate availability of funds.

Despite the recognition of the problems of qualitative housing which has been the major concern of government and individuals in Nigeria, there have been efforts to see that people get houses when there is a need for it. Following problems have been affecting housing delivery, some are the expensive building materials, financial arrangement which is deficient, arrangement in finance, high cost of building materials; deficiency of house finance arrangement, and stringent attitude when issuing loans (Raji 2008). Provision of housing in Nigeria is being faced with lots of problems Adenuga (2013), as inadequacy of housing units distribution, inappropriate technology; rural to urban migration; high cost of building materials; infrastructure development; mortgage funds and housing loans that are not available; also, the land use system affects people. Ometon (2002) in Adenuga (2013) also claimed that the high cost of building materials has been preventing people from affording building houses.

### 2.4 Impact of Social Welfare Agencies on Artisans Building Personal Houses in Osogbo City

Social welfare in Nigeria was being practised by our forefathers among themselves as traditional social work practice. It later became an official work being practised during the time of missionaries, and this continued after World War II (1939–1945) till today. Among their activities are organising, coordinating and training social welfare agencies. Social welfare is being practised by Government, Non-governmental and Philanthropic organisations. Among their activities are supporting and caring for people that are vulnerable in society, like elderly people, indigent children, impaired persons, mentally ill persons, the poor, prisoners and ex-convicts, (Oriji 2018). Krcatovich (2017) in Oriji (2018) also opines social welfare services could come in form of cash assistance for the disabled and elderly, school lunches being free or at a reduced cost, assistance on housing loans, health insurance providers and medical devices.

Walden University (2021) asserted social workers help people in overcoming difficult life's situations. They help people to strengthen themselves by making use of opportunities from non-profits and government entities as efforts rendered by social welfare. On different occasions, workers of social welfare support their members by counselling, facilitating, advocates making sure governments change harmful laws, support government's assistance programmes, start new nonprofits initiatives aimed at helping people through difficult times and also focus on housing assistance. Upon all, the activities

of social welfare in Nigeria are not well developed, while they are poorly funded. This paper, therefore, examined accessing safe affordable housing for artisans in Osogbo City of Osun State, Nigeria with the following research questions.

### 3 Methodology

The design for this study is a cross-sectional technique. Response to questions formulated from the objectives was collected using statistical data. The questionnaire was the major instrument employed. Artisans from various fields in Osogbo City formed the population of research work, comprising mechanics, plumbers, rewire, panel beaters, dealers in woodworks, tailors, bricklayers, leather workers, tillers, painters, tie and dye who were selected randomly from the two local government areas of Osogbo City. These are Osogbo Central and Olorunda Local government areas.

Out of 160 questionnaires distributed, 150 were completed, returned and considered being useful for the study. The questionnaire was involved in the collection of primary data, while journals, textbooks, occasional publications, and seminar papers were used as secondary data. Data collected from the variables of the study were analysed using descriptive statistics such as simple percentages while chi-square was also involved in the study. These helped in clarifying results.

## 4 Results and Discussion

### 4.1 Research Question 1: What Are the Factors Limiting Artisans from Affording to Build a Safe House in Osogbo City, Osun State, Nigeria?

**Table 1.** Factors limiting artisans from affording to build a safe house in Osogbo City.

No	Factors	Yes	%	No	%
1	High cost of land	142	94.7	8	5.3
2	Fear of falling into the hands of dubious/fake land sellers	150	100	0	0
3	Expensive building materials	142	94.7	8	5.3
4	Uneasy registration of land	52	34.7	98	65.3
5	Inexperienced/unskilled labour	80	53.3	70	46.7
6	High charges of labour/workers	90	60	60	40
7	Lack of funds	127	84.7	23	15.3
8	Lack of housing loan	105	70	45	30
9	Land crisis	120	80	30	20

From Table 1, the major factor limiting artisans from affording to build a safe house in Osogbo city is the fear of falling into the hands of dubious/fake land sellers, all the

respondents 150 (100%) attested to this. This was closely followed by expensive land and building materials with 142 (94.7%) respondents respectively. Others are lack of funds 127 (84.7%), land crisis 120 (80%), lack of housing loan 105 (70%), high charges of labour/workers 90 (60%) and inexperienced/unskilled labour 80 (53.3%). Only a factor, high cost of registering land, 52 (34.7%) was not a potent factor limiting artisans from affording to build a safe house in Osogbo City.

#### 4.2 Research Question 2: What Can the Social Welfare Agencies Do to Alleviate the Sufferings of Artisans from Affording Building Safe Houses in Osogbo City, Osun State, Nigeria?

**Table 2.** Social Welfare method that could be used to alleviate the sufferings of artisans from accessing affordable housing in Osogbo City.

No	Activities	Yes	%	No	%
1	Counselling	142	94.7	8	5.3
2	Source for fund	113	75.3	37	24.7
3	Organising meetings	113	75.3	37	24.7
4	Introducing them to where to get cheap building materials	128	85.3	22	14.7
5	Assistance through housing loans	135	90	15	10
6	Support Government Assistance Programme	113	75.3	37	24.7

From Table 2, the major method that Social welfare agencies could use to alleviate the sufferings of artisans from accessing affordable housing in Osogbo City is through Counselling, 142 (94.7%). Other respondents are in form of assistance through a housing loan, 135 (90%); introducing them to where they could get cheap building materials, 128 (85.3%); others are sourcing for the fund, organising meetings, and supporting government assistance programme with 113 (75.3%) of the respondents asserting to this.

**Research Hypothesis:** Factors limiting artisans from assessing safe affordable housing has no significant relationship with their living in Osogbo.

From Table 3: All the values of chi-square calculated are greater than the chi-square table. The hypothesis earlier stated that there is no significant relationship between factors limiting artisans from accessing safe affordable housing and their living in Osogbo is hereby rejected. It shows that there is a significant relationship between factors limiting artisans from accessing safe affordable housing and their living in Osogbo.

Research question 1 shows that factors limiting artisans from affording building a safe house in Osogbo are fear of falling into the hands of dubious/fake land sellers, 150 (100%); high cost of land and building materials, 142 (94.7%). These findings are in corroboration with the view of Igbinoba (2009) that the cost attached to a plot of land in cities is always beyond the reach of the urban poor; Adenuga (2013), also reiterated high cost of building materials has been preventing people from affording to build a house.

**Table 3.** Chi-square table showing the relationship between factors limiting artisans from accessing safe affordable housing and their living in Osogbo.

O	E	o-e	(o-e) <sup>2</sup>	chi = cal	Df	chi-tab	Remark
150	75	75	5625	75.0	3	7.8	Sig
142	75	67	4489	59.9	3	7.8	Sig
150	75	75	5625	75.0	3	7.8	Sig
150	75	75	5625	75.0	3	7.8	Sig
142	75	67	4489	59.9	3	7.8	Sig
150	75	75	5625	75.0	3	7.8	Sig
142	75	67	4489	59.9	3	7.8	Sig
0	75	-75	5625	75.0	3	7.8	Sig
8	75	-67	4489	59.9	3	7.8	Sig
0	75	-75	5625	75.0	3	7.8	Sig
0	75	-75	5625	75.0	3	7.8	Sig
8	75	-67	4489	59.9	3	7.8	Sig
0	75	-75	5625	75.0	3	7.8	Sig
8	75	-67	4489	59.9	3	7.8	Sig

Findings from research question 2 show that Social welfare agencies could alleviate the sufferings of artisans to afford safe housing through counselling, 142 (94.7%) and assistance through housing loans, 135 (90%). The findings are in agreement with the views of Walden University (2021), Krcatovich (2017); that Social Welfare services could come in form of cash assistance through housing loans.

The research hypothesis stated there would be no significant relationship between factors limiting artisans from accessing safe affordable housing and their living in Osogbo. Findings revealed the hypothesis was rejected, showing there is a significant relationship between factors limiting artisans from accessing affordable housing and their living in Osogbo. This finding is in line with Forsyth (2003), that accessing affordable houses will depend on people's level of income, prices, the standard of houses and where the houses are located.

## 5 Conclusion

Artisans should not experience difficulties in accessing safe houses due to the fear of fake land sellers, and the high cost of land and building materials. For artisans to afford to rent or building safe houses there should be involvement of non-governmental organizations, loan schemes and funds through social welfare agencies. There is a dire need to access adequate, safe, secured, healthy, available and not expensive housing for artisans in Osogbo City, Osun state, to make their living in the city affordable.

### *Recommendations*

Artisans are advised on associating themselves alongside social welfare agencies to afford to access and building safe housing in Osogbo City, Osun State, Nigeria.

Government housing loan scheme is advised to be extended to artisans as this was their major complaint, and one observes that it will be of immense assistance to both the respondents and researcher to interact with the people in the city to know what exactly they are facing in terms of the affordable housing scheme.

Severe punishment is advised to be meted by the government on dubious/fake landowners and sellers in Nigeria who sells a piece of land to many people or ask a person to buy the same piece of land several times, especially in the cities.

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# Adoption of Indoor Environmental Quality Assessment Framework for Naturally Ventilated Classrooms in Basic Schools in Ghana

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**Abstract. Purpose:** In Ghana, the assessment that is normally conducted on buildings is that which is done during the defect liability period to find out if the building elements and installations are working well. The aspect that affects the health and wellbeing of the occupants-indoor environmental quality, is however hardly considered in the assessment. The paper aims at investigating the processes and components involved in developing a framework for the assessment of IEQ of indoor spaces especially naturally ventilated classrooms of basic schools.

**Design/Methodology/Approach:** Articles from journals and conferences were reviewed to examine the trends that research on IEQ assessment frameworks for classrooms of basic schools have taken over the years. Areas reviewed include types of IEQ assessments, processes involved in the development of IEQ assessment framework, and the components of IEQ assessment frameworks.

**Findings:** Gaps identified in this review are as follows: Most of the IEQ Frameworks reviewed so far do not emphasize design and building characteristics and their roles played in the provision of adequate IEQ in classrooms. There is no framework for assessing the indoor environmental quality of classrooms of basic schools in Ghana.

**Research Limitation/Implications:** This research focused on the development of a framework for assessing the indoor environmental quality of classrooms of basic schools in Ghana.

**Practical Implication:** This study gives an insight into An IEQ assessment framework for classrooms in basic schools that will create awareness of the components of IEQ and factors that contribute to healthy IEQ by providing a uniform mode of assessment that will allow for specific results and follow up actions where problems are identified.

**Social Implication:** Results from IEQ Assessment of classrooms in basic schools in Ghana will also help improve the design and construction of classrooms by eliminating building elements that compromise IEQ and replace them with elements that promote better IEQ conditions.

**Originality/Value:** A framework for assessing the indoor environmental quality of classrooms of basic schools in Ghana was established.

**Keyword:** Acoustic comfort · Assessment framework · Indoor environmental quality · Thermal comfort · Visual comfort

# 1 Introduction

The built environment protects the external environment and comfortable conditions for humans to live in and thus influences the life of every person on earth (Kaklauskas and Gudauskas 2016, Djovack and Kukek 2019). Buildings, enclose spaces to provide shelter, modify climate by being a barrier against inclement weather and providing privacy (Douglas 1996, Amasuomo et al. 2017). Buildings are, however, major contributors to the negative effects experienced in the environment through energy and resource consumption, pollution and global warming (Veys et al. 2019, Sharpe 2019).

School facilities provide the physical and social environments to promote effective daily interaction between students and teachers, for learning and academic development. The most important function of school facilities is to provide safe and healthy learning spaces for students (Hassanain and Iftikhar 2015). One indoor space in which children spend most of their time apart from the home is the classroom in schools. However, in comparison to other buildings, indoor environmental quality (IEQ) in classrooms in basic schools has seen limited studies, and consequently, the attention given to the adverse effect on the children's health in these environments is limited (Sá et al. 2017).

Indoor Environmental Quality (IEQ) refers to diverse sub-domains or conditions inside a building that affect its occupants or users (USGBC 2019). These include indoor air quality (IAQ), visual comfort, thermal comfort, acoustics comfort, drinking water, ergonomics, electromagnetic radiation, and many related factors (USGBC 2019, Mujeeb 2019, Fadeyi et al. 2014) It is a very important scientific domain that deals with various aspects that govern the health, comfort, and productivity of the occupants and determine the value of a building (Mujeeb 2019). Improved indoor environmental quality of buildings can enhance the quality of life of occupants (USGBC 2019). Studies have been conducted in past years to analyze how different indoor environmental conditions affect occupants' comfort (Choi et al. 2013, Barrett et al. 2015, Wargocki et al. 2012, Wang et al. 2021). Research conducted on the effect of the environment on the health of children concludes that environmental hazards have an impact on the health and development of children (WHO 2020).

Building Performance Evaluation (BPE) is the main method used to track and maintain quality indoor environments. Post-occupancy evaluation (POE), an aspect of BPE, has been used to assess the performance of buildings in terms of the indoor environment during occupancy, and the effects it has on occupants (Andargie and Azar 2019).

The aim of this paper is to reviews from literature, available IEQ assessment frameworks developed for classrooms in basic schools. A framework for the assessment of IEQ of basic school classrooms enables stakeholders in the building industry to be mindful of the provision of ideal indoor environments of classroom buildings (Soccio 2016).

The relevance of this study is that findings will facilitate the development of an assessment framework for classrooms in basic schools in Ghana, (which can be incorporated into the development of an infrastructural policy for basic schools in Ghana). Moreover, the development of frameworks or guidelines will help to regulate the provision of ideal indoor conditions for classrooms.

## 2 Methodology

A desktop review of the literature was conducted to determine existing knowledge with regards to existing frameworks for the assessment of IEQ in classrooms of basic schools.

A search was conducted through search engines like Science Direct, Google Scholar, SCOPUS and Research Gate for articles with the keywords: Indoor Environmental Quality, IEQ, assessment framework, classrooms, basic schools, primary schools, elementary schools. A perusal of abstracts of articles resulting from the search determined the least relevance of the articles to the focus of the study, especially for ‘the basic schools’. A search with ‘post-occupancy evaluation of classrooms’ however yielded more results most of which were related to classrooms of institutions of higher learning with a limited number focusing on IEQ. However, there were a few more studies on IEQ assessment frameworks on different themes and in different locations. Studies on guidelines and tools for post-occupancy evaluation of schools were reviewed to augment knowledge on assessment framework development. Articles reviewed were those published between 2015 to 2021.

## 3 Theories Underpinning the Study

An assessment framework contains details on how an assessment is to be operationalized. It is a combination of theory and practice. Frameworks help to improve both validity and reliability in assessment, and allow developers to create vigorous assessment instruments more expediently (Pearce et al. 2015; Table 1).

**Table 1.** List of some assessment frameworks reviewed

Authors	Topic	Objective	Target	Location /Facility	Keywords	Variables
Amasuomo et al. (2016)	Development of a Building Performance Assessment and Design Tool for Residential Buildings in Nigeria. ( name of framework: <b>Comprehensive Performance Assessment System for Nigeria (CPASN)</b> )	To assist the Nigerian government with its building codes and policies and building practitioners with the design process	Nigerian Government	Nigeria/Residential Facilities	Performance Assessment; Nigeria; Design Tool; LEED; BREEAM; Residential Building	i) Review of existing building rating systems such as LEED and BREEAM, ii) development of a system from the review iii) proposal for the adaptation of the system to the requirements of the Nigerian National Building Code for residential buildings

(continued)

**Table 1.** (continued)

Authors	Topic	Objective	Target	Location /Facility	Keywords	Variables
Rickenbacker et al. (2019)	Development of a Framework for Indoor Air Quality Assessments in Energy Conservation Districts	To monitor and address indoor air pollution in the context of an energy conservation district in Pittsburgh, Pennsylvania,	Energy conservation district, Pennsylvania	United States of America/Different Buildings	Indoor Air Quality; Energy Conservation; Survey; Particulate Matter; Commercial Buildings; Green Buildings; Communities	i) Preparation for data collection, ii) Data collection -field monitoring, iii) data synthesis, iv) feedback to facilities managers of chosen buildings based on the raw data summaries, v) conduct an engineering intervention within one of the buildings that 'underperformed', vi) recommendations made vii) creation of IAQ checklist based on recommendations, viii) creation of an IAQ survey instrument and aggregate baseline to address indoor air pollution for over 500 participating buildings
Ibrahim et al. (2021)	A holistic framework for an information system for the management of indoor environmental qualities (IEQ) inbuilt facilities	To enable the architects and the facility managers to sustainably manage and monitor IEQs inbuilt facilities	Architects and facility managers	Universal/Different Facilities	"Framework; IEQ; Information System; Open Database; Big Data Analytics; Universal; Facilities Management; Life Cycle	i) Measurement of IEQ indicators, ii) storing of data for IEQ indicators, iii) Evaluation of IEQ indicators, iv) Updating of IEQ indicators, v) implementation of corrective measures
Andargie and Azar (2019)	An applied framework to evaluate the impact of indoor office environmental factors on occupants' comfort and working conditions	To develop a comprehensive data collection and analysis framework for evaluating the impact of office indoor building environment on occupants' comfort, happiness, and performance	Occupants	United Arab Emirates/ Offices	Indoor Environmental Conditions Comfort, Productivity, Happiness Demographics; United Arab Emirates (UAE)	i) Survey development and testing, ii) Performance test development and testing, iii) Indoor environmental monitoring station development and calibration, iv) Data collection, v) Data analysis

(continued)

**Table 1.** (continued)

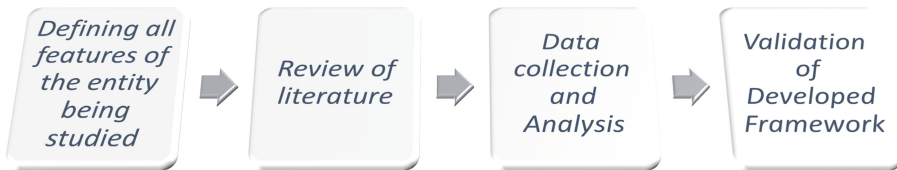
Authors	Topic	Objective	Target	Location /Facility	Keywords	Variables
Hassanain and Iftikhar (2015)	Framework model for post-occupancy evaluation of school facilities	To present an IDEFO framework model for the post-occupancy valuation of school facilities	Design professionals, school administrators and facilities managers	Saudi Arabia/ Schools	School; Post-Occupancy Evaluation; Functional; Performance Elements; Technical	i) Identification of the performance requirements of school facilities; ii) a walk-through evaluation and a focussed group discussion; iii) development & administration of a user satisfaction survey; iv) analysis of collected data and reporting of findings; v) development of a plan of remedial actions;
Hameen et al., (2020)	Protocol for Post Occupancy Evaluation in Schools to Improve Indoor Environmental Quality and Energy Efficiency	to develop a unified protocol for POE and measurements (+M) of critical indoor environmental quality variables in school facilities regardless of unknowns and building types	Stakeholders of schools	United States of America/ Basic Schools and Secondary Schools	Post Occupancy Evaluation; IEQ; IAQ; Energy Efficiency; Schools; Protocol	Data collection: indoor environmental quality monitoring measurements and occupancy surveys and interviews, using already established monitoring and survey methods
Soccio (2016)	A New Post Occupancy Evaluation Tool for Assessing the Indoor Environment Quality of Learning Environments	Development of A New IEQ Evaluation Tool To Support Evidence-Based Design of Schools	Design professionals	Australia/ Primary and middle schools	Indoor Environment Quality, Classroom, Design Professional, Info-graphic, Health	i) data collection, ii) processing of collected data, iii) determination of the level of performance of parameters, and iv) communication of results of the evaluation

Some developed countries have frameworks or guidelines that guide the provision of adequate indoor environmental quality in schools through design and construction. A few developing countries like Rwanda, South Africa also have guidelines for schools that address IEQ. Ghana presently does not have an infrastructural policy for education. It is important that in the development of such a document a section is provided which guides the assessment of IEQ in schools towards the provision of comfort, health and wellbeing of the occupants.

### 3.1 Processes Involved in the Development of an IEQ Assessment Framework

According to Figueirido et al. (2021) the development of frameworks involves processes that are determined by the goals or purpose for which the framework is needed. Some of the processes discovered from literature include Defining all features of the entity being studied.

Review of literature; Data Collection and Analyses and Validation of developed framework (Fig. 1).



**Fig. 1.** Processes involved in the development of an IEQ assessment framework.

#### 3.1.1 Defining All Features of the Entity Being Studied

Frameworks are developed to streamline or guide practices in a community. Since there is a no-one-size fits all framework, the features of the area of study or community for which the framework is being developed are first established (Figueirido et al. 2021). These include the goal of the framework, the target group, and the scope. The target group of policies or frameworks must be considered when the frameworks are being developed. The development of an assessment framework for IEQ in classrooms demands that the needs and views of the target group are considered, and as such, they need to define the scope and target of the framework. The next section discusses the next step which is the review of the literature.

#### 3.1.2 Review of Literature

The commencement of framework development involves reviewing the literature on the area of study. There are instances where literature review has been used as the sole method (Ibrahim et al. 2021, Olawumi et al. 2020) or in addition to other methods in the development of a framework (Andargie and Azar 2019). For example, Ibrahim et al. (2021) conducted a literature review of selected recent journal publications, within the

domain of facilities management and IEQ research, for the development of a holistic framework for an information system for the management of indoor environmental quality (IEQ) inbuilt facilities in the United Arab Emirates (UAE). Andargie and Azar, (2019) conducted a review of data collection techniques and studies from literature as a stage in the development of an integrated data collection and analysis framework for indoor evaluation of occupants in offices. Soccio (2016) carried out a literature review to identify the IEQ parameters needed to develop an evaluation tool that provides information about the indoor environmental quality (IEQ) of learning environments. Olawumi et al. (2020) conducted a content analysis of literature that included relevant guidelines and existing rating systems to develop a Building Sustainability Assessment Method (BSAM) for developing countries in sub-Saharan Africa. The literature conducted by these authors did not consider the influence of building characteristics on IEQ conditions.

Other frameworks, guidelines or tools have been reviewed to enable the researchers to gain more information into the development of other frameworks or improving upon existing frameworks (Amasuomo et al. 2016, Ibrahim et al. 2021). Amasuomo et al. (2016) reviewed the Building Research Establishment Environmental Assessment Method (BREEAM) and Leadership in Energy and Environmental Design (LEED) assessment tools to identify key areas to be studied in the development of a performance assessment tool for Nigeria and discovered that some aspects of these tools were geared towards the urban rich and did not apply to many buildings in Nigeria because of climate and style of building. Olawumi et al. (2020) reviewed the literature on green building standards for BSAM for developing countries in sub-Saharan Africa and discovered among other issues that there are 'no related schemes suited for the local context of countries in Africa'. Ibrahim et al. (2021) also noted that there were geographical and contextual limitations in the application of online assessment tools on buildings. Omar and Noguchi (2020) reviewed literature from journals and grey literature to establish a database and point of entry to identify the contribution of typology of building materials in the realization of SDGs. This was for the development of a framework for policymakers, designers, and construction stakeholders regarding the implementation of the 2030 Agenda concerning building materials and sustainable development. One of the gains of the review conducted by Omar and Noguchi (2020) was that it enabled the realisation of the importance of defining and selecting building materials based on their surrounding environmental context. The South African School Standard, the United Kingdom Building Code and primary school design guidelines, UNICEF guidelines on child-friendly schools for Africa, Thailand and Iraq were reviewed towards the development of the Rwandan School Policy (Rwanda Ministry of Education 2009). Soccio (2016) also reviewed the Mobile Architecture and Built Environment Laboratory (MABEL) system which was originally developed to assess internal environment performance for commercial, industrial, and residential buildings and found a loophole in MABEL in terms of lack of effective presentation and analysis of the results for feedback. The EduTool: IEQ was developed to address the loopholes found.

The next section discusses the data collection and analyses process of an IEQ framework development.

### 3.1.3 Data Collection and Analyses

Another process or step used in the development of a framework is data collection.

‘The traditional approach for analysing building performance is based on physical measurements, in addition to separate studies of organisational or user behaviour’ (Støre-Valen and Lohne 2016). After gathering information from literature, data is gathered using quantitative and qualitative methods. Qualitative data include perceptions, beliefs, and attitudes and quantitative data include numerical information (WHO 2003). There are different aspects of data collection; some researchers use either only quantitative or qualitative data collection methods and some use both quantitative and qualitative methods of gathering data. Hameen et al. (2020) used both quantitative and qualitative data collection methods in the form of advanced indoor environmental quality monitoring measurements and occupancy surveys and interviews. Rickenbacker et al. (2019) embarked on field measurements of components of indoor air as part of the process of developing a framework for monitoring and addressing indoor air pollution towards energy conservation.

Andargie and Azar (2019) developed a POE survey in the form of questionnaires to assess the comfort levels of occupants in their workspace. The use of the questionnaire as against other data collection methods, such as interviews, was because questionnaires are relatively easy to distribute and can be used to collect data from a large sample in a short period (Andargie and Azar 2019). For data collection, some researchers used existing guidelines in gathering data for IEQ but tailored them to serve the purpose for which the research was being conducted. Hameen et al (2020) tailored the National Environmental Assessment Toolkit (NEAT), developed by Carnegie Mellon University’s Centre for Building Performance and Diagnostics for measuring the IEQ of office buildings, and qualitative methods to formulate protocols for the measurement of IEQ parameters in schools. Hassanain (2015) proposed a framework model for conducting POE of primary school buildings in Saudi Arabia. The framework model was not new but existed in the practice of POE; however, the framework model was presented in a new format (Integrated Definition for Function Modelling, (IDEFo model)), which according to Hassanain (2015), is more legible and descriptive. Anderson (2021) developed IEQ Compass: School, from an existing IEQ assessment tool, called IEQ Compass: Residential, for the assessment of IEQ in schools in Denmark. Data collection involved many strategies which are determined by the purpose of the framework being developed. What is noteworthy is that though physical measurements of indoor parameters provide objective data, they are not enough in portraying a holistic IEQ outlook to the existing IEQ situation. There is the need to use walkthrough or observational surveys and occupants’ surveys to provide a holistic insight into the existing situation (Hassanain 2015, Sadick 2018). Subjective data from occupant surveys complements physical measurement data to enable a detailed analysis of indoor environments (Sadick 2018).

### 3.1.4 Validation of Developed Framework

Some developers of frameworks validate the frameworks by using them on a pilot basis to determine their effectiveness and their shortcomings. Andargie and Azar’s (2019) integrated data collection and analysis framework for comprehensive evaluation of the



impact of office indoor building environment on occupants' comfort, satisfaction, and work performance was validated after development by using it to assess two educational buildings in the United Arab Emirates. Soccio (2016) validated the Edu Tool: IEQ, which is an evaluation tool that provides information about the indoor environmental quality (IEQ) of learning environments, by evaluating ten (10) schools with it. Figueirido et al.'s (2021) life cycle sustainability framework to help with decision making on building projects by stakeholders in the building industry was validated on a residential building. Amasuomo et al. (2016), validated the Building Performance Assessment and Design Tool for Residential Buildings in Nigeria through simulation of a building designed with the tool. Hameen et al. (2020) validated the Protocol for Post Occupancy Evaluation in Schools developed by using it to assess eight (8) schools made up of kindergarten, primary and secondary schools. What has been noted in the frameworks reviewed is that the assessments conducted do not cover building designs and whether the designs and components of the buildings correspond with the roles expected from these designs and components in providing good IEQ. The next section discusses what an assessment framework entails.

### 3.2 Components of an IEQ Assessment Framework

From the review of literature on IEQ assessment frameworks, it has been discovered that IEQ assessment frameworks comprise processes or stages through which the outputs are realised or gained. The processes are dependent on the aim and the expected output required from applying the framework or tool. IEQ Assessment framework processes involve steps that will enable assessors to evaluate the facility being assessed and obtain feedback from stakeholders and occupants of the facilities.

In the conceptual information system framework proposed by Ibrahim et al. (2021) to facilitate the sustainable management and monitoring of IEQ inbuilt facilities by architects and facility managers, the framework comprises 5 main processes including (i) measurement of IEQ indicators, (ii) storing of data for IEQ indicators, (iii) evaluation of IEQ indicators, (iv) updating IEQ indicators, and (v) implementation of the corrective measures. Each of the processes has multiple inputs to perform each of its underlying activities and outputs as outcomes.

There are four stages involved in using Soccio's (2016) EduTool: *IEQ*. These stages are (i) data collection, (ii) processing of collected data, (iii) determination of the level of performance of parameters, and (iv) communication of results of the evaluation.

Andargie and Azar's (2019) framework comprised of five processes: (i) Survey development and testing, (ii) Performance test development and testing, (iii) Indoor environmental monitoring station development and calibration, (iv) Data collection, (v) Data analysis (Table 2).

**Table 2.** Components of IEQ assessment framework

Component	Authors
• Identify performance indicators, create baselines and ethical issues	Hassanian (2015), WHO (2011), Hameen et al. (2020)
• Data collection	
<i>Quantitative method</i>	
• Measurement of indoor parameters	WHO (2011), Ibrahim et al. (2021), Hameen et al. (2020)
<i>Qualitative (survey)</i>	
• Observational survey/walkthrough	WHO (2011), Hameen et al. (2020), Hassanain (2015)
• Interviews with occupants and stakeholders in the built environment	WHO (2011), Hameen et al. (2020)
• Questionnaires to occupants	WHO (2011), Hassanain (2015), Hameen et al. (2020)
• Evaluating/analysis of data	WHO (2011), Ibrahim et al. (2021), Hameen et al. (2020), Hassanain (2015)
• Update database	WHO (2011), Ibrahim (2021)
• Remedial action/corrective measures	Ibrahim (2021), Hassanain (2015)
• Report writing	WHO (2011), Ibrahim (2021), Hameen et al. (2020), Hassanain (2015)

Review of articles on IEQ assessment frameworks identified six steps under which all the components can be found (Table. 2).

### 3.2.1 Identify Performance Indicators, Create Baselines and Address Ethical Issues

There is the need to identify performance indicators for the area or facility to be studied, to ensure relevance to the framework (Hassanain 2015, WHO 2011). There is also the need for the establishment of baselines against which measured parameters will be compared (WHO 2011, Rickenbacker et al. 2019). There is also the need to have a database or storage of data that can be updated after every assessment to keep track of progress (WHO 2011, Ibrahim et al. 2021). Ethical requirements with regards to the assessment like calibration, permissions, etc., must be fulfilled before the assessment takes place (Hameen et al. 2020). Hassanain 2015, divided performance requirements into two groups: technical requirements (thermal comfort, indoor air quality, acoustic comfort, visual comfort, and fire resistance requirements), and functional requirements (requirements for the design of classrooms). These were the benchmarks used for assessment.

### 3.2.2 Data Collection

Following the establishment of performance indicators, creating baselines, and addressing ethical issues, the next component found in reviewed IEQ assessment frameworks is data collection (WHO 2011, Hassanain 2015, Andargie and Azar 2019, Hameen et al. 2021, Ibrahim et al. 2021). Data collection involves both qualitative and quantitative methods. Qualitative and quantitative data are both essential for the establishment of baselines for evaluations and enables the effective planning of interventions for environmental health and wellness (WHO 2003) The quantitative method involves the measurement of IEQ parameter whilst the qualitative involve observational survey (walkthrough of the facility taking notes of their characteristics), interviews with and questionnaires to occupants and managers of facilities. Some authors employed only the quantitative method, whilst others used only qualitative to collect data with the frameworks (Ibrahim et al. 2021, Hassanain 2015). Other IEQ assessment frameworks reviewed used both quantitative and qualitative methods (Hameen et al. 2020, WHO 2020) In the Post Occupancy Evaluation Tool developed for Assessing the Indoor Environment Quality of Learning Environments by Soccio (2016), subjective data from survey was collected but was not used because objective data was regarded as more credible.

### 3.2.3 Evaluation/Analysis of Data

Raw data gathered with the assessment frameworks are analysed or evaluated to provide a picture of the existing IEQ situations and the views of the stakeholders as required (WHO 2011, Hassanain 2015, Andargie and Azar 2019, Hameen et al. 2021, Ibrahim et al. 2021). In analysing data collected with the framework developed, Andargie and Azar used ordinal logistic regression coupled with Spearman rank correlations to identify drivers of occupants' comfort, happiness and productivity. The outcomes of the assessment provide feedback about the post-occupancy conditions of the facilities that were reviewed and create a significant understanding of the indoor environmental performance (Hassanain 2015, Ibrahim et al. 2021).

### 3.2.4 Update Database

After evaluation of data, there is updating of database where a database exists. Ibrahim et al. (2021) having created a database of standardised IEQ data, updated it whenever assessment was conducted. Guidelines from WHO (2011) also include updating of the database after analysis of data collected. Not all IEQ assessment frameworks include creating a database or updating the same. Other authors like Hassanain (2015) and Andargie and Azar (2019) did not have databases or systems for updating databases. However, the creation of a database with which to compare assessment results provides historic data and helps keep track of progress in the performance of buildings.

### 3.2.5 Remedial Action

After evaluating data collected and identifying the issues that may be wrong with the facility, remedial actions are determined and executed, by personnel in charge of the facility. Ibrahim et al. (2021) and Hassanain (2015) have remedial actions or corrective

measures as a step to be taken in IEQ assessment frameworks developed. Employing remedial action does not appear in other IEQ assessment frameworks. This suggests that this action can be incorporated in a framework depending on the aim for developing the framework.

### 3.2.6 Report Writing

The final stage of the components identified through a review of literature on the development of IEQ assessment frameworks is report writing. The report is written following evaluation and, remedial action (where necessary) as done by WHO (2011), Hassanain (2015), Andargie and Azar (2019), Hameen et al. (2021), Ibrahim et al. (2021).

IEQ assessment frameworks direct or guide the assessment of IEQ parameters to provide ideal indoor environmental conditions for occupants. The next section discusses the IEQ parameters assessed in the reviewed assessment frameworks.

### 3.2.7 Parameters Assessed in Frameworks

Research on IEQ assessment frameworks involves the assessment of attributes of IEQ that is found to be relevant to the area of study. The parameters common to IEQ assessment frameworks from reviewed literature are Thermal Comfort (TC), Visual Comfort (VC), Acoustic Comfort (AC), Indoor Air Quality (IAQ) (Soccio 2016, Rickenbacker et al. 2019, Andargie et al. 2019, Hameen et al. 2020, Olawumi et al. 2020, Anderson et al. 2021, Ibrahim et al. 2021, WHO 2004, 2010, 2020). Depending on the aim of the framework or tool, other parameters like fire protection, electromagnetic pollution and ergonomics are added to the four mentioned above (Devitofrancesco et al. 2019, Hassanain 2015). Within these parameters, some numerous attributes/criteria have been assessed, depending on the identified needs for assessment.

Anderson et al. (2021) had a total of 16 attributes under the four categories assessed for the IEQ Compass: Schools developed. Hassanain's (2015) Framework Model for Post-Occupancy Evaluation of School Facilities assesses a total of eight attributes under the four parameters, two under each. Devitofrancesco et al. (2019) developed an Indoor Environmental Quality Assessment Tool for the Rating of Offices in Real Working Conditions and had a total of seventeen attributes under five parameters: IAQ, TC, VC, AC, and electromagnetic pollution. These attributes are derived from literature reviews and data collected in areas of study.

The literature reviewed on IEQ assessment frameworks places more emphasis on user perspectives and the IEQ levels in the classrooms and other indoor spaces. A look at the design and building characteristics of the classrooms and their influence on the existing IEQ conditions need to be researched since the physical, chemical and biological characteristics of buildings can affect the physiological and psychological health and well-being of their occupants (Sassi 2006). Some of the processes and components discovered in the development of reviewed IEQ assessment frameworks will be adopted in the development of an assessment framework for naturally ventilated classrooms in basic schools in Ghana. Addition variables such as design and building characteristics will be considered in the formulation of the framework.

## 4 Findings

- i. Most of the frameworks are made to suit the countries in which they are made. (Amasuomoa et al. 2016, Rickenbacker et al. 2019, Hassanain 2016, Soccio 2016, Støre-Valen and Lohne 2016, Hameen et al. 2020, Andargie and Azar 2019). There is the need for an IEQ framework to be developed for classrooms in basic schools in Ghana which will resolve design and construction issues that may be in existence.
- ii. Indoor Environmental Quality has been worked on mostly in adults' settings, i.e., offices, residences, universities, hospitals and the results and feedback from which standards are set are regarding adults. There is the need for more studies in basic schools where children spend about a third of their time to ascertain existing conditions and determine the ideal conditions for them in terms of IEQ.
- iii. Few IEQ frameworks emphasize design and building characteristics and their roles played in the provision of adequate IEQ in classrooms.
- iv. There is no set agreement among researchers on how to conduct IEQ assessment to obtain data on all the important variables.
- v. The IEQ assessment processes have not been streamlined for easy utilization by non-technical personnel.
- vi. There is no framework for assessing the indoor environmental quality of classrooms of basic schools in Ghana.

## 5 Conclusion

This paper aimed to review existing literature on IEQ assessment frameworks for classrooms in basic schools. The review has revealed that there are not many IEQ assessment frameworks for classrooms in basic schools in general, and none in Ghana. IEQ assessment frameworks and tools reviewed employed processes such as literature review, data collection and analysis before the frameworks are formulated. Others also adapted already existing tools and frameworks to suit the current objectives for developing the framework. Validation of IEQ assessment frameworks on case studies has been conducted in some cases to receive feedback for remedial action. An IEQ assessment framework for classrooms in basic schools will serve as a guide to stakeholders in the education and construction sectors in Ghana to provide better performing classrooms for the comfort and wellbeing of occupants.

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# Assessing the Level of Sustainable Affordable Housing Consciousness Using Frugal Innovation

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**Abstract. Purpose:** The purpose of this research was to establish the level of consciousness to sustainable affordable housing (SAH) using frugal innovation (FI).

**Design/Methodology/Approach:** This was done using quantitative data on stakeholder's within the housing and construction industry to establish their perception of the feasibility, cost implication and the desire or wish to own SAH using FI. A total of 103 questionnaires were distributed for the data collection. Data were analysed using descriptive statistics.

**Findings:** The study revealed that stakeholders had a very low level of consciousness or awareness of FI, as well as the concept of SAH using FI and 54% of stakeholders were hearing of FI for the first time.

**Research Limitation/Implications:** The study focused on stakeholders who were construction and housing professionals in the public and private sector in Ghana.

**Practical Implication:** The knowledge from this study would help housing developers with a better approach to developing houses to meet the various classes of people in a sustainable affordable manner.

**Social Implication:** This study will bridge the knowledge gap of stakeholders as well as improve the policy direction of governments, academic institutions, housing developers, UN-SDGs and UN-Habitat international in the implementation of housing programmes.

**Originality/Value:** The novelty of this study is born from the fact that it attempts to address the housing deficit of the unserved mass majority at the bottom of the pyramid (BOP) through sustainable affordable consciousness based on the frugal innovation concept.

**Keyword:** Affordable · Consciousness · Frugal innovation · Housing · Sustainable

## 1 Introduction

With the current COVID-19 protocols of social distance and isolation sustainable affordable housing using frugal innovation would be the way forward. The purpose of this



research is to assess the level of sustainable affordable housing (SAH) consciousness using frugal innovation (FI) in Ghana. The current housing shortages in Ghana have crossed 2 million units, this does not, however, account for the projected housing needs for isolation and social distancing for COVID-19. This implies that the government will have to build more than 200,000 houses every year for the next decade to close the gap (Minister for Works and Housing 2019). However, frugal Innovation is increasingly becoming a standard against which alternative sustainable solutions can be resolved (Basu et al. 2013). Unresolved global problems such as mitigating poverty and exclusion are outlined in the 17 Sustainable Development Goals (SDGs) (Arnold 2018). Frugal innovation is clearly defined as low-cost innovation (LCIs) developed or manufactured to serve customers at the bottom of the pyramid (BOP) of the unserved mass market (Lim and Fujimoto 2019). “The unserved” refers to the group of individuals/people who cannot afford a certain product, services or housing due to the cost of product or services which may be as a result of its complexity or sophistication, the functional specifications, the structural components and complex designs nature of the product or service making it expensive (Kahle et al. 2013, Lim and Fujimoto 2019). In addition, Frugal innovation aims to optimize the usage of materials and financial resources across the entire value chain (development, production, delivery, use and disposal) for the use of minimal raw materials, the reuse of existing parts, lightweight structures, the use of cutting-edge technologies to achieve low costs and to have a low price for the cost of ownership while at the same time satisfying the core functional requirements. Frugal innovation is the development of low-cost mass-market products or services available to all social classes, including the less prosperous segments (Sammut-bonnici et al. 2015). It’s marked by scarce capital to develop low-cost technologies that are safe for the climate and populations. In contrast to traditional product production methods, these resource-constrained product development techniques may give rise to more sustainable goods, leading to reduced usage of energy and greater efficiencies in the supply chain (Sharma and Iyer 2012, Khan 2016). FI is also aligned with sustainability because it is more affordable and offer better sustainability than the conventional approach to production. It is further, distinguished by decreasing the use of resources (raw materials, manufacturing resources, electricity, heat, water, waste, financial resources) (Albert 2019). In achieving social sustainability, frugal innovation plays an important role; it supports SDGs and leads to the broader objective of sustainable development (Khan 2016).

## 2 Consciousness to SAH Using Frugal Innovation

This section contains research on the consciousness of sustainable affordable housing using frugal innovation. However, for this research, the terms consciousness and awareness will be used interchangeably in this study to mean the same thing.

According to Nduka and Ogunsanmi (2016), the concept of awareness is “the creation of a base audience for a product, service, or problem”. Awareness is characterised as social groups, individuals being aware of, and sensitive to their surroundings (Kele 2007). Umar and Khamidi (2012) describe sustainable building construction knowledge as the appropriate strategic and advocacy activities conducted to help people understand the essentials and priorities of goals and the requirements in task completion. Abolore (2012)

aver that the understanding of sustainable building construction practices is determined by individual actions of stakeholders, including their thirst for expertise, full immersion, and serious commitment to sustainable building principles. When stakeholders are aware of sustainable affordable housing, using frugal innovation, the concept will work well (Du Plessis 2007). However, implementation of SAH using FI will largely begin with awareness and interest, leading to knowledge acquisition and finally converted to an increase in demand and implementation of concept (Abidin 2010). The success of sustainable affordable housing through frugal innovation is heavily reliant on public awareness of the problem. Given there is frequently an extensive correlation between recognition and support for causes and policies. Therefore, understanding of SAH using FI should be positively connected with such funding (Anzagira et al. 2021). It is possible to raise consciousness and sensibility to guide individual actions or react to issues (Engin and Cam 2005). Previous research on awareness education has found it has a positive impact on various subjects, including information security, software development, and innovation (Sahinaslan et al. 2009, Ergin 2008). Therefore, education is important in terms of raising consciousness and sensibility in terms of the rising demand for sustainable affordable housing using frugal innovation (PwC Global, n.d). In response to the 2030 Agenda for Sustainable Growth, all the sustainable development goals (SDGs) and priorities will be conveyed to other civil society organisations (CSOs), traditional rulers, and oppressed community groups as part of a change-oriented engagement strategy (United Nations 2019).

According to Tiwari et al. (2017), incorporating frugal innovation into the debate of environmental sustainability and circular economy could result in a greater understanding of frugal options. Organizational tools that provide multinational business are often recognised, but little consideration is given to the impact of frugal innovation structures on the sustainability of larger informal economic business systems and livelihood arrangements (Meagher 2018). Nevertheless, in policy institutions, this knowledge is still lacking. Furthermore, the sceptic's in governments institutions seems to fear that frugal innovation may results in the contraction of governments institutions GDP apart from negatively affecting employment probable due to the market target of frugal innovation of low-income target (Tiwari et al. 2017). Complementary interaction with the BOP, alternatively, necessitates a better understanding of economies in the informal structures in and of themselves, raw materials, for corporate actors to construct new low-cost market ecosystems (Meagher 2018). It has been stated one of the critical barriers to green building initiatives is a lack of public knowledge. For a long time, raising public consciousness has been correlated with increasing support for causes and policies. Advocates for health problems including AIDS, bowel cancer, mental depression, and the latest COVID-19 pandemic have all used the power of public awareness to increase support for their cause. Knowledge and education are often credited with increased levels of support, even though there is only limited evidence awareness alone is responsible for increased support (Irwin 1990, Anzagira et al. 2021). Umar and Khamidi (2012), proposed that radio and television advertisements, a website created specifically for green building campaigns, and media relations in articles and press releases are key resources in sensitising the public to green buildings. Furthermore, it was discovered that most stakeholders were aware of sustainable building and most of their knowledge comes

from their academic work, the media, workshops/conferences, and the internet (Ametepey et al. 2015, Anzagira et al. 2021). Also, Oke et al. (2019) discovered a low level of knowledge of sustainable affordable housing among construction professionals in Zambia's housing and construction industry. Similarly, Alabi's (2012), James and Matipa's (2004), and Al-Sanad (2015) research findings also revealed the level of sustainability consciousness in developing countries like Nigeria, Zambia, and Kuwait is poor. Conversely, although there was some recognition among construction professionals, the actual implementation was lacking. Nevertheless, it is established that government rules and regulations would be required to enforce implementation (Ametepey et al. 2015). Furthermore, Oke et al. (2019), Abidin (2010) and Bowen et al. (2010) also concluded Malaysia and South Africa, respectively, had a high level of awareness on sustainable construction with low implementation. This is likely because the housing and construction sector is client-based, and therefore acceptance and subsequent implementation of these practices is contingent on client awareness. Therefore, it is critical for various stakeholders in the housing sector to be aware of affordable housing using frugal innovation, to contribute to the adoption and introduction of SAH using FI in the Ghanaian housing sector (Oke et al. 2019).

### 3 Research Methodology

An extensive literature review was conducted on sustainable affordable housing using frugal innovation to establish the level of consciousness among stakeholders within the construction and housing sector in Ghana (Syed-Jamaludin et al. 2018). The quantitative research design was used for stakeholders to provide objective and accurate responses for the study (Creswell 2014). Cross-sectional structured survey questionnaires were used for the research design instrument for data collection. The purposive non-probability sampling was the research technique used to identify stakeholders within the housing and construction industry with the knowledge, experience, accessed and were willing to provide the needed information were contacted for the data collection (Oke et al. 2019, Debrah et al. 2020, Anzagira et al. 2021). The questionnaire was designed using Google survey form and administered online. Out of 200 questionnaires that were distributed to stakeholders in the construction and housing sector in Ghana with professional background in architects, quantity surveyors, consultants, housing and construction engineers, construction academics, contractors etc. 103 questionnaires were returned answered. The data was analysed using the descriptive statistics to extract the response into percentages and frequencies based on similar previous studies (Otalı and Ujene 2020, Anzagira et al. 2021). In addition, further analysis was conducted using ANOVA to compare the stakeholder's professional background influences in relation to perception of implementation, cost and desire or wish to own sustainable affordable housing using frugal innovation. The educational level of respondents included PhD, Master's Degree, Bachelor's degree (Bsc), Higher National Diploma (HND), Technician (CTC I/II/III)/Advance, from both public and private companies/organization/institutions such as consultancy firms, construction companies, housing developers, municipal and districts engineers, academic and research institutions and other related housing and construction industry players.

## 4 Data Analysis

### 4.1 Knowledge of Sustainable Affordable Housing Using Frugal Innovation

Figure 1 depicts stakeholder knowledge of frugal innovation, sustainable housing, affordable housing, sustainable affordable housing, and sustainable affordable housing using frugal innovation if they have ever heard of it. Respondents were asked to select any of the terms they have ever heard of or know in Fig. 1. According to the responses, affordable housing seems the most common term known to respondents, accounting for 75.5% of the total. Sustainable housing was the second most common term known to respondents, accounting for 66.3%, and sustainable affordable housing was the third most common term known to respondents, accounting for 57.1%. However, 18.4% of the respondents were hearing the term frugal innovation for the first time through this study, while only 10.2% of the respondents ever heard of the concept of sustainable affordable housing using frugal innovation.

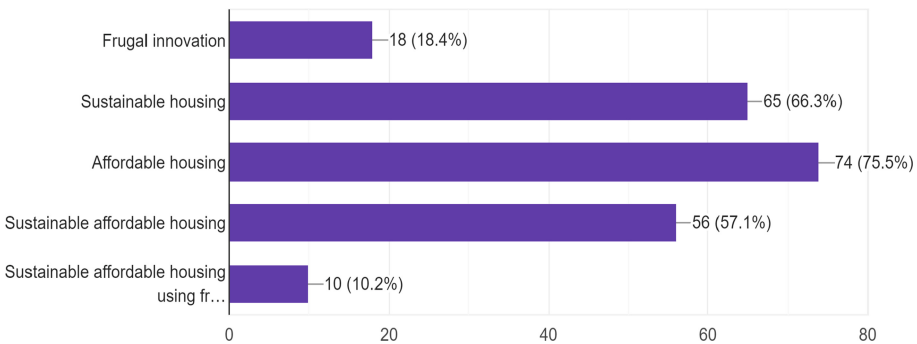
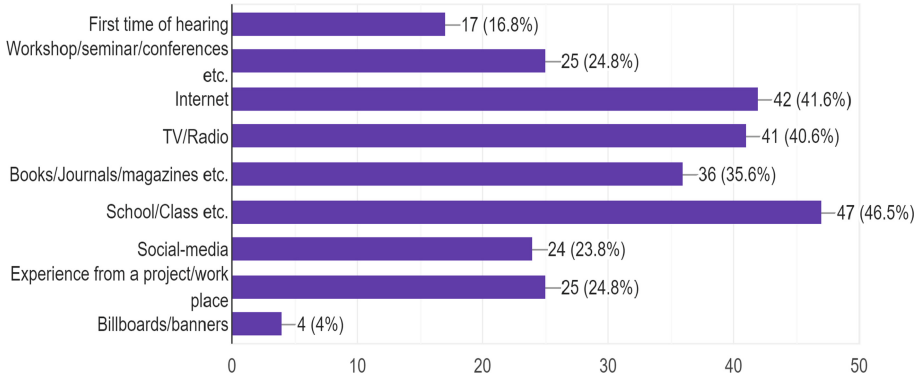


Fig. 1. Stakeholder knowledge of frugal innovation

### 4.2 Source Ever Heard of Sustainable Affordable Housing

Stakeholders were asked to choose from a list of any among multiple possible sources they have ever heard or encountered the terms sustainable affordable housing in Fig. 2. With 47 stakeholders representing 46.5% of the general responses, it can be seen that majority of respondents source of exposure to the word sustainable affordable housing was in school/class. Then came 42 stakeholders representing 41.6% of the general respondents hearing about sustainable affordable housing through the internet. 41 stakeholders also representing 40.6% of the general respondents said they learned about sustainable affordable housing using frugal innovation from the TV/Radio, while 36 stakeholders (35.6%) said they learned about it from books/journals/magazines, and 25 respondents representing 24.8% of the general responses said they learned about it from a project/workplace or a workshop/seminar/conference. With 24 of respondents representing 23.8% of the general, social media followed afterwards. However, via the

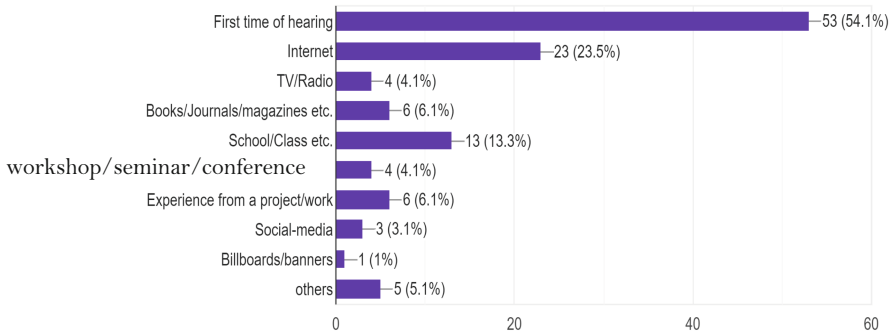
study's questionnaire, 16.8% (17 stakeholders) of stakeholders learned about sustainable affordable housing for the first time, and only 4% (4 stakeholders) knew about sustainable affordable housing from billboards and banners.



**Fig. 2.** Information on sustainable affordable housing

### 4.3 Source Ever Heard of Frugal Innovation

Stakeholders were further, asked to choose from a list of any among multiple possible sources they ever heard the term frugal innovation. From Fig. 3 the results showed that the majority of the respondents heard the concept of frugal innovation for the first time through this study, it was revealed from the data that 54.1% of the total respondents indicated that was their first time hearing frugal innovation through this study, while the second commonplace in which respondents heard frugal innovation was through the Internet, representing 23.5% of the responses, 13.3% heard frugal innovation for the first time in school/class, also experience from work and books/journals/magazines had the same score of 6.1%, and 5.1% stakeholders heard about frugal innovation from



**Fig. 3.** Information of frugal innovation

other sources that were not captured in the questionnaire for this study, TV/Radio and workshop/seminar/conference was later with the same score of 4.1%, followed by social media and billboards/banners with 3.1%, respectively.

#### 4.4 Discussion on Knowledge of Sustainable Affordable Housing Using Frugal Innovation

With 75.5% of general responses, the study in Fig. 1 showed that affordable housing is the most common concept known to actors in Ghana's housing and construction markets. Finally, 66.3% of respondents identified sustainable housing as a term they knew, followed by 57.1%, who identified sustainable affordable housing as a term they knew. However, 18.4% and 10.2% of the general response revealed that frugal innovation and sustainable affordable housing using frugal innovation are not common terms among stakeholders. According to the results from Fig. 2, the main source of consciousness or knowledge of sustainable, affordable housing was school/class (46.5%), followed by the Internet (41.6%), TV/radio (40.6%) and books/journals/magazines (35.6%). On the contrary from Fig. 3 it was revealed that this study exposed 54.1% of stakeholders to the word frugal innovation for the first time. Therefore, this study is even more relevant in terms of filling the knowledge gap for sustainable affordable housing through frugal innovation. A small percentage of stakeholders (23.5%) had prior exposure to the internet, while 13.3% had learned about it in school or class. The findings of the study showed that there is a very low level of consciousness or awareness of sustainable affordable housing using the frugal innovation concept among stakeholders. Previous research has confirmed that, while frugality is not new, and has existed since the mid-sixteenth century (Soni and Krishnan 2014, Roiland 2016, Tiwari et al. 2016). On the contrary, to popular belief, frugal innovation is a relatively new area of study that has recently gained traction in both practical and academic circles (Bhatti and Ventresca 2013). The expression and definition of frugal innovation were first coined in the article "First Break All Rules" in *The Economist* in 2010 (Soni and Krishnan 2014). After that, a broader public became aware of frugal innovation, and many academics have analysed it, contrasted it to other forms of innovation, and attempted to describe it (Zeschky et al. 2011, Weyrauch and Herstatt 2016, Herstatt and Tivari 2015, Hossain 2018, Michelini et al. 2018). Apart from that, for the time being, frugal innovation research is focused mostly on manufacturing, medical health, and services, with little or no research in the housing and construction market. Hence, the probable reason for the low level of awareness of SAH using FI among stakeholders with the housing and construction industry in Ghana.

The study further, confirms previous findings that knowledge education has a positive impact on various topics, including information security, software growth, and innovation (Sahinaslan et al. 2009, Ergin 2008). Therefore, in terms of raising consciousness and sensibility, awareness education is successful at the rising demand for sustainable affordable housing using frugal innovation (PwC Global n.d.). In response to the 2030 Agenda for Sustainable Growth, all the Sustainable Development Goals (SDGs) and priorities will be conveyed to other civil society organisations (CSOs), traditional rulers, and oppressed community groups as part of a change-oriented engagement strategy

(United Nations 2019). Umar and Khamidi (2012) have proposed that radio and television advertisements, websites created specifically for sustainable building projects, and media relations in articles and press releases are important resources for educating the public about sustainable affordable housing using frugal innovation. Furthermore, most stakeholders were aware of sustainable construction and their major sources of knowledge are their academic work, the media, workshops/conferences, and the internet (Ametepey et al. 2015, Anzagira et al. 2021).

#### **4.5 Analysis of the Perception on Implementation, Cost and Desire for SAH Using FI**

##### **4.5.1 Perception on Implementation**

Table 1 gives an illustration of the perception of implementation, cost implication and the desire or wish of stakeholders to own sustainable affordable housing using frugal innovation. On the perception of implementation, respondents were asked to rank on their own opinion to what extent they think the frugal innovation concept can be a possibility to sustainable affordable housing to addressing housing deficit from options with a key; 1 = Very possible, 2 = Possible, 3 = Not sure, 4 = Not possible and 5 = Not very possible. From the study, it was revealed that the majority of stakeholders were of the view sustainable affordable housing using frugal innovation was possible representing 47.6% of the total responses, furthermore 28.2% of stakeholders think is very possible to address sustainable affordable housing using frugal innovation. However, 23 respondents representing 22.3% of the total were not sure of the possibility of addressing sustainable affordable housing deficit using frugal innovation, while only 2 (1.9%) respondents think it not very possible to address sustainable affordable housing using the frugal innovation concept.

##### **4.5.2 Desire or Wish to Own SAH Using FI**

Stakeholders were also to state to what extent they would wish or desire to own sustainable affordable housing using frugal innovation from various options with a key; 1 = Very highly wishful, 2 = highly, wishful, 3 = Not sure, 4 = Don't wish and 5 = Don't highly wish. From the data, it was revealed 60 respondents representing 58.3% of the total responses would wish to own sustainable affordable housing using the frugal innovation concept. Additionally, 22 respondents representing 21.4% would very highly wish to own sustainable affordable housing using frugal innovation, while only 20.4% were not sure if they would like to own sustainable affordable housing using frugal innovation.

##### **4.5.3 Perception on Cost**

Respondents were again asked to give their perception on cost regarding sustainable affordable housing, using frugal innovation from five (5) options with a key; 1 = Very costly, 2 = Costly, 3 = Neutral, 4 = Not costly and 5 = Not very costly. From the table, it can be established that the majority of the respondents representing 39.8% were not sure or had no idea on the cost associated with sustainable affordable housing using frugal innovation, while 29.1% followed subsequently were of the perception that sustainable

affordable housing using frugal innovation was costly. Compared, 20.4% were of the perception that sustainable affordable housing using frugal innovation was not costly, whereas 9.7% were of the perception that sustainable affordable housing using frugal innovation was very costly.

**Table 1.** Perception of implementation, cost and desire for SAH using frugal innovation

Perception of implementation, cost and desire for SAH using frugal innovation		
	Frequency	Percent
<i>Perception of implementation</i>		
Very possible	29	28.2
Possible	49	47.6
Not sure	23	22.3
Not possible	2	1.9
Not very possible	–	–
<b>Total</b>	<b>103</b>	<b>100.0</b>
<i>Desire or wish for SAH using FI</i>		
Very highly wishful	22	21.4
highly wishful	60	58.3
Not sure	21	20.4
Don't wish	–	–
Don't highly wish	–	–
<b>Total</b>	<b>103</b>	<b>100.0</b>
<i>Perception of cost</i>		
Very costly	10	9.7
Costly	30	29.1
Neutral	41	39.8
Not costly	21	20.4
Not very costly	1	1.0
<b>Total</b>	<b>103</b>	<b>100.0</b>

#### 4.6 Discussion of Perception on Implementation Cost and Desire or Wish to Own

From the analysis from Table 1 it was revealed that most stakeholders representing 47.6% believe that sustainable affordable housing using frugal innovation is feasible, while 28.2% believe that addressing Ghana's housing deficit is very possible. Therefore, approximately 75.8% of housing stakeholders envision a frugal innovation concept as a significant possibility in resolving the massive housing shortage in a sustainable, affordable manner. The study reinforced stakeholders' beliefs that frugal innovation can be



used to solve sustainable affordable housing, with 58.3% of respondents wishing and 21.4% much wishing to own such a housing facility in Ghana. Following the findings, the study concludes approximately 79.7% of stakeholders in the housing sector in Ghana want to own sustainable affordable housing using frugal innovation.

According to the report, 39.8% of stakeholders in the construction and housing sectors were unsure about the cost implications of creating sustainable affordable housing through frugal innovation. However, 29.1% of respondents believed that sustainable affordable housing (SAH) using frugal innovation (FI) was expensive. Comparatively, 20.4% believed SAH using FI was not expensive. In general, there were different perceptions of the cost of developing sustainable affordable housing using frugal innovation. These results were not unexpected, although the study's respondents were stakeholders in Ghana's construction and housing sectors, and thus presumed to be well-versed in the costs of housing and construction products. It is important to recognise that frugal innovation was a new concept to stakeholders in the housing sector, and approximately 54% of respondents learned of it for the first time through this study. Hence, the possible reason majority of stakeholders were not certain or lack much information on the cost of its implementation in housing.

#### 4.7 ANOVA Analysis of SAH Using FI

Analysis of variance (ANOVA) is used to detect the differences between various experimental groups means of several samples, the purpose is to test for significant differences between class means (Anon 2014, Sawyer 2009). A one-way ANOVA was conducted to compare the level of consciousness in respect to professional background effect on perception of implementation, desire or wish to own and perception of cost implication of stakeholders on sustainable affordable housing (SAH) using frugal innovation (FI). Although, the 1-way ANOVA does not tell everything about the variables. However, it can be used to establish that there is a significant difference between various conditions in an experiment or test (Anon 2014). On the other hand, it does not show where this effect exists. The results of the study showed that there was a significant impact among the various professional backgrounds of stakeholders and their perception, or consciousness levels on the feasibility of achieving SAH with frugal innovation at  $p = .05$  level for the three conditions, i.e. the degree of freedom (df), the F value (F) and the Sig. Value or p value) as follows;  $[F(3, 99) = 12.49, p = 0.00]$ . Again, there was a significant effect among the professional background of stakeholders and the extend of wishing to own SAH using frugal innovation at  $[F(3, 99) = 13.43, p = 0.00]$ . However, there was no significant effect at  $[F(3, 99) = 13.43, p = 0.18]$  among professional background and the perception of cost implication to SAH using frugal innovation among stakeholders in the housing and construction sector.

**Table 2.** ANOVA

ANOVA						
		Sum of squares	df	Mean square	F	Sig.
Extend think sustainable affordable housing can be achieved/feasibility	Between groups	16.466	3	5.489	12.493	.000
	Within groups	43.495	99	.439		
	Total	59.961	102			
Extend wish to own sustainable affordable using frugal innovation	Between groups	12.433	3	4.144	13.427	.000
	Within groups	30.557	99	.309		
	Total	42.990	102			
Perception of the cost of sustainable affordable using frugal innovation	Between groups	4.230	3	1.410	1.668	.179
	Within groups	83.693	99	.845		
	Total	87.922	102			

**4.8 Post Hoc Comparisons**

A post hoc test was used to look at the differences between the various professional backgrounds of stakeholders to their responses by testing each possible pair of groups among the various professionals’ backgrounds. This is typically conducted after there is a fact that ANOVA was significant. The Tukey test was used to compare each condition to all other conditions on the mean score of stakeholder’s professional context regarding their thoughts on the feasibility of SAH using frugal innovation, as well as to decide where significance exists among variance for the sample. Table 3 shows there were significant differences between the various professional backgrounds as follows: (M = 2.14, SD = .69) for architects only, (M = 2.00, SD = .61) for all engineers in the housing and construction industry. (M = 2.00, SD = .00) for other types of professionals in the housing and construction industry, (M = 2.00) for professionals who were both lecturers and quantity surveyors, as well as both architects and lecturers, (M = 2.00, SD = 1.41) for both engineers and lecturers, (M = 1.95, SD = .75) for students only, and (M = 1.91, SD = .67) for quantity surveyors only, as shown in the table. In addition, the mean score for stakeholders wishing to own SAH using frugal innovation was significantly different depending on their professional background: (M = 2.34, SD = .57) for quantity surveyors only, (M = 2.14, SD = .38) for architects only. Stakeholders with a professional background of both engineers and lecturers, both architects and lecturers, and both engineers and lecturers, alternatively, had the same mean score (M = 2.00, SD = .00). As shown in Table 4, (M = 2.00, SD = .61) for all engineers in the housing and building industry, (M = 2.00, SD = 1.00) for only lecturers, (M = 2.00, SD = .1.41) for both engineers and lecturers, and (M = 1.86, SD = .67) for students only.

**Table 3.** Descriptive statistics

Descriptive statistics				
	Professional background_	Mean	Std. deviation	N
Perception on implementation of SAH using FI	Architect	2.1429	.69007	7
	Architect, Lecturer	2.0000		1
	Engineer (all categories)	2.0000	.61237	17
	Engineer (all categories), Lecturer	2.0000	1.41421	2
	Lecturer	1.6667	.57735	3
	Others	2.0000	.00000	3
	Quantity Surveyor	1.9130	.66831	23
	Quantity Surveyor, Lecturer	2.0000		1
	Quantity Surveyor, Lecturer, Student	1.0000	.00000	3
	Student	1.9535	.75446	43
	<b>Total</b>	<b>1.9320</b>	<b>.68973</b>	<b>103</b>
Desire or wish to own SAH using FI	Architect	2.1429	.37796	7
	Architect, Lecturer	2.0000		1
	Engineer (all categories)	2.0000	.61237	17
	Engineer (all categories), Lecturer	2.0000	.00000	2
	Lecturer	2.0000	1.00000	3
	Others	1.6667	.57735	3
	Quantity Surveyor	2.3478	.57277	23
	Quantity Surveyor, Lecturer	2.0000		1
	Quantity Surveyor, Lecturer, Student	1.0000	.00000	3
	Student	1.8605	.67547	43
	<b>Total</b>	<b>1.9903</b>	<b>.64921</b>	<b>103</b>

#### 4.9 Discussion of Analysis Using ANOVA on SAH Using Frugal Innovation

The analysis of the study from Table 2 revealed there is a significant influence of stakeholder's professional backgrounds on the level of consciousness of sustainable affordable housing (SAH) using frugal innovation concerning thinking interns of feasibility and desire or wishing to own such houses. On the contrary, the study revealed there was no significant influence of stakeholder professional background on the perception of cost

implication to SAH using frugal innovation among stakeholders in the housing and construction sector. However, from Table 3, the study further revealed there is a higher significant influence on the thoughts of architects only as compared to all other professions on the feasibility of sustainable affordable housing (SAH) using frugal innovation to thinking interns of feasibility with a mean score and standard deviation of ( $M = 2.14$ ,  $SD = .69$ ). Also, engineers of all categories only followed thereafter as high significant influence perception of SAH using FI is feasible with ( $M = 2.00$ ,  $SD = .61$ ), afterwards were other forms of professionals within the housing and construction industry with significant influence on the feasibility of SAH using FI with ( $M = 2.00$ ,  $SD = .00$ ), stakeholders who were both lecturers and quantity surveyors, as well as lecturers both architects and lecturers by profession followed with the same mean of ( $M = 2.00$ ), engineers and lecturers, students only, quantity surveyors only with ( $M = 1.95$ ,  $SD = 1.41$ ), ( $M = 1.95$ ,  $SD = .57$ ), ( $M = 1.95$ ,  $SD = .67$ ) followed afterwards respectively.

In addition, the study revealed that stakeholder professional background has a higher significant impact on the desire or wish to own SAH using FI. From the table it was revealed that stakeholders who were quantity surveyors by profession only with ( $M = 2.34$ ,  $SD = .57$ ) has a higher significant impact on their desire or wish to own SAH using FI as compare to all the other professionals, afterwards were architects only with ( $M = 2.14$ ,  $SD = .38$ ) significantly higher in interns of desire or wish, following was stakeholders who are both engineers and lecturers as a profession with ( $M = 2.00$ ,  $SD = .00$ ), afterwards only engineers of all categories within the housing and construction industry, lecturers only, lecturers and quantity surveyors, as well as stakeholders who were both architects and lecturers, had the same mean score, also, both engineers and lecturers with the following ( $M = 2.00$ ,  $SD = .61$ ), ( $M = 2.00$ ,  $SD = 1.00$ ), ( $M = 2.00$ ), ( $M = 2.00$ ,  $SD = .141$ ) as their respective significant impacts on the desire or wish to own SAH using FI.

## 5 Conclusion and Recommendations

The purpose of this research was to establish the level of consciousness to sustainable affordable housing using frugal innovation. This was done using quantitative data analysis on the level of consciousness on frugal innovation, sustainable housing, affordable housing, sustainable affordable housing, and sustainable affordable housing using frugal innovation, as well as data on stakeholder's perception of feasibility of implementation, desire or wish to own as well as the perception of cost implication on the subject matter for this study. The study revealed that stakeholders within the housing and construction sector had a very low level of consciousness or awareness of frugal innovation, as well as the concept of sustainable affordable housing using frugal innovation and 54% of stakeholders was even heard of it for the first time. However, stakeholders are much familiar with the term affordable housing, sustainable housing as well as sustainable affordable housing. The commonplace of awareness of most stakeholders on the housing and construction sector in Ghana is in schools, Internet sources, TV/radio and books/journals/magazines. The majority 75.8% of stakeholders however believe sustainable affordable housing using frugal innovation is feasible to resolve the massive housing shortage in a sustainable, affordable manner. Moreover, it was discovered with

much support for the concept, with 79.7% wishing to own sustainable affordable housing using frugal innovation in Ghana. Further analysis using 1-way ANOVA revealed that there is a significant influence of stakeholder's professional backgrounds on the level of consciousness of sustainable affordable housing (SAH) using frugal innovation regarding perception interns of implementation or feasibility and desire or wishing to own such houses. On the contrary, the study revealed there was no significant influence of stakeholder professional background on the perception of cost implication to SAH using frugal innovation. There is a higher significant influence on the perception of architects only as compared to all other professions on the feasibility of sustainable affordable housing (SAH) using frugal innovation, followed by engineers of all categories only and other forms of professionals. In addition, the study revealed that stakeholder professional background has a higher significant impact on the desire or wish to own SAH using FI. However, quantity surveyors by profession only had a higher significant impact on the desire or wish to own SAH using FI as compare to all the other professionals. After the surveyors were architects only, the subsequent was stakeholders who are both engineers and lecturers as professions.

Frugal innovation has had a lot of breakthroughs in several industries, especially in the manufacturing, health and services sectors. Therefore, there are prospects for it to be used as a game-changer in addressing the large housing deficit in a sustainable affordable manner in Ghana and other developing countries globally. Generally, there were varying perceptions of the cost of developing sustainable affordable housing using frugal innovation. while the majority of stakeholders were not certain on the cost implication, some think SAH using FI would be expensive, some think it would be cheap so generally, there was no consensus among stakeholders on the cost implications of developing sustainable affordable housing through frugal innovation, therefore further research in this dimension would be very significant for future studies. However, this was probably because the majority of stakeholders were hearing of frugal innovation for the first time through this study, hence, the possible reason majority of stakeholders were not certain or lack much information on the cost of its implementation in housing. This research will contribute significantly to the knowledge gap in the literature on the level of consciousness on the possibility of achieving sustainable affordable housing using frugal innovation concept to the development and construction of affordable housing in general; it will also help stakeholders including the government, academic institutions and housing solutions practitioners to improve their policy orientation. This study will also contribute to the UN-SDGs and UN-Habitat policymakers on the possibility of applying the frugal innovation concept in the drive to make cities inclusive, secure, resilient, and prosperous by 2030, as part of the sustainable cities agenda. Future research works should study the drivers for sustainable affordable housing using frugal innovation, as well as developing a framework for sustainable affordable housing using frugal innovation.

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# Emerging Contractors' Challenges with the Compliance of Occupational Health and Safety Standards in South Africa

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**Abstract. Purpose:** Compliance with health and safety regulations has become a significant issue in the construction industry. The study's objective was to identify the challenges faced by emerging contractors in complying with Occupational Health and Safety (OHS) regulatory requirements in South Africa's construction sector and better understand perceptions of emerging contractors regarding OHS in the construction industry.

**Methodology:** A quantitative research approach was used to gather information from the respondents. Seventy-eight (78) structured sets of questionnaires were sent to randomly selected construction professionals operating from the Gauteng province, of which 42 responded. Data received were analyzed via Excel statistical tool to calculate the frequencies, percentages, and mean scores.

**Findings:** It was found that the most significant influence behind the lack of OHS compliance observed on the construction site by emerging SMME contractors is the lack of financial allowances made when tendering for work. Emerging contractors operate in a competitive market where the price is essential when bidding for work. As a result, to win work, they aim to bid at the most competitive rate possible. This research further revealed that by removing OHS-related expenses from the bid price, emerging contractors believe that they have a better chance of winning tender, with the consequence of poor OHS compliance on construction sites.

**Implication:** There is an urgent need to educate the emerging contractors on the need for pricing for health and safety-related items in tender documents and how the compliance of the health and safety at their project sites should be a paramount priority to keep their workers safe. Those who flout the health and safety regulations at their project sites should be blacklisted.

**Keywords:** Emerging · Contractors · Health · Safety · Compliance · Construction

## 1 Introduction

Characteristically the construction sector in developing countries tends to be integral to the fabric of developing economies (Kongolo 2010). The situation in South Africa is no



different. In the first quarter of 2020, the construction sector contributed approximately R70,039.94 billion to South Africa's gross domestic product (GDP) (Economics 2020). As a result of this contribution to the local economy, the South African construction sector is responsible for millions of South Africans' employment directly and indirectly. Although South Africa's construction sector has many different stakeholders who partake in the industry, 35% of the industry comprises Small, Medium, and Micro Enterprises (SMME's) (Moilwa 2013). These SMME's are responsible for the employment of over 60% of the construction industry, as they tend to adopt labour-intensive methods to execute works (Moilwa 2013). The inclusion and predominance of sub-contractors and subcontracting in the construction sector are not likely to change as South Africa's economy and construction sector develops over time (Liedholm and Mead 2013).

In developed economies such as the United Kingdom, sub-contracting is still prevalent in their construction sector (Manu et al. 2013). Thus, it is important to deal with and understand the challenges faced by subcontractors in South Africa as their presence in the construction is likely to grow over time. As their presence grows, so will their influence on the overall construction sector (Manu et al. 2013). Subcontracting lends itself well to construction culture for several reasons, including flexible labour allocation, execution of specialized work, helping principal contractors mitigate financial risk, among others (Manu et al. 2013). However, despite all the contribution subcontracting brings to the construction sector and the economy, it is important to acknowledge all is not rosy when it comes to Occupational Health and Safety (OHS) practices. OHS accident levels are considerably higher in developing countries than in developed countries (Kheni et al. 2008). SMME's have a considerable influence on these figures as they employ the most labour-intensive construction sector methods (Kheni et al. 2008).

There is also concern about the lack of recent quantifiable South African construction-related OHS data on accidents that take place on construction sites (Haupt et al. 2014). The most recent figures published by the Department of Labour date back to data collected between 2004 to 2007 (Haupt et al. 2014). The data collected indicates an increasing trend in work-related injuries in the construction sector. It also shows that average construction-related injuries are higher per 100 people employed than in other industries (Haupt et al. 2014). A study conducted by Kheni et al. (2008) on the management of OHS by small and medium-sized construction companies with particular focus on the Ghanaian construction sector attributes the high number of OHS related injuries amongst SMME's to low literacy levels, labour-intensive methods of working, poor and insufficient management, and cultural influence. It can be assumed that South African SMME's face similar influences regarding injuries at work and OHS compliance. With the South African government rallying behind the inclusion of emerging contractors in the South African construction sector as stakeholders to aid job creation, it is important to investigate the challenges that they face in the attempt to provide a safe working environment for the people whom they employ (Trade & Industry 1995).

In the Construction National Blitz Inspection, an inspection that the Department of Labour carried out (DoL) at various construction sites around the country, it was discovered that on average, 52.5% of all South African construction sites were not compliant with the Occupational Health and Safety Act (Moilwa 2013). Although marginal, the

Construction National Blitz results show that more sites are non-compliant than a complaint regarding the set OHS legislation in South Africa. This finding alludes to deep challenges regarding safety on construction sites and alludes to poor construction OHS cultural ideals within the industry. The culture of casualization and sub-contracting means that a large portion of the non-compliance documented by the Construction National Blitz results from SMME's and emerging contractors' failure to comply with OHS regulations, as the findings documented are a sum of the industries (Moilwa 2013).

For the most part, emerging contractors are the most disadvantaged and ill-equipped to deal with the OHS requirements for site work (Kongolo 2010). And through sub-contracting, principal contractors are often pushing the burden of OHS for their sites onto sub-contractors that are often ill-equipped, ill-informed, and lack the resources and technical expertise to comply with the relevant OHS regulatory requirements (Chiocha et al. 2011). Principal contractors also fail to provide sub-contractors with a safe site for works; however, work tends to commence despite these difficulties due to the industry's nature. The problem being alluded to be complex and influenced by many variables; however, the bottom line remains; construction sites in South Africa are generally unsafe for work.

From an academic standpoint, there has been a considerable amount of literature written regarding OHS in South Africa, although the bulk of the literature written by select academics (Smallwood 2015, Goldswain and Smallwood 2015, Chiocha et al. 2011), to name a few, focus on the role's consultants and culture has played in influencing OHS in South Africa and the rest of Africa. Smallwood (2015) proposed a model that South African architects could use to design structures that would allow for safer construction. His work showed how design could influence construction safety and opened up the conversation around how tertiary institutions could make future architects more aware of their influence on construction safety through their designs (Goldswain and Smallwood 2015). Despite the vast array of available literature concerning OHS in South Africa's construction sector, very little academic literature has been written focusing on the OHS challenges faced by SMME contractors in the South African construction sector, hence the need for this study.

## **2 Literature Review**

### **2.1 Construction Health and Safety in South Africa**

Construction OHS in South Africa is underperforming when compared to the OHS standards being upheld in other industrial sectors within the South African economy, with construction OHS fatality and disablement figures recorded as higher than the national all-industry average, and the number of construction-related injuries has increased considerably in recent years (Hlati 2019). Work-related accidents recorded in the construction sector are disproportionately greater than the contribution the construction sector has on the economy compared to adjoining industrial sectors. This is not attributed to the construction sector being primarily more risk-averse regarding the nature of the work undertaken, but rather because of poor OHS compliance which has been observed across the construction industry (Hlati 2019). It is crucial to monitor all injury and fatality figures across all industries, as the Department of Labour is mandated to do so.

Furthermore, it is their responsibility to ensure that all South African industries provide a safe work environment. The construction sector is no different in that all OHS-related incidents have to be measured, recorded, and analyzed (Haupt et al. 2014). Quantifying the lack of OHS compliance observed in the construction sector, relevant data must be analyzed. The relevance of a data set is primarily dependent on its accuracy and the time the data was collated. In the case of South Africa's construction sector, The Department of Labour is legislatively mandated to be responsible for all labour-related issues, including the collation and publication of OHS data received provincially to the greater public per Sect. 24 of the Occupational Health and Safety Act (South Africa 2012).

Despite the clear allocation of responsibility, difficulties have been encountered when academics and industry stakeholders alike have sought relevant data associated with construction OHS. The disparity has been observed over the accuracy and relevance of the data published (Smallwood and Geminiani 2008). However, despite the unavailability of reliable centralized data regarding construction OHS figures, the information that has been extrapolated has shown a gradual year-on-year increase in the OHS incidents recorded on construction sites and poor OHS compliance throughout the construction sector (CIDB 2009). This has led to academic literature interrogating the effectiveness of the national inspectorate's ability to perform the various tasks they are mandated to perform. It was found that the Department of Labour is ineffective in its ability to conduct its duties (Smallwood and Geminiani 2008). Moreover, the Department of Labour did not have enough construction knowledge to execute their duties concerning the construction sector, nor is their more noticeable deliverable the construction blitz considered effective (Smallwood and Geminiani 2008). Despite the unavailability of accurate and relevant year on year data the industry at large can generate a picture of OHS situation in the construction industry from some of the data that has been made available by the Department of Labour in conjunction with the Federated Employers' Mutual Assurance Company (ILO 2020).

## 2.2 Construction Related OHS Legislation in South Africa

There are primarily three legislation pieces that have an overarching impact on workers' safety in the construction sector. These are The Labour Relations Act, The Basic Conditions of Employment Act, and The National Building Regulations and Standards Act. The legislation governing the construction sector is considered to be comprehensive even by global standards. As a result, the shortcomings observed in construction OHS cannot be directly attributed to the quality and effectiveness of the presiding legislation in South Africa (CIDB 2009). Furthermore, the Department of Labour has explicitly stated that the challenges with construction OHS are not a result of the legislation but rather the perception and influence of construction practitioners (Samuel 2017).

The Occupational Health and Safety Act is the presiding construction OHS regulation in the South African construction sector, with the enforcing agent being the Department of Labour's OHS inspectorate. Research has shown that the Department of Labour has been inadequate in its attempts to enforce The Occupational Health and Safety Act (Smallwood and Geminiani 2008). However, the enforcement of the regulation and its application can be viewed separately as regulation can have an impact even with poor enforcement, provided that the industry is aware of the regulation and adheres to it as

expected by construction practitioners. Research suggests that construction regulations have impacted the construction industry although, the impact observed is not easily quantifiable (Neale 2013).

The academia has observed that construction regulations have highlighted the importance of OHS among construction stakeholders and have dictated how OHS is handled on construction sites (Haupt and Smallwood 2006). Regulation's primary objective is to facilitate the prevention of work-related injuries. This primary objective can only be achieved through the adequate implementation and enforcement of construction regulations. No matter how good the construction regulations might be, their effectiveness is wholly dependent on their enforcement, which is limited to the relevant inspectorate and requires the entire construction value chain (Swuste et al. 2012). The desired results from effective OHS regulations are safer working environments being achieved downstream; however, the upstream and midstream construction projects' components must all be mindful of the regulations and implement them at all stages of the works (Swuste et al. 2012). Therefore, the construction regulations Act addresses contractors, subcontractors, consultants, and clients (South Africa 2014). Despite this, the Construction Industry Development Board (CIDB) believes that improvements can still be made to better facilitate effective OHS culture by amending construction OHS regulations to emphasize OHS's importance in the project initiation and design phases (CIDB 2009).

### 2.3 Subcontractor OHS Compliance

Assessing the OHS compliance of subcontractors in South Africa's construction sector is a worthwhile endeavour due to the pivotal role and influence subcontractors have on South Africa's construction sector. It is estimated that subcontractors have executed up to 70% of all building-related construction work (CIDB 2013). These statistics suggest that more subcontractors execute work on construction sites than principal contractors meaning that subcontractors have a tremendous influence on OHS compliance. Therefore, with subcontracting being associated with poor OHS outcomes, the challenges subcontractors must face regarding OHS compliance be addressed so that OHS compliance can be positively influenced (Yung 2009).

While subcontracting often offers an array of economic advantages, it does also bring negative drawbacks. Academic research has shown that there is a direct correlation between subcontracting and poor OHS outcomes (Manu et al. 2013). Subcontractors are primarily profit-driven, facing immense competition; thus, human resource development is often not at the forefront of their business agenda; therefore, employees often only develop through experience as training is seldom offered (Chiang 2009). Subcontractors tend to be SMME's; thus, they often do not have access to the expensive plant, leading them to adopt labour-intensive work methods to execute works. These labour-intensive methods bring an added risk factor to work often performed by subcontractors (Chiocha et al. 2011). Subcontractors vary in sophistication; however, in developing countries, there is a tendency for subcontractors to emerge informally from a group of labourers previously employed by a principal contractor (CIDB 2013).

### 3 Research Approach and Design

The quantitative research approach was adopted. The quantitative research approach is whereby quantifiable data is collected from a pool of participants through sampling methods. The quantitative data collected are analyzed numerically, and conclusions are drawn from the findings (McCombes 2019). This study's target population consisted of contractors and subcontractors classified as SMME's and work on construction sites either as principal contractors, subcontractors, specialist contractors, and/or labour-only contractors registered in the CIDB contractor's database and operating from Gauteng. Gauteng province was selected because it has a huge number of emerging contractors registered and operating from there, and also it is the province with the most economic activities. Random sampling was then used to select from the target population based on their availability to respond to the questionnaire. According to Polit and Beck (2017), random sampling allows each member within the target population to have an equal chance of being selected. The respondent had to be working for the identified SMME contractor as a construction professional.

A self-administered questionnaire was issued to the participants through personal distribution or electronically distributed via mail. The questionnaire had a list of pre-determined questions; this ensures that quantitative data can be extrapolated from the participant's engagement. Questions were posed on a Likert sliding scale that varied from a scale from one to five. Likert scales allow research participants to rank a statement or question posed on a continuum (Pilot 2017). Out of 120 questionnaires sent out, 42 responded, indicating a response rate of 35%. Excel statistical tool was then used to analyze the received data by generating frequencies, percentages, and mean values. The data was then presented in table format. The features of the respondents are indicated in Table 1.

**Table 1.** Respondent's features

Respondents	No. of respondents	Percentage	Respondents	No. of respondents	percentage
<i>Gender</i>			<i>Years of experience</i>		
Male		17%	0–5 years	23	55%
Female		83%	5–10 years	7	17%
<b>Total</b>	<b>42</b>	<b>100%</b>	10–15 years	5	12%
<i>Educational level</i>			15–20 years	6	
Undergrad degree/Btech	7	17%	Over 20 years	1	2%
Hons degree	1	2%	<b>Total</b>	<b>42</b>	<b>100%</b>
Master's degree	5	12%	<i>Job titles</i>		

(continued)

**Table 1.** (continued)

Respondents	No. of respondents	Percentage	Respondents	No. of respondents	percentage
Diploma	10	24%	Business Owner/Director	22	52%
Matric	17	40%	Construction Manager/Foreman	12	29%
High School not completed	2	5%	Safety Officer	2	5%
<b>Total</b>	<b>42</b>	<b>100%</b>	Quantity Surveyor	3	7%
			Engineer	3	7%
			<b>Total</b>	<b>42</b>	<b>100%</b>

From Table 1, it is evident that most (83%) of the respondents are female, 40% have Matric qualification, 55% of them have 5 years of experience in the construction industry as emerging contractors, and 52% are owners of the business. This means they have insight information about the OHS practices and management on site; thus, their views on the subject matter are highly appropriate.

## 4 Findings

### 4.1 PPE Related Perceptions

The respondents were asked whether they use PPE on construction sites as a norm and whether PPE is considered when the company tenders for work. The respondent's responses are indicated in Table 2.

**Table 2.** Respondents perceptions on PPE

Question posed	Never (1)	Rarely (2)	Sometimes (3)	Often (4)	Always (5)	Mean
Price PPE when tendering for work	12	10	24	20	60	3.00
Employees work on construction sites without PPE	23	10	18	12	25	2.09
Main contractor does not care if employees work on site without PPE	22	10	27	20	5	2.00

From the findings, Price PPE when tendering for work is considered significant since it had the highest mean score of 3.00. With regard to the Main contractor does not care

if employees work on-site without PPE, had a low mean score of 2.21, which does not influence the use of PPE. Whilst most of the contractors revealed that employees work on construction sites without PPE, recording a mean score of 2.00.

#### 4.2 PPEs Provision Responsibility

Table 3 shows the research participant's response to a question posed regarding who should purchase PPE for personal on-site. From the feedback, we observe that 59.5% of respondents believe that the main contractor should purchase PPE for site personal. In comparison, 38.1% believe that each subcontractor is responsible for purchasing PPE for their staff. A minority of 2.4% of respondents believe that each employee should be responsible for purchasing their PPE on site. This indicates that even subcontractors anticipate that the main contractor they are working under will take care of PPEs for their workers.

**Table 3.** Respondents view on who should purchase PPE for personal on-site

Purchase of PPE to site	Frequency	Percentage
Main contractor	25	59.5%
Subcontractors	16	38.1%
Employees	1	2.4%
<b>Total</b>	<b>42</b>	<b>100%</b>

#### 4.3 Internal OHS Processes

The purpose of the questions in Table 4 was to interrogate OHS-related procedures within the research participants' companies. This set of questions sought to see if OHS officers are employed on all projects, and whether OHS files for the site are prepared by a qualified OHS officer.

From Table 4, the respondent's responses are significant. Emerging contractors are aware of OHS policies governing the project (mean score 4.52). This indicates that the emerging contractors are aware of the implications for not complying with OHS policies on site. Respondents believe all employees are always provided with PPEs, with a mean score of 4.38. This is followed by engaging a qualified OHS officer who always puts together the OHS files, with a mean score of 4.17. Lastly, with a mean score of 3.97, the majority of the sites did not have OHS officers employed.

**Table 4.** Internal OHS processes

Question posed	Never (1)	Rarely (2)	Sometimes (3)	Often (4)	Always (5)	Mean
I am aware of the OHS policies adopted in my respective construction site	0	6	3	36	145	4.52
PPE is provided to all employees on site	3	2	6	28	145	4.38
OHS file is prepared by a qualified OHS officer	6	2	9	8	150	4.17
OHS officer is employed in all projects	4	6	18	24	115	3.97

#### 4.4 OHS Training

The purpose of these questions was to interrogate the level of OHS-related training prevalent within SMME contractors and whether principal contractors do skills transfer on OHS-related training for smaller contractors they are in business with (Table 5).

**Table 5.** OHS training

Question posed	Totally disagree (1)	Disagree (2)	Agree (3)	Totally agree (4)	Mean
All staff are trained on OHS compliance on site	3	8	57	64	3.15
Staff have enough knowledge on OHS regulations	3	6	72	48	3.07
The main contractor normally trains subcontractor staff on OHS compliance	2	10	75	40	3.02

From the above, it can be seen that the participants attest that staff is trained on OHS compliance on their relative construction site with the highest mean score of 3.15. The means an overwhelming majority of participants identify OHS training for all staff on-site to be the norm. This is encouraging feedback that suggests that the OHS-related



issues encountered on construction sites across the country are not due to a lack of OHS-related training, as it appears that on-site personal receive more training than not. Again, the majority of the respondents believe their workers are knowledgeable in OHS regulations with a mean score of 3.07, whilst others stated that their workers are usually trained by the main contractors regarding OHS compliance, with the least mean score of 3.02. This also indicates that workers are very cognizant of OHS matters on site.

#### 4.5 Cost of OHS to SMME Contractors

The purpose of these questions was to interrogate OHS and PPE's cost implications to emerging SMME contractors and identify how the costs associated with PPE and OHS might be a factor that affects OHS compliance amongst contractors. Again, the question is to investigate whether emerging contractors make provisions for PPE and OHS compliance when tendering for new work and the implications of OHS non-conformances.

**Table 6.** Cost of OHS to SMME contractors

Question posed	Totally disagree (1)	Disagree (2)	Agree (3)	Totally agree (4)	Mean
Company has intentions of training staff on OHS compliance in future	1	4	63	72	3.34
Training of employees on OHS should be the cost of the company	1	2	78	56	3.24
The cost of OHS & PPE is too expensive	1	26	45	52	2.96
Including the cost of OHS and PPE in a tender makes the tender uncompetitive	3	28	48	36	2.71
Not including the cost of OHS increases my chances of winning a tender	6	28	39	36	2.57

Table 6 shows that with a mean score of 3.34, the respondents believe the company must train the workers about OHS requirements and that cost for training workers on

OHS should be absorbed by the company, with a mean of 3.24. However, with the mean score of 2.96, it is significant to state participants believe the cost of OHS and PPE are too expensive. Again with a means score of 2.71, the respondents opine that when the cost of OHS is priced, it makes them uncompetitive, thus limiting their chances of winning the tender. With the least mean score of 2.57, respondents believe that not including OHS price in the tender enhances their propensity to win. This points to a potential cause for non-conformance amongst subcontractors regarding OHS compliance.

#### 4.6 OHS Responsibility On-site

Respondents were then asked about who they believe is responsible for site safety; the results are indicated in Table 7. The majority (52%) of the respondents believe individual employees on-site should be responsible for ensuring OHS standards are complied with. However, 26.2% of them believe the contractor should ensure all workers obey the OHS. Again, others (11.9%) put the OHS check on the construction manager. This indicates that respondents are aware of the importance of a worker's own safety.

**Table 7.** OHS responsibility on site

Who's responsibility is it to ensure that OHS standards are upheld on-site?	No. of respondents	Percentages
Everyone on site is responsible for OHS standards being upheld	22	52,4%
The main contractor on site	11	26,2%
The construction manager on site	5	11,9%
Each subcontractor is responsible for their own OHS compliance	4	9,5%
<b>Total</b>	<b>42</b>	<b>100%</b>

## 5 Discussion

### 5.1 Emerging Contractors Awareness of OHS on Site

The research has discovered that SMME contractors believe that a safe work environment is necessary for the execution of work, and thus they are familiar with the OHS Act with the highest mean score of 4.52 (see Table 4). This research has shown that SMME contractors are aware of OHS policy that affects their work. They also have acknowledged the importance and purpose of OHS in construction projects, with the highest mean score of 3.34 (see Table 6). SMME contractors are also prepared to train their workers on OHS requirements and also believe they should bear the cost of the worker's training (mean score of 3.24 as indicated in Table 6). These findings are contrary to Kheni et al.' (2008) findings, where they attributed low compliance level of OHS by SMME contractors

in Ghana to low literacy levels and high labour-intensive methods of working. Also, the lack of emerging contractor's compliance with OHS regulations has been attributed to their ill-informed status of OHS regulations (Chiocha et al. 2011), contrary to this study's findings. However, the findings support the findings of Chiang (2009), where he identified that due to lack of profit resulting from stiff competition faced by SMME contractors, employee's OHS training is seldom, making them learn through experiences on the job.

## 5.2 OHS Compliance Challenges of Emerging Contractors

The findings show that the price pressure faced and low-profit margins that come with a competitive contracting industry mean that costs outside of the expenses directly related to the execution of works might prove too expansive for small emerging contractors to meet. This was rated as the second most important factor regarding the cost associated with OHS, with a mean score of 2.96 (see Table 6). Thus, PPE and OHS compliance price is a factor that strongly affects non-conformance concerning OHS on construction sites. The construction industry is price-driven; built environment products are assets, and projects are undertaken mostly for financial gain. As a result, the entire industry is shaped by commerce. The competition observed in the industry increases as work becomes increasingly hard to find due to a contracting economy and a decrease in economic and building activity (Botha 2020). As the competition increases, so do the measures companies are willing to take to win tenders and sustain their businesses. The research findings have shown that SMME contractors believe that they have a better chance of winning tenders if they do not price PPE in their bids. This factor was rated 4<sup>th</sup> with a mean score of 2.71, as stated in Table 6. Chiang (2009) has also observed that primarily subcontractors are profit-driven, and with the immense competition they face in the tendering process, they care less about employee protection and development. These findings are concerning as the industry's competitive nature appears to be disincentivizing provisions that should be in place for the purchase of PPE and other OHS-related expenditures. Especially because once the tender is awarded to the contractor, they will be expected to provide and comply with the PPE and OHS regulations for the site they will be working. Suppose they have not priced PPE and OHS-related expenses in order to increase their chances of winning; they will face difficulties with OHS compliance on-site because complying will diminish their profit margins. They will most likely look for ways to avoid spending money on OHS-related expenses, which in turn will lead to an unsafe work environment that is more likely to have work-related accidents, injuries, and fatalities because of non-conformances.

Again, the perception of the emerging contractors that the OHS compliance is too expensive (mean score of 2.96) is a challenge that limits their ability to acquire PPE for their workers to be compliant. As a result of the omission of OHS pricing in tender documents due to fear of losing the contract, emerging contractors are already handicapped financially; thus, spending additional income to acquire OHS equipment for the site workers becomes a challenge to them. This again supports the findings of Chiang (2009) that due to the quest to achieve profit, employee safety gadgets are not at the forefront of SMME contractor's planning. Again, another challenge identified is the perception of the main contractor being responsible for providing the OHS gadgets needed by all

site workers. The majority (59.30%) of respondents believe that the main contractor should purchase PPE for all personal on-site. This finding's significance is noticeable because it is related to another finding in this research relating to the pricing of PPE and OHS-related items when tendering for work. Despite the financial reasons described above, it is possible that because participants believe that the principal contractor should purchase PPE for the entire site, they don't need to price it in their tender documents. This finding also corresponds with Kongolo's (2010) findings that emerging contractors are ill-equipped to deal with OHS matters on site, believing that main contractors are responsible. Again, according to Chiocha et al. (2011), subcontractors are pushed by the main contractors to carry the burden of OHS on the project, although they are ill-equipped and lack resources and technical knowhow to comply with OHS requirements as they might have anticipated that OHS compliance will be the responsibility of the main contractor. Therefore, it is not surprising that the Construction National Blitz Inspection, done by the Department of Labour (DoL) at construction sites in South Africa, discovered prevalent non-compliant with the Occupational Health and Safety Act (Moiwa 2013).

## 6 Conclusion

The study has identified that the primary factor that hinders emerging contractors from complying with OHS regulations on construction sites is the lack of financial provisions for OHS-related expenditure when tendering for work. This results from the competitive nature of emerging SMME contractors in the construction industry, making them believe that they have a higher chance of being appointed for work if their bid amount does not include OHS costs for the work to be carried out. This might have contributed to poor OHS compliance observed on construction sites. The research has also shown that most emerging contractors are aware of the importance of OHS on-site and the importance of training staff on good OHS habits. Emerging contractors understand the importance of safety, yet they find it challenging to implement the necessary safety measures required on-site because of financial constraints. Based on the findings, the study recommends making the provisions for the pricing of OHS-related expenditure compulsory for all contractors tendering for work and not just the principal contractor. No principal contractor should accept and consider a tender for any work item unless that subcontractor has priced for PPE and OHS-related expenditure. The construction sector's entry barriers need to be raised and defined to prevent a situation where individuals work for companies without understanding the industry, regulations, values, and construction-related work for monetary gain alone.

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# Alternative Sustainable Methods for Reconstruction and Development Housing Construction: The Perspective of Built Environment Students

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**Abstract. Purpose:** The South African government is currently struggling to meet the demand for social housing for the less privileged and low-income earners citizens. The modern, alternative sustainable construction methods are believed to be faster and cheaper. Yet, the implementation of modern sustainable construction methods in the provision of Reconstruction and Development Programme (RDP) housing has been slow-moving. The study investigates the built environment students' perception concerning the feasibility of adopting alternative construction strategies in RDP houses provision.

**Methodology:** A questionnaire was used to survey 73 senior built environment students randomly selected at the University of the Free State and the Central University of Technology. Data received were analyzed via Excel statistical tool to calculate the frequencies, percentages, and mean values.

**Findings:** The findings show that alternative construction methods can be applied to RDP housing; however, the students perceive various barriers to using alternative construction methods to RDP housing. The barriers include affordability, lack of interest from the government, lack of proven innovations, and lack of authorities' understanding of the benefits. The most viable alternative construction methods among the respondents from the options given are renewable energy, re-use of waste materials, design for disassembly of units, and community members participating as labourers in the construction process.

**Implication:** The implication is that there should be an urgent need to advance knowledge among students in the built environment in this construction method to improve the skills needed for implementation in the social housing programme to improve cost savings and other associated benefits.

**Keywords:** Alternative · Construction method · Barriers · Built environment · RDP housing

## 1 Introduction

The African National Congress (ANC) (1994) states that The Reconstruction and Development Programme (RDP) is a chassis that blends and rationalizes a socio-economic

blueprint. The policy aims to utilize citizens and the nation's resources for doing away with the effects of apartheid to the realization of a democratic tomorrow that is non-racial and non-sexist. The ANC conceived the RDP's origins in consultation with other institutions such as non-government organizations and research bodies (ANC 1994). The RDP is a perpetual programme that is firmly planted into the core values of the nation's leading political party, ANC (ANC 1994). However, the RDP's perpetuity can be said only applies to the "reconstruction" fragment of the term. Procter (2015) defines development as "The process in which someone or something grows or changes and becomes more advanced."

Given the above, can it be said that RDP housing's design and construction methods have "developed"? Moyo and Mamabolo (2014) argue that another government's development programme, the National Development Plan, have invalidated the potentially more warranting RDP. The lack of development in RDP housing is reflected in the rudimentary way the houses were still designed in the 19<sup>th</sup> century. Kubba (2017) states that building inhabitants' output and health are being negatively affected by buildings that have been planned and built conventionally. Besides, the maintenance and operative costs of these buildings have become increasingly expensive. A macroeconomic problem affecting RDPs is South Africa's energy crisis. Pretorius et al. (2015) say that the electricity tariff grew markedly due to the electrical grid's pressure. To meet the urge for heating and energy, lower-income families resort to the burning of solid fuel. The demand on the grid also causes increased emissions caused by the decay of the power stations.

Ross et al. (2010) addressed the evaluation framework of 49 indicators to assess how several case studies implemented the six principles of sustainable construction. Implementations such as the re-use of existing buildings, utilization of non-toxic products, providing settlements with adequate density and suitable locations are some of the sustainable methods that were implemented in the case studies. Osman and Herthogs (2010) investigated sustainable design and construction of South African social housing and deduced that design geometry, standardization, buildability, and efficient design are key factors in providing economics and effective life cycle design in social housing. The sustainability and quality issues in South African housing have been overlooked at the cost of promoting political agendas and improving economic indicators (Du Plessis 2001). The nation's deficit for housing provision is continuously on the rise even as the supply is orientated towards quantity instead of considering the implementation of sustainable construction (Ross et al. 2010). Du Plessis (2001) states that South Africa needs to move on from lacklustre housing and environmental circumstances found in poor and low-income communities by implementing sustainable construction.

This study will also assess alternative construction methods using an evaluation framework of certain sustainable principles. The South African government is currently struggling to meet the demand for social housing for the less privileged and low-income earners citizens. The modern, alternative sustainable construction methods are believed to be faster and cheaper. Yet, the implementation of modern sustainable construction methods in the provision of RDP housing has not been encouraging. The study seeks to offer the perspective of built environment students regarding adopting alternative sustainable construction methods in the RDP housing provision.



## 2 Theories Underpinning the Study

### 2.1 Reconstruction and Development Housing (RDP) in South Africa

Greyling (2009) explains that the government's housing where the cumulative income is less than R3 500 is referred to as RDP housing. These houses are usually large enough to accommodate a single-family into a basic single storey. Already existing buildings could also be altered into RDPs over and above the new houses being built. Existing buildings used for low-cost housing are usually prevalent in large cities' central business districts (Greyling 2009). Nelson Mandela's ANC government implemented the Reconstruction and Development Programme in 1994. Negotiations, consultations, and discussions took place amongst the ANC and its allies, comprising of the Congress of South African Trade Union (COSATU), the South African Communist Party (SACP), and other various stakeholders that represent the broader population (Gauteng Department of Housing 2009). Solving socio-economic issues that existed due to apartheid was the predominant aim when the Reconstruction and Development Programme was being developed and implemented. By distributing tax income for development projects, the state's goal was to mitigate poverty and furnish more formidable social services for South Africans previously disadvantaged (Hall 2005). However, the Reconstruction and Development programme is about alleviating poverty; it aims to build a rugged macro-economic atmosphere for the disadvantaged (Charlton 2013). Furthermore, Charlton and Meth (2017) say that the purpose of RDP housing is to cater to the basic requirements that South African families have a right to, such as sanitation, access to education, healthcare, electricity, and clean water. The RDP is aimed more so at South Africans that are disadvantaged.

Families are bestowed with another chance at improving their quality of life due to the multitudinous houses being constructed from the Reconstruction and Development Programme (Manomano 2013). Beneficiaries of the programme usually originate from squatter camp boarding where problems such as crime are concerning, and the unhealthy living conditions can lead to diseases spreading over and above other health issues. RDP housing aims to protect its residents against crime and the aforementioned environmental factors (Manomano 2013). However, the government is floundering in terms of meeting the demand for social housing as a whole. To speed up the process of providing housing, developers are stimulated to assist the government with the provision of new supplies of housing (Greyling 2009). RDP housing construction occurs typically on the periphery of cities where undeveloped plots are relatively affordable (Sobuza 2011). However, Goebel (2007) says there are vast disadvantages to developing on the outskirts of cities. These include a lack of schools, shops, and medical facilities.

As mentioned, Greyling (2009) reiterates that the RDP develops new dwellings and reconstructs buildings that are already in existence. One key principle of sustainable construction is to maximize resource reuse to avoid and reduce waste (Kibert 2008). The justification for rejuvenating existing buildings for social housing is due to the intensive use of land in cities – resulting in an ever-growing scarcity of sites to build on. A benefit of developing pre-existing buildings into affordable housing is that they have already been zoned for residential use, which results in time saved that would otherwise have been used for the re-zoning process (Sobuza 2011). The basic process of converting

existing buildings into RDPs is to select buildings that are still fairly in a condition to be occupied, and the interior must be redone so it meets the requirements they can be used for (Manomano 2013).

RDP housing's initial specifications generally comprise two-room masonry buildings with a corrugated iron roof (Greyling 2009). There has been an upgrade of the specifications since the initial years of the programme. A unit is now usually a 5-room masonry structure with either corrugated iron roof sheeting or clay tiles, depending on the region. A geyser for hot water is optional (Fox and Tulip 2014). Despite the improvements, most RDP houses built before 1997 do not meet the National Home Building Regulations Council (NHBRC) standards (Fox and Tulip 2014).

## 2.2 The Problems Associated with RDP Construction

In 1994, the government aimed to mitigate the housing backlog by building 300 000 houses annually (City of Tshwane 2009). The setbacks were numerous. However, Manomano (2013) says that 1 million houses were built in the 6 years after. Despite this claim, goal-driven projects such as the RDP housing scheme present problems where quantity is more important than quality (Hall 2005). An audit conducted by the Department of Housing discovered that RDP structures do not meet the standards of the NHBRC (City of Tshwane 2009). The main issues with these structures are that many of them had construction problems such as loose and/or leaky doors and windows. Roofs also showed apparent defects as well as sanitary spaces (Fox and Tulip 2014). Fox and Tulip (2014) further state that before the NHBRC was established, the houses measured at only 16 m<sup>2</sup>. The regulations from the council mentioned above stated that there had to be an extension on the houses. The extra room was added and increased the total area to about 40 m<sup>2</sup> (SAPA 2008).

The theft of building material during RDP housing construction is a prevalent concern (Greyling 2009). This subsequently led to many houses having to be constructed again due to their poor quality. Many prospective beneficiaries were left distraught due to the number of years they have waited to be allocated houses (Sobuza 2011). The repurchasing of stolen material is also seen as a waste of money by the government (Greyling 2009). Sobuza (2011) continues to say that illegal occupation is also prevalent in RDP housing, as many occupants could not provide valid title deeds during inspections. The government is scrapping to keep up with the perennial demand for low-cost housing. As the government attempts to lure private developers into investing in low-cost housing, they encounter challenges due to such projects' low profitability (Fox and Tulip 2014). However, Greyling (2009) adds that government can use legislation to have private developers build low-cost housing to a certain degree. The provision of peripheral infrastructure is an issue for areas zoned for RDP developments. Although there is an acceptable degree of access roads to RDP housing projects in the peripheries of towns, much of the area is uncovered soil instead of paving with hardly any vegetation covering (Fox and Tulip 2014). Govender et al. (2011) state that the maintenance of existing infrastructure is also imperative. Potholes are found, which leads to other issues. The city of Cape Town (2014) says that the maintenance of infrastructure is the government's responsibility. However, physical maintenance of the houses is the responsibility of the end-users as well (Govender et al. 2011).

### 2.3 Sustainability in Construction

It is often noted that the construction sector is hostile and not friendly to the natural environment. The perennial wrecking and subsequent monumental effects the building industry has on the environment have been scrutinized by many researchers (Davies and Davies 2017). The concept of sustainable construction is still in its formative stages in developing countries such as South Africa instead of the relatively widespread implementation it has had in developed countries. The need for sustainable construction stems from the concept of providing an ideal standard to produce a built environment that makes provision for current human requirements as well as the needs for future generations (Davies and Davies 2017). A report by Du Plessis (2007) stated that most developing nations have the burden of overcoming imperative threats such as the lack of housing and infrastructure, astronomical rates of poverty, inadequate institutions, high urbanization rates, lackluster economies, and substandard human development indices. There is also an ambiguity with the construction activities in the context of developing countries. There have been attempts on multiple occasions to consolidate the gaps in housing and infrastructure requirements to instigate socio-economic development and activities that injuriously affect the environment socially and economically (Du Plessis 2007). Davies and Davies (2017) therefore suggest that as sustainability is becoming a grave issue globally, there is a need for developing countries to focus on attempting to curb the severe implications associated with it. However, Thorpe and Ryan (2007) discovered an insufficiency concerning inroads made in developing nations regarding sustainable construction. For sustainable construction to be realized, construction sector stakeholders have imperative roles to play.

### 2.4 Alternative Construction Methods in the Housing Sector

Many alternative construction methods that can generally be applied in RDP housing have already been appraised in the previous section. This section aims to focus on alternative construction methods that can counteract the problems specifically found in RDP housing. McGaffin (2018) states that RDP houses in different provinces usually consist of different materials due to the differences in climatic conditions. McGaffin (2018) further states that houses in different regions vary in terms of development due to and economic benefits being realized when using locally sourced materials. The use of recycled material was of low priority when the government built the first RDP houses due to their focus on meeting quantity for the lowest cost (Oldfield 2000). The City of Tshwane (2009) states that sustainability has been given attention by using local materials and the local community in recent projects.

The first alternative method that would benefit RDP housing greatly is the use of pile or raft foundations. Greyling (2009) states that RDP housing prevalently uses strip foundations. The use of strip foundations is not suitable in all regions of the country, especially the Free State, where Ntapane's (2007) geotechnical ground report states that the province mostly consists of clay soil. Ntapane (2007) further reports that strip foundations are not the ideal foundation types for clay soil conditions, as they could cause wall cracks. Greyling (2009) states that current RDP houses use standard steel windows and door frames. McGaffin (2018) then reported coastal area developments preferring

to use wooden windows, doorframes, and doors to prevent rust formation. As stated in the problems associated with RDP housing, high water tables could risk flooding in a particular area (Goebel 2007). Some solutions exist to prevent the ingress of water but would prove to be too expensive. An economical solution would be for projects to simply not be built on sites with a high water table (Goebel 2007).

Finally, gutters are not being used in RDP housing is stated as another problem (Hotton 2005). While the inclusion of gutters is not inherently seen as an alternative construction method, how the gutters are used could create alternative solutions. Hotton (2005) suggests that gutters can mitigate soil erosion, as water can be diverted to a stormwater system or used for irrigation or flushing toilets after being collected. Dewick and Miozzo (2004) state that many alternative construction methods can solve the issues concerned with social housing. However, the adaptation of these methods is hampered mainly by their cost. These solutions require niche materials and specialist supplies (Dewick and Miozzo 2004). Despite that, alternative construction methods that incur a minimal cost are shown to exist and deemed effective from other projects.

### 3 Methodology

The research approach adopted for the study is quantitative. According to Fischler (2015), a quantitative research approach decodes a research problem. A survey was done among the built environment students studying at the University of the Free State and the Central University of Technology in Bloemfontein, Free State of South Africa. Since the study is about the perception of the built environment students on the adoption of alternative construction methods (ACM) in the provision of the RDP houses, only students from the second year of study were included in the sample as they may have acceptable knowledge on ACM based on what they have studied. The collated data can be sourced from a group or multiple survey questions being asked by an entity to produce numerical aggregates (QuestionPro 2020). The prime reason for using a survey was the simplicity of surveys (Humans of Data 2020). Secondly, survey questions are easily distributed to a wide range of respondents within the target population in digital form, and therefore, it was less time-consuming compared to other face-to-face (Humans of Data 2020). The study was done during the COVID-19 pandemic, where the human movement was restricted; thus, using survey questions allowed for easy distribution compared to face-to-face interviews.

Closed-ended questions in the form of a Likert scale were used, where the respondents have to tick based on their opinions. The questions were divided into two sections; the first section dealt with the respondents' demographic data whilst the second section examined their views on the possibility of adopting alternative construction methods in the provision of the RDP houses. In all, 120 sets of questionnaires were distributed, of which 73 responded, indicating a response rate of 61%. Data received were then analyzed using descriptive statistics in an easily interpretable way and for the conclusion to be consequently drawn (Flick 2015). The demographic data of the respondents are shown in Table 1.

**Table 1.** Demographics of the respondents

Respondents features	Frequency	Percentages	Respondents features	Frequency	Percentages
<i>Gender</i>			<i>Year of study</i>		
Male	45	61.6%	Second-year	31	42.5%
Female	28	38.4%	Third-year	32	43.8%
<b>Total</b>	<b>73</b>	<b>100%</b>	Fourth year	10	13.7%
<i>Age</i>			<b>Total</b>	<b>73</b>	<b>100%</b>
18–20	34	46.6%	<i>Study programme</i>		
21–23	36	49.3%	Quantity surveying	38	52.1%
24–26	3	4.1%	Architecture	12	16.4%
<b>Total</b>	<b>73</b>	<b>100%</b>	Engineering	17	23.3%
<i>Work experience</i>			Other	6	8.2%
Experience	12	16.4%	<b>Total</b>	<b>73</b>	<b>100%</b>
No experience	61	83.6%	<i>Familiarity with alternative construction methods</i>		
<b>Total</b>	<b>73</b>	<b>100%</b>	Yes	69	95%
			No	4	5%
			<b>Total</b>	<b>73</b>	<b>100%</b>

From Table 1, it is indicated that 61.6% of the respondents are males, 49.3% are within the age of 21 to 23, and 43.8% are in their third year of study. Again, most respondents (52.1%) study quantity surveying, whilst the majority (83.6%) have no work experience. Also, 95% of the respondents are familiar with the ACM. These statistics indicate that males dominate the built environment students. Since the respondents are students, they are yet to enter the job market after school; hence, a lack of work experience is evident. Since the study is about their perception of the adaptability of ACM in the provision of RDP houses, their views will be interesting as they may have the same views or perceptions when they enter the built environment market.

## 4 Findings

### 4.1 Respondent's Opinion on General Barriers to the Implementation of Sustainable Construction Methods in RDP Housing

The question sought to find out the various barriers to alternative construction implementation in RDP housing. The ranking for these general barriers to implementing sustainable methods to RDP housing is from 1 to 5, with 1 being the least challenging factor and 5 being the most challenging factor. The respondent's responses are shown in Table 2.

**Table 2.** Opinion of respondents to general barriers to the implementation of sustainable methods in RDP housing

Alternative construction method implementation challenges	SD (1)	D (2)	N/D (3)	A (4)	SA (5)	Mean	Ranking
Affordability	1	10	12	36	270	4.50	1
Lack of interest from the government	7	20	30	56	170	3.88	2
Lack of proven innovation	10	18	21	108	100	3.55	3
Lack of understanding of benefits from authorities	10	22	27	100	90	3.41	4
Material durability issues	5	34	63	64	70	3.23	5
Maintenance related problems	12	28	81	44	45	2.88	6
Lack of awareness of sustainable development from end-users	14	68	21	36	45	2.52	7
Lack of demand from the public	26	56	27	16	30	2.12	8
Dislike by end-users	24	48	18	20	20	1.78	9

According to the findings, the most challenging factor for ACM adoption in the RDP housing according to the respondents indicated that affordability, with a mean score of 4.5, followed by a lack of interest from the government (mean score = 3.88). Other factors considered challenging are lack of proven innovations (mean score = 3.55), lack of understanding of benefits from authorities (mean score = 3.41), and material durability issues (mean score = 3.23). These five factors are the respondent's challenging factors for implementing ACM in providing RDP houses. The remaining factors mitigating against the adoption of ACM in the provision of the RPD houses are maintenance related problems (mean score = 2.8), lack of awareness of sustainable development from end-users (mean score = 2.52), lack of demand from the public (mean score = 2.12), and dislike by end-users (mean score = 1.78).

#### 4.2 Viability of Alternative Construction Methods in RDP Housing

Respondents were also asked to share their opinions on the viability of implementing alternative construction principles in RDP housing construction. Respondents believe that all the listed alternative construction principles could be applied in the construction of RDP houses. Renewable energy was considered to be highly applicable in the RDP housing construction (95%), followed by the reuse of waste materials (87%) and then design for disassembling of units (69%). Other significant alternative construction principles that could be incorporated in the RDP housing construction suggested by the respondents are passive thermal design (67%) and community participation in the construction process (66%). The respondent's responses are shown in Table 3.

**Table 3.** Alternative construction principles measured against their viability of implementation

Alternative construction principles	Yes	No
Renewable energy	69 (95%)	4 (5%)
Passive thermal design	49 (67%)	24 (33%)
Aesthetic appearance	47 (65%)	26 (35%)
Community participation in the construction process	48 (66%)	25 (34%)
Water harvesting	46 (63%)	27 (37%)
Design for disassembling of units	50 (69%)	23 (31%)
Low embodied energy materials	44 (60%)	29 (40%)
More durable materials and structure	42 (58%)	31 (42%)
Reuse of waste materials	64 (87%)	9 (13%)
Minimising land use	41 (56%)	32 (44%)

### 4.3 Challenges Contractors Face in Implementing Alternative Methods

In the survey, respondents were asked to rank the challenges contractors are most likely to face in implementing alternative construction strategies on a scale of 1 to 5, with 1 being the least challenging factor and 5 being the most challenging. The contractor's challenges are shown in Table 4.

**Table 4.** Challenges contractors may face in implementing alternative methods

Alternative construction method implementation challenges	SD (1)	D (2)	N/D (3)	A (4)	SA (5)	Mean	Ranking
Sustainable raw materials are expensive	6	14	24	16	280	3.65	1
Lack of skilled labour on sustainable projects	6	12	18	136	40	2.91	2
A struggle to integrate technology into the construction process	9	18	105	68	15	2.84	3
Inexperienced of working with sustainable materials	20	60	45	52	10	2.59	4
Implementation of sustainable strategies is time-consuming	32	48	27	20	20	2.04	5

The highest-ranked challenges for contractors implementing alternative construction methods cited by the respondents are sustainable raw materials being expensive (mean score of 3.65). The second-highest ranked challenge is the lack of skilled labour to work on projects with sustainable strategies (mean score of 2.91). Third-ranked is a struggle to integrate technology into the construction process (mean score of 2.84), followed by

the lack of skilled labour to work on sustainable projects (ranked 4) with a mean score of 2.59 and implementing sustainable strategies in time-consuming (ranked 5) with a mean score of 2.04. This means that the built students foresee cost as the main hindrance contractors cannot recommend ACM to the government.

## 5 Discussion

### 5.1 The Viable Alternative Construction Methods that Can Be Implemented in RDP Housing

The first research objective was to determine viable alternative construction methods that can be implemented in RDP housing. From the findings, the respondents acknowledged the viability of various alternative construction methods such as renewable energy, passive thermal design; aesthetic appearance; community members participating as part of the construction labour; water harvesting; design for disassembly of units, low embodied energy materials; more durable materials and structure; reuse of waste materials and minimizing land use. The findings support Moolla et al.'s (2011) proposal that one of the major alternative construction methods to design for is the orientation of the longest side of a building that should face north for maximum incoming solar radiation absorption. An extension of the roof overhang is recommended on the house's northern and western sides due to the surplus solar radiation. The overhang will provide shade in the summer, and the sun's rays will enter through the window during winter due to the sun's low angle during the winter months. Again, the passive thermal design was ranked fourth in terms of the most viable alternative methods. It has been suggested that reusable plastic panels that are moulded off-site and eventually moulded on-site are alternatives for daylight energy for houses (Moladi 2019). Again, the reuse of recyclable waste materials was considered by the respondents as a highly viable option. Its application in the construction of the RDP houses has been identified by Oldfield (2000) as less prioritized as the government focuses on meeting quantity at the lowest cost possible. Surprisingly, water harvesting was not considered a highly viable option. This may be the easiest sustainable construction principle that could be implemented in the RDP housing construction to resolve persistent water problems in the RDP housing communities.

### 5.2 The Challenges Faced in Applying ACM in the RDP Housing Programme

The second research objective was to identify the challenges that can be expected when applying alternative construction methods compared to traditional methods. From the findings, the top 5 challenges in the ACM in the RDP housing construction are affordability (mean score of 4.5), lack of interest from the government (mean score of 3.88), lack of proven innovations (mean score of 3.55), lack of understanding of benefits from authorities (mean score of 3.41), and material durability issues (mean score of 3.23). Dewick and Miozzo (2004) have also raised the issue of affordable being a barrier to implementing ACM in the RDP housing where they stated that various ACM could be used to resolve the concerns that engulfed the social housing; however, the cost aspects have curtailed their adoption. Govender et al. (2011) argue that there is skepticism to alternative construction methods instead of brick and mortar housing due to



material durability issues. This also supports the respondents' views that material durability issues are a challenge to the adoption of ACM for the RDP houses. Again it has been identified that the building policy in South Africa is more concerned about the environment compared to the building materials (Du Plessis 2007). Taylor and Norval (1995) suggest that the rapid delivery of social houses is a means of job creation for economic and social sustainability rather than building sustainability. Again, Ross et al. (2010) opine that although the new Housing Policy and Strategy for South Africa in 1994 mentions sustainable construction, insufficient strategies have been made to link efficient thermal properties of housing and the energy sector generation requirements. Instead, the government's strategy has been to meet the number of houses built with little regard for building sustainability. Thus the lack of interest and understanding for the adoption of ACM on the part of the government stated by the respondents correspond with the evidence from the literature. Ofori et al. (2006) iterate that the government's policy must take precedence for energy saving and sustainable construction. For the environment to be more sustainable in the country, legislation must be considered for change. Adequate regulations, policies, and bodies do not currently exist to advocate for sustainability, and the ones that do exist have not been put in place from a practical point of view. Yudelson (2009) also suggests that alternative building principles should take precedence by comprehensively transforming policies such as performance regulations for construction works to be more sustainable.

## 6 Conclusion

According to the empirical findings, sustainable alternative construction methods are believed to reduce the cost and time of constructing and operating RDP housing. The ACM and sustainable construction principles could be implemented in the housing sector, including RDP. However, challenges such as affordability, lack of interest from the government, lack of proven innovations, lack of understanding of benefits from authorities, and material durability issues obstruct the implementation of these alternative methods, not only from the government's side as the employer. From the contractor's standpoint, respondents believe that problems such as the cost of sustainable building materials, integrating technology into the construction process, implementing alternative strategies being too time-consuming, a lack of proven innovations, and skilled labour to execute sustainable projects and sustainable projects being too time-consuming, are hampering their effort to undertake the sustainable project. If these are addressed, the housing situation will improve eventually in terms of quality and cost. Therefore, it is recommended that the government consider investing in research and development in tertiary institutions to help find various ways to apply ACM in the social housing sector. Built environment students should be extensively trained on the available ACM methods in the housing sector and their designs and applicability to enhance their implementation capacity after school. Building environment students' skills training on ACM should be improved and prepare them for the ACM implementation. The housing regulation should be strengthened concerning sustainable construction, and these regulations should be enforced in the housing sector.

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# Quality Assurance Management for Higher Education Harmonization Agenda's Sustainability in Africa

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**Abstract. Purpose:** This study investigated quality assurance management for higher education harmonization agenda's in Africa. In achieving the aim various objectives were employed which are identify the ways of managing information systems for higher education harmonization agenda's sustainability in Africa, evaluate the ways of managing facilities for higher education and determine the ways of managing personnel for higher education harmonization agenda's sustainability in Africa.

**Design/Methodology/Approach:** Simple random sampling technique was used, based on the diverse nature of the population. The study adopted an analytic survey design while the population of the study was 1,225 recognized universities in Africa comprising 639 universities in the southern hemisphere and 586 universities in the northern hemisphere. The sample for the study was 484 universities and their heads of quality assurance unit which consisted of 246 universities and their quality assurance heads in the southern hemisphere and 238 universities and their heads in the northern hemisphere. The data obtained from the study were analysed and presented in tables.

**Findings:** Findings of the study revealed that the quality assurance heads agreed on the ways of managing information systems, records and documents, facilities and personnel for higher education harmonization agenda's sustainability in Africa.

**Research Limitation/Implications:** The study focused on quality assurance management practices for higher education harmonization agenda sustainability in Africa.

**Practical Implication:** The knowledge advanced in this study will inform all higher education stakeholders of the factors that significantly enhance the sustenance of the harmonization agenda in Africa.

**Social Implication:** The knowledge advanced by this study will help the harmonization agenda which is geared towards enhancing the integration, collaboration, cooperation, partnership and coherence of educational programmes in higher institutions around the continent such that knowledge, ideas and other best practices can be shared across the continent for the benefit of all.

**Originality/Value:** The novelty of this study lies in the harmonization of the activities such as the management of information, documents and records, facilities and personnel of higher educational institutions for the development of Africa.

**Keyword:** Evaluation · Harmonization · Quality assurance · Higher education · Sustainability

## 1 Introduction

Africa is no doubt one of the most populated continents in the world with sufficient human and natural resources for speedy growth and development. Unfortunately, research has shown that the continent is still dependent on other continents and this has created series of an economic, social and political vacuum in the continent which needs to be filled. To deal with this situation, educational scholars have pointed out that higher educational institutions hold the key to the emancipation of the continent like other continents of the world. This has necessitated the harmonization of the activities of higher educational institutions for the development of the continent.

The harmonization of the developmental agenda of Africa is a necessity to compete favourably with other continents of the world. Similarly, there is a continental call for the sustainability of the existing harmonizing plan as well as enhancement of the existing structure to push the continent towards the path of development. This drive has continued to attract the attention of educational stakeholders around the continent for a long time. The harmonization agenda is geared towards enhancing the integration, collaboration, cooperation, partnership and coherence of educational programmes in higher institutions around the continent such that knowledge, ideas and other best practices can be shared across the continent for the benefit of all. The harmonization of the developmental agenda of the continent through higher educational institutions has continued to draw attention among stakeholders in all sectors. Woldegiorgis (2013) asserted that:

Harmonization, as applied to education, is not synonymous with uniformity, standardization, regulation, condensation homogenization or unification of all higher education systems. Rather, harmonization refers to the coordination of educational programmes with agreements to minimum academic standards and ensuring equivalence and comparability of qualifications between and within countries. Harmonization, as it is applied to African higher education, for example, is intended to promote the comparability of degree programmes and recognition of their equivalencies across the continent, thus facilitating the promotion of quality and mobility of both staff and students in the continent (AAU as cited in Woldegiorgis 2013).

However, higher educational institutions have a major role to play in the achievement of this objective. The quality of the harmonization objective depends largely on the existence, institution and management of quality assurance practices in every ramification. This no doubt will play a major role in the attainment of quality harmonization sustainability agenda. According to Doherty (2015) (n.d.:75), “quality assurance is a proactive approach which attempts to identify problems and deal with them immediately, or even better prevent them from happening at all”. It can therefore be deduced on this premise that the institutionalization of quality assurance practices in every ramification will contribute greatly to the sustainability of the harmonization agenda in the continent. Similarly, the management of these quality assurance practices is relevant to

the achievement of this objective. Quality assurance management which is the application of management principles such as planning, directing and organizing into the quality assurance process is therefore important for the actualization of this objective (Amir 2015, Elijah et al. 2019).

Quality in an education system can only be assured when issues about the management of information, documents and records, facilities, personnel among others are given due attention. It is the management of these components of quality assurance that makes goals and objectives in the education sector achievable. According to Amini-Philips and Elijah (2019) educational scholars have quipped that the management of relevant information in an education system contributes to the smooth administration of the system. The continent through the safeguarding of information, sorting and planning and demanding for feedbacks on useful information is a quality assurance practice that cannot be ignored in the interest of the continent. Furthermore, the Policy on Information Management in the Education Sector (2014) pointed out that information management is a necessity especially in a decentralized system such as we have in Africa.

The management of existing documents and records plays an important role in the attainment of relevant educational goals and objectives. According to Ibara (2010) records and documentation are important for accountability in any institution. It was further quipped by Ibara (2010) that quality organizational performance, task accomplishment, and measurable outcomes are important and depends on records and documentation. In the same manner, Akanbi as cited in Amanchukwu and Ololube (2015:12) asserted that “the purpose of record-keeping for effective school management is to ensure that accurate and proper records are kept of student achievement and growth, school activities and matters that will promote school efficiency and effectiveness”. This quality assurance practice is relevant to higher education institutions harmonization sustainability agenda in Africa.

In a related dimension, educational scholars have also quipped that the management of available school facilities is also important for the assurance of quality in schools. The management of school facilities in terms of their quality and quantity contributes greatly to quality assurance and for the attainment of relevant educational goals and objectives. Asiabak (2008:11) stated that “facilities management is the application of scientific methods in the planning, organizing, decision-making, coordination and controlling of the physical environment of learning for the actualization of the educational goals and objectives”. This practice helps to ensure that staff and students have all it takes to meet their educational goals and objectives for the benefit of all educational stakeholders.

The management of people in any educational institution is also crucial to sustainable development in educational institutions across all levels (Elijah 2019). Management of school personnel is important for the transmission of the needed skills and knowledge which can be used to develop the content across all levels. Explaining further, Okoh and Abraham (2009:307) asserted that “personnel management in public schools can be described as the process of getting qualified personnel to provide instructional services necessary for the attainment of the goals of the system”. Similarly, Arikewuyo and Adegbesan as cited in Okoh and Abraham (2009:307) opine that it is the responsibility of the personnel department to recruit, develop, induct and motivate workers. All of these actions are taken to enable the workforce to contribute to the attainment of the

harmonization agenda of the continent. It was based on this premise that Prachi as cited in Agunwa and Valentine (2019:391) stated that “personnel management focuses on using and maintaining a satisfied workforce” that will contribute to outlined goals and objectives. This practice is relevant for quality assurance in the attainment of outlined developmental agenda.

The management of the factors that contribute to quality assurance is important for higher education harmonization sustainability. This process which involves planning, organizing, directing and controlling the various operative function of procuring, developing, maintaining and utilizing of educational resources. Vaghela (2015) and Elijah (2019) are fundamental for the attainment of the harmonization agenda. This practice needs to be developed as a culture for the growth and development of the continent like other continents of the world. Quality assurance management makes the harmonization agenda possible by unifying educational inputs, processes and output for possible exchange in programmes and policies for the development of the continent.

Africa has continued to struggle economically, socially and politically when compared with other continents of the world. It is also not surprising as higher institutions in Africa which are supposed to be the wheel for socio-economic growth and development in the continent cannot compete with others around the world as revealed in several higher education rankings. The slow pace of growth and development in the continent pose a threat to the sustainable development of the continent.

The inability of higher education institutions to compete favourably with others around the world has been attributed by researchers to the poor quality of educational outputs in terms of quality of graduate as well as the performance of students. In addition to this, doubts have also been raised as regard the quality of educational processes which are supposed to produce quality educational output. This development has continued to raise fears among concerned citizens who are worried if the continent will be able to attain sustainable and harmonized development like other continents of the world. It has therefore become imperative to investigate quality assurance management practices for higher education harmonization agenda sustainability in Africa.

The study investigated quality assurance management for higher education harmonization agenda’s sustainability in Africa. In specific terms, the study sought to: Identify the ways of managing information systems for higher education harmonization agenda’s sustainability in Africa; Examine the ways of managing documents and records for higher education harmonization agenda’s sustainability in Africa; Evaluate the ways of managing facilities for higher education harmonization agenda’s sustainability in Africa and Determine the ways of managing personnel for higher education harmonization agenda’s sustainability in Africa.

## 2 Methodology

The study adopted an analytic survey design while the population of the study was 1,225 recognized universities in Africa comprising 639 universities in the southern hemisphere and 586 universities in the northern hemisphere. The sample for the study was 484 universities and 484 heads of quality assurance units which consisted of 246 universities and their quality assurance heads in particular in the southern hemisphere and 238



universities and their heads in particular in the northern hemisphere. The sampling technique adopted for the study was a simple random technique. The instrument used for data collection was a 20 items questionnaire titled Quality Assurance Management for Higher Education Harmonization Agenda's Sustainability in Africa Questionnaire (QAMHEHASAQ). The instrument was responded to on a four-point modified Likert scale of Strongly Agreed (SA), Agreed (A), Disagreed (D) and Strongly Disagreed (SD) with weighted values of 4, 3, 2 and 1 respectively. The instrument was validated by Measurement and Evaluation experts while Cronbach alpha was used to estimate the internal consistency of the instrument with an index of 0.76 which was considered adequate for the study. Research questions raised were answered using mean, standard deviation and rank order while the hypotheses were tested using z-test at 0.05 level of significance.

### 3 Findings

**Research Question One:** What are the ways of managing information systems for higher education harmonization agenda's sustainability in Africa?

**Table 1.** Mean, standard deviation and rank order on the ways of managing information systems for higher education harmonization agenda's sustainability in Africa

S/No	Items	Northern hemisphere n = 246		Southern hemisphere n = 238		Mean set	Rank	Decision
		Mean	SD	Mean	SD			
1	Information is planned before it is released	3.18	0.68	2.98	0.86	3.08	1 <sup>st</sup>	Agreed
2	Multiple information medium are used for communication	3.07	0.66	2.70	0.91	2.89	2 <sup>nd</sup>	Agreed
3	Important information are digitalized	2.99	0.83	2.53	0.99	2.76	3 <sup>rd</sup>	Agreed
4	There is provision for feedback on all information	2.61	0.92	2.68	0.92	2.65	4 <sup>th</sup>	Agreed
5	Information are regularly assured	2.51	1.09	2.71	0.90	2.61	5 <sup>th</sup>	Agreed
	<b>Grand Mean and Standard Deviation</b>	<b>2.87</b>	<b>0.84</b>	<b>2.72</b>	<b>0.92</b>	<b>2.80</b>		<b>Agreed</b>

Table 1 showed that the responses of the heads of quality assurance in the northern hemisphere to items 1, 2, 3, 4 and 5 were 3.18, 3.07, 2.99, 2.61 and 2.51 while the responses of the heads of quality assurance in the southern hemisphere had mean scores of 2.98, 2.70, 2.53, 2.68 and 2.71. All of the items were above the criterion mean score of 2.50 used for decision making and as such were agreed. The rank showed that item 1



came first that information is planned before it is released while item 5 came 5<sup>th</sup> meaning that information is assured as way of managing information systems. Similarly, the heads of quality assurance in the northern hemisphere responded with a grand mean score of 2.87 and the heads of quality assurance in the southern hemisphere with a mean score of 2.72 implying that the respondents both agreed on the ways of managing information systems for higher education harmonization agenda's sustainability in Africa. This was also supported by the average mean score of 2.80 in the study.

**Research Question Two:** What are the ways of managing documents and records for higher education harmonization agenda's sustainability in Africa?

**Table 2.** Mean, standard deviation and rank order on the ways of managing documents and records for higher education harmonization agenda's sustainability in Africa

S/No	Items	Northern hemisphere n = 246		Southern hemisphere n = 238		Mean set	Rank	Decision
		Mean	SD	Mean	SD			
6	Documents and records are regularly utilized	3.09	0.70	2.80	0.82	2.95	1 <sup>st</sup>	Agreed
7	Mutilation of documents and records is prohibited	2.83	0.85	2.99	0.79	2.91	2 <sup>nd</sup>	Agreed
8	There is provision for easy retrieval of documents and records	2.98	0.68	2.71	0.89	2.85	3 <sup>rd</sup>	Agreed
9	Documents and records are stored in cabinets	2.60	0.94	2.66	0.89	2.63	4 <sup>th</sup>	Agreed
10	Versioning of records is a general practice	2.54	1.11	2.68	0.88	2.61	5 <sup>th</sup>	Agreed
	<b>Grand Mean and Standard Deviation</b>	<b>2.81</b>	<b>0.86</b>	<b>2.77</b>	<b>0.85</b>	<b>2.79</b>		<b>Agreed</b>

In Table 2, it was revealed that items 6, 7, 8, 9 and 10 were responded to by the heads of quality assurance in the northern hemisphere with mean scores of 3.09, 2.83, 2.93, 2.60 as well as 2.54. The heads of quality assurance in the southern hemisphere on the other hand responded to the same set of items with mean values of 2.80, 2.99, 2.71, 2.66 and 2.68. The entire items were above the criterion mean score of 2.50 used for decision making and implied that they were all agreed. The ranking showed that item 6 came 1<sup>st</sup> while item 10 came 5<sup>th</sup> as ways of managing records and documents. The grand mean

score of 2.81 from the heads of quality assurance in the northern hemisphere as well as 2.77 from the heads of quality assurance in the southern hemisphere showed that the respondents both agreed on the ways of managing documents and records for higher education harmonization agenda's sustainability in Africa. This was also supported by the average mean score of 2.79 in the study.

**Research Question Three:** What are the ways of managing facilities for higher education harmonization agenda's sustainability in Africa?

**Table 3.** Mean, standard deviation and rank order on the ways of managing facilities for higher education harmonization agenda's sustainability in Africa

S/No	Items	Northern hemisphere n = 246		Southern hemisphere n = 238		Mean set	Rank	Decision
		Mean	SD	Mean	SD			
11	Policy directives on minimum standards in relation to school facilities are enforced	2.69	0.82	2.97	0.83	2.83	1 <sup>st</sup>	Agreed
12	Sites for facility construction are based on existing school plan	3.04	0.68	2.73	0.97	2.89	2 <sup>nd</sup>	Agreed
13	There is routine maintenance of facilities	2.98	0.83	2.55	0.96	2.77	3 <sup>rd</sup>	Agreed
14	Need assessment on relevant facilities is compulsory	2.79	0.97	2.74	0.87	2.77	4 <sup>th</sup>	Agreed
15	Facility funding is a regular practice	2.70	0.95	2.69	0.90	2.70	5 <sup>th</sup>	Agreed
	<b>Grand Mean and Standard Deviation</b>	<b>2.84</b>	<b>0.85</b>	<b>2.74</b>	<b>0.91</b>	<b>2.79</b>		<b>Agreed</b>

Table 3 indicated that items 11, 12, 13, 14 and 15 were responded to by the heads of quality assurance in the northern hemisphere with mean scores of 2.69, 3.04, 2.98, 2.79 and 2.70 while the heads of quality assurance in the southern hemisphere responded to the same set of items with mean scores of 2.97, 2.73, 2.55, 2.74 and 2.69. These items were all above the criterion mean score of 2.50 used for decision making and as such were all agreed. Item 11 came 1<sup>st</sup> in the ranking while item 15 came 5<sup>th</sup> on the ways of managing facilities. In the grand mean summary, the mean score of 2.84 from the heads of quality assurance in the northern hemisphere as well as 2.74 from the heads of quality assurance in the southern hemisphere showed that the respondents both agreed on the

ways of managing facilities for higher education harmonization agenda's sustainability in Africa. This was also supported by the average mean score of 2.79 in the study.

**Research Question Four:** What are the ways of managing personnel for higher education harmonization agenda's sustainability in Africa? (Table 4)

**Table 4.** Mean, standard deviation and rank order on the ways of managing personnel for higher education harmonization agenda's sustainability in Africa

S/No	Items	Northern Hemisphere n = 246		Southern Hemisphere n = 238		Mean set $\bar{X}\bar{X}$	Rank	Decision
		Mean $\bar{X}_1$	SD	Mean $\bar{X}_2$	SD			
16	Motivation of staff is a constant practice	2.53	0.77	2.69	0.90	2.75	1 <sup>st</sup>	Agreed
17	Appraisal of personnel is carried out regularly	2.51	0.85	2.96	0.87	2.74	2 <sup>nd</sup>	Agreed
18	Personnel are exposed to training and development programmes	2.66	0.73	2.66	0.94	2.66	3 <sup>rd</sup>	Agreed
19	Recruitment and specialization is a major practice	2.61	0.75	2.68	0.93	2.65	4 <sup>th</sup>	Agreed
20	Responsibilities are assigned based on specialization	2.63	0.64	2.51	0.99	2.57	5 <sup>th</sup>	Agreed
	<b>Grand Mean and Standard Deviation</b>	<b>2.59</b>	<b>0.75</b>	<b>2.70</b>	<b>0.93</b>	<b>2.67</b>		<b>Agreed</b>

It was indicated in the study that items 16, 17, 18, 19 and 20 were responded to by the heads of quality assurance in the northern hemisphere with mean scores of 2.53, 2.51, 2.66, 2.61 and 2.63 while the same set of items were responded to by the heads of quality assurance in the southern hemisphere sampled for the study with mean scores of 2.69, 2.96, 2.66, 2.68, 2.51. These items were all agreed since the mean values were above the criterion mean score of 2.50 used for decision making. In the study, item 16 came 1<sup>st</sup> while item 20 came 5<sup>th</sup> in the ranking on the ways of managing personnel. The grand mean scores of 2.59 from the heads of quality assurance in the northern hemisphere as well as 2.70 from the heads of quality assurance in the southern hemisphere showed that they both agreed on the ways of managing personnel for higher education harmonization agenda's sustainability in Africa. This was also supported by the average mean score of 2.67 in the study.

### 3.1 Test of Hypotheses

**HO<sub>1</sub>:** There is no significant difference in the perception of heads of quality assurance in the northern hemisphere and heads of quality assurance in the southern hemisphere on the ways of managing information systems for higher education harmonization agenda’s sustainability in Africa.

**Table 5.** Summary of z-test analysis on the significant difference in the perception of heads of quality assurance in the northern hemisphere and heads of quality assurance in the southern hemisphere on the ways of managing information systems for higher education harmonization agenda’s sustainability in Africa

Variable	n	Mean	SD	df	z-cal.	z-crit.	Level of significance	Decision
Northern hemisphere	246	2.87	0.84	482	1.88	1.96	0.05	Not rejected
Southern hemisphere	238	2.72	0.92					

In Table 5, it was revealed that the value of z-crit. was 1.96 at 482 degrees of freedom and 0.05 level of significance while the value of z-cal. was 1.88. Since the value of z-cal. of 1.88 was less than the value of z-crit. of 1.96, the null hypothesis was not rejected implying that there was no significant difference in the perception of heads of quality assurance in the northern hemisphere and heads of quality assurance in the southern hemisphere on the ways of managing information systems for higher education harmonization agenda’s sustainability in Africa.

**HO<sub>2</sub>:** There is no significant difference in the perception of heads of quality assurance in the northern hemisphere and heads of quality assurance in the southern hemisphere on the ways of managing documents and records for higher education harmonization agenda’s sustainability in Africa.

**Table 6.** Summary of z-test analysis on the significant difference in the perception of heads of quality assurance in the northern hemisphere and heads of quality assurance in the southern hemisphere on the ways of managing documents and records for higher education harmonization agenda’s sustainability in Africa

Variable	n	Mean	SD	df	z-cal.	z-crit.	Level of significance	Decision
Northern hemisphere	246	2.81	0.86	482	0.52	1.96	0.05	Not rejected
Southern hemisphere	238	2.77	0.85					

In Table 6, it was revealed that the value of z-crit. was 1.96 at 482 degrees of freedom and 0.05 level of significance while the value of z-cal. was 0.52 as estimated. The value of z-cal. of 0.52 was less than the value of z-crit. of 1.96 and as such the null hypothesis was not rejected indicating that there was no significant difference in the perception of heads of quality assurance in the northern hemisphere and heads of quality assurance in the southern hemisphere on the ways of managing documents and records for higher education harmonization agenda's sustainability in Africa.

**HO<sub>3</sub>:** There is no significant difference in the perception of heads of quality assurance in the northern hemisphere and heads of quality assurance in the southern hemisphere on the ways of managing facilities for higher education harmonization agenda's sustainability in Africa.

**Table 7.** Summary of z-test analysis on the significant difference in the perception of heads of quality assurance in the northern hemisphere and heads of quality assurance in the southern hemisphere on the ways of managing facilities for higher education harmonization agenda's sustainability in Africa

Variable	n	Mean	SD	df	z-cal.	z-crit.	Level of significance	Decision
Northern hemisphere	246	2.84	0.85	482	1.25	1.96	0.05	Not rejected
Southern hemisphere	238	2.74	0.91					

In Table 7, it was indicated that the value of z-crit. was 1.96 at 482 degrees of freedom and 0.05 level of significance while the value of z-cal. was 1.25. Therefore, since the value of z-cal. of 1.25 was less than the value of z-crit. of 1.96, the null hypothesis was not rejected suggesting that there was no significant difference in the perception of heads of quality assurance in the northern hemisphere and heads of quality assurance in the southern hemisphere on the ways of managing facilities for higher education harmonization agenda's sustainability in Africa.

**HO<sub>4</sub>:** There is no significant difference in the perception of heads of quality assurance in the northern hemisphere and heads of quality assurance in the southern hemisphere on the ways of managing personnel for higher education harmonization agenda's sustainability in Africa.

In Table 8, it was revealed that the value of z-crit. was 1.96 at 482 degrees of freedom and 0.05 level of significance while the value of z-cal. was 1.45. Since the value of z-cal. of 1.45 was less than the value of z-crit. of 1.96, the null hypothesis was not rejected implying that there was no significant difference in the perception of heads of quality assurance in the northern hemisphere and heads of quality assurance in the southern hemisphere on the ways of managing personnel for higher education harmonization agenda's sustainability in Africa.

**Table 8.** Summary of z-test analysis on the significant difference in the perception of heads of quality assurance in the northern hemisphere and heads of quality assurance in the southern hemisphere on the ways of managing personnel for higher education harmonization agenda's sustainability in Africa

Variable	n	Mean	SD	df	z-cal.	z-crit.	Level of significance	Decision
Northern hemisphere	246	2.59	0.75	482	1.45	1.96	0.05	Not rejected
Southern hemisphere	238	2.70	0.93					

## 4 Discussion

### 4.1 Ways of Managing Information Systems for Higher Education Harmonization Agenda's Sustainability in Africa

The management of information systems plays a significant role in the harmonization of the sustainability agenda through higher education in Africa. The respondents used for the study agreed on the ways of managing information systems for higher education harmonization agenda's sustainability in Africa and this aligns with the outcome of the study conducted by Kimura (2005) which indicated that no difference existed in the management of information systems being adopted in educational institutions used for the study. The information they say is the power since it has the capacity of improving on existing structures and processes in any organization. The quality assurance heads in higher institutions in African sampled for the study agreed on the various items listed as ways of improving the information systems for higher education harmonization agendas sustainability in Africa. However, among all the alternative ways listed, it was indicated that the planning of information was strategic in the achievement of this goal. Information planning is important as it helps to ensure that key objectives are taken into consideration before the information is circulated. Any information that is not properly planned including the channel through which it will be communicated may not be able to achieve the intended harmonization agenda.

The respondents also indicated from their responses that the assurance of information was the least of the ways adopted in the management of information systems in these institutions. This implies that information circulated among higher education institutions may not be able to generate the required level of credibility. This may explain why some information is not treated with the sense of urgency and necessity that it deserves in the sustainability of the harmonization agenda in higher education institutions in Africa. Based on this premise, measures need to be put in place to ensure that information passed across in higher education institutions are as credible as possible and must be passed using appropriate channels for it to be relevant to end-users and also contribute to the sustainability of the harmonization agenda in higher education institutions in Africa. The essence of this cannot be overemphasized as Marire (2018) pointed out in the result of their study that the management of information systems assists in service delivery to

a high extent to informal organizations. Educational outcomes, as well as quality service delivery, can be achieved by assuring information users that the programmes, policies and practices being circulated are credible enough to be enforced for the development of higher education across the continent.

#### **4.2 Ways of Managing Documents and Records for Higher Education Harmonization Agenda's Sustainability in Africa**

Heads of quality assurance in higher educational institutions sampled for the study agreed across the northern and southern hemispheres on the ways of managing documents and records for higher education harmonization agenda's sustainability in Africa. This agrees with the findings of a related study carried out by Allahmagani (2014) which showed that schools in Kaduna similarly keep their records across all areas. This implies that most of these educational institutions keep their records and other documents in a similar manner. However, there is a need for higher educational institutions to improve on the ways of managing documents and records in their technology-driven era. This is because of the list of items investigated in the study. There was a low preference given to the versioning of documents and records which has become a regular practice in most developed countries. The versioning of records makes documents and records available in different versions which can be accessed by individuals based on their preference.

However, there was a high regard for the utilization of records and documents as indicated from the responses of the respondents of the study. This implies that documents and records available in these institutions are often utilized. This practice needs to be encouraged the more where records and documents in higher education institutions in African can be shared and utilized for educational purposes in any part of the continent. This will go a long way to strengthen the harmonization agenda in higher education institutions in Africa. The utilization of records and documents across institutions in the continent does not only provide relevant information but also helps to ensure that the continent is pursuing relevant and sustainable educational goals and objectives that will contribute to the growth and development of the continent at large. This is why record management policies must be developed across these institutions. In their study, Adade et al. (2018) observed the absence of national policy on records management and the lack of guidelines for academic records management in schools. This among other challenges to record and document management must be addressed for higher education harmonization agenda's sustainability in Africa.

#### **4.3 Ways of Managing Facilities for Higher Education Harmonization Agenda's Sustainability in Africa**

The study showed that the heads of quality assurance sampled for the study agreed on the ways of managing facilities for higher education harmonization agenda's sustainability in Africa. This findings is at variance with a related study carried out by Lavy and Bilbo (2009) which showed that there was poor quality of facilities maintenance and management practices in large public schools in Texas. It was also revealed that nevertheless, the schools follow the guidelines set by the US Department of Education to have comparatively more detailed and contemporary information about their facility's

condition. This establishes the need for monitoring the rate of compliance of educational institutions on some of these policies. In this study, there was a strong agreement that policy directives on facilities were adhered to in these institutions. This plays a major role in the attainment of minimum standards in education service delivery across the continent in its pursuit of harmonization of its sustainability agenda.

Furthermore, the study showed that the list of the items responded to on the management of facilities was the funding of facilities. If the continent must achieve its higher education harmonization agenda's sustainability, great attention must be given to the funding of facilities. A study by Allagoa (2017) showed that management of school plants in public secondary schools in Rivers State is very low and faced with challenges and in most cases, this is usually due to the poor allocation of funds to the provision and maintenance of facilities. Supporting this position, Fadahunsi et al. (2019) also found out in their study that adoption of facilities management principles in Covenant University has benefited the institution in the form of improved health and safety, good and neat environment, quality services and functional buildings. However, it was revealed in the study that costs benefit analysis, auditing and control and performance analysis were part of the instruments used for achieving this feat. Higher education institutions in Africa must therefore give adequate attention to the funding, provision and maintenance of facilities for higher education harmonization agenda's sustainability in Africa.

#### **4.4 Ways of Managing Personnel for Higher Education Harmonization Agenda's Sustainability in Africa**

Personnel play an important role in the attainment of goals and objectives in any organization. The respondents used for the study agreed on the ways of managing personnel for higher education harmonization agenda's sustainability in Africa. In the study, the respondents agreed that one of the major ways that this is done is through the motivation of staff. This no doubt is important as the motivation of staff in any organization can lead to the attainment of key organizational goals and objectives. This finding however disagrees with the outcome of a similar study by Teir and Zhang (2016) which showed that there were variations in the number of institutions that apply these practices in Palestinian institutions. This calls for the need for a harmonized employee management strategy across higher education institutions if sustainable development must be attained. This is because the failure to do so will continue to result in lop-sided development across the continent.

However, the least on the items raised was the assignment of responsibilities based on areas of specialization. In their study, Lucky (2019) identified that cohesiveness is important in the attainment of educational goals and objectives. This no doubt includes ensuring that personnel are assigned to areas where they are specialized. If personnel in the school are deployed to areas where they are not competent, the multiplier effect will be in the form of slow educational advancement not only in the educational institution in question but also across the continent. It is therefore important for policies and legislations to be developed to ensure that personnel are only deployed to their areas of speciality and regular training should also be provided. This will make it easy for personnel to be transferred for knowledge sharing across the continent and also contribute to the higher education harmonization agenda's sustainability in Africa.



## 5 Conclusion

The following conclusions were made based on the findings of the study:

It was revealed in the findings of the study that heads of quality assurance in the northern and southern hemispheres in the selected institutions agreed on the management of information systems, documents and records, personnel and facilities for higher education harmonization agenda's sustainability in Africa.

### 5.1 Recommendations

Recommendations made in line with the findings of the study are as follows:

1. Information in higher educational institutions in Africa needs to be digitalized and made available to all end-users in educational institutions across the continent. This will make it easy for all educational stakeholders to access information that can be harnessed and applied for the attainment of the harmonization agenda on the continent.
2. Educational administrators need to ensure that documents and records in their respective institutions are stored in different versions to make it easy for planning activities to be carried for the development of the region as a whole.
3. There is a need for approved budgetary allocation for the procurement and maintenance of facilities in schools as this is important for the provision and maintenance of school facilities which will contribute to the attainment of the goals and objectives of education in the long run.
4. There is a need for personnel management policies to be institutionalized across all higher educational institutions in the continent. This will make it easy for the transfer of personnel across different educational institutions in the continent. This will go a long way to enhance the sustenance of the harmonization agenda on the continent.

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# Socio-economic and Demographic Analysis on Resilience to Food Insecurity in Tanzania: Context of Covid-19

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**Abstract. Purpose:** This paper analyses the influence of socioeconomic and demographic characteristics on resilience to food insecurity among smallholder farmers in eastern and central parts of Tanzania.

**Design/Methodology/Approach:** A cross-section design was used where secondary and primary data were collected from 160 randomly selected smallholder farmers. The survey, focus group discussion, key informant interviews, and observation methods were used as sources of data.

**Findings:** Findings demonstrate that smallholder farmers in Morogoro region have higher resilience Means of 57.879 than Dodoma region that have 51.496. It also proves that resilience to food insecurity has positive coefficients ( $\beta$ ) for the region of the respondents, sex, household size, age, additional sources of income, and background of the individual as; 4.495, 2.223, 2.114, 0.012, 1.334, 0.001 respectively. It also indicated negative coefficients ( $\beta$ ) with religion, landholding size, marital status, and ethnicity as;  $-2.553$ ,  $-0.874$ ,  $-0.985$ , and  $-3.885$  respectively.

**Research Limitation/Implication:** The study engrossed just socioeconomic and demographic characteristics that were related to resilience to food insecurity among smallholder farmers in eastern and central parts of Tanzania.

**Social Implication:** It is imperious for various stakeholders including policy and decision-makers to recognize socioeconomic and demographic characteristics as key factors when addressing resilience mechanisms to food insecurity among smallholder farmers during the Covid-19 pandemic in developing countries including Tanzania.

**Originality:** The facts of this study lies in socioeconomic and demographic characteristics that were related to resilience to food insecurity among smallholder farmers in eastern and central parts of Tanzania.

**Keywords:** Demographic · Food insecurity · Resilience · Smallholder farmers · Socioeconomic

## 1 Introduction

The economic crisis resulting from COVID-19 has had negative impacts on food security especially on smallholder farmers who face some challenges to get agricultural

inputs (Pereira and Oliveira 2020) Majorities of the small-holder farmers from developing countries are reported to be highly impacted by the COVID-19 Pandemic on their production (WHO 2020; FAO 2020; WFP 2020; USDA 2020). The situation of smallholder farmers in most developing countries including Tanzania is worse because they are faced with COVID 19 challenges which they were not prepared for before (IFAD 2021). Little is known on the influence of social-economic and demographic characteristics of smallholder farmers on resilience to food insecurity, particularly during the Covid-19 pandemic. This paper aims to analyze the influence of social-economic and demographic characteristics of smallholder farmers on resilience to food insecurity particularly during the Covid-19 pandemic in the eastern and central parts of Tanzania. The paper was guided by three objectives which are:-to examine social-economic and demographic characteristics of smallholder farmers in eastern and central parts of Tanzania and to analyze the influence of social-economic and demographic characteristics on resilience to food insecurity among smallholder farmers in eastern and central parts of Tanzania.

## **2 Theories Underpinning the Study**

### **2.1 Entitlement Theory**

This study used entitlement (famine) theory by Sen (1981). The theory explains that famine emerges not because of food inadequacy but because of people's lack of access to food. Only those with entitlements are able to access food. Such entitlements are derived from the ranks of human and physical capital, access to common property resources and variety of social contracts at household (Maxwell and Frankenberg 1992). The theory acknowledges that there is no food security for a household without resources which can be grounded from physical assets However, this study has decided to use this theory because it recognizes the role of resources like land, man power which can be owned by smallholder farmers targeted in the study.

## **3 Methodology**

### **3.1 Research Design**

A cross-sectional research design was used to collect data. A mixed research approach of qualitative and quantitative data was used to allow triangulation of results as well as generating new insights on the analysis of the influence of social-economic and demographic characteristics on resilience to food insecurity among smallholder farmers.

### **3.2 Population**

According to the Tanzania census of 2012, the average number of smallholder farmers in the selected villages of Mkalama and Kigwe in the regions Dodoma and Morogoro respectively and Dodoma regions were 1200 (URT 2014).

### 3.3 Sampling Techniques

Both non-probability and Probability sampling techniques were used in the study. For non-probability sampling, purposive sampling was used and simple random sampling was used for probability sampling.

### 3.4 Sample Size

By using Yamane formula to compute the sample size, the targeted smallholder framers sample populations were 1200 households.

$$n = \frac{N}{1 + N(e)^2} \quad (1)$$

When applying Yamane formula to the population of 2000 smallholder farmers at Mkalama and Kigwe villages in Morogoro and Dodoma region respectively.

*sample size* =  $\frac{1200}{1+1200(0.05)^2} = 300$ . Therefore, the sample size was 300.

### 3.5 Data Analysis

Data analysis to quantify resilience mechanisms used by small farmers were done using the Analysis of Variance (ANOVA) to compare the significance means of both absorptive, adaptive and transformative while also comparing its relationship region wise. Socio-economic and demographic characteristics with other related household factors were analyzed using the multiple regression analysis. Characteristics like; additional sources of income, numbers of livestock, religion, land size and household's size were assumed to be individuals' inherent predictors that could influence resilience to food security among small holder-farmers.

The model structure was given as  $Y_i = \beta_0 + \beta_1x_i + e_i$

Where;

$Y_i$  = Aggregated Resilience Index as a Dependent variable

$\beta_0$  = A Constant

$\beta_i$  = Coefficients of the predictors

$x_i$  = + Predictors

X1 = Region

X2 = Sex

X3 = Age

X4 = Education

X5 = Marital status

X6 = Ethnicity

X7 = Additional income source

X8 = Household size

X9 = Religion

X10 = Landholding size

X11 = Background of an individual

$e_i$  = An error Term

## 4 Findings and Discussion

To counter fact resilience mechanism to food insecurity among smallholder farmers in Morogoro and Dodoma region the Mean aggregated resilience index was obtained from absorptive, adaptive, and transformative mechanisms. Absorptive mechanisms mentioned in both regions of the study area:- consuming reserved food, using savings to buy food, consume edible wild plants, consume edible wild animals, sell nonproductive assets, harvesting crops early, delaying debt repayments and borrowing money from relatives and friends. Adaptive mechanisms mentioned were selling livestock to buy food, lend money from financial institutions, doing petty business to generate, planting drought-resistant crops, changing income-generating activities, selling assets including land and practising controlled harvesting of edible wild plants. The Transformative mechanisms were adopting conservation agriculture, livelihoods diversification, preservation of harvested edible wild food, joining community-based savings and credit associations and asking for government assistance.

Results from Table 1 shows that Morogoro region has a higher Aggregated Mean index of 57.879 compared to Dodoma region which has Aggregated Mean index of 51.496. The higher the aggregated resilience mechanisms the higher the ability to captivate shocks and stress resulted by food insecurity especially during COVID-19 pandemic. The difference in Mean aggregated resilience mechanisms between the two regions were statistically significant at  $p = 0.003$ . The findings were similar to those of Béné et al. (2018) who proposed that for the community to have stable resilience need to curb all levels of resilience (the aggregated dimensions) which include absorptive, adaptive and transformative dimensions. Therefore, to that regard, smallholder farmers of Morogoro region are more likely to bounce back quickly from stress and shocks resulting from food insecurity than their counterparts in Dodoma region due to the high Mean aggregated resilience index. The findings also justify that due to the impacts of COVID-19, smallholder farmers of Morogoro Region can little suffer as compared to those of Dodoma Region.

**Table 1.** Mean aggregated resilience index by regions

Resilience	Region	n	Mean	Std. deviation	Std. error sig.
Aggregated	Dodoma	69	51.496	7.127	.472
	Morogoro	81	57.879	6.136	.342
	Total	150	54.575	6.164	.376

### Multiple Regression Analysis on Socio-economic and Demographic Factors Influencing Resilience to Food Security

It is sensible using the aggregated mean resilience level when trying to ascertain factors that influence it; one is capable of applying the combined strategies when trying to address food insecurity issues in the household. Therefore, the total resilience level as (Aggregated Resilience index) was regressed with socio-economic characteristics

and other factors like additional sources of income, the background of an individual (indigenous or immigrant), household size, religion, and landholding size, were assumed to be individuals' inherent predictors that could influence the resilience levels of the individual at the household level.

Multiple regression analysis was done to determine the influence of respondents and other selected variables which were modelled to explain the determinants of aggregated resilience index. For this study, the multiple regression analysis was done to weigh the individual respondents' characteristics and their magnitude of influence on the aggregated resilience level. The expected relationship of individual respondents' characteristics and the aggregated resilience level are mixed. For instance, sex is a binary variable that is included to estimate the impact of the sex of the respondent. In many cases, females are more knowledgeable on wild food plants relying on knowledge passed to them from parents and they could easily manage to search for wild foods in case of difficulties particularly during the COVID-19 pandemic. However, men also being the decision-makers in the households are the ones assumed to have more economic power and equally could decide on alternative means to absorb, adapt or transform shocks. Firstly, if a husband was dead due to or if alive and was transferred to work in another station or stayed home due to COVID-19 pandemic. Secondly, if a married woman had quit formal employment and decided to manage other household decisions including what steps to be taken during shocks and managing all protection requirements against the COVID-19 pandemic. In such a case, female managed households would have better-aggregated resilience as the wife would have a better opportunity to offer close follow-up and supervision of household needs especially children and sick people at household. For these reasons, the expected sign for this variable in the model can be either negative or positive. The variable education is the number of years of schooling achieved by the respondent is used as a proxy for managerial decisions. A high level of educational achievement may lead to a better assessment of the importance and complexities of making good decisions on alternative ways to take that could add to resilience, including efficient storage and or preservation of foods for use during difficult moments including high seasonal of COVID-19 pandemic. The expected sign for the education variable is positive. Household size is the variable considered positive with some expectations that the households with a large number of members are likely to suffer little with food insecurity incidences because it has a good number of workers or labourers to engage especially during the COVID-19 pandemic where some people lost their job compared to the household with small numbers.

In this study, the background of the respondent was considered indigenous and immigrants. This represents the number of years stayed in the area how an individual has been experiencing the situation of food insecurity and hence being knowledgeable on various mechanisms to employ during difficult times and adding to his/her aggregated resilience. This variable is aimed at capturing the livelihoods and living experiences one had. Based on challenges that one come across, and solved them and continued to survive it is assumed that indigenous people have accumulated experiences to opt for different coping strategies in the area because they have born to that area and they have inherited different mechanisms across generations to lessen food insecurity condition especially during COVID-19 pandemic. The expected sign for indigenous is positive.

Similarly, age was intended either to capture experiences one had but also on the other side the weaknesses one had as she/he grew older hence representing her/his failure in looking for alternatives due to immobility and hence impacting on the overall resilience level, this might also be caused by COVID-19 pandemic where old people are mostly impacted by pandemic. Marital status, showed the collective nature of the household by husband and wife supporting each other during difficulties compared to widowed and or divorced women. The Region of the respondents is partly related to the type(s) of ethnic group(s) like Gogo, Kagulu, Zigua, Maasai and Sukuma these were the ethnic groups found in the study area. These ethnic groups have different histories on how to deal with food insecurity situations based on their cultures and local traditions knowledge. Religion is a variable expected to have impacts due to the assumption that there are churches or mosques which have self-help mechanisms for their members including entrepreneurial training etc. on how to become resilient to food insecurity. Landholding size is a variable expected to have a positive impact due to the assumption that the household with a large portion of land has more chance of not being shocked with food insecurity incidences compared to the household owning a small land size. The assumption is that the household with a large size, first have a high chance of producing more crops than those with a small portion of land, the second assumption is that they can sell part of the land portion and be able to purchase food and became food secured during shocks of COVID-19 pandemic.

Therefore, a negative sign of a regression coefficient implied that the predictor variable was negatively associated with the individuals' aggregated resilience level while a positive sign implied that the predictor variable was positively associated with aggregated resilience level and increased the aggregated resilience level of an individual. All assumptions under multiple regression were considered where results in Table 2 show that the coefficient of correlation between the predicted values and the observed values of aggregated resilience was 0.88 or 88% as a level at which the observed aggregated resilience was explained by the predictors included in the equation. The coefficient of determination was 0.7744 meaning that the selected predictors explained about 77% of the level of the aggregated resilience index observed among respondents with an Adjusted R squared value of 0.698.

From the findings presented in Table 2, the coefficient for the region was positive and had the highest contribution to impacting the level of resilience mechanisms taken by respondents with a coefficient of 4.595 and a standard error of 0.808 indicating that smallholder farmers in Morogoro region were more resilient than those from Dodoma region and the predictor was found to be statistically significant at  $p = 0.001$ . This was also supported by Kalumanga et al. (2020); Ansah et al. (2019) who argued that geographical position determines the food security of a particular area. Again, the sex of the respondent was positively associated with the resilience index indicating that women were more knowledgeable in applying resilience mechanisms during food insecurity than men and had a coefficient of 2.323 with a standard error of 0.767 and the predictor was found to be statistically significant at  $p = 0.004$ . Other scholars including Kalumanga (2018) and Pingali (2006) contended that women suffer little food insecurity incidences because they utilize more resilience to food security including preparing wild foods.



**Table 2.** Multiple regression Results on Socio-economic and Demographic factors influencing resilience level

R = 0.88 R <sup>2</sup> = 0.7744 Adjusted R squared = 0.698					
Predictor variables	Unstandardized coefficients		Standardized coefficients	t	Sign. level
	$\beta$	Std. error	Beta		
Constant	49.312	4.317		11.422	.000
Respondent from region	4.595	.808	.292	5.564	.001
Sex of the respondent	2.323	.767	.147	2.920	.004
Household size	2.114	.716	.139	2.176	.003
Additional source of income	1.143	.612	.171	1.716	.004
Age of the respondent	.0116	.521	.002	.028	.004
Marital status of the respondent	-.764	.655	-.075	-1.399	.111
Education of respondent	-1.183	.761	-.180	-2.551	.002
Ethnicity	-2.866	.412	-.224	-4.356	.021
Religion	-2.553	.874	-.197	-.289	.062
Background of an individual	.001	.017	.004	.070	.722
Land holding size in acres	-.622	.413	-.019	-1.416	.266

Moreover, the household size of the respondents was positively related to the resilience index indicating that the smaller the household size the more able to cope with the situation of food insecurity especially during the COVID-19 pandemic and had the coefficient of 2.114 and the standard error of 0.716. The larger the household size the difficult it is to cope with the situation of food insecurity especially during the COVID-19 pandemic. Thus, households with a small number of household members were more resilient to food insecurity than those with a large number of household members and the predictor was found to be statistically significant at  $p = 0.003$ . Similar findings by Lyakurwa et al. (2017); Udmale et al. (2020) propounded that a large number of household members are more likely to suffer from food insecurity regardless of resilience mechanisms to steady them.

The age of the respondents was positively associated with the resilience levels applied during food insecurity and had a coefficient of 0.116 with a standard error of 0.521. However, the influence of age on levels of resilience mechanisms applied was statistically significant ( $p = 0.004$ ) because older people are poor in applying resilience mechanisms

than the middle-aged individuals who are energetic and active in engaging in various income-generating activities especially during the COVID-19 pandemic. Age showed positive significance because older people face a momentous risk of developing severe illness if they contract diseases due to physiological changes that come with ageing and potential underlying health conditions. Thus old people are at high risk to be infected with the COVID-19 pandemic just why they exhibit less utilization of resilience to food insecurity because they fear to contact people around their environment. Other findings including that of Knippenberg et al. (2017); Smith and Frankenberger (2018) connotes that old people are at high risk to face food insecurity because of the inability to apply technical resilience's. Landholding size was negatively associated with the resilience levels and had a coefficient of  $-0.622$  with a standard error of  $-0.413$  and its influence was not statistically significant  $0.266$ . The results implied that land size does not guarantee the household to have good production and enough food this is because due to poor rainfall distribution patterns of the area even if the households will cultivate a large area, due to poor rainfall distribution crops are likely to fail. Furthermore COVID-19 pandemic has interfered with crop production by creating a high cost of inputs and limited access to markets among smallholder farmers.

Religion was negatively associated with the resilience levels and had a coefficient of  $-2.553$  with a standard error of  $0.874$  and its influence was not statistically significant ( $0.62$ ). The results implied that religion does pledge the household to have good resilience mechanisms to food insecurity during COVID-19 pandemic. Marital status was negatively associated with the level of resilience with a coefficient of  $-0.764$  and a standard error of  $0.655$  implying that the divorced and widowed suffered the least during food insecurity than the married and unmarried individuals, probably because once they are divorced or widowed, they become better in planning and take the sole responsibility to address all the household needs for their own survival. However, marital status as a predictor was not statistically significant ( $p = 0.111$ ). The education level of the respondents was negatively associated with the level of application of resilience mechanisms by smallholder farmers and had a coefficient of  $-1.183$  with a standard error of  $0.761$  implying that lowly educated individuals were more competent and knowledgeable in local knowledge and knew many edible wild plants that could be used as food during severe food insecurity. The local knowledge on tendering native food will enable them not to suffer much from food insecurity during the COVID-19 pandemic. The highly educated individuals were the majority who are employed or with better living conditions which make them better positioned to use an additional source of income or their salaries to buy food. This group is more doubting with their survival during COVID-19 because some of them especially who are employed in low profile private sectors lose a job. The relationship between education and the level of applying resilience mechanisms was found to be statistically significant at  $p = 0.002$ .

Ethnicity was negatively associated with the level at which one applied the resilience mechanisms and had a coefficient of  $-2.866$  with a standard error of  $0.412$  implying that the Gogo people in Dodoma region were more knowledgeable with the means to address food insecurity challenges than Kagulu in Morogoro region because they have been facing food insecurity several times due to their geographical location being semi-arid. Ethnicity as a predictor was found to be statistically significant at  $p = 0.021$ .

Additional sources of income were positively related to the level of resilience one had as the income could be used to buy food during deficit especially during the COVID-19 pandemic season. An additional source of income as a predictor had a coefficient of 1.143 and a standard error of 0.612 implying that with more additional sources of income one is better positioned to address food insecurity issues during the COVID-19 pandemic seasonal. The same findings were noted by Singh et al. (2021) who reported that those individuals with more than one source of income are most likely to survive hunger during Covid-19. An additional source of income as a predictor and its influence on the level of resilience mechanisms applied was statistically significant at ( $p = 0.004$ ). Households with additional sources of income also consumed less unhealthy food, because more additional income makes it possible to purchase high-quality food items.

Background of an individual considered indigenous and immigrant people in that area and it was positively associated with the level of applying resilience mechanisms. Despite being the lowest contributor with a coefficient of 0.001 and a standard error of 0.017 it implied that those indigenous people had enough experience on local means of addressing food insecurity and they suffered little compared to immigrant ones who had little experience in the areas during the COVID-19 pandemic. Similar findings were connoted by other scholars including Tyler (2020); Kieu and Islam (2020); Faustine (2016) and Liwenga (2003) who argued that the background of an individual and environmental acquaintance adds value to mitigating food insecurity shocks. Indigenous were more knowledgeable of the periods in which they have to make preparations for tackling food insecurity issues in the community by storing and preserving foods to be used later. However, duration of stay for indigenous as a predictor of factors influencing resilience levels was not found to be statistically significant ( $p = 0.722$ ).

## 5 Conclusion and Recommendations

Socio-economic and demographic characteristics play essential roles in determining the household resilience to food insecurity especially during the COVID-19 pandemic among smallholder farmers. To come up with effective resilience to food insecurity and create stable and resilient communities among smallholder farmers during the COVID-19 pandemic, policymakers and other stakeholders has to contemplate key Socioeconomic and demographic variables. These effective variables include- the region of the respondents (geographical location), sex, household size, age, additional sources of income, and background of the individual whether she/he is indigenous. Understanding effective variables will enable addressers to come up with a stable and resilient community against food insecurity, especially during the COVID-19 pandemic.

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# A Multicriteria Decision Making Approach for Evaluating Crop Residues for Sustainable Briquette Production in Ghana

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**Abstract. Purpose:** This study has evaluated and prioritised crop residue feedstock (groundnut husk, cassava stalks, maize cob, rice husk, sorghum husk, and millet husk) for sustainable briquette production to replace wood fuel in Ghana.

**Design:** The study used the Bioenergy and Food Security Rapid Appraisal (BEFS RA) tool and Multicriteria Decision Making (MCDM) methods to achieve the research goal. The key selected criteria for MCDM analysis were production cost, net present value, internal rate of return, feedstock availability, total job creation, potential number of plants, and number of households supplied. The criteria importance through intercriteria correlation (CRITIC) method was used to determine the criteria decision matrix's weights, subsequently integrated into evaluation based on distance from average solution (EDAS) to rank and select the feedstocks.

**Findings:** EDAS findings fully correlate with results from other MCDM methods tested on the same decision matrix. The results indicate that cassava stalk and maize cob are promising and outshine the other feedstocks for sustainable development.

**Research Limitation/Implication:** Briquette production is likely to be hampered by a lack of awareness about its use, readily available carbonised briquettes in the local market, and readily available cookstoves to burn the briquettes.

**Practical Implication:** The study findings would help decision-makers know which crop residue feedstock to select for sustainable briquette production in Ghana.

**Social Implication:** The study findings are vital to all stakeholders and policy-makers towards promoting clean fuel for cooking and heating to reduce pollution in Ghana.

**Originality/Value:** The novelty of this study stems from the utilisation of multiple criteria to assess and prioritise feedstocks for producing briquettes which are limited in other studies. Also, briquette production on a scale was considered in this study.

**Keywords:** Biomass feedstocks · Briquette · Crop residues · Decision making · Sustainable development

## 1 Introduction

Energy consumption drives socio-economic development for every country. Globally, energy is needed for cooking and heating applications. However, using clean fuel for cooking and heating is a necessity to save human lives. Firewood and charcoal are mostly the primary fuel sources for cooking and heating in most developing countries, including Ghana. About 700 million African people use solid fuels comprising wood, charcoal, dung, crop residues, and coal primarily for cooking and heating. This figure is expected to surge to about 850–900 by the end of the decade (World Bank Group 2014). However, the combustion of firewood continues to harm health, such as respiratory, heart diseases, lung cancer, and eye irritations due to high emissions. According to the World Bank Group (2014), almost 600,000 people in Africa lose their lives yearly from air pollution produced by inefficient and harmful traditional cooking fuels and stoves.

The transition into clean fuels such as biogas, liquified petroleum gas, briquette/pellet for cooking, heating, and electricity generation to achieve sustainable development has gained the attention of researchers across the globe. Presently, the consumption of charcoal and firewood is high in rural, suburban, and urban communities in Ghana. For instance, biomass, mainly charcoal and firewood, contributed to 37.4% of the final energy consumed in 2019 (Energy Commission 2020). Crop residues have the potential to be converted into briquettes for cooking. The direct combustion of crop residues is inefficient for cooking. However, briquetting the crop residues is an effective way to use them for energy production.

Briquette has been identified as a potential alternative to firewood and charcoal due to its efficacy and safety for cooking. Briquettes are formed by compacting or densifying biomass to increase its bulk density. Biomass briquetting enhances the processability of biomass, increases its volumetric calorific value, lowers transportation costs, and provides effective management of crop residues (Yilmaz et al. 2015). Ghana expects to produce about 65,000 tonnes and 100,000 tonnes of briquettes by 2025 and 2030, respectively (Energy Commission 2019).

Presently, a plethora of studies exists on briquette production across the globe. For instance, Mohedas (2011) used a combustion and durability test to investigate the viability of utilising sawdust to produce briquettes to replace firewood for rural communities in Ghana. It was observed that sawdust briquettes could replace wood or charcoal without hindering a person's ability to cook. According to Mitchual et al. (2013), by combining maize cob and *Ceiba pentandra* sawdust, briquettes can be produced at room temperature utilising minimal compacting pressure and no binder. Tembe et al. (2014) revealed that a hybrid of Bambara shells, rice husk, and peanut shells has a good prospect for producing briquettes for domestic cooking. A study by Oyelaran et al. (2015) indicates that the burning properties of groundnut shell and waste paper admixture briquettes tested produce enough heat required for cooking. Furthermore, the properties of groundnut shell biomass briquettes produced by compaction with waste paper were satisfactory and consistent with previous research involving agro-waste briquettes. Yilmaz et al. (2015) experimented on converting rice husk into briquettes for cooking in Turkey. The results showed that the briquettes were very good due to their higher shatter index,

tumbler index, compressive resistance, and water resistance. Also, the briquettes have a suitable particle size and moisture content. In Ethiopia, Asmare (2019) utilised municipal biomass waste to manufacture briquettes. The experimental results showed that the carbon content, combustion efficiency, and fanning time of the briquette produced are acceptable and comparable to standard values. A study by Nsubuga et al. (2020) shows that Jackfruit waste can be converted into briquettes. However, the briquettes produced have higher heating values, though diverse scholars disagree on the particle size impact on briquettes' higher and lower heating values.

The selection of choices is a complex problem since it considers technical, economic, environmental, and social criteria. Multicriteria decision making (MCDM) approaches are resilient methods for evaluating and choosing alternatives that have several criteria (Yazdani-Chamzini et al. 2013). Globally, MCDM approaches have been used to select the best alternative in various fields, including agriculture resource management, immigration, transportation, investment, environment, defense, and so on (Kumar et al. 2017).

The study aims to determine the most suitable feedstock, the best production capacity, and the socio-economic benefits of each production system. Also, it aims to prioritise crop residue feedstocks for sustainable briquette production. It provides analysis for the production of briquettes on a large scale.

## 2 Materials and Method

### 2.1 Selection of Feedstock

Ghana cultivates several crops for food consumption, and most of these crop residues normally left to waste have the potential for bioenergy. This study adopts six crop residue feedstocks from Azasi et al. (2020), which have substantial potential for briquette production. These crop residue feedstocks include maize cob, cassava stalk, rice husk, groundnut husk, sorghum husk, and millet husk. The crop residues chosen for assessment have a high carbon content and are easily combustible, making them appropriate for briquette compaction.

### 2.2 Study Approach

The study integrates the Bioenergy and Food Security Rapid Appraisal (BEFS RA) tool and Multicriteria Decision Making (MCDM) methods to achieve the research goal. Figure 1 displays the flow of analysis with the BEFS RA module and MCDM approaches. The BEFS RA tool is developed by the Food and Agricultural Organization of the United Nations (FAO 2021). The briquettes component under the energy end-use option module is designed to assist in assessing the prospects for developing biomass briquettes for household consumers. The BEFS RA results are categorised into techno-economic, socio-economic, and financial criteria. These results formed the decision matrix for MCDM to select the best feedstock for prioritisation and development. Table 1 presents pertinent input parameters used in the BEFS RA tool for the briquette component. The

MCDM approaches are employed to select the best feedstock appropriate for briquette production based on techno-economic, social-economic, and financial criteria. The study adopts two MCDM approaches: Criteria Importance Through Intercriteria Correlation (CRITIC). The CRITIC method was used to evaluate weights for criteria. After that, EDAS is used to rank and select the biomass feedstock based on the criteria chosen. Table 2 shows selected criteria with their respective benefit attributes for decision-making. For the negative criterion, less is better, and more is better for the positive criterion.

**Table 1.** Selected criteria with their respective attributes for MCDM analysis

Criteria	Unit	Benefit attribute
Production cost	(USD/kg)	Negative
Net present value	(USD)	Negative
Internal rate of return	(%)	Positive
Feedstock availability	(tonne/year)	Positive
Total job creation	-	Positive
Potential number of plants	-	Positive
Number of households supplied	-	Positive

**2.2.1 Criteria Importance Through Intercriteria Correlation (CRITIC) Method**

The CRITIC method is applied to estimate criteria objective weights when decision-makers or experts have a conflicting view on the value of weights for criteria. This helps experts or decision-makers to prevent being biased towards awarding scores to criteria. The CRITIC algorithm incorporates the following steps to estimate criteria objective weights (Diakoulaki et al. 1995).

**Step 1:** Normalise the decision matrix ( $\bar{X}_{ij}$ ) as follow:

$$\bar{X}_{ij} = \frac{X_{ij} - X_j^{\text{worset}}}{X_j^{\text{best}} - X_j^{\text{worset}}} \tag{1}$$

Where  $X_{ij}$  are the values in the decision matrix;  $X_j^{\text{best}}$  are the best values in the decision matrix that exist in the column;  $X_j^{\text{worst}}$  are the worst values in the decision matrix that exist in the column.

**Step 2:** Compute the standard deviation ( $\sigma_j$ ) for each criterion using Eq. 2:

$$\sigma_j = \frac{\sqrt{(\sum X_i - \mu)^2}}{N} \tag{2}$$



Where N is the size of the population;  $\mu$  is the mean population;  $X_{ij}$  are the elements in the decision matrix;

**Step 3:** Determine the symmetric matrix of  $m \times n$  with element  $r_{jk}$ , which is the linear correlation coefficient between the vectors  $x_j$  and  $x_k$ .

**Step 4:** Compute the degree of conflict generated by criterion  $j$  relative to the rest of the criteria using Eq. 3.

$$\sum_{k=1}^m 1 - r_{jk} \tag{3}$$

Where  $r_{jk}$  denotes the linear correlation coefficient between the vectors  $x_j$  and  $x_k$ .

**Step 5:** Calculate the quantity of information  $C_j$  for each criterion as follows:

$$C_j = \sigma_j * \sum_{k=1}^m 1 - r_{jk} \tag{4}$$

**Step 6:** Calculate the objective weight  $W_j$  for each criterion using Eq. 5:

$$w_j = C_j / \sum_{i=1}^m C_j \tag{5}$$

**2.2.2 Evaluation Based on Distance from Average Solution (EDAS)**

EDAS is a newly developed MCDM by Zavadskas et al. (2015). EDAS is robust for selecting systems having numerous conflicting criteria. The algorithm is based on the distances of options from the criteria’ average scores (Kahraman et al. 2017). The EDAS algorithm uses the following steps to rank the crop residue feedstocks (Kahraman et al. 2017):

**Step 1:** Compute the average solution ( $AV_j$ ) using Eq. 6:

$$AV_j = \frac{\sum_{i=1}^n X_{ij}}{n} \tag{6}$$

Where  $X_{ij}$  are the elements of the decision matrix;  $n$  is the number of criteria.

**Step 2:** Calculate the positive distance from average ( $PDA_{ij}$ ) using Eqs. 7a and 7b. If  $j$ th criterion is beneficial,

$$PDA_{ij} = \frac{\max(0, (X_{ij} - AV_j))}{AV_j} \tag{7a}$$

If jth criterion is non-beneficial

$$PDA_{ij} = \frac{\max(0, (AV_j - X_j))}{AV_j} \tag{7b}$$

**Step 3:** Calculate the negative distance from average (NDA<sub>ij</sub>) using Eqs. 8a and 8b:

If jth criterion is beneficial,

$$NDA_{ij} = \frac{\max(0, (AV_j - X_j))}{AV_j} \tag{8a}$$

If jth criterion is non-beneficial,

$$NDA_{ij} = \frac{\max(0, (X_{ij} - AV_j))}{AV_j} \tag{8b}$$

**Step 4:** Calculate the weighted sum PDA<sub>ij</sub> (SP<sub>i</sub>) using Eq. 9

$$SP_i = \sum_{j=1}^m w_j PDA_{ij} \tag{9}$$

**Step 5:** Calculate the weighted sum NDA<sub>ij</sub> (SN<sub>i</sub>) as follows:

$$SN_i = \sum_{j=1}^m w_j NDA_{ij} \tag{10}$$

**Step 6:** Calculate normalise values of SP<sub>i</sub> and SN<sub>i</sub> using Eqs. 11 and 12, respectively:

$$NSP_i = \frac{SP_i}{\max_i(SP_i)} \tag{11}$$

$$NSN_i = 1 - \frac{SN_i}{\max_i(SN_i)} \tag{12}$$

**Step 7:** Normalise the values of NSP<sub>i</sub> and NSN<sub>i</sub> as follows:

$$AS_i = \frac{1}{2}(NSP_i + NSN_i) \tag{13}$$

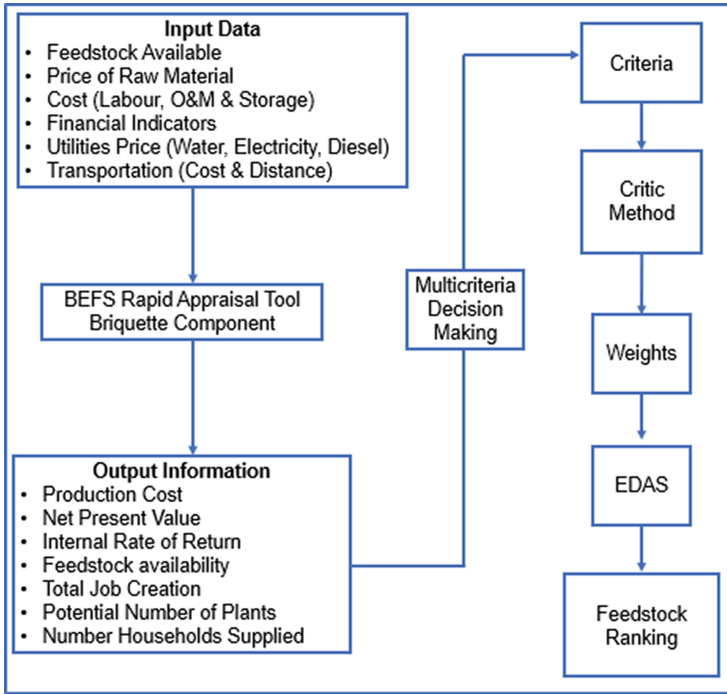


Fig. 1. Flow of analysis with BEFS RA module and MCDM methods

### 3 Results and Discussion

Table 2 illustrates summary of key input parameters for BEFS RA tool. The BEFS RA tool categorises briquette production into 4 different scales, namely, 4 kg/hr, 40 kg/hr, 400 kg/hr, 4000 kg/hr. This study concentrated on 4000 kg/hr since it targets large briquette production to serve the whole country.

Table 2. Summary of key input parameters for BEFS RA tool

Parameter	Value	Remarks/Reference
Selected residues technical potential	-	Adopted from Azasi et al. (2020)
Water price (USD/m <sup>3</sup> )	0.47	Average water tariff for households in Ghana (PURC 2020)
Diesel price (USD/L)	1.03	Price includes delivery and transportation (GlobalPetrolPrices 2020)
Electricity (USD/kWh)	0.11	Average electricity tariff for households in Ghana (PURC 2020)

(continued)

**Table 2.** (continued)

Parameter	Value	Remarks/Reference
Skilled worker (USD/person-hr)	2	It comprises professionals with specific skills and expertise, including machine operators, managers, etc.
Unskilled worker (USD/person-hr)	1.5	It comprises personnel with no special skills. These could be trainees or people performing tasks that could be taught in a few days
Working hours/day	8	Typical working hours for workers in Ghana
Transportation cost (USD/t/km)	0.09	Cost assumed for transportation of feedstock from the collection point to the briquette plant
Operating days /year	300	Typical average working days in Ghana
Operating hours/day	8	Typical average operating hours for workers in Ghana
Storage safety rate of product (%)	20	Author's assumption based on other similar projects
Plant overhead (%)	30	Percentage of costs for service, facilities, payroll overhead, etc.
Maintenance (%)	20	Cost for maintenance of equipment's, including labour and materials
General and administrative (%)	8	Cost to cover rents, insurance, and salaries of managerial, administrative, and executive staff
Discount rate (%)	10	(Bank of Ghana 2020)
Loan ratio (%)	50	Typical loan ratio for typical projects in Ghana
Loan interest rate (%)	12	Assumed loan interest for this project
Loan term (years)	5	Typical loan terms given to clients in Ghana
Project lifetime (years)	20	A typical similar project lifetime is between 20–25 years

Table 3 presents the techno-economic, socio-economic, and financial output for the selected feedstocks under investigation. It forms the decision matrix for MCDM. It can be observed that one feedstock has a higher value in one criterion and a lower value in another criterion. For instance, sorghum husk has the lowest production cost and internal rate of return. Rice husk also has the highest internal rate of return. Maize cob has the highest net present value and total job creation. Also, cassava stalk has the highest feedstock availability and produces the highest briquette supplied to households. This result shows that it is prudent and logical to assess the feedstocks based on several criteria to validate and justify the selected feedstock to prioritise sustainable briquette production.

**Table 3.** Decision matrix for MCDM

Criteria	Maize cob	Cassava stalk	Rice husk	Groundnut husk	Sorghum husk	Millet husk
Production cost (USD/kg)	0.054	0.049	0.047	0.060	0.048	0.049
Net present value (1000 USD)	881	1,729	2,219	-264	1,918	1,835
Internal rate of return (%)	13	14	15	0	15	14
Feedstock availability (tonnes/yr)	606,631	1,591,927	173,438	217,610	682,285	457,116
Total job creation	33,480	12,670	4,224	4,270	3,960	6,660
Potential number of plants	27	70	8	10	30	20
Number of households supplied	41,327	107,974	11,971	15,005	46,318	30,960

Table 4 presents the estimated criteria quantity of information and weights. Equations 1–5 were used to compute the objective weights for the criteria. The criteria weights are critical for EDAS in ranking the feedstocks. It can be observed that total job creation has the highest weight and is the most important criteria for the feedstocks. Next is net present value and production cost. The lowest criteria weights are attributed to household supplies and feedstock availability. The remaining criteria have intermediate weights. However, the variation between the criteria weights is significant but minimal. The weight difference between total job creation and feedstock availability is about 51%. Also, the difference between net present value and household supply is about 26%.

Tables 5 and 6 present the positive distance average (PDA) and negative distance average (NDA). The PDA and NDA were computed using Eqs. 7 and 8, respectively.

It can be observed that maize cob and cassava stalks have the highest PDA values compared to the other feedstocks (Table 5). Likewise, maize cob and cassava stalk husk have the lowest NDA value (Table 6). Higher PDA values positively affect feedstocks ranking, and lower NDA values negatively affect feedstocks ranking. The results indicate that the PDA and NDA values are consistent and likely to impact EDAS to rank the feedstocks accurately.

**Table 4.** CRITIC results for criteria weights

Criteria	$C_j$	$W_j$
Production cost	1.308870981	0.144209637
Net present value	1.320367515	0.14547631
Internal rate of return	1.146179692	0.126284531
Feedstock availability	1.046131799	0.115261389
Total job creation	2.157212518	0.237678762
Potential number of plants	1.049989852	0.115686464
Number of households supplied	1.047416245	0.115402907

**Table 5.** Positive distance average

Feedstock	Production cost	Net present value	Internal rate of return	Feedstock availability	Total job creation	Potential number of plants	Number of households supplied
Maize cob	0.000	0.000	0.099	0.000	2.078	0.000	0.000
Cassava stalk	0.042	0.247	0.183	1.561	0.165	1.545	1.555
Rice husk	0.081	0.601	0.268	0.000	0.000	0.000	0.000
Groundnut husk	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sorghum husk	0.062	0.384	0.268	0.098	0.000	0.091	0.096
Millet husk	0.042	0.324	0.183	0.000	0.000	0.000	0.000

**Table 6.** Negative distance from average

Feedstock	Production cost	Net present value	Internal rate of return	Feedstock availability	Total job creation	Potential number of plants	Households supplied
Maize cob	0.055	0.365	0.000	0.024	0.000	0.018	0.022
Cassava stalk	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Rice husk	0.000	0.000	0.000	0.721	0.612	0.709	0.717
Groundnut husk	0.173	1.190	1.000	0.650	0.607	0.636	0.645
Sorghum husk	0.000	0.000	0.000	0.000	0.636	0.000	0.000
Millet husk	0.000	0.000	0.000	0.264	0.388	0.273	0.267

Table 7 presents feedstock rankings based on EDAS. The feedstocks'  $SP_i$  and  $SN_i$  values were computed using Eqs. 9 and 10, respectively. Also, the feedstocks  $NSP_i$  and  $NSN_i$  were calculated based on Eq. 11 and Eq. 12, respectively. The final  $AS_i$  for ranking the feedstocks was estimated using Eq. 13. The feedstocks with an  $AS_i$  score of 1 are the best. It can be seen that cassava stalk ranks in the first position with an  $AS_i$  score of 1, followed by maize cob (0.844), sorghum husk (0.493), millet husk (0.426), rice husk (0.319), and groundnut husk (0). This implies that cassava stalk is the best feedstock for sustainable briquette production based on techno-economic, socio-economic, and financial criteria in the MCDM perspective. Though maize cob ranks second, the  $AS_i$  score is nearly close to cassava stalk with just a 17% difference. However, sorghum husk, which ranks third in the  $AS_i$  score, is 67% lower than cassava stalks. Furthermore, it is prudent to test and check the resilience of the same decision matrix on other MCDM to validate EDAS results. Figure 2 displays feedstock ranking based on other MCDM approaches. It can be observed that findings from Technique of Order Preference Similarity to the Ideal Solution (TOPSIS), Complex Proportional Assessment (COPRAS), Multi-Objective Optimization on the Basis of Ratio Analysis (MOORA), and Viekriterijumsko Kompromisno Rangiranje (VIKOR) are nearly consistent and comparable to EDAS findings. Again, MOORA and COPRAS rankings are in full correlation with EDAS rankings. Yet, there is a slight deviation from TOPSIS and VIKOR, which ranks maize cob as the best feedstock compared to EDAS, which ranked cassava stalk. Also, VIKOR exhibited a slight deviation for millet husk and sorghum husk rankings compared to the other MCDM methods. It can be concluded that the ranking of the feedstocks did not vary much. This indicates that cassava stalk is promising and outshines the other feedstocks based on the five MCDM methods. Thus, it is profitable for policymakers to prioritise cassava stalk and maize cob based on the MCDM perspective for sustainable development. The next best feedstock is millet husk, and the worst feedstocks are rice husk and groundnut husk.

**Table 7.** EDAS ranking for feedstocks

Feedstock	$SP_i$	$SN_i$	$NSP_i$	$NSN_i$	$AS_i$	Rank
Maize cob	0.506	0.068	0.788	0.901	0.844	2
Cassava stalk	0.643	0	1	1	1	1
Rice husk	0.133	0.393	0.207	0.432	0.319	5
Groundnut husk	0	0.692	0	0	0	6
Sorghum husk	0.131	0.151	0.205	0.782	0.493	3
Millet husk	0.076	0.185	0.119	0.732	0.426	4

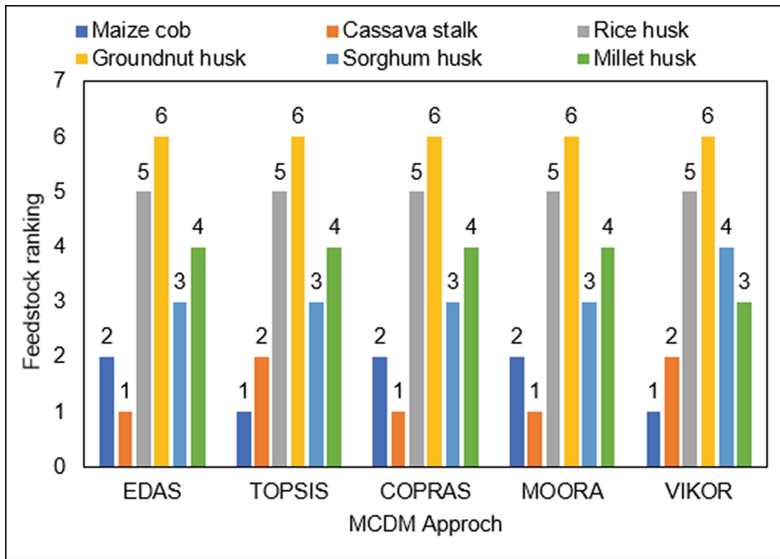


Fig. 2. Comparison of feedstock rankings based on different MCDM.

## 4 Conclusion

This study focused on prioritising feedstock for briquette production. Findings from EDAS indicate that cassava stalk is the best and most promising feedstock for briquette production. The final feedstock ranking is as follows: Cassava stalk > maize cob > sorghum husk > millet husk > rice husk > groundnut husk. Also, additional MCDM tested on the same decision matrix agrees with EDAS findings and validates it. Based on these findings, decision-makers and policymakers should encourage briquettes for cooking in rural and urban households. Although Ghana has a high potential for briquetting to replace wood fuel, the production of briquettes is likely to be hampered by (i) a lack of awareness about the use of briquettes; (ii) readily available carbonised briquettes in the local market; and (iii) readily available cookstoves to burn the briquettes. Future studies should consider using other decision-making approaches for weight determination, such as Shanon entropy, to compare results to the Criteria Importance Through Intercriteria Correlation (Critic) method.

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# Surface Modification of Vegetal Fibre

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**Abstract. Purpose:** The purpose of this review paper was to document a one stop-shop data that could guide researchers and industry players in the selection of appropriate vegetal surface modification method to treat vegetal fibre surface in order to enhance inter fibre-polymer mechanical bonding in composites.

**Design/Methodology/Approach:** Content analysis was the selected methodology for this study, with particular emphasis on systematic review of manifest content. A systematic review was employed to cover a period of eight years; from 2010 to 2017 from the Microsoft Bing database. The manifest contents of 20 out of 120 research documents were finally selected and manually coded for detail review and analysis.

**Findings:** Among the findings include the following: (1) the major surface modification techniques employed for fibre-polymer developments are mechanical, biological and chemical; (2) Chemical treatment is the most effective and efficient technique. (3) Chemical agents may act as compatibilizing agent, coupling agent, or both. (4) Among the chemical agents, alkaline and silane solutions were the most effective.

**Research Limitation/Implications:** Human coding technique adopted has limitations considering the fact that computer-based analysis can be helpful with large electronic data sets by reducing time and prevent the need for employing several human coders to derive inter-coder reliability. The study was also limited by dwelling on only eight-year period from 2010 to 2017. Considering as many documents as possible, and more recent research documents as such, could be more useful to such studies.

**Practical Implication:** It is intended that the paper will guide both industry players and researchers as to the most suitable method that should be adopted to improve upon the adhesion properties of vegetal fibre-polymer composites during composite development and manufacturing.

**Social Implication:** The knowledge obtained in this paper when applied will facilitate sustainable development by making use of waste vegetal fibre and polymer waste through efficient and effective recycling of these materials to produce new composite materials by industry players.

**Originality/Value:** This study is novel in the sense that it establishes the fact that at the fibre and matrix interface, better interlocking bonding could be realized thus improving the properties of vegetal fibre and the resulting composite; and that varying the type of technique utilized in surface modification of vegetal or cellulosic fibre influences the properties of composites developed from fibre and polymer blend.

**Keywords:** Biological · Chemical · Physical · Surface · Treatment

## 1 Introduction

Mechanical properties of vegetal fibre-matrix composites are enhanced by good and strong interfacial adhesive forces between the two materials. However, the presence of silica bodies that are attached to circular surface craters which are uniformly spread across fibre surface; the presence of hydroxyl group of high cellulose content in vegetal fibre; and the presence of oil residue on fibre surface lead to poor mechanical and physical characteristics of the composite. Ester component of oil residue may also negatively affect the interactions between the coupling agent and fibre as well as coupling efficiency between polymer matrix and fibre. Thus the presence of cellulose, pectin, lignin and waxy substances may have negative effects on the performance of the composite. Fortunately, fibre properties can be enhanced significantly by modifying the surface of the fibre. Physically, biologically or chemically treating fibres may improve its surface properties and hence renders it more compatible with the matrix. The purpose of this review paper is to obtain a single stop-shop document that could guide researchers and industry players in the selection of appropriate vegetal surface modification method to treat vegetal fibre surface in order to enhance inter fibre-plastic mechanical bonding.

## 2 Methodology

Content analysis was the selected methodology for this study, with particular emphasis on systematic review of manifest content. Content analysis may be defined as the study of documents which might be texts of various formats, words, pictures, audio or video. It could be used to examine arrangements in communication in a repeated and systematic way (Alan 2011). With this technique past research documents are reviewed to identify the gap in relation to the documented studies in context. Thus the five-step process proposed by Denyer and Tranfield (2009) to systematically review literature was adopted. This process involves formulating questions on the study, selecting required documents, assessing the selected documents, analysing, and finally, documenting the result.

In order to achieve the objectives of the study and to obtain the most recent and appropriate academic research work related to surface modification of vegetal fibre, a systematic review was employed to cover a period of eleven years; from 2012 to 2021 from the Microsoft Bing database. The Microsoft Bing database contains reputable number of research documents globally. The eight year span between 2010 and 2017 was justifiable since a larger proportion of recent research work in the subject area, were carried out during this period.

An intense search on the Microsoft Bing was carried out using the “title-abstract-keyword” mechanism. The keywords for the search included “biological surface treatment”; “chemical surface modification”; “physical surface treatment”; “biological modification”; “chemical modification”; and “physical modification”. The search yielded 73,700 documents. Upon further screening using the keywords “silane”; “alkalis”; “plasma”; “corona discharge”; “enzyme”; “fungi”; and “bacteria”, 2211 documents were

identified. Additional restrictions were made employing the keywords “materials technology”; “material science”; “composites”; and “materials engineering”, with particular reference to the type of document. Document titles were then screened again to yield 120 publications. When the abstracts were analysed, 20 of the 120 research documents were finally selected and manually coded for detail review and analysis of the manifest contents (Lee et al. 2001). The results are presented in the next section of this paper.

### 3 Findings and Discussion

#### 3.1 Physical Surface Modification

Physical treatments mostly in vogue for modifying vegetal fibre are plasma, corona, steam explosion, high energy irradiation (such as ultraviolet, laser, gamma rays). Recent methods are super-heated steam and microwave treatments. Similar to chemical treatments, the aim of physical treatment of fibre is to modify the surface and structural characteristics of fibre to enhance interfacial adhesion between the microstructure of fibre and basic monomer unit of the polymer matrix. Physical treatments rather enhance the mechanical adhesion between fibre and matrix as a means of enhancing fibre-matrix component characteristics but not chemical adhesion.

Plasma is the fourth dimension of matter which is gaseous in nature with neutral and charged particles but zero charge density. Types of plasma treatment include atmospheric pressure plasma, low-pressure plasma, low-temperature plasma, and atmospheric glow discharge treatments. Gases usually employed also include nitrogen, oxygen, air and helium. During the surface modification process, a feeding gas (e.g. Oxygen) is excited by an electric current to generate plasmic matter (jet) through the fibre. The plasma stream so generated is composed of free radicals, ions, electrons which roughs, etches, cleans or and activates fibre surface thus modifying the surface characteristics and properties of the fibre. Plasma is also eco-friendly (Baltazar-y-Jimenez et al. 2008; Kalia et al. 2013).

Corona discharge treatment, also referred to as air plasma treatment activates fibre surface oxidation by modifying the surface energy of cellulose in fibre cells through the application of high voltage electrode. Mechanical adhesion between fibre and matrix is improved thus resulting in greater interlocking between the two phases (Faruk et al. 2012; Ragoubi et al. 2010).

The introduction of exploded steam onto vegetable fibre improves fibre dispersal within the matrix and also advances better adhesive forces between the two fibre-matrix phases. The process is in two stages. The first stage involves the introduction of high temperature and high-pressure shock steam through the fibre while the second stage deal with mechanical separation or splitting of fibre by violent discharge or explosion into a collecting medium. Steam exploded lignocellulose fibre may further undergo chemical treatment to enhance fibre-matrix adhesion between interfaces and inter-phases of composites (Brugnago et al. 2011; Satyanarayana 2004).

Microwave treatment of lignocellulose fibre reduces the weight of fibre due to moisture loss within cellulose and lignin contents of fibre. During the process, dielectric properties such as dielectric constant are reduced thus lowering the fibre's ability to store energy. Thus greater microwave energy dissipation leads to higher dielectric loss of fibre. Higher microwave energy dissipation leads to greater heat generation; improved

fibre surface evaporation of moisture and consequent reduction of fibre weight and size. Weight loss and size reduction by microwave treatment are pronounced mostly in oil palm empty fruit bunch fibre, followed by oil palm mesocarp fibre and oil palm kernel in that order (Chang et al. 2017). Microwave treatment may have to be supplemented by chemical or physical treatment in order to achieve acceptable enhanced surface modification of fibre. The process is highly eco-friendly.

Superheated steam may be applied to vegetal fibre to change the surface characteristics and properties. Studies by Mahmud et al. (2013) and Bahrain et al. (2012) provide superheated steam as a potential treatment technique for modifying lignocellulose material properties for bio composite fabrication. During the treatment process, superheated steam from a boiler is injected through fibre material in a heating chamber. The purpose of the heating chamber is to maintain the temperature of superheated steam as the steaming process proceeds. Superheating of lignocellulose fibre has a great influence on chemical composition; morphological properties; and thermal stability. It increases thermal degradation temperature; improves hydrophobic properties; and enhances surface roughness through the removal of silica bodies in fibre surface craters. Thus superheating treatment has better physical, thermal and chemical effects on properties of vegetal fibre; and is eco-friendly (Nordin et al. 2013; Megashah et al. 2018).

### 3.2 Biological Surface Treatment

Enzymic and fungal treatments are the most common and attractive biological treatments due to positive effects on lignocellulose fibre properties with regards to the fibre-matrix composite formation. Treatment of fibre with bacterial Nano cellulose has also become attractive in fibre surface modification studies. Biological treatments are eco-friendly and introduce selective removal mechanism to pectin and hemicellulose with or no application of external energy (Garunathan et al. 2015).

The enzyme cellulase is usually employed in the surface modification process through fibre cell wall degradation. In the process, the cell wall is stripped, (delamination and collapse) giving way to growth of new finer fibrils. These new fibrils are more hydrophobic and responsible for the improved fibre-matrix adhesion at the molecular level and macro-structural phase of composite material. Advantages of the enzyme treatment of fibre include gentle enzyme-fibre interactions; availability of particular enzymes for specific purposes; safer fibre surface transformations; and eco-friendliness (Kalia et al. 2013; Pallesen 1996). The effect of enzymatic hydrolysis is relatively more pronounced in hemicellulose, reducing hemicellulose content and thereby relatively increasing lignocellulose content of the fibre (Megashah et al. 2018).

Fungi treatment involves three stages. Fungi addition to fibre is preceded with autoclave sterilization at 120 °C for 15 min. The required percentage of fungi is then added to fibre and incubated for 2 weeks at 27 °C. The third and final stage involves sterilization, washing and over-drying of fungi-fibre content. White rot fungus is usually applied in fungi treatment of this nature. The fungal treatment has many advantages. Comparatively, it is eco-friendly and efficient. It also increases fibre hydro-phobicity by dissolving hemicellulose present in the fibre. It removes lignin from the fibre. It further

removes silica bodies from circular craters which are uniformly spread over fibre surface roughness. Subsequently, interfacial adhesion within a fibre-matrix composite is increased and enhanced (Kabir et al. 2012; Nikkhah et al. 2007; Pickering et al. 2007).

Treatment with bacterial Nano cellulose involves the addition of Nano-sized cellulose material produced by bacteria in a controlled culture medium with fibre. Produced cellulose is deposited in situ on fibre surface to improve interfacial adhesion between fibre and matrix. The technique provides a better spread of bacterial cellulose within the composite; thus facilitating improved bond between the (mechanical) fibre and matrix (Lee et al. 2014). *A. xylinum* (bacteria) has been successfully employed to treat sisal fibre by this method. The presence of lignin is a disincentive to thermal degradation, ultraviolet degradation and char formation (Azwa et al. 2013). Though the method has some advantages, it may be more beneficial in situations where a high percentage of lignin content in the composite will hinder certain desired properties.

### 3.3 Chemical Surface Modification

Two fundamental limitations, by which the potential use of natural fibre as polymer reinforcement, exist. First, the strength of composites is relatively low due to incompatibility between fibre and polymer matrix; and second, the tendency of fibre and polymer to aggregate as a result of fibre affinity to water (Ragoubi et al. 2010; Saheb and Jog 1999). It is a truism that fibre-polymer matrix compatibility issues can be overcome by the addition of coupling agents (George et al. 2001; Sobczak et al. 2013). However, biochar can also be incorporated as a new technique of composite characteristics enhancement (Das et al. 2015a; Das et al. 2015b; Das et al. 2016a; Das et al. 2016b; De Vaillance et al. 2015; Kwon et al. 2014; Li et al. 2014; Samotu et al. 2015; Oladele and Okoro 2016).

The main constituents of biochar include oxygen; hydrogen; and between 60% and 90% of carbon (Nachenius et al. 2013). Due to its pore size distribution; packing and density; bulk surface area; and particle size distribution biochar can also be employed to lessen emissions of nitrous oxide into the atmosphere and bind heavy metals in water and soil particles (Cernansky 2015). Pyrolysis is a common method employed to convert organic waste materials into biochar, liquids and non-condensable gases at temperatures ranging from 400 °C and 700 °C (Das et al. 2015b; Cernansky 2015). The properties of biochar depend mainly on the temperature of pyrolysis and other factors such as the type of organic waste and method of processing technique (Das et al. 2015b).

Hydrophilic nature of vegetal fibre can be circumvented through the use of fibre surface modifications. This is due to the presence of hydroxyl (OH) and/or carboxylic (COOH) groups in hemicelluloses; pectins; and cellulose though the tendency of OH group in cellulose to be made available is less. This is as a result of crystalline nature and high linearity of cellulose chains in microfibrils of vegetal fibre. On the other hand, lignin, another structural component of lignocellulose fibre is hydrophobic but to a lesser degree (Stokke et al. 2014). Since polymers are hydrophobic there is poor surface wetting between fibre-polymer interfacial linkages. This brings about voids and reduced stress transfer within resulting composites. Another limitation of vegetal fibre as a reinforcement material in the plastic composite is the ability and tendency of the composite to absorb moisture under atmospheric conditions. Variations in weather conditions such as temperature; humidity; and pressure may induce atmospheric related condition stresses

that may swell the vegetal fibre and eventually lead to composite damage and failure. The presence of moisture that is induced into composite may also lead to fungal and microbial damage and consequential failure (Vaisanen et al. 2016). As indicated earlier in this paper many techniques are available to overcome these limitations. However, the chemical treatment appears to be the most efficient and hence the most employed.

Chemical treatments of vegetal fibre aim at creating better chemical bonding between fibre and polymer matrix through compatibility and adhesion; and are the most employed technique employed by researchers. Compatibilization aims at enhancing wetting between fibre and polymer matrix while adhesion or coupling purposes to enhance the chemical reaction between polymer matrix and fibre interface. Bio functional chemical reagents such as MAPP act as both compatibilizer and coupling agents. The main difference between compatibilizers and coupling agents is that compatibilizers do not ensure strong adhesive bonds (chemical) between fibre and matrix at the molecular level. Since dispersants reduce interfacial surface energy; reduce fibre-matrix interfacial separation; and allow new interface formation, they are classified under compatibilizers (Lu et al. 2000). Thus incompatibility or dispersion and high water affinity and aggregation caused by vegetal fibre are the main limitations in fibre-plastic composite formation (Faruk et al. 2012; Saheb and Jog 1999; Sobczak et al. 2013).

The next section, therefore, deals with empirical studies on the effect of chemical surface modification on selected properties of fibre-plastic polymer composites. Emphasis is laid on oil palm fibre and plastic composites. Plastics considered include polyethylene (PE); polypropylene (PP); polyvinyl chloride (PVC); polyurethane (PU); Epoxy and polyester. While the first four are thermoplastics, the last three are thermosets.

Chemical treatment involves facilitation of efficient coupling and interfacial reactions through the exposure of responsible reactive functional groups on fibre surface to enhance composite mechanical properties (Mohammed et al. 2015). Chemical methods introduce hydrophobic characteristics to vegetal fibre and improve fibre-matrix compatibility. Though several chemical methods of fibre treatment are available (Shinoj et al. 2011) the most effective and therefore referable are alkali; silane; acetylation; benzoylation; peroxide; permanganate; isocyanate; maleated coupling; and peracetic acid (PA) (Shinoj et al. 2011; Jabbar 2017).

Vegetal fibre surface treatment using alkaline solution has been found attractive among fibre-based composite researchers. It functions by modifying the physical orientation of cellulose molecules. For instance, when the alkaline solution is introduced into cellulose it penetrates the space in-between the lattice planes thus swelling the cellulose. This causes significant separation of cellulose macromolecules at large distances. -OH group, which is sensitive to alkali, therefore, breaks down and leaches out of the fibre structure by reacting with H-OH molecules of water. The monoclinic crystalline lattice of natural fibre (cellulose-I) is thereby converted to Na-cellulose-I. Cellulose-I molecules can be converted to different polymorphous shapes through chemical interaction with chemicals. Na-cellulose I is a product of the reaction between the remaining reactive molecules (OH and cellulose) present which form fibre-cell-O-Na groups between the molecular chains of cellulose (John and Anandjiwala 2008).

Thus, two processes help reduce the hydrophilic nature of the fibre. First, a portion of cellulose leaches out through water; and two, another portion is bound to fibre-cell



through the fibre-cell-O-Na groups and cellulose molecular chains. These two processes increase the hydrophobic property of the fibre. Na-ions present in Na cellulose-I are finally rinsed off with water forming crystalline cellulose – II structure. Alkaline treatment also reduces the contents of hemicellulose, lignin, pectin, wax and oil. It thus significantly increase fibre length-diameter (aspect) ratio by reducing fibre diameter; surface roughness is also improved both contributing to exposed fibre surface area and effective and efficient attraction between fibre and matrix.

Transformation of the crystalline lattice of cellulose from cellulose-I through alkali-cellulose-I to cellulose-II is influenced by the type of alkali (NaOH, LiOH or KOH) and alkali concentration. Nevertheless, there is an optimum concentration beyond which cellulose structure could be destroyed to impart negative influence on composite characteristics. Van de Weyenberg et al. (2006) submitted a schematic representation of crystalline lattice transformations from cellulose-I to cellulose-II by alkali treatment. It has also been established that sodium hydroxide effectively modifies fibre surface better than other alkalis due to the favorable size of sodium ion, Na<sup>+</sup>. The small size of Na<sup>+</sup> penetrates and fits crystalline lattice of cellulose macromolecules better than larger K<sup>+</sup> and Li<sup>+</sup> ions (Fengel and Wegener 1983).

Silane treatment has also been found to be active in reducing the hydrophilic nature of the vegetal fibre. As a multifunctional compound, it acts as a coupling agent to improve fibre surface performance by bridging fibre surface and matrix through siloxane formation. Silands are formed due to moisture in fibre and hydrolysable alkoxy groups in silane. Siloxane bridge or linkage is formed when one end of siloxane reacts the matrix functional group while the other end also reacts with the hydroxyl groups in fibre cell. This ensures continuous link among unit structures of hydroxyl and matrices functional groups within the composite (Nasution et al. 2015; Sreekala et al. 2001).

Acetylation is a process by which an acetyl functional group, (CH<sub>3</sub>COO-) is introduced into an organic compound through the method of esterification. In the case of fibre surface treatment, the purpose is to modify the dimensional stability of the fibre-matrix composite. This is achieved when the acetyl functional group renders hydroxyl groups in fibre inactive making it hydrophobic. To render its effect more significant acetylation treatment is preferably preceded with alkaline treatments; or other chemical treatment such as maleic anhydride-g (MA) (Nasution et al. 2015; Sreekala et al. 2001).

According to Joseph et al. (2003), the benzoyl group when introduced replaces hydroxyl group in cellulose and attaches to it thus impacting on the hydrophilic characteristics of the fibre and rather rendering it hydrophilic. This enhances the interfacial linkage between fibre and matrix. Benzoyl chloride is the most widely applied in vegetal fibre treatment of the fibre-polymer composite formation.

Peroxide treatment of vegetal fibre, however, involves the introduction of ROOR functional groups which include peroxide ion; organic peroxide; organic hydro-peroxide; peracid and per acetic acid (a type of peroxy acids) (Sreekala et al. 2001). Hydrogen peroxide, benzoyl peroxide and dicumyl peroxide are the most widely used peroxides for treating vegetal fibre. Similar to benzoylation and acetylation, peroxide requires pretreatment (Megashah et al. 2018). The Peroxide group decomposes readily to introduce free radical to interact with the hydroxyl group of fibre and demobilizes it, thus



ensuring better interaction between fibre and matrix interface. For the total decomposition of ROOR and effective fibre/matrix adhesion, higher temperatures are required (Sreekala et al. 2001). Peracetic acid has been found to exhibit extreme removal potential of particularly lignin in lignocellulose fibres (as well as hemicellulose) (Megashah et al. 2018).

Potassium permanganate (KMnO<sub>4</sub>) in acetone solution is used in graft copolymerization of vegetal fibre. The treatment is initiated by soaking fibre in the solution. The concentration of KMnO<sub>4</sub> is cautiously controlled so that Mn<sup>2+</sup> ions can be greatly reactive to ensure easy facilitation of the process. During the process, Mn<sup>2+</sup> ions react with a hydroxyl group in cellulose to form cellulose-manganate thus demobilizing the hydroxyl group and rendering fibre more hydrophobic. This enhances fibre-matrix adhesion and improves chemical interlocking tendencies (Joseph et al. 2006).

The functions of the isocyanate functional group (-N=C=O) responsible for isocyanate treatment of vegetal fibre influences cellulose and lignin by reacting with the hydroxyl group. During the process, urethane is generated, forming a strong covalent linkage and better fibre-matrix interface. Mechanical properties of the fibre are further enhanced by the formation of urea when isocyanate reacts with moisture in cellulose and lignin. Urea subsequently reacts with hydroxyl groups in the fibre thus enhancing the hydrophobic characteristics of the fibre-matrix composite (George et al. 2001).

Introduction of anhydride groups by adding maleic anhydride coupling agent to vegetal fibre surface create covalent bonds between anhydride groups and hydroxyl groups of fibre. This forms the interfacial bridge between the two that results in the efficient interlocking linkage. The maleic anhydride coupling agent is usually used when Polyethylene or Polypropylene matrix is used to pair with vegetal fibre. It does not affect crystalline structure but rather an amorphous region within the fibre cell. It improves hydrophobic characteristics of fibre by reacting with hydroxyl groups to produce brush-like long-chain polymer blanket around the fibre thus improving bonding at fiber-matrix interface. Coupling agent maleic anhydride is preferable to other coupling agents due to better interaction it generates between fibre and matrix (Nasution et al. 2015).

The commonest and best-preferred graft polymerization agents are acryl acid (CH<sub>2</sub> = CHCOOH), acrylonitrile (CH<sub>2</sub>=CH-C≡N), and vinyl monomers of various types. During grafting, free radicals such as COOH and C≡N (carbolic and nitrile radical groups) react with cellulose which then creates efficient interaction between cellulose and matrix monomer to improve facial interlocking characteristics (Kalia et al. 2013).

## 4 Conclusion

Surface modification of vegetal fibre, whether physical, chemical or biological, has the tendency to improve interfacial adhesion between fibre and matrix of composites. At the fibre and matrix interphase, better interlocking bonding is achieved thus enhancing the properties of the polymer matrix. Though these techniques are applicable, chemical treatment methods appear to produce better results and therefore profoundly popular among researchers. Even with chemical treatments, silane and alkali treatments have been recommended by many researchers based on experimental results. With physical techniques, microwave and superheating methods appear to be recent while bacterial

cellulose application is the most recently researched biological method. The most recent way of treating lignocellulose fibre is the hybrid application where multi-treatment methods are employed. By employing chemical, physical and or biological methods stepwise or consecutively, better fibre surface improvement may be achieved. This will further enhance fibre-matrix adhesion and improve the properties of composite materials. It is evidential that fibre surface modification can greatly impact on fibre-matrix interfacial adhesion; and hence properties such as mechanical, thermal, and physical characteristics could be enhanced. Other properties of fibre and polymer matrix composites, such as physical weathering/degradation and tribology among others, could also be positively impacted through fibre surface modification.

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# Determining the Level of Economic Efficacy of Mandatory and Supplementary Schemes in the Post-retirement Period

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**Abstract. Purpose:** This paper presents the investigation on the level of economic efficacy due to mandatory and supplementary schemes in the post-retirement period among National Social Security Fund (NSSF) beneficiaries taking Morogoro as a case for study. The main argument is that once the reasonable level of economic efficacy is achieved it is likely to decrease the direct national economic losses relative to global gross domestic product.

**Design/Methodology/Approach:** Purposive sampling technique was used to select 100 respondents under the condition that they should be NSSF retired beneficiaries. Descriptive statistics were used to analyze quantitative data which enabled researchers to generate frequencies and percentages under the objectives of the study. The level of economic efficacy was measured through Economic Efficacy Summated Index (EESI).

**Findings:** Findings revealed that the economic efficacy level due to NSSF services to the retired population was at a moderate level. This was pre-determined by lack of significant association between background characteristics of respondents and a monthly income as well as low extent under which NSSF serve its clients at the time of disbursing terminal benefits.

**Research Limitation/Implications:** The study's target population was retired officials who some of them were not found in Morogoro region. This forced a researcher to use telephone interviews which have many shortfalls in social science research.

**Practical Implication:** The knowledge generated from this study will inform Social Security employees on empowering more Tanzanian workers so that the benefits they give them may positively contribute to decreasing the direct national economic losses relative to global gross domestic product.

**Social Implication:** The knowledge generated from this study will inform economic policymakers on empowering more Social Security Funds so that they may positively contribute to decreasing the direct national economic losses relative to global gross domestic product.

**Originality/Value:** The originality of this paper is backed up by the life Life Cycle Model (LCM) which assumes that NSSF beneficiaries were expected to execute to stages in their economic behaviour. One stage is the accumulation stage at the time they were young and energetic while the second stage being the spending stage depending on one's serving/accumulation. Thus, these two stages are the ones that differentiate one level of economic efficacy and the other.

**Keywords:** Beneficiaries · Level of economic efficacy · Mandatory · National social security fund · Supplementary schemes

## 1 Introduction

It is estimated that comparatively aged people with 50+ at work is anticipated to rise rapidly in prospect, from seventeen (17) percent in 2005 to twenty-seven (27) percent in 2050 (UN 2007; US Bureau of Statistics 2017). In America for instance, the proportion of aged workers is associated with an increase in life expectancy, thus the population is anticipated to have a longer life expectancy in coming years such that by 2060 life expectancy for the total population is anticipated to shoot from 79.7 in 2017 to 85.6 in 2060 (Medina et al. 2020). In Africa ageing is said to increase exponentially, and for this in for instance, in the year 2012, people aged 60+ were said to be found in Africa. Additionally, in Tanzania the country-wise census showed that the same age group was estimated to be 1.9Million people. This is not something to be quiet of if a country cares about her people and aims at bringing sustainable development for all groups of people. In the same background, African countries have been adopting many strategies, policies, and programmes so that they can tackle ageing phenomena to old working groups especially, those who are about to retire. Because ageing is a socio-economic issue, mechanisms like Social Security Fund become pivotal in safeguarding the said age group. By so doing the retired people are being empowered economically, thus contribute to National Gross Product (GDP) which eventually spear heard the global economy. Tanzania like any nation under United Nations has adopted 17 Sustainable Development Goals. Among these goals; for example, goal number eight is to transform people's lives by considering economic growth for all groups of people. In Tanzania the Social Security Funds have a direct relationship with people's economic efficacy.

The services provided by SSFs in Tanzania for the retirees handle solely the public servants and this fund is called Public Service Social Security Fund (PSSSF) and for the non-public institutions called National Social Security Fund (NSSF) of which this paper is the focus. However, the retirement benefit was previously managed by other pension funds before they were merged into PSSSF. Upon comparing NSSF and PSSSF in terms of time, NSSF is older than PSSSF, and it is suitable for being studied than PSSSF. One fundamental question that may remain is that even though these funds and particularly NSSF for this piece of work, how its services translated into the economic efficacy of the retired people?

## 2 Theories Underpinning the Study

Theoretically, this paper has been underpinned by the life Life Cycle Model as laid down and explicated by Cremer (2009). This model theorize that people live under the two stages of the model in their economic behaviour; these are i) The one makes him/her save, ii) Consume what one serves. It operates under the assumption that people need to accumulate during the first stage and consume in the second stage. Now, to this paper, which is assessing the economic efficacy of the retirees; the model assumes that in the

first stage, public or private servants/workers are young and energetic perform many tasks which enable them to earn income to the extent of accumulating so that they can upgrade their economic efficacy in the prospect. Now, the more one works the more he/she is rewarded, whether in terms of salary or other remunerations. The amount of salary or the more one is remunerated the more he/she impacts in his serving, the more he/she accumulates, the more the determination of the second stage of the model. This model has a direct link with what has been studied in this paper, NSSF being a fund for the private sector employees. Its income depends on the accumulation of the employee who is a stakeholder of the fund. The strength of NSSF depends on the saving habits of its members. In the early years of one's work and employment, every employee accumulates the fund and feeds NSSF. However, at the time of retirement, the same fund changes from being fed to feeding its members. The employees who were contributors at the first stage when they were young and energetic, change into being "beneficiaries". However, the benefits which are harvested at old age depend on one's serving trend, tendencies and behaviour when he/she was young. Thus, the manifestation of the Life Cycle Model in the piece of work assessing the economic efficacy levels as the results of NSSF among the retired population.

## **2.1 Where is the Problem?**

Becoming old is a universal phenomenon for everyone living in this universe. But, again becoming old goes hand in hand with reduced capacity for one to work so that he/she can earn income for the future self-sustaining. It has been aired out through literature that minimal preparations such as saving as stipulated in the Life Cycle Model, has negative consequences in one's Life Expectancy. Thus, Life expectancy in Western Europe for instance increased from 32 (in 1800) to over 80 years in 2011 because of high economic efficacy. The problem is that Old age is always accompanied by a general deterioration in physical capacities to engage in productive activities, then social security funds become important organs in sustaining the old people to uplift their life expectancy. In this line of thinking, the current Tanzanian National Bureau of Statistics (NBS 2012) in Tanzania, life expectancy raised from 43 in 1960 to 58 years in 2011 which may imply the increase of the old population in the country. If that happens, then immediate measures need to be taken to handle the unproductive population. It is a time of making a careful inquiry on the machinery which are responsible for safeguarding unproductive population; for this case, retirees; and the machinery to be scrutinized are like NSSF. The scrutiny has been the point of departure and imperative because despite all the steps taken by the government, the livelihood of the old population is still low, and the economic efficacy due to the operation of Social Security Funds is questionable, thus the need to assess the role of NSSF as a case study in providing funds for the beneficiaries and their contribution to economic efficacy. This is in line with the study conducted by ILO (2018) in Tanzania mainland which showed a need to discuss social protection which can alleviate poverty and increase GDP.

### **3 Methodology**

#### **3.1 Research Design**

The design which laid behind the emergence of this paper is the descriptive research design. This design was used in harmony with mixed research approaches; ie quantitative and qualitative approaches. This design was appropriate as it allowed the researcher to collect, analyze and present data both qualitatively and quantitatively. The design enabled the collection of data once in a time.

#### **3.2 Study Population**

According to the nature of the study; this paper drew a sample from NSSF post members who were contributing to this security fund before they were retired. Using NSSF registers, 100 interviewees and respondents were selected as the main sample for data collection. The selection was guided by the literature review by Bailey (1994) who agrees with this selection that without considering the size of the population at the locality, thirty percent of the total population meets the minimum standards to conduct a study. Through examination of the sample, this assumption qualified the choice of the sample size.

#### **3.3 Sampling Techniques**

The paper used purposive sampling techniques as the sample had the condition that the respondents should be NSSF contributors before their retirement time. This technique was used when the NSSF registers were used to select the target population. But since NSSF is operating all over the country, then simple random sampling technique was used to select Morogoro region. Again, a simple random sampling technique was used to select respondents from the list in the book register.

#### **3.4 Data Collection Methods and Tools**

As said before that the paper used both qualitative and quantitative approaches, and then both methods and tools for collecting the same were used. For the case of the survey method, questionnaire as an appropriate tool was used to collect quantitative data while for the case of an interview, the interview guide with open-ended questions was used to collect qualitative data. Both qualitative and quantitative data complemented each other such that one approach could mimic the disadvantages of the other. These methods and their associated tools were sequentially used through physical/in-person data collection; however, some of them were reached through mobile phone interviews.

#### **3.5 Data Processing and Data Analysis**

The analysis was done through qualitatively and quantitatively techniques. The analysis was performed concerning pre-set specific objectives. Together with specific objectives, background characteristics were also analyzed. These characteristics were analyzed descriptively in the preliminary analysis. But later, they were analyzed inferentially



by Chi-Square by determining the association of each background characteristic to the dependent variable which is monthly income. The level of economic efficacy which was the main objective of the paper was achieved through calibration of the Composite Economic Efficacy Index (CEEI). This index was composed of 4 domains each having a convergent relationship with the index. The domains included Economic Performance Outcome (EPA), Vicarious Economic Experience (VEE), Verbal Economic Persuasion (VEP) and lastly, Physiological Economic Feedback (PEF). These domains were constituted by several questions that were pre-supposed to measure the said domain. Each statement in the domain was assigned a score presupposed to measure the quality of that domain. This type of analysis has been adopted from “quality-adjusted life-years,” family economic analysis which different from other types of economic analysis, incorporates the dimension of “quality of life” into the measurement of NSSF benefits.

## 4 Findings and Discussion

### 4.1 Social Demographic Characteristics

#### 4.1.1 Age of Respondent

Concerning age, it was found that the majority (69%) of the sampled population were between the ages of 55 to 65, while 28% had the range age of 66 and 75. Furthermore, a very small portion of 3% was of the ageing from 76 to 75. With these data, it can be said that years below 55 and above 76 were not part of the population that was studied. This is witnessed in Table 1. The connotation for the said results is that a large number of post retired NSSF beneficiaries were retired while they were still energetic to work for national productivity. The other implication is that because the fund itself serves private employees. There is the possibility of continual working even after receiving their terminal benefits due to retirement age, unlike public servant retired employees. Because of this assertion, one of the respondents comments that:

*“..... I retired 4 years ago due to old age, as a public servant. However, I can still work if I can be re-employed because the pension I am getting is not enough compared to the salary I was getting.....”*

This finding concurs with the NSSF policies whereby one is given terminal benefits not only because of the older age but because of many reasons including being terminated from work, when employment ceases or any other reason as stipulated in their guidelines. This claim is backed up by the (NSSF Operation Guide 2012) which clearly show how one can cease to be an employee even though he/she may still be energetic.

#### 4.1.2 Sex

When assessing the impact of the Social Security Fund on the population, the researcher needed to capture gender-disaggregated data. This was due to the reason that both men women have the rights of benefit equally in the government plans and policies. Hence, it was found that the majority (73%) constituted the sampled population in comparison to only a little (27%) female of the total sample population. This data is alarming

that in Tanzania a large portion of the labour force is still dominated by men. The same line of thinking is substantiated by (NBS 2012) when this national census displays an equal occupation of works, especially in public offices. Again this data has something say in private sectors whereby many women work under un formalized kind of occupation. But their male counterparts, even though they may be working under private/self-employment, the level of formalization is higher compared to females.

### 4.1.3 Education Level

Education is very instrumental in enabling one to acquire a decent job whether private or public. It is education that again enables one to have creativity in everyday endeavours which may, in turn, elevate economic efficacy. In this case study paper, it was found that a reasonable number (47%) of retirees had elementary specialized credentials or qualifications, that is to say, certificates or diplomas respectively. Additionally, 36% of the population were found to have a secondary level of education, furthermore, 14% were diagnosed to attain the primary level of education. It was only a very small portion (3%) who were university graduates.

**Table 1.** Background characteristics (BC)

Sn	Background Characteristics (BC)	Frequency	Percent (%)
Age of respondent			
1	76 to 79	3.00	3.00
2	66 to 75	28.00	28.00
3	55 to 65	69.00	69.00
	<b>Sub-total of BC</b>	100.00	100.00
Sex of respondent			
1	Men	73.00	73.00
2	Women	27.00	27.00
	<b>Sub-total of BC</b>	100.00	100.00
Status of marriage			
1	Married status	54.00	54.00
2	Single status	20.00	20.00
3	Widowed status	11.00	11.00
4	Divorced status	15.00	15.00
	<b>Sub-total of BC</b>	100.00	100.00
Level of education attained			

(continued)

**Table 1.** (continued)

Sn	Background Characteristics (BC)	Frequency	Percent (%)
1	Elementary level	14.00	14.00
2	Secondary level	36.00	36.00
3	Qualified/Certificate	47.00	47.00
4	Graduate	3.00	3.00
	<b>Sub-total of BC</b>	100.00	100.00

**Source:** Research findings in Morogoro Region, 2016

**4.1.4 The Size of Household and Monthly Income**

The association linking the size of the household and monthly income was assessed. After analysis, it was found that the majority (68%) of respondents were earning at a moderate level. The mean score in the descriptive statistics output was found to be 166,800/= per month which signifies a moderate level. Likewise, it was further found that there were respondents who acknowledged earning low income; these were signified by the average of Tsh. 75,394/=. These two were contrasted with respondents who were found to have high earnings of the average income of Tsh.588,790/=.Using the Chi-Square test, the association between household size and monthly earnings showed a significant association by p-value = 0.0738 which is statistically higher than 0.05. This tendency indicates that there was a trivial relationship that could link the size of the household and the monthly income given. The exceptional remark was recognised; that is, you could find a respondent in the study area but his/her family living in another locality; for example Morogoro and Dar es Salaam.

*“.....We are staying three in my house; however, in Dar es Salaam there are many people and dependants than in this house. My wife who is a nurse-midwife is still working in Dar es Salaam, she stays with my six children and three dependants. I just came here after retirements staying with some people to help me some few manual works.....”*

Due to that scenario, an insignificant association between respondent’s locality, monthly earnings and the size of the household was found. But when the additional investigation was posed to the same interviewee, on the root course of having two localities, it was clearly said that (Table 2):

*“.....I always fail to get a proper way of dividing my NSSF monthly benefits, the small amount I get fits more when I am in village settings where most products are being harvested from my farm. The spending of money becomes minimal as few items are bought here. The case becomes different when I send the same money to Dar es Salaam where there is, first a relatively large family size compared to the one I am staying with. Secondly, the cost of living is comparatively high in Dar es Salaam than in Mvomero district.....”*

**Table 2.** The size of household and Monthly income

The size of household	Monthly payment			
	Low income	Moderate income	High income	Total
2	1	6	4	11
3	0	16	10	26
4	0	15	7	22
5	0	14	3	17
6	0	8	3	11
7	0	4	1	5
8	0	2	1	3
9	0	0	1	1
10	0	1	1	2
11	0	1	1	2
	1	68	31	100
X = 0.738	Likelihood Ratio = 0.894	Linear by Linear Association = 0.602		

**4.2 Facilitation of the Benefits to NSSF Post Retired Members**

**4.2.1 The Time When the Pension Fund is Received**

One of the dimensions which were assessed was the operations of NSSF in providing services to its members. Among many issues, time, when the fund was disbursed, was one of the factors which were assessed. Qualitatively, one of the interviewees commented:

*“.....we always delay in making some computation and calculations once the beneficiary retires. This makes us not pay our client timely as the calculations and computations are not done by a single person, single unit. It is system-oriented which needs synchronization.....”*

Social Security Administration (2018) describes the same phenomena on the delay of disbursing the fund to the beneficiaries something which is making the social security funds like NSSF ineffective.

**4.2.2 Sufficiency of Retirement Pension Fund**

Giving the fund has been one thing but the beneficiary getting enough funds had been another thing. In asking the beneficiaries using the Likert Scale, it was found that the majority (61%) of all sampled populations agreed of getting insufficient retirement benefits. The same was affirmed by 27% of the sampled population. Thus, upon appealing to the model which has underpinned this study from the beginning, it may be said that most respondents did not invest much in the first stage of the model as the results they most of them harvested little at the retirement time. Hence reducing serving is affecting much

not only the individual economic efficacy but also the global economy. This finding is in line with Bauer (2020) who talks about the insufficient terminal benefits given and their acceleration to the poverty circle.

**4.2.3 Sufficiency of Monthly Pension Fund**

There has been a clear indication of whether apart from the terminal benefits given by the pension fund, the monthly fund has been instrumental in making the retirees economically alive. But it has been unfortunately what was found from the field was the opposite phenomenon. Thus, 61% of the total population said that the monthly fund was insufficient. This has been making many retirees remain in abject poverty as pointed out by (Yamlinga et al. 2021) in Tanzania NSSF beneficiaries do not have houses to inhabit after their retirement. Bureaucracy at the time of pension payment (Table 3).

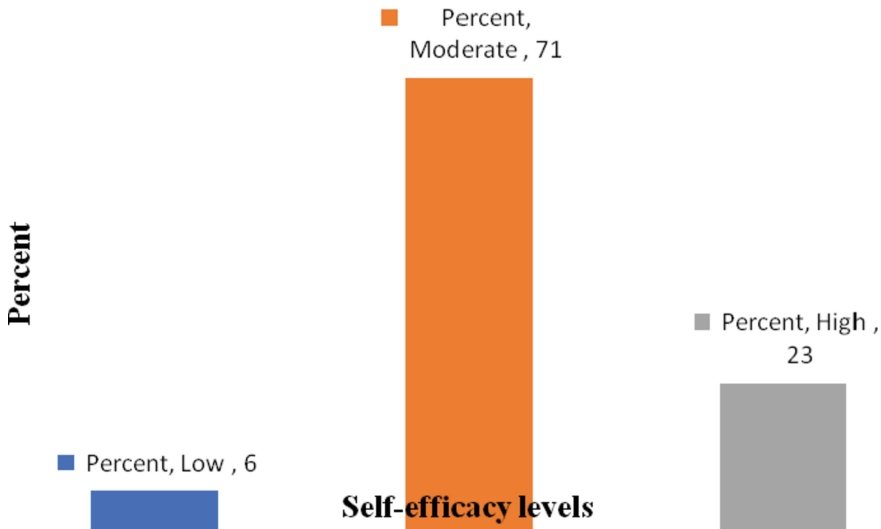
**Table 3.** Practices by NSSF in disbursing terminal benefits (n = 100)

SN	Statements implying the extent of facilitation	Disagree		Undecided		Agree	
		Frequency	P (%)	Frequency	P(%)	Frequency	P(%)
1	The fund is disbursed timely	44.00	44.00	10.00	10.00	46.00	46.00
	I don't get my monthly benefit timely	43.00	43.00	19.00	19.00	38.00	38.00
2	The terminal benefits at the retirement time is insufficient	61.00	61.00	12.00	19.00	27.00	27.00
3	I get adequate my periodical fund	65.00	65.00	0.00	0.00	35.00	35.00
4	I receive adequate fund every month	55.00	55.00	14.00	14.00	31.00	31.00
5	The procedures of getting fund is too bureaucratic	70.00	70.00	10.00	10.00	20.00	20.00
6	The procedures of getting fund is not bureaucratic	65.00	65.00	0.00	0.00	35.00	35.00
7	Schemes regulations are in favour of retired people	66.00	66.00	1.00	1.00	33.00	33.00

**4.3 Level of Economic Efficacy of NSSF to Post Retired Beneficiaries**

The main purpose of the paper has been to determine the level of economic efficacy, as related services provided by NSSF to post retired population. Findings in Fig. 1 are informative on the levels of economic efficacy. It was generally found that the majority (71%) of all interviewed respondents had moderate economic efficacy. The implication to this is those retirees who were serving their fund did serve much to extent that they could feel economically empowered at their retirement age as substantiated hereunder:

*“...To be sincere I am slightly satisfied with the economic efficacy of mandatory and supplementary schemes because I have been receiving my retirement pension fund with difficulties. In addition, I always feel uncomfortable when I receive my pension fund since it is insufficient to suffice my family day to day expenses ...”.*



**Fig. 1.** Levels of Economic Efficacy of among retired people

## 5 Conclusion and Recommendations

In the association between the background characteristics and NSSF monthly earnings, the study has concluded an insignificant relationship. Again the household size and locality of the respondent, have also shown insignificant association. About how NSSF facilitate its beneficiaries in terms of time and sufficiency of the fund; the response has been negative and moderate respectively.

These two above findings have resulted in a moderate economic efficacy among the sampled population.

It is therefore recommended to the policymakers to make sure that they make a good follow up to the social security funds including NSSF to uplift their economic efficacy through facilitating their beneficiaries. The Ministry concerning Work and employment in Tanzania should carefully oversee the relationship existing between NSSF and NSSF beneficiaries to enable beneficiaries to access high-quality benefits including health services and improve their economic efficacy.

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# Societal Perception of National Resilience to a Pandemic

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**Abstract. Purpose:** This study analyses the COVID-19 pandemic management strategy and proposes a national resilience definition, to aid coping capacity policy formulation over communal pandemic situations.

**Design/Methodology/Approach:** Cross-sectional survey design. Sample of size 415 respondents; thirteen resilience indicators under five broad variables. Descriptive statistics, Pearson correlation  $r$  and Linear regression  $r$ . data analyses.

**Findings:** High responses reliability validity rate at  $\alpha$  of .9 for all the variables. Significant regression equation at  $(F(4, 410) = 1724.84, p < .001, R^2 = .94)$ . NR -13p predicted as equal to 3.35-.25 for Pandemic containment capacity, -.17 for Resources dependence, .05 for Communication and -.13 for Corruption eradication measures at .01 level of significance. Hence, National resilience in a pandemic is currently weak. The study validates a definition of the term 'national resilience-pandemic' on five multidimensional bases.

**Research Limitation/Implications:** The new national resilience definition is for Nigeria only, but could guide further research in other areas of national resilience worldwide.

**Practical Implication:** This study aids medical practice to minimise negative emotions in a pandemic, improves community health attitude. Enhances therapeutic, pathological approaches to resilience. Aids finance and economic planning through resources dependence and accountability strategies.

**Social Implication:** Insight to policymakers for decision making, towards health facilities capacity building in human resources and infrastructure. Communication improvement between the government and the governed.

**Originality/Value:** Addition of a health pandemic situation to a resilience concept; and two new variables of communication and corruption to novel resilience research. A new resilience equation emanates from Nigeria.

**Keywords:** Communication · Corruption · COVID-19 · National resilience · Pandemic containment · Resources dependence



## 1 Introduction

The novel SARS-CoV-2 Coronavirus (COVID-19) originated from Wuhan, China as a result of natural evolution (Qian et al. 2020). It spreads uncontrollably throughout the World. The index case of COVID-19 in Nigeria emanated from Lagos in Lagos State, one of the thirty-six states in Nigeria. The nation has hitherto prepared for the COVID-19 pandemic with infrastructural provision to contain it, based on the earlier experience in eradicating the EBOLA outbreak in February 2014. Providing and maintaining such an unprecedented infrastructure level akin to testing centres, materials and labour with palliatives within a short space of time could be stressful and should yield the desired result. However, contrary to the expectation, the COVID-19 pandemic cases continue to rise. For instance, the Nigerian Centre of Disease Control (NCDC) (2020a) explains that the national record of the infected persons lingers. The pandemic continues to ravage the nation which further expanded test facilities, lockdown, and other containment strategies devoid of the desired result (Rahman and Shaban 2020). Furthermore, the COVID-19 pandemic becomes too chronic for Nigeria to handle especially with a high population density of 206 million people (Worldometer 2020). The population pressurizes the infrastructure, exposing the fragile resilience capacity of the country (Osho and Adishi 2019). The situation becomes bothersome aside from the lingering Boko Haram insurgency in the country among other problems. Therefore, the resilience capability to contain the destructive, fearful, exhausting, financial sapping and fatal health crisis presented by COVID-19 is crucial, to minimising the pressure on government resources. Hence, the government's ability to face the pandemic challenges, consequences, tension and possibly contain them is essential as a reliance strategy.

Resilience means the ability to recover from a misfortune after the incident (Cambridge University Press 2021). Pandemic Resilience studies are crucial, given the need to end the fatality arising therefrom. More so, the debate over the term resilience is insufficient concerning a pandemic as for a disaster. Furthermore, COVID-19 pandemic complications have extended beyond human comprehension (The Economist 2020), it has become an object of change requiring a nation's resilience strategy. Hence, this study aligns the pandemic and resilience issues in a nation without a clear resilience definition because resilience must be measurable, measured, monitored and evaluated to avoid policy-somersault (Callueng et al. 2020). Although, some earlier studies on disaster have examined national resilience (NR) based on 25, 13 and 5 indexes (Callueng et al. 2020, Canetti et al. 2013, Eshel et al. 2020, Havko et al. 2017; Kimhi and Eshel 2018). Some other scholars such as Canetti et al. (2013) also establish NR-United States of America (USA) and Israel, while Callueng et al. (2020) cover NR in Filipino, but none on a pandemic situation in an economy in transition such as Nigeria. Kimhi and Eshel (2018) deliberate on 24 NR measures, Callueng et al. (2020) extend their study to Europe and Israel. Their effort yields 13 NR indexes from the earlier 24 NR measures. However, they omitted the social aspect of human life as enshrined in the social contract theory escalated in this study. Given the inconclusive discussions on NR in the pandemic situation and the gaps mentioned above, additional scholarly efforts are necessary. Therefore, this study examines NR through analysis of specific risk and threat profiles in an African environment. In this case, risk includes exposure of citizens to pandemic attack, over-burdened health facilities, high risk of the health-workers lives due to contact with

the COVID-19 patients and high mortality rate among others. This study, therefore, dwells on the societal perception of national resilience to a pandemic situation. This study covers a national resilience concept measuring index in the pandemic situations to the existing research body as a novelty. The study exposes the weakness of national resilience in a developing economy, rare in research on the COVID-19 pandemic. The study establishes the essential role of effective communication in containing the novel coronavirus and similar pandemics towards the wellbeing, regeneration and coexistence of humanity. It added a health pandemic situation to a resilience concept. This study covers two additional management science constructs of communication and corruption to pandemic and resilience researches. This study is inimitable, it combines relationship and effects statistical analyses in a single study as further contributions to knowledge towards the transformation of the identified problem.

An unobservable shock could destroy a nation and exhibit catastrophic behavioural connotations as observed in the fatality level experienced in the unprecedented COVID-19 pandemic. Consistent with the social contract theory, the stress, fears, and hopelessness of the people in a pandemic situation concern this study because a Nation's distress and fatality level in a pandemic could affect other national limiting factors of economic challenges if ignored. Henceforward, this study's motivation is the stressful and dreadful pandemic that cuts across many facets of human social lives, with far-reaching effects on national resilience. The complications need to be retreated to pave the way for healthy living, rejuvenation and regeneration. The effort is to earn the dividends of a robust resilience policy based on effective pandemic containment capacity (PCC), resources adequacy (RA), corruption eradication (CE) and effective communication (C) for national resilience (NR).

This study navigates pandemic threats to lives by analysing the COVID-19 management towards proposing the pandemic national resilience definition to aid strategies for coping with communal pandemic situations in Nigeria. Hence, the objective is to examine the various resilience variables as to whether or not pandemic containment capacity, resources dependence, communication and corruption eradication relate and how they affect national resilience on an individual construct basis. Given the preceding, four research questions are pursued: to what extent does pandemic containment capacity affect national resilience? How does resources dependence affect national resilience? How is the effect of communication on national resilience? How does corruption affect national resilience in Nigeria?

## **2 Theories Underpinning the Study**

### **2.1 Resilience City Concept**

Resilience City Concept (RCC) is an extension of vulnerability issues. It relates to the authority's adaptive capacity to unusual occurrences such as a disaster or a pandemic. The concept concerns the Government's ability to cope with a significant contingency such as the COVID-19 pandemic. For instance, in pandemic management, Government needs to respond based on the event presentation, resources capability and capacity to manage the situation. They need to apply some palliative measures based on the requirement of a particular individual local environment regarding the people's culture,

lifestyle, and livelihood condition. Authorities need to explain and communicate their operational measures to the people in an understandable format.

However, Giddens (2014) warns that embracing a concept from other areas to social sciences requires questioning the consequences. Hence, the need for this study especially as resilience has divergent definitions. For example, Mierzejewska and Wdowicka (2018) argue that the resilient city concept is a country's ability to regenerate in a disaster, whether human-made or natural. However, in this study, RCC suggests the Government ability to deal decisively, appropriately, without corruption with whatever condition manifests in a pandemic, consistent with the Government and the governed as enshrined in John Locke social contract phenomenon.

## 2.2 Social Contract Theory

The foremost proponents of the social contract theory are Hobbes, Locke and Rousseau; they have drawn different pictures of the 'state of nature', the 'terms of the contract' and the character of sovereignty which appear as a 'consequence of the state' in 1651 (Gauga 2007). The trio considers the State of nature as a pre-contractual stage of human existence. Social contract theory, therefore, places a moral obligation on the sovereign bound by natural law to provide basic needs of man such as security (Giddens 2014). Nweke and Nkwede (2019) argue a social contract path between the Governed and the Nigerian State as established in the Nigerian Constitution 1999 (Federal Government of Nigeria 1999). Nonetheless, John Locke's principles apply to the present study because it spells out clearly how the governed can hold the Government accountable in managing the affairs and resources of the State (Nussbaum 2003, 2004a, 2004b). Gauga (2007), Berdufi and Dushi (2015), Ritzer and Stepnisky (2021) explain that Social contract theory addresses the source of government legitimacy, the conception of an individual's freedom and equality. They explain that if a government fails to recognise the public power, the peoples' will shall prevail in the society's best interests. The people's might could change the leadership through elections. The State in chaos would require a strong resilience to survive in the face of multiple calamities occasioned by a pandemic. The resilience struggle calls for pandemic containment capacity with resources adequacy. It also requires communication of strategies to the citizens to carry them along. Another issue in resilience is a trust which necessitates a corrupt-free management style to gain the peoples' confidence and followership.

## 2.3 Pandemic Containment Capacity

Nigeria is the third-largest country in Africa, the most populous and populated country in West Africa and the epicentre of COVID-19 in the Sub-Saharan African region. Nigeria has the highest COVID-19 morbidity and the most considerable mortality (NCDC 2020b). Nigeria houses the Economic Community of West African States (ECOWAS). According to Osayomi et al. (2020). Nigeria has the status of West African Regional Champion against COVID-19 by ECOWAS, through the challenge of effectively coordinating the subcontinent in containing the coronavirus. However, scholars such as Miller and Blumstein (2020) explain that containment is the main focal point in pandemic management. Nonetheless, the pandemic situation is beyond the containment procedure of

health science and medicine, but some aspects of humanities disciplines such as accounting and management, because pandemic management should be all-inclusive. The capacity to contain the pandemic is crucial for the resilience of a nation. This study, therefore, hypothesises that; Ho<sub>1</sub>: Pandemic containment capacity would not significantly predict national resilience.

## 2.4 Resources Dependence

Pandemic management requires meeting the peoples' expectations and rising demand in health infrastructure and pharmacological requirements alongside other basic amenities which costs money. Resources' adequacy is essential to tackle the family needs as they arise. According to Havko et al. (2017), resources should be available to cushion the effects of anticipation, flexibility mitigation and reduction of physical, economic and social impacts of disasters in the families within a country (Friedline et al. 2021). Hence, government financial intervention is required to aid the rising need for infrastructure. Government resources should, therefore, be adequate to minimise debt costs and improve sustainable wealth creation. The aforementioned necessity calls for concern. Hence, hypothesis 2: Ho<sub>2</sub>: Resource adequacy would not significantly predict national resilience.

## 2.5 Communication

Effective communication is necessary to manage a pandemic because the information is necessary to allay fear and encourage the people to be hopeful and trust the system as reliable to meet their needs. Communication should be two-way to enable the authority to address the fears or complaints of the people. Moreover, through effective communication, authorities will feel the people's pulse and plan for developing and improving strategies to address the problem in society's best interest (Mayfield and Mayfield 2017). Hence, hypothesis 3; Ho<sub>3</sub>: Communication would not significantly predict national resilience.

## 2.6 Corruption Eradication

Corruption manifests in all areas of management in places with a disorganised regulatory system. Some scholars such as Ferrari and Salustri (2020) opine that the health sector is susceptible to corruption. Corruption in the health management area could lead to fatality uprising in the COVID-19 pandemic. Therefore, it could be difficult to achieve sustainable national resilience unless harmful corruption is eradicated. It is thus hypothesized that; Ho<sub>4</sub>: Corruption eradication would not significantly predict national resilience. It is expected that the hypotheses would be supported given the circumstance of the pandemic and the researchers' experience. To explore the possibility of the hypotheses outcome this study engages a robust research methodology to gauge what resilience is and should be in an environment.

### 3 Methodology

This study uses a cross-sectional survey design for simplicity, affordability, objectivity. Nkurumah (2015) argues that the cross-sectional survey design is reliable and time-saving. This study entropy is on national resilience in handling the COVID-19 pandemic, and primary data is ideal because it affords the opportunity of collective input involving those who experience the subject matter and can give reliable and cogent information on the subject matter.

The study sample emanates from the Nigerian population of 206 million people (Worldometer 2020), adults are 106 million with a literacy rate of 62% (MacroTrends 2021). Hence, the study population is 65.6 million. A sample of size 415 literate adult respondents emerged, utilizing Yamane (1967) sample size formula:  $n = \frac{N}{1+N(e)^2}$

where  $n$  is the sample size,  $N$  is the target population size and  $e$  is the margin of error. The survey instrument is a questionnaire with two sections. Respondents' biodata is in section A, while section B consists of research-related questions in a five-point Likert-scale format. This study assembles resilience measurement information from earlier studies (Callueng et al. 2020, Kimhi and Eshel 2018, Qian et al. 2020). The study earlier employs a pilot study that reported a Cronbach alpha of .9. The result of the pilot study assists in improving the final questionnaire incorporating the local environment ideal with content and construct improvements from two academics in accounting and a one in medicine. The questionnaire is designed with the google form (Google.com 2020). However, because of reliability assessment, the questionnaire copies distributed are slightly adjusted upwards by 10% from 204 to 224 based on the researcher's experience. Hence, with a 95% response rate, the final sample size utilised for the study is 215 respondents, after mutilated and unreturned instrument copies.

The distribution of the questionnaire copies is by convenient sampling method following Bamfo-Agyei and Atepor (2018). Instrument distribution is by electronic means. Starting from the 14 indexes NRS-Filipino (Kimhi and Eshel 2018) to five items NRS-Israel and USA (Callueng et al. 2020), this study concentrates on NR-Nigeria pandemic under thirteen indexes. Hence, this study identifies some social influences on national resilience, covering thirteen indexes under five variables. The indexes bother on the nation's capability to ameliorate the masses sufferings; minimise psychological pain, eradicate obstacles and avoid total collapse. The factors include task force efficiency in driving the strategies to curb a pandemic. Community access to health care facilities, economic development reliefs such as bank interest rate deductions, the Country's capacity to curtail foreseeable health hazards, resources adequacy, public and private organisations' collaborative strategies to curb a pandemic. Others are full payment of workers' salaries, effective communication and information sharing, fair distribution of palliatives, corruption, and marginalisation. The indexes analysis covers five variables: pandemic containment capacity (PCC), resources dependency (RD), communication (C), corruption eradication (CE) variables and demography as a construct for national resilience (NR). The study variables arise two-fold; from the government and peoples' perception about government responsiveness, rather than focusing on the government alone as per earlier studies (Callueng et al. 2020, Kimhi and Eshel 2018). NR-13pandemic includes communication and corruption eradication constructs because they are essential in global resilience strategy, and are necessary constructs to balance social justice

in line with social contract theory. Descriptive statistics, Pearson correlation and Multiple regression statistical analysis are employed for analysis. Mojekwu and Iwuji (2012) use multiple regression analysis. The resilience list of independent variables for predicting NR-13p consists of PCC; RD; C and CE. Following the trend in Kimhi and Eshel (2018), they are regressed against the respondents’ demographic characteristics as a construct for the dependent variable, that is, the national resilience-pandemic. The analyses are towards ascertaining appropriate descriptions and relationships among the variables. More so, this study is concerned about the concise precision and prediction of one variable over the other. The analyses are aided with the IBM SPSS version 24. A linear regression model for the study is built on the straight-line equation of  $Y = a + bX$ . X serves as the independent construct upon which Y depends, a is the intercept of the model and b is the model slope. Hence, the economic model for this study is:

$$NR - 13p = \beta_0 + \beta_1PCC + \beta_2 RDt + \beta_3Ct + \beta_4 CEt + \epsilon$$

$$\beta_1 > 0, \beta_2 > 0, \beta_3 > 0 \text{ and } \beta_4 > 0.$$

Where:  $\beta_0$  is the Intercept coefficient.  $\beta$  is the Coefficient for each of the dependent variables and  $\epsilon$  is the error term.

### 4 Findings

The data analysis results are depicted in Tables 1, 2, 3, 4, 5, 6, 7 and 8. Table 1 covers respondents’ biodata. The respondents’ views on the thirteen resilience measures are depicted in Table 2. The Pandemic containment capacity (PCC) is covered by items 1 to 3; Resources dependence (RD) is gauged under items 4 to7; Communication (C) is under items 8 to 10; Corruption eradication (CE) is covered in items 11 to 13 respectively. Overall, the thirteen indexes validity test return a Cronbach Alpha of .97, .98, .95 and .91 for measures of PCC, RD, C and CE respectively. The results imply that highly reliable data are used for this study.

**Table 1.** Respondents’ biodata

S/N	Variable	Measurement	Frequency	%
1	Respondent’s job type	Entrepreneur/self employed	110	26.51
		Paid-employment	305	73.49
		<b>Total</b>	<b>415</b>	<b>100</b>
2	Highest academic qualification	Technical certificate/National diploma	42	10.23
		Graduate degree or its equivalent	220	53.02
		Postgraduate degree	153	36.74

(continued)

**Table 1.** (continued)

S/N	Variable	Measurement	Frequency	%
		<b>Total</b>	<b>415</b>	<b>100</b>
3	Nationality	Nigeria	415	100
		Others	–	–
		<b>Total</b>	<b>415</b>	<b>100</b>

Source: Researchers' Field Survey, 2020.

Table 1 shows that entrepreneurs/self-employed and paid-employment respondents contribute to this study, but those in paid-employment are in majority representing 73.49% (305 respondents). The academic qualification of the respondents reveals that more than half of the respondents (220, 53.02%) are holders of a graduate degree or its equivalent. While 36.74% of the respondents possess postgraduate degrees. About 10% (42 respondents) are holders of technical certificates or national diplomas. The respondents are all educated, engaged Nigerians who are familiar with the research environment and the issue at stake. Hence, their responses are reliable.

**Table 2.** Descriptive analysis of National Resilient-13 pandemic indexes

S/N	Variable	Description	Mean	Std. Deviation
1	PCC	Efficiency of covid 19 task force in driving the established strategies to curb the pandemic	3.41	.99
2	PCC	Access to timely and efficient preventive health facilities during the pandemic COVID-19 Test kits are available in my local government test centre	2.43	.98
3	PCC	Capacity to contain foreseeable health hazards	2.39	.99
4	RD	Government has enough resources to combat COVID-19.215 responses	3.61	.98
5	RD	Economic development stimulus of Informal credit is available in my community	2.20	1.01
6	RD	Regular economic development relieves such as Bank interest rate reduction	2.52	.90
7	RD	Workers' salaries government paid workers salary fully during the pandemic	3.13	.77
8	C	Communication and Information about the pandemic is adequate	3.52	.90
9	C	Public and private communities are strategizing together to end the pandemic	1.88	1.05

(continued)

**Table 2.** (continued)

S/N	Variable	Description	Mean	Std. Deviation
10	C	Effective community information aids access to timely and efficient preventive health facilities to manage my well-being during the pandemic	2.33	.94
11	CE	There is fair distribution of government palliatives in my community	2.45	1.04
12	CE	Presence of corruption on palliatives distribution by the elites in my community	1.88	1.05
13	CE	Women were marginalized in the distribution of palliatives in my community	3.68	1.13
		Valid N (listwise)		

**N = 415; Scale: Max. = 5; Min. = 1**

Source: Researchers' Field Survey 2020.

Table 2 reveals respondents' opinions on the thirteen indexes. Item 1 of the Table shows that respondents agree that the government COVID-19 task force efficiently drive the strategies to curb the pandemic ( $\mu = 3.41$ ;  $\sigma = .99$ ). Item 2 on access to timely and efficient preventive health facilities, respondents deny having such access with a below-average result ( $\mu = 2.43$ ;  $\sigma = .98$ ). This result implies that pandemic containment is slow with the likelihood of a high fatality rate as the respondents talk in unison. Item 3 shows that respondents disagree that Nigeria can curtail foreseeable health hazards. This result further compounds the PCC level of the country at  $\mu = 2.39$ ;  $\sigma = .99$ .

Item 4 indicates that the majority of the respondents believe that government has the resources to combat COVID-19 ( $\mu = 3.61$ ;  $\sigma = .98$ ). However, they disagree that there is the economic dependent stimulus of informal credit facilities in the community during this pandemic as shown in item 5 with a below-average result ( $\mu = 2.2$ ;  $\sigma = .101$ ). Item 6 result on the regularity of the economic development stimulus is discouraging with the low outcome ( $\mu = 2.52$ ;  $\sigma = .9$ ). In Item 7, the respondents agree that workers' salaries are regularly paid ( $\mu = 3.13$ ;  $\sigma = .77$ ). The result buttresses that there is resources dependence for Nigerians during the pandemic.

Item 8 shows that respondents affirm the adequacy of communication and information about the pandemic ( $\mu = 3.52$ ;  $\sigma = .09$ ). Nonetheless, public and private organisations collaboration initiatives to end the pandemic is dissatisfactory ( $\mu = 1.88$ ;  $\sigma = .105$ ). Respondents disagree that it is effective community information on curtailment of foreseeable health hazards ( $\mu = 2.33$ ;  $\sigma = .94$ ).

Test of the fairness in palliative distribution during the lockdown under item 11 of the Table reveals that an overwhelming majority of the respondents deny fair distribution of government palliatives ( $\mu = 2.45$ ;  $\sigma = .104$ ). Corruption prevails in palliatives management with low outcome ( $\mu = 1.88$ ;  $\sigma = .105$ ). However, despite the high level of corruption, the women were not marginalized, Hence, corruption cuts across all genders were tested under item 13 of the Table ( $\mu = 3.68$ ;  $\sigma = .113$ ).



**Table 3.** Descriptive statistics of the dependent and independent variables

Variable	Mean	Std. Deviation
National resilience	1.79	.48
Pandemic containment capacity	2.74	.9
Resources dependence	3.46	.86
Communication	2.58	.91
Corruption eradication	3.01	1.01

**N = 415; Scale: Max. = 5; Min. = 1**

*Source: Researchers' Field Survey, 2020.*

The descriptive statistical analysis in Table 3 shows mean levels of 1.79, 2.74, 3.46, 2.58 and 3.01 for the national resilience pandemic, containment capacity, resource dependence, communication and corruption eradication variables respectively. The standard deviations are below 1 for all the constructs. The result indicates that most respondents expressed their opinion which means that most Nigerians feel the same way most of the time about the constructs under study.

**Table 4.** Dependent and independent variables correlation results

		National resilience	Pandemic containment capacity	Resources dependence	Communication	Corruption eradication
National resilience	Pearson Correlation	1				
	Sig. (2-tailed)					
Pandemic containment	Pearson Correlation	-.96**	1			
	Sig. (2-tailed)	.000				
Capacity resources	Pearson Correlation	-.94**	.911**	1		
	Sig. (2-tailed)	.000	.000			
Dependence communication	Pearson Correlation	-.90**	.892**	.933**	1	
	Sig. (2-tailed)	.000	.000	.000		
Corruption eradication	Pearson Correlation	-.95**	.943**	.949**	.966**	1
	Sig. (2-tailed)	.000	.000	.000	.000	

\*\* Correlation is significant at the 0.01 level (2-tailed). N = 415

*Source: Researchers' Field Survey, 2020.*

To ascertain the relationships among the variables tested using Pearson correlation statistical analysis as shown in Table 4. Results show a significant strong positive relationship between the dependent and independent variables tested at  $(r(415) = -.96, p$

= .001) for Pandemic containment capacity; (r (415) = -.94, p = .001) for Resources' dependence; (r (415) = -.90 p = .001) for communication and (r (415) = -.95, p = .001) for Corruption eradication. Hence, the variables are worth examining together.

**Table 5.** Model Summary<sup>b</sup> of the dependent and independent variables

Model	R	R Square	Adjusted R square	Std. Error of the estimate	Durbin-Watson
1	.97 <sup>a</sup>	.94	.94	.12	.21

<sup>a</sup> Predictors: (Constant), Corruption Eradication, Pandemic Containment Capacity, Resources Dependence, Communication

<sup>b</sup> Dependent Variable: National resilience

Source: Researchers' Field Survey, 2020

**Table 6.** ANOVA<sup>a</sup> of the dependent and independent variables

Model		Sum of squares	Df	Mean square	F	Sig.
1	Regression	93.14	4	23.28	1724.84	.000 <sup>b</sup>
	Residual	5.53	410	.01		
	Total	98.68	414			

<sup>a</sup> Dependent Variable: National resilience

<sup>b</sup> Predictors: (Constant), Corruption Eradication, Pandemic Containment Capacity, Resources Dependence, Communication

Source: Researchers' Field Survey, 2020

In Tables 5, 6, 7 and 8, the multiple linear regression result reveals a significant regression equation at (F (4, 410) = 1724.84, p < .001, R<sup>2</sup> = .94). Respondents predicted NR -13p as equal to 3.35-.25 for Pandemic containment capacity, -.17 for Resources dependence, .05 for Communication and -.13 for Corruption eradication measures. The objects of measurement for each unit of NR-13p therefore, decreased by .25, .17 and .13 for each unit of Pandemic containment capacity, resources dependence and corruption eradication variables respectively and increased by .05 for each unit of communication variables. All the independent variables are coded according to their Likert scale strength and they are significant predictors of the dependent variable. In Table 4. 8, no collinearity issue is found in data diagnosed because none of the variance proportions lines has values above .90. Regorz (2020) argues that at least two predictors in the variance proportions line depict a high value above .90 connotes collinearity. Hence, the hypotheses are not supported. Table 5 also shows an R of .97 indicating that the determinant variables predict National Resilience almost fully. The result for pandemic containment capacity supports the findings in Kapoor and Buitter (2020), Mierzejewska and Wdowicka (2018). The finding on resources dependence supports the findings in WHO (2020). The result for corruption eradication supports the findings in Igiebor (2019). The result for communication supports the findings in Antwi-Boasiako and Nyarkoh (2020).

**Table 7.** Coefficients<sup>a</sup> of the dependent and independent variables

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.	Collinearity statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	3.35	.03		114.69	.000		
	Pandemic containment capacity	-.25	.02	-.50	-13.66	.000	.100	10.01
	Resources dependence	-.17	.02	-.30	-7.83	.000	.091	10.97
	Communication	.05	.03	.10	2.14	.033	.060	16.74
	Corruption eradication	-.13	.03	-.28	-4.28	.000	.031	31.75

<sup>a</sup> Dependent Variable: National resilience  
Source: *Researchers' Field Survey, 2020*

**Table 8.** Collinearity diagnostics of the dependent and independent variables

Model	Dimension	Eigenvalue	Condition index	Variance proportions				
				(Constant)	Pandemic containment capacity	Resources dependence	Communication	Corruption eradication
1	1	4.90	1.00	.00	.00	.00	.00	.00
	2	.08	7.81	.35	.01	.00	.01	.00
	3	.01	19.82	.00	.54	.00	.20	.00
	4	.00	33.92	.64	.08	.96	.18	.01
	5	.00	46.18	.00	.37	.04	.60	.99

<sup>a</sup> Dependent Variable: National resilience  
Source: *Researchers' Field Survey, 2020*

## 5 Discussion

### 5.1 Pandemic Containment Capacity

The task force efficiency to drive the coronavirus containment strategy is encouraging. However, given the low mean score of 2.74 as shown in Table 3 and the negative significant effect of  $-.96$  of PCC on NR recorded in Table 7, substandard health facility is a limiting factor, policymakers became victims of their policy due to the lockdown measure across the globe. The gigantic level of coronavirus complications calls for a rethink by policymakers. The capacity to contain foreseeable health hazards result is substandard. Nonetheless, technically no experience to tackle coronavirus, but respondents have been exposed to information to boost their confidence and manage future

health hazards. The results contradict the Social contract theory's expectation from the State of Nigeria. Kapoor and Buitter (2020) aver that policy-makers should make or mar the resilience city concept because they are capable. The study argues that the risk of doing too much too quickly outweighs the risk of feet dragging.

## 5.2 Resources Dependence

The resource inadequacy is dangerous for a country's resilience profile as per the negative effect of  $-.94$  on Nr as shown in Table 7. Resources are required to achieve multi-faceted pandemic control mechanisms such as contact tracking, quarantine, research, information dissemination, and total lockdown consequences. Thus the private sector aid is desirable to combat the pandemic. In support of this study's findings, WHO (2020) identifies Nigeria as one of the risk-prone countries with inadequate resources to fight the pandemic. This study observes that the economic development stimulus measurement shows a total failure of resources dependence despite the government pronouncement that banks should reduce the interest rate. The government ability to continue paying workers' salaries during the pandemic boosts welfare and conforms with the social contract principle. Of concern is that Nigeria which is densely populated has the most considerable air traffic in Sub Saharan Africa, inadequate resources can negatively affect the global efforts at containing the pandemic.

## 5.3 Communication

Finding on communication variable calls for concern to minimise belief in fake news and falsehood. Misinformation could reduce government trustworthiness with a negative consequence on national health resilience as depicted in Table 3 with a loan mean score of 2.58. Table 7 clearly pinpoints the negative significant effect of communication on national resilience at  $-.9$ . Van Bavel et al. (2020) advocate persuasion. Faith-based information dissemination avenues are effective in pandemic management (Qian et al. 2020). Aworinde (2020) argues that government officeholders still embark on medical tourism. A mentality that has retarded Public-Private Partnership Initiative (PPPI) in Nigeria. However, with COVID-19, it is necessary to spend the budget at home for many reasons such as job creation, infrastructure availability, national pride of ownership and patriotism. The result of low community information sharing could be due to the lockdown, where experience sharing and friendly discussion are limited. Baker et al. (2016). argue that effective communication impacts society. Another avenue of information dissemination such as radio was underutilised during the pandemic. There was concentration on the print and audio-visual media which are not within reach of the masses. However, social media thrived in disseminating some unguided information, including fake news, especially on palliative management.

## 5.4 Corruption Eradication

The high level of inefficiency recorded in palliative distribution is dangerous for a country's resilience. Hoarding essential materials based on zero-sum thinking is self-destroying because by refusing to spread palliatives, one will keep spreading the infectious disease to one's detriment. Hence, the negative significant effect of  $.9$  of CE on

NR is bothersome. Some scholars argue that corruption in Nigeria is a major inhibiting factor to policy actualisation (Igiebor 2019, Ijewereme 2015, Omolehinwa 2012). The aforementioned scholars have identified reasons such as poverty, low transparency and accountability as inhibiting factors (Ijewereme 2015, Omolehinwa 2012). They have also proffered solutions ranging from top to bottom transparency in official conduct, sincerity of purpose, leading by example and punishment to erring officers (Ijewereme 2015, Omolehinwa 2012). However, the situation deteriorates as per Transparency International (2020) ranking, which shows a deteriorating corruption perception index score for Nigeria at 27% for 2018 and 26% for 2019. Ernst and Young (2021) has advised businesses to embrace the resilience process for averting phishing and other cyber scams that can affect donors' confidence in coronavirus donation management.

### 5.5 Defining National Resilience in Pandemic (NR-13p)

Given the foregoing, on the whole, the current resilience status connotes negative national resilience. Hence, the linear equation as associated with the regression outputs is as follows:

$$NR - 13p = 3.35 - .25PCCt - .17PRDt - .13CEt + .05Ct + \varepsilon$$

$$\beta_1 > 0, \beta_2 > 0, \beta_3 > 0 \text{ and } \beta_4 > 0.$$

A definition is proposed and further tested for validity by a group of five comprising independent Nigerian academics and professionals who are not involved in this study. They are two academics in management and economics, from two different Universities in Nigeria. Besides, a Medical practitioner, a Chartered Accountant and a Lawyer partake in the validity review. The independent analysts are carefully chosen based on their academic and professional callings, including role-playing in health, resources allocation and legal drafting management. They were presented with the 415 respondents' perception of the 13 indexes tested. They rated the definition as ideal and satisfactory.

## 6 Conclusion and Recommendations

### 6.1 Conclusion

In satisfying the objectives, findings show that the Nigerian Resilience currently in terms of pandemic containment capacity is below average, due to corruption and resources independence. This study establishes the effectiveness of communication in containing pandemic, towards the regeneration of humanity. No demographic issues obtain. However, the health and corruption pandemics could result in peril if an appropriate national resilience is not defined. Therefore, in satisfying objective two, what National Resilience in the pandemic situation means to Nigerians is elaborated. Thus, as an added contribution to knowledge, in this study Nigerians have defined their *NR-13pandemic to mean Nigeria's capability to overcome pandemics, through efficient pandemic containment capacity, resources dependence by all, in a corrupt-free environment with an effective communication strategy that promotes equal opportunities and permeates the grassroots irrespective of class, creed or gender.*

## 6.2 Recommendations

Taking advantage of the Public-Private Partnership Initiative in Nigeria to fund government hospitals could improve the cooperation between the government and public healthcare providers. Government officials' failure in health tourism during the pandemic, emphasises the need to improve the Country's health-care facility. Efficiency in healthcare delivery system is desirable. Donor agencies need to support Nigeria in resource building to avoid unending pandemic in the internal arena since the Country has a high international air-traffic influx and inadequate resources to fight the pandemic. Mores, government, donor agencies and the World Bank should list corruption eradication rate as a condition precedent to facility drawdown on a specific periodical basis to boost national Resilience. However, any attempt to shrink the media will worsen national Resilience in terms of communication and corruption. Freedom of expression in all media encourages feedback for improvement in an open society.

## 6.3 Suggestion for Further Research

National Resilience relates with the stability of a country covering, health, security, economy, education and the environment. However, this study is conducted during the novel coronavirus pandemic, making it possible to assess the facts on the ground for Resilience in a pandemic situation. Nonetheless, while this study is being concluded, another area of national resiliency manifest in the END-SARS protest that claims live and properties across Nigeria. In contrast, this study covers a pandemic resilience only. Hence, further research could cover the perception of Nigerians on NR-Security.

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# VTI Anisotropy in Wellbore Strengthening Model

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**Abstract. Purpose:** This work analytically studies the effect of the anisotropic elastic properties on fracture width distribution and fracture re-initiating pressure (FRIP).

**Design/Methodology/Approach:** A semi-analytic fracture model is derived by incorporating in-situ stresses as functions of anisotropic elastic properties with  $K_I \geq K_{IC}$ . The dislocation method is used.

**Findings:** It is observed that elastic anisotropic properties such as Young's moduli and Biot anisotropy had inverse relationships on fracture width. That for the Poisson's ratio had a direct relationship on fracture width. Wellbore breakout only influence fracture width for  $\Delta\omega_{bo} = \pi/12$ . Uniaxial compressive strengths show a positive relationship with fracture width for incremental changes greater than  $2.5 \text{ N/m}^{-2}$ . The study further confirms the positive relationships wellbore geometry and fracture length had on fracture width.

**Research Limitation/Implications:** This engineering performs an analytical study whose results were verified with results from a numerical study of the problem. It is devoid of experiments and experimental results.

**Practical Implication:** The results from this work affords a more accurate prediction of fracture geometry and inform wellbore sizing for specific fracture jobs. The influence of rock anisotropy and wellbore parameters, specifically wellbore break out and uniaxial compressive strength can accurately be predicted.

**Social Implication:** The knowledge advanced by this study will enlighten academics and industry players on the new methods for sustainable good strengthening applications.

**Originality/Value:** The novelty of this study lies in the prediction of the influences of elastic anisotropy, wellbore breakout and uniaxial compressive on fracture width distribution. Another uniqueness of this work is the fact that it confirms already existing correspondence of the effects of wellbore geometry and fracture lengths on fracture width distribution.

**Keyword:** Anisotropy · Fracture · Lost circulation · Near-wellbore · Wellbore strengthening

## 1 Introduction

Wellbore strengthening is one technique used to prevent wellbore-instability issues. The wellbore strengthening approach is used to firstly increase the fracture gradient, widen the mud window and consequently mitigate mud losses. Since its inception in the 1980s, various methods and techniques outlining different mechanisms have been implemented (Feng and Gray 2017). The fracture-based technique introduces wellbore-strengthening materials (WSM) to plug preexisting or induced wellbore fractures to increase fracture re-opening pressure (FROP).

Various width distribution models have been developed to describe induced fractures for wellbore strengthening application. The accuracy of a fracture width prediction model could positively influence lost circulation prevention design and operations (Alberty and Mclean 2004). An aspect of one of the inefficiencies associated with this strengthening process lies in the inaccuracies in predicting induced fracture geometry (Mehrabian et al. 2015; Morita and Fuh 2012; Shahri et al. 2014). Various semi-analytical solutions have been developed to solve such inconsistencies (Carbonell and Detournay 1995; Mehrabian et al. 2015; Shahri et al. 2014; Warren 1982). Hillerborg et al. (1976) developed a model for predicting fracture width of aggregated materials. Their analytical solution assumed stresses to be acting perpendicular to a narrowly opened crack. Morita and Fuh (2012) developed an approximate solution that predicts fracture width as a function of wellbore pressure, in-situ stress, and rock properties. Its limitation, however is that the fracture width was inputted to determine fracture length. Of particular interest is the use of singular integral formulations on stress fields and solutions presented via the Gauss–Chebyshev polynomial. For example, Warren (1982) applied the aforementioned technique to develop a finite edge dislocation model whose boundary lay in an infinite elastic plane on a circular wellbore. His model was solved semi-analytically by Carbonell and Detournay 1995 to estimate fracture propagation pressure and the fracture length is inputted. Shahri et al. (2014) followed up on Carbonell and Detournay 1995 solution to design a semi-analytical workflow with FRIP calculations to predict fracture width distribution. Their work incorporated near wellbore stress variation, changes in fluid pressure within fracture, in-situ stress anisotropy, and wellbore trajectory in 3 dimensions. The problem with the above methods is that the analytical models require fracture length as an input parameter. To overcome this challenge, numerical schemes have also been developed that do not require such input parameter (Alberty and Mclean 2004; Fuh et al. 1992; Morita and Fuh 2012; Zhong et al. 2017). Zhong et al. (2017) developed a numerical simulation procedure based on Shahri et al. (2014) to predict real-time fracture width and length. Their work also showed strong dependence of fracture propagation, FROP as well as induced fracture geometry on well conditions, WSM, rock and fluid properties. Also, boundary and finite-element methods have been used to simulate and predict pressurized wellbore with two symmetric fractures under anisotropic stress field conditions (Feng et al. 2014; Wang et al. 2017). The drawback of these numerical techniques is the high cost of computation.

Rock anisotropy encapsulates reservoir anisotropy. Anisotropic elastic properties such Young's moduli, Poisson ratios and Biot's anisotropy are very important in describing more accurately fluid flow interaction with stress field in heterogeneous reservoirs.

These parameters have direct effects on in situ stresses in rocks (Amadei 1996; Carroll 1979). Tensor forms of the Poisson's ratios and Young's moduli have demonstrated strong dependence on stress state, pore pressure, rock porosity, permeability (Al-Tahini and Abousleiman 2010; Azeemuddin et al. 2001; Havens and Batzle 2011; Klimentos et al. 1998). The same has been done for the Biot anisotropy with success (Bui and Tutuncu 2013).

In situ stresses as functions of anisotropic elastic properties are incorporated into a fracture model derived using the dislocation method (Carbonell and Detournay 1995; Shahri et al. 2014; Warren 1982; Zhong et al. 2017) to capture reservoir heterogeneity. To the authors' knowledge, wellbore strengthening models that capture elastic anisotropy do not exist in the literature. This work studies the effect of the anisotropic elastic properties on fracture width distribution and fracture re-initiating pressure (FRIP) for wellbore strengthening practices. The fracture toughness is also made to be less than the wellbore pressure to allow for the determination of fracture re-initiation pressure. The resulting model is validated against numerical data. Anisotropic Young's moduli, Poisson ratio, Biot coefficients and other parameters such as wellbore breakouts and uniaxial compressive strengths of rock are evaluated and their influence on fracture width distribution and FRIP assessed. The results show that elastic anisotropic properties have inverse relationships on fracture width except for the Poisson's ratio, which has a direct relationship with fracture width. Small values of wellbore breakout have been determined to influence fracture width. Uniaxial compressive strengths show a positive relationship with fracture width. The results from this work afford a more accurate prediction of fracture geometry and inform wellbore sizing for specific fracture jobs. The influence of rock anisotropy and wellbore parameters, specifically wellbore break out and uniaxial compressive strength can accurately be predicted.

## 2 Mathematical Modeling

### 2.1 In Situ Stress and Anisotropic Elasticity

Three anisotropic elastic parameters of interest will be briefly stated as functions of in situ stresses. According to Carroll (1979) Hooke's law for a reservoir rock with anisotropic elastic consideration in tensor notation is stated as

$$\epsilon_{ij} = C_{ijkl}(\sigma_{kl} - \alpha_{kl}p_p) \quad (1)$$

where,  $\epsilon_{ij}$  and  $\sigma_{kl}$  are the strain and stress tensors respectively and  $p_p$  represents the reservoir pore pressure. The Biot tensor  $\alpha_{kl} = \alpha I$ , and  $I$  represents the identity element for an isotropic material (Bui and Tutuncu 2013). The third direction is perpendicular to the plane of isotropy and the tensor  $C$  is given as

$$C_{ijkl} = \begin{bmatrix} \frac{1}{E_h} & -\frac{\nu_h}{E_h} & -\frac{\nu_v}{E_h} & 0 & 0 & 0 \\ -\frac{\nu_h}{E_h} & \frac{1}{E_h} & -\frac{\nu_v}{E_h} & 0 & 0 & 0 \\ -\frac{\nu_h}{E_h} & -\frac{\nu_h}{E_h} & \frac{1}{E_h} & 0 & 0 & 0 \\ 0 & 0 & 0 & G_v & 0 & 0 \\ 0 & 0 & 0 & 0 & G_v & 0 \\ 0 & 0 & 0 & 0 & \frac{2(1+\nu_h)}{E_h} & 0 \end{bmatrix} \quad (2)$$

where,  $E_h$  is the Young’s modulus in the plane of transverse isotropy,  $E_v$  is the Young’s modulus in the plane normal to the plane transverse isotropy,  $G_v$  is shear modulus in the plane normal to the plane of transverse isotropy,  $\nu_h$  is the Poisson’s ratio in the plane of transverse isotropy and  $\nu_v$  is the Poisson’s ratio in the plane normal to the plane transverse isotropy. For a horizontal bedding plane, the horizontal stresses can be obtained by combining Eqs. (1) and (2) (Amadei 1996), resulting in

$$\sigma_h = \frac{E_h}{E_v} \cdot \frac{\nu_v}{1 - \nu_h} (\sigma_v - \alpha_v p_p) + \frac{E_h}{1 - \nu_h^2} (\epsilon_h + \nu_h \epsilon_H) + \alpha_h p_p \tag{3}$$

where,  $\alpha_h$  is the Biot’s coefficient in the plane of transverse isotropy,  $\alpha_v$  is the Biot coefficient in the plane normal to the plane of transverse isotropy,  $\epsilon_h$  is the minimum horizontal strain and  $\epsilon_H$  is the maximum horizontal strain. Equations (3) introduce the effect of anisotropy. For a uniaxial strain condition, the equation reduces to the isotropic case for  $E_h/E_v = \nu_h/\nu_v = 1$  and  $\alpha_v = \alpha_h = \alpha_H = \alpha$ . The maximum horizontal stress expression obtained from wellbore measurements is used (Barton et al. 1988)

$$\sigma_H = \frac{\sigma_c + \sigma_T + p_p + p_f - \sigma_h(1 + 2\cos(\pi - \omega_{bo}))}{1 - 2\cos(\pi - \omega_{bo})} \tag{4}$$

$\sigma_c$  is the uniaxial compressive strength,  $\sigma_T$  is the thermal strength,  $\omega_{bo}$  is the wellbore breakout and  $p_f$  is the fluid pressure inside the fracture.

Previous works considered anisotropy only in situ stress (Alberly and Mclean 2004; Carbonell and Detournay 1995; Fuh et al. 1992; Mehrabian et al. 2015; Morita and Fuh 2012; Shahri et al. 2014; Warren 1982; Zhong et al. 2017). This work considers an additional anisotropy in the elastic properties (anisotropic Young’s moduli, Poisson ratio, Biot coefficient) and wellbore characteristics (wellbore breakouts and uniaxial compressive strengths).

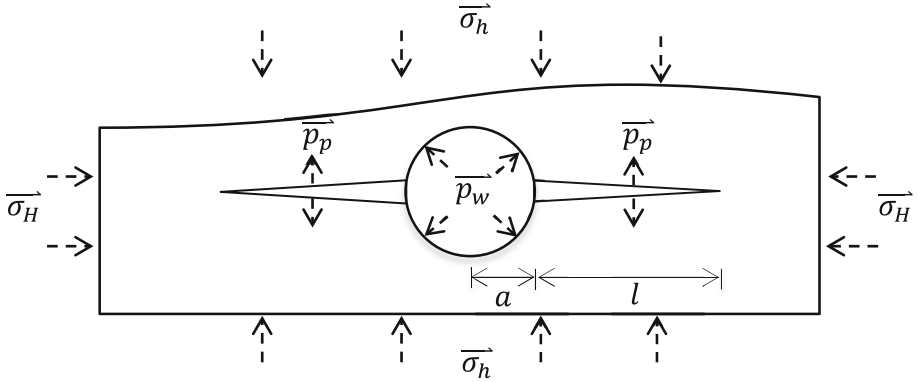
### 2.2 The Dislocation Density Function

The model is semi-analytical, one with an elastic anisotropic medium with two symmetric infinite edge fractures. The fracture surfaces are subjected to the wellbore pressure such that  $p_p = p_w$ . To determine the fracture width distribution, the dislocation density function would have to be determined. The following is a detailed calculation of the dislocation density function from Shahri et al. (2014) which has been adapted and modified to contain elastic anisotropic effects.

Using Fig. 1 as a guide, the double symmetric fracture surface stress distribution is expressed using the singular integral formulation as found in (Carbonell and Detournay 1995; Muskhelishvili 1953; Warren 1982) and is expressed as

$$\sigma_{yy}(x) = \frac{1}{\pi} \int_a^b f(L) \left[ \frac{1}{x - L} + \psi(x, L) + \frac{1}{-x - L} + \psi(-x, L) \right] dL \tag{5}$$

where  $L$  is the position of the dislocation tip,  $f(L)$  is the dislocation density function and the stress field is located at  $x$ . The fracture opening is a maximum at the fracture mouth



**Fig. 1.** Wellbore with two symmetric edge fracture

such that  $f(a) = 0$  and  $a$  is the wellbore radius.  $\psi(\pm x, L)$  is a regular function defined over  $a \leq x \leq L$ ;

$$\psi(x, L) = \frac{L^2 - a^2}{x^2 L} + \frac{a^2(L^2 - a^2)^2}{L(\pm xL - a^2)^3} - \frac{L(L^2 - a^2)}{(\pm xL - a^2)^2} - \frac{L}{\pm xL - a^2} \quad (6)$$

During fracture initiation, the stress on the surface of the crack is zero. At  $y = 0$ , the fracture surface stress is (Muskhelishvili 1953)

$$\sigma_{yy}(x) = -p_p(x) - \frac{a^2}{x^2} p_w - \frac{1}{2} \left( \frac{a^2}{x^2} - \frac{3a^4}{x^4} \right) \sigma_H - \frac{1}{2} \left( 2 + \frac{a^2}{x^2} \frac{3a^4}{x^4} \right) \sigma_h \quad (7)$$

The stress calculated using Eq. (7) characterizes one fracture and the effect of a second fracture is obtained via Eq. (5). Also, substituting Eqs. (3) and (4) into Eq. (7) produces a stress function. This stress function is dependent on anisotropic in situ stresses, anisotropic elastic properties and wellbore characteristics. The integral in Eq. (5) has Cauchy type singularities and to solve it, the following coordinate transformations are made;

$$L = \frac{1}{2}(b - a)t_k + \frac{1}{2}(b + a), \quad -1 \leq t_k \leq 1 \quad (8)$$

$$x = \frac{1}{2}(b - a)\gamma_j + \frac{1}{2}(b + a), \quad -1 \leq \gamma_j \leq 1 \quad (9)$$

where  $t_k$  and  $\gamma_j$  are arguments of the Chebyshev polynomial of the first and second kinds of order  $m$  respectively, such that

$$t_k = \cos\left(\frac{2k - 1}{2m}\pi\right), \quad k = 1, 2, \dots, m \quad (10)$$

$$\gamma_j = \cos\left(\frac{r}{m}\pi\right), \quad j = 1, 2, \dots, m - 1 \quad (11)$$

Substituting Eqs. (7)–(11) into Eq. (5) and using the Gauss–Chebyshev integration formula.

$$\tilde{\sigma}(\gamma_j) = \sum_{k=1}^m \frac{F(t_k)}{m} \left[ \frac{1}{\gamma_j - t_k} + \frac{1}{-\gamma_j - t_k - \frac{2(b+a)}{(b-a)}} + \left( \frac{b-a}{2} \right) \{ \psi(\gamma_j, t_k) + \psi(-\gamma_j, t_k) \} \right] \quad (12)$$

$$\frac{1}{m} \sum_{k=1}^m (-1)^k F(t_k) \sqrt{\left( \frac{1-t_k}{1+t_k} \right)} = 0 \quad (13)$$

In this work,  $m = 200$  and as such a series of 200 simultaneous equations are obtained from which 200  $F(t_k)$  values are obtained using the Gaussian elimination method. The distribution of  $F(t_k)$  is then used to calculate the fracture width.

### 2.3 Fracture Width Distribution

The continuous fracture width at any position parallel to the fracture surface can be written as

$$W(x) = \frac{4(1 - \nu_h^2)}{E_h} \int_x^b f(L) dL \quad (14)$$

Re-writing the integral of Eq. (14) as a Gauss-Chebyshev approximation and substituting Eq. (8) into the re-written form of Eq. (14) gives the discrete fracture width distribution in the form

$$W(t_k) = \frac{2\pi(b-a)}{m} \frac{(1 - \nu_h^2)}{E_h} \sum_{k=1}^m F(t_k) \quad (15)$$

For fracture propagation to occur, the stress intensity must exceed the fracture toughness. The stress intensity factor can be calculated from Eq. (16) (Carbonell and Detournay 1995)

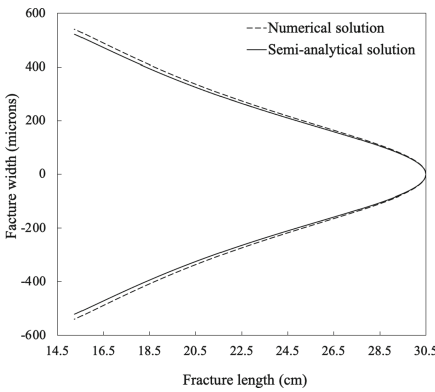
$$K_I = \frac{\sqrt{2\pi(b-a)}}{2m} \sum_{k=1}^m (-1)^{k-1} F(t_k) \left( \frac{1-t_k}{1+t_k} \right)^{-\frac{1}{2}} \quad (16)$$

**2.4 Model Validation**

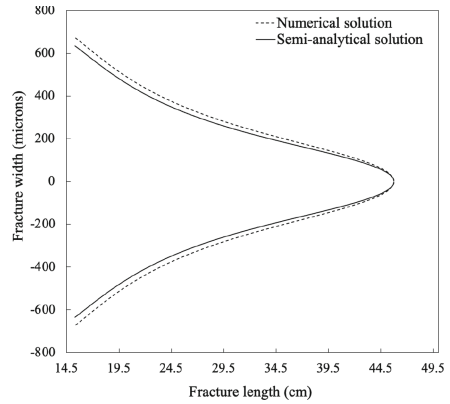
The fracture model was validated against finite element solution and the data used are shown in Table 1. Comparison between the semi-analytical results in this study and the numerical solution by Guo et al. (2011) shows evidence of a consistent phenomenon and a close agreement is also observed (Figs. 2 and 3). Therefore, the semi-analytical fracture model presented can thus be used to predict fracture behaviour at given conditions.

**Table 1.** Input parameters for model verifications

$E_h$ (MPa)	$E_v$ (MPa)	$\nu_h$	$\nu_v$	$a$ (m)	$b$ (m)	$p_w$ (kPa)	$\sigma_c$ (kPa)	$\sigma_T$ (kPa)	$\omega_b\theta$ (rad)	$\alpha_h$	$\alpha_v$
7515.29	5033.17	0.225	0.194	0.1524	0.3048	63.43	86.87	0	0	0.81	0.94



**Fig. 2.** Semi-analytical and numerical models for  $L = 15.24$  cm ( $\sigma_H/\sigma_h = 1.5$ )



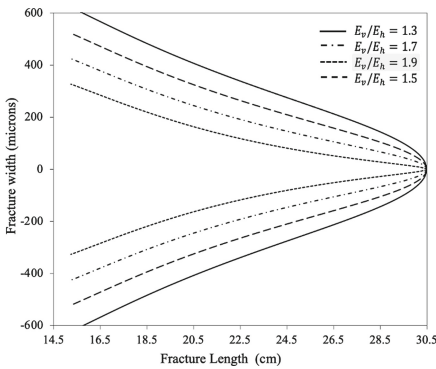
**Fig. 3.** Semi-analytical and numerical models for  $L = 30.48$  cm ( $\sigma_H/\sigma_h = 1.5$ )

**3 Results and Discussions**

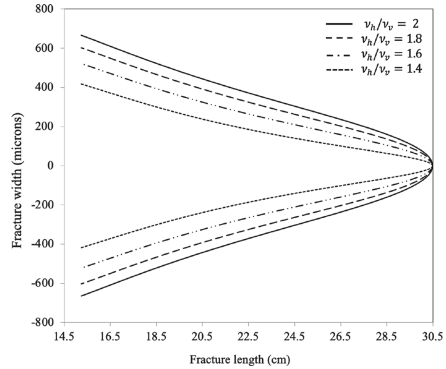
The proposed semi-analytical model is used to predict the influence of elastic anisotropy, wellbore breakout and uniaxial compressive strength on fracture opening. The model’s prediction ignores the effects of tectonic strain ( $\epsilon_h = \epsilon_H \approx 0$ ).

Anisotropic Young’s moduli had an inverse effect on the fracture width profile and this is depicted in Fig. 4. The modulus measures the formation’s ability to withstand changes in the plane of transverse isotropy. It is there expected from the study that increasing values of  $E_h/E_v$  will narrow the fracture opening. From this result, it is believed that increasing values of Young’s moduli for the isotropic case in the models of Shahri et al. (2014) and Zhong et al. (2017) will also narrow the width profile.

The effect of Poisson’s ratio on the fracture profile is shown in Fig. 5. For uniaxial stress, the Poisson ratio is expressed as a quotient of transverse strain to longitudinal strain. Since the minimum horizontal stress is approximated as the fracture closure pressure, Poisson’s ratio in the plane normal to the plane transverse isotropy is expected to be higher than the Poisson’s ratio in the plane of transverse isotropy. As such the stress that is transmitted horizontally is heavily reliant on the  $\nu_h$  and the fracture opening broadens as the ratio  $\nu_h/\nu_v$  increases. Higher values of the ratio in the direction of the fracture surface correspondingly increase the fracture width. This phenomenon is contrary to the isotropic Poisson’s ratio that shows no significant effect on fracture opening as reported by Shahri et al. (2014). It is quite clear, that a single value to represent the Poisson ratio masks the effects of the true transmission of stress horizontally as compared to the anisotropic Poisson ratios.



**Fig. 4.** Influence of anisotropic Young’s moduli on fracture width profile

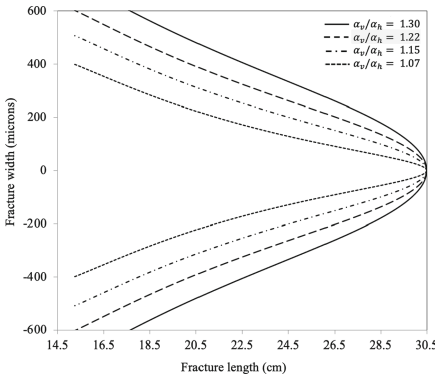


**Fig. 5.** Influence of anisotropic Poisson’s ratio on fracture width profile

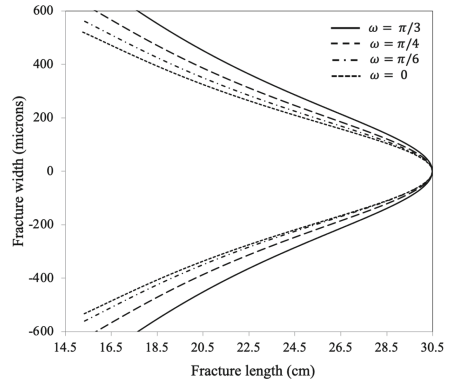
The Biot anisotropy influences the shape of the fracture width profile as seen in Fig. 6. The Biot constant tracks deformation of a formation which is considered poroelastic. Due to deposition and compaction caused by overburden, significant elasticity is experienced in the plane of transverse isotropy. The fracture propagation which is in the plane normal to the plane of transverse isotropy is more affected by  $\alpha_v$  component. It is for this reason that the values of  $\alpha_v/\alpha_h > 1$  increases fracture width as shown in Fig. 6.

The wellbore breakouts, which are a type of rock failure around the walls of the wellbore, occur when the quotient of maximum tensile principal stress to the maximum compressive principal stress increases beyond the shear strength limit of the rock formation. It is an angular measure of the azimuth angle of the breakout at the borehole wall. Regions around the wellbore centered at the azimuth of the least  $\sigma_h$  will experience





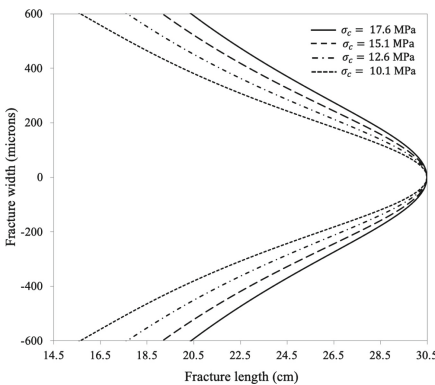
**Fig. 6.** Influence of Biot's anisotropic on fracture width profile



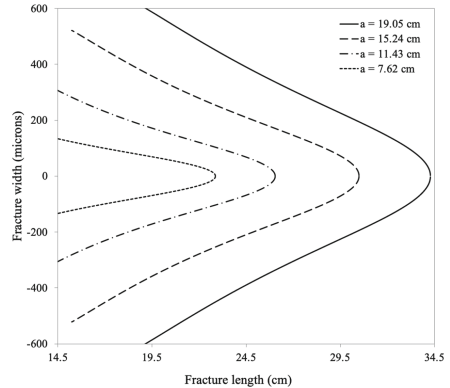
**Fig. 7.** Influence of wellbore breakout on fracture width profile

breakout since compressive stress is high. In Fig. 7, the fracture width profile responded differently to two sets of wellbore breakouts. For  $0 \leq \omega_{bo} < \pi/6$ , there was no significant change in the fracture width profile except for  $\Delta\omega_{bo} = \pi/12$  beyond  $\omega_{bo} = \pi/6$ , where the fracture width widens. These breakout values may be the points of localized compressive shear activity.

The uniaxial compressive strength, also known as the unconfined compressive strength measures the maximum axial compressive strength that the wellbore can withstand before failing. Small changes of the uniaxial compressive strength ( $\Delta\sigma_c < 1\text{MPa}$ ) shows no significant influence on fracture width profile. Increasing the change in the order of 2.5 MPa widens the fracture opening, more so leading to the fracture destruction as observed in Fig. 8.

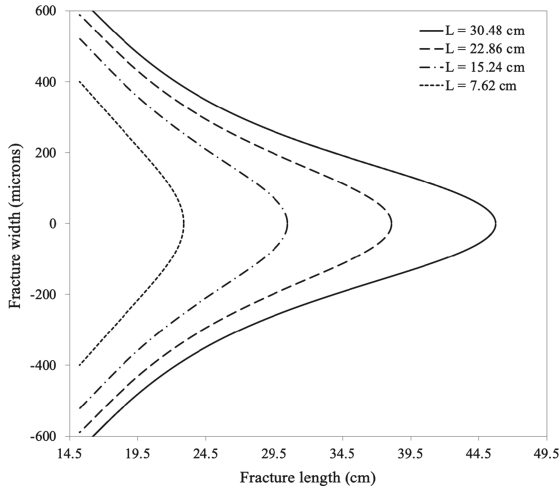


**Fig. 8.** Influence of uniaxial compressive strengths on fracture width profile



**Fig. 9.** Influence of wellbore radius on fracture width profile

The effects of wellbore geometry and fracture lengths on fracture width profile were also studied. Figures 9 and 10 show that smaller wellbore radius causes narrow fracture



**Fig. 10.** Influence of fracture length on fracture width profile

opening and the fracture opening widens as the induced fracture propagates respectively and this collaborates what was observed by Guo et al. (2011) and Shahri et al. (2014).

## 4 Conclusion

Semi-analytical modelling has been performed to predict the influences of elastic anisotropy, wellbore breakout and uniaxial compressive on fracture width distribution. Also, the effects of wellbore geometry and fracture lengths on fracture width distribution have been confirmed. Some conclusions are as follows:

- Elastic anisotropic properties such as Young's moduli and Biot anisotropy had inverse relationship on fracture width while Poisson's ratios had a positive relationship on fracture width.
- Smaller values of wellbore breakout had no significant influence on fracture width except for  $\Delta\omega_{bo} = \pi/12$  beyond  $\omega_{bo} = \pi/6$ .
- Uniaxial compressive strengths showed positive relationships to fracture width for incremental changes greater than 2.5 MPa.
- The study also confirmed the positive relationships wellbore geometry and fracture length have on the width of a fracture.

**Conflict of Interest.** Richard Nii Ayitey Akoto, Dariusz Knez and Lawrence Atepor declare that they have no conflict of interest.

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# Health and Safety Hazards Confronting Mortuary Attendants

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**Abstract. Purpose:** The purpose of this study was to explore the main sources of health and safety hazards confronting mortuary attendants in the Sekondi-Takoradi Metropolis (STM).

**Design/Methodology/Approach:** Data from 16 Mortuary Attendants (MAs) purposively selected from all three functional mortuary facilities in the STM was analysed. A 25-item interview guide and 24-item observation checklist were used to gather the data. The phenomenological Analysis (PA) approach was used to analyse the data.

**Findings:** Findings revealed that the main sources of health and safety hazards at the morgues included: i) exposure to chemical and biological agents, ii) exposure to ergonomic conditions, iii) exposure to extreme temperature variation, iv) exposure to workplace violence and psychological conditions, v) exposure to noise, and vi) exposure to irregular working time arrangements.

**Research Limitations/Implications:** A total of three mortuary facilities with a sample of 16 MAs limited the generalizability of the research findings.

**Practical Implication:** The knowledge carried in this study will draw the attention of MAs and their managers to the main sources of hazards at the morgue, and significantly influence attitudes and safety practices of the MAs.

**Social Implication:** The knowledge carried in this study will influence policy decisions of health managers regarding MAs, and significantly improve work practices and work environments for MAs.

**Originality/Value:** The paucity of studies regarding Mortuary Attendants in Ghana highlights the novelty of this study. The study unveiled a scary normalisation of hazards such as extreme temperature variations, workplace violence and psychological conditions, and irregular working arrangements by MAs in Ghana.

**Keywords:** Compliance · First aid · Hazard · Mortuary attendants · Sekondi-Takoradi

## 1 Introduction

Globally, about 2.78 million lives of workers are lost annually due to accidents and diseases at work, and an additional 374 million employees sustain work accidents (ILO

2019). Also, Hämäläinen et al. (2017) estimated that diseases relating to work alone represent the largest proportion of work-related mortality and further account for 2.4 million (86.3%) of all estimated deaths occurring globally. For example, cancer was ranked the number one main cause of work-related fatalities (ILO 2019). Meanwhile, workers with the potential for long working careers, in terms of years, are the most impacted (ILO 2003). These findings exclude data from most developing countries, especially Africa, where there is no reliable data on OHS (ILO 2003). Meanwhile, health is an inalienable right and is at the heart of human progress (The Global Health Initiative Strategy 2010). Moreover, Sustainable Development Goals 11.2 provides that cities and human dwellings are made inclusive, safe, robust, and sustainable (UN 2016).

Though OHS risks and hazards are associated with all work environments, some are disproportionately affected (Hämäläinen et al. 2017). Accordingly, healthcare employees are confronted with a heightened risk of exposure to infectious diseases (Chang et al. 2020), including the novel coronavirus (COVID-19) (WHO 2020). It is, therefore, imperative to prioritise the safety of healthcare employees not only to ensure consistency in care but also to protect them from being infected and avoid transmitting diseases to others they come into contact with. Muchiri (2003) attributes the ineffective enforcement and inspection of OHS services in most African countries to: i) the general lack of adequate information, ii) lack of comprehensive OHS policy, iii) unsatisfactory cadre of trained occupational health and safety experts, and iv) poor infrastructure and funding. Furthermore, adherence to OHS practices in the health sector in sub-Saharan Africa is poor (WHO), and needs much attention.

Mortuary attendants are one group of healthcare personnel that receives little or no attention from employers even though their working environments expose them to greater dangers (Litana and Kapambwe 2017). Thus, health-care managers in most African countries hardly pay attention to the health and safety concerns at the morgue, a situation that exposes these MAs to all sorts of risks including electric shock and fires, back, neck, and arm pains (Sirongo 2014). Meanwhile, the work of the MA dignifies and gives respect to the dead, a value profoundly embedded in all civilisations, cultures, and religions (Government of Ireland 2013). However, it can be tough to balance the respect for the dead with the health and safety of those (MAs) who come into contact with the bare dead body all the time. These MAs come into contact with people who may have died of infectious diseases such as the Coronavirus and other highly infectious diseases. These diseases could mutate to new strands and become difficult to manage if contracted by these MAs without proper health and safety measures (WHO 2020). Records show that the mortuaries in the Sekondi-Takoradi Metropolis receive dead bodies from the neighbouring countries such as Burkina Faso, Cote D'Ivoire and Mali (WHO 2019), with some of these countries recording infectious disease outbreaks such as Dengue and Lassa fevers, and currently COVID-19 (WHO 2020). Though a good body of evidence regarding infection controls among the living exists, not much evidence exists that pertains to the management of dead bodies (Government of Ireland).

The increasing need for mortuary services, especially in sub-Saharan Africa, will potentially worsen the OHS problems of MAs given recent increases in infectious disease outbreaks. In the face of limited resources and competing priorities, particularly since the outbreak of COVID-19, health managers are unable to adequately resource mortuary

facilities (Coronavirus: Mortuary Workers to Boycott Dead Bodies 2020, Okoth-Okelloh et al. 2013). Though the mandate of hospitals is to “save lives”, or at least “delay death”, people continue to die from all sort of diseases, daily, and that puts a strain on mortuary facilities (Sirongo 2014). Ghana, over the years, has been plagued with several workplace accidents in both the formal and informal sectors of the economy (Ansah 2017). It must be understood that most work-related accidents in Ghana, as is the case in most developing countries, remain largely unreported (MELR 2019). However, addressing these OHS challenges remains problematic because of lack of national policy and commitment of government and employers (Anaman and Osei-Amponsah 2007).

Ghana has a number of legislations/laws on OHS, albeit fragmentary and narrow in scope and content, and ineffective. Some of these legislations/laws include: i) C148 - Working Environment (Air Pollution, Noise and Vibration) Convention, 1977, ratified on 27th May, 1986, ii) Workmen’s Compensation Act 1987 (PNDCL 187), iii) Labour Act, 2003. Act 651, and iv) the Mortuaries and Funeral Facilities Act, 1998 (Act 563) (Anaman and Osei-Amponsah 2007). Therefore, to deal with some of these inefficiencies and protect the health sector workers, the Ministry of Health, Ghana, developed and started implementing a guideline on OHS for the health sector since 2010 (MoH 2010). Among its 10 broad safety policy objectives is the demand from health-care managers to promote safer and healthier work compounds, work practices, and procedures for every staff of the health sector to reduce occupational injuries and illnesses (MoH). Meanwhile, there is no available evidence of a study on the subject in Ghana, and very few in Africa (Adamu and Lawani 2018, Douglas and Peterside 2016). *Therefore, the purpose of this study was to explore the main sources of health and safety hazards confronting mortuary attendants in the Sekondi-Takoradi Metropolis (STM).*

## 2 Theoretical Base of the Study

### 2.1 The Compensating Wage Differentials (CWDs) Theory

The compensating wage differentials (CWDs) theory, the theoretical foundation of this study, underscores the attitude of potential employees to jobs with relatively high levels of exposure to occupational hazards. The theory drew inspiration from the sub-optimal allocation of job market risks by Smith (1776), and argued that potential employees will rather opt for jobs with relatively higher levels of risk because of the high remunerations they offer (Pouliakas and Theodossiou 2009, 2010a, 2010b, 2010c). This position is strongly upheld by Geest (2006) who reported of a sturdy increase in the number of job seekers, especially young men, expressing interest and involved in mortuary work from across all tribes in Ghana. Geest explained that notwithstanding the strong negative cultural beliefs around mortuary work, there is an increase in the number of young people working at the morgue. Historically, the trade in Ghana used to be the preserve of a few older men with northern heritage but this has completely changed over the years (Geest). The theory further explained that workers who are risk-averse will favourably consider job offers from organisations that have relatively safer work conditions, while workers that are less risk-averse will be more desirous of working for organisations with relatively higher levels of exposure to risk (Marin and Psacharopoulos 1982, Smith 1776).

Regardless of the popularity about the reliability of the CWD theory amongst researchers, some disagree with the estimation of the risk variables (Lalive 2003). According to the critics, there are measurement errors in the risk variables used in the theory which they attribute to “aggregation bias” (Lalive). In addition, the aggregation bias clouds the relevant differences in the degree of work-related risks confronted by workers who undertake different duties, even if they are categorised within the same occupation (Arabsheibani and Marin 2000). Sandy and Elliott (2005) criticised the CWDs theory for overstating the influence of job disamenities on workers who are unsatisfied with their remuneration and further questioned the validity of CWDs gotten from workers’ answers to questions of work risk.

Notwithstanding the argument advanced by critics of the CWDs theory, its assessment of the attitude of potential employees to job offers is relevant for mortuary work (Geest 2006). However, the theory does not go further to explain how potential employees would react to poor working conditions while on the job. Furthermore, while all industries have hazards that confront workers, it is important to highlight hazards that are unique to specific jobs. The current study therefore seeks to fill this gap in theory by *exploring the main sources of hazards confronting mortuary attendants in STM*.

### 3 Methods

The study adopted the Phenomenological Analysis (PA) approach in analysing the health and safety experiences of MAs in the STM. As a research methodology, PA is a type of qualitative research that dwells on the study of a person’s lived experiences within the world (Neubauer et al. 2019). Phenomenological Analysis allows the researcher to focus on how persons perceive an event or phenomena, instead of simply how the phenomena exist in a vacuum (Regoli 2017). Accordingly, awareness and knowledge of participants, exposure to chemical and biological agents, ergonomic conditions, extreme temperature variations, workplace violence and psychological conditions, noise, irregular working time arrangements, hand hygiene, personal hygiene, use of PPE, and working posture of the various MAs and their facilities were assessed. The participants included 16 MAs purposively selected from all three functional mortuary facilities in the STM, the Western Regional Hospital (6 MAs), Takoradi Hospital (4 MAs), and Effman’s Clinic (6 MAs) in the Western Region of Ghana.

#### 3.1 Instrument and Ethical Consideration

An interview guide made up of 25 items and observation checklist of 24 items were used to gather the data. The interview guide explored the demographic details of the MAs (i.e. age, gender, level of formal education, and work experience), awareness and knowledge about the Safety Policy Guide of MoH, and conditions under which the MAs work. The observation checklist explored the safety adequacy of the working environments and other safety requirements expected at mortuary facilities, availability and use of PPE, and work practices. The questions and checklist were derived from literature (Douglas and Peterside 2016, Litana and Kapambwe 2017, Shashi et al. 2016). Some of the open-ended questions included: “*What are your main responsibilities as an MA under the OHS*



*policy?”*, “*What does the OHS policy say about the responsibilities of management for MAs?”*, “*What areas of your specific duties were covered during your pre-deployment orientation?”* and “*Describe the nature of medical screening you went through during your recruitment.*”

In strict compliance with the national COVID-19 safety protocols (face masking, handwashing, and physical distancing), participants were contacted in person at the mortuaries for the interviews. The interviews were conducted mostly on Saturday afternoons and late afternoons when they were less busy at work, and during break period (12–2 pm) on weekdays, to prevent interference with the routine activities of the MAs. Impromptu assessment of work practices was conducted during peak working hours, like Fridays and Saturday mornings, using the checklist. The observations were also conducted in the various mortuaries. A walk-through assessment of the mortuary was conducted using the observation checklist and covered the following: floor (whether hard and durable, moisture resistant, and others), walls (whether thick, durable and permanent, and others), doors (whether wide sliding and fly proof), corridors (whether wide and not less than 8fts.), water supply (whether regular, both hot/cold available, adequate sinks, and others), and emergency facilities (whether emergency lighting in place, smoke/thermal detectors functional, and others) (Douglas and Peterside 2016, Lincoln and Guba 1985).

The facilities were visited on daily basis for three weeks each. The interviews lasted between 30 and 45 min while the observations took between 30 and 50 min. The data was collected in July, 2020. To ensure confidentiality and anonymity of participants, responses were coded instead of the use of names of persons or units.

Ethical approval was procured from the University of Cape Coast Institutional Review Board (UCCIRB) (reference ID: UCC/IRB/A/2016/730). The initial prepared instruments were reviewed by the OHS Focal Person of the Western Regional Hospital, and further assessed by a lecturer in Health Promotion and a Professor in Environmental Health. All participants were assured of anonymity and confidentiality of their information. Moreover, they all signed informed consent forms before taking part in the study. We did not provide any reward to any of the participants, and the study was voluntary; where participants were informed, they could opt out at any time without associated cost.

## 4 Data Analysis

The Phenomenological Analysis (PA) approach was adopted in analysing the data, i.e. the transcripts. The analysis involved reading the transcript severally to appreciate the meanings espoused, ascertaining noteworthy phrases, and paraphrasing them in general terms, which was carried out by the first and second authors (Riley et al. 2018a). These processes aided in developing meanings from the transcripts and corroborate them, via research team discussions to reach consensus. The main themes identified were further developed and distilled into sub-themes for ease of comprehension of all themes, and according to the purpose of the study (Riley et al. 2018b). All three authors read the emerged sub-themes and resolved any discrepancies.

Using the PA, manual transcriptions were done for each audio recording and all names mentioned in the interviews were anonymised using pseudonyms to ensure confidentiality. In keeping with trustworthiness, the following principles were applied: credibility, transferability, dependability, confirmability, reflexivity, and authenticity. To attain credibility, all researchers did prolong and thorough reading of transcripts to establish a good “fit” between participants’ views and the researchers’ characterisation of them (Guba and Lincoln 1989, Tobin and Begley 2004). To ensure transferability of findings, the researchers provided deep description of findings (Lincoln and Guba 1994). In keeping with dependability, the researchers applied enough rigour in logically and clearly documenting and auditing all research processes and findings (Koch 1994, Tobin and Begley). Further, the researchers have kept all raw data from the field and clearly reported all processes involved in their acquisition (Halpren 1983). To attain confirmability, the researchers ensured that all findings, interpretations, and conclusions reached are directly drawn from the field data. Comprehensive notes were taken during analysis and interpretation as the study progressed (Tobin and Begley). Further, the choice of methods and approaches to data analysis were clearly explained (Koch). Reflexivity was attained by documenting and critically examining all research processes, including internal and external dialogues (Tobin and Begley). Finally, authenticity was achieved through a thorough description of participants’ experiences (Tobin and Begley).

#### 4.1 Results

Participants were 16 MAs from all three functional mortuary facilities in the STM, that is the Western Regional Hospital (6 MAs), Takoradi Hospital (4 MAs), and Effman’s Clinic (6 MAs) in the Western Region, Ghana. Using Phenomenological analysis, three main themes and nine sub-themes emerged: i) theme one: awareness and knowledge, ii) theme two: the main sources of health and safety challenges (sub-themes 1. exposure to chemical and biological agents, 2. exposure to ergonomic conditions, 3. exposure to extreme temperature variations, 4. exposure to workplace violence and psychological conditions, 5. exposure to noise, and 6. exposure to irregular working time arrangements), iii) theme three: safety practices (sub-themes 1. hand hygiene, 2. working posture, and 3. use of personal protective equipment).

##### ***Theme One: Awareness and Knowledge***

The theme that emerged was awareness and knowledge about responsibilities of MAs and their management. Results show very low awareness and knowledge about the OHS Policy Guide of MoH among the MAs. In an attempt to mention the responsibilities as enshrined in the Safety Policy Guide, a 43-yr-old male MA (WRHMA2) with over 15 yrs’ experience said: “*We are not expected to drink alcohol while on duty; we must not be late to work; we must not be lazy at work; and we must not fight at work*”, contrary to the policy guide (MoH 2010). The MAs also demonstrated low knowledge about the responsibilities of hospital management (employers) under the policy. None of the MAs could correctly mention the role of their superiors in promoting safe and healthy job environments, work practices, and procedures to reduce job-related injuries and illnesses among them (MAs). Mortuary attendant (WRHMA2) answered again: “*They must pay us our salary; provide us with our working tools and materials; fight for us, that is solve*

*our problems like our risk allowances must be part of our salary and not paid by the hospital.”*

***Theme Two: The Main Sources of Health and Safety Challenges***

This theme produced six sub-themes which included: i) exposures to chemical and biological agents, ii) ergonomic conditions, iii) extreme temperature variations, iv) workplace violence and psychological conditions, v) noise, and vi) irregular working arrangements.

***Sub-theme One: Exposure to Chemical and Biological Agents:*** Chemical and biological agents were found to be common sources of exposures in mortuary facilities in the metropolis. Majority of MAs regularly come into contact with formaldehyde, detergents, and solvents in the course of their work, mostly through inhalation and direct skin contact. Incidence of body fluids from cadaver, formaldehyde, and other fixatives splash into the faces of MAs. Chemicals are routinely handled at the morgue without appropriate protections. A 42-yr-old male MA (THMA1) with over 3 yrs’ experience said: *“I have been exposed to formaldehyde and other chemicals severally, I’ve even lost count. Even just last week, I suffered a heavy splash into my face and actually into my eyes when a tube of the embalming machine disconnected from a vein of a body I was working on.”* Another 33-yr-old male MA (ECMA1) with over 3 yrs’ experience said: *“Two years ago, when we were still using formaldehyde, the experience was terrible. The vapour from the formalin creates difficulty in breathing and produces a ‘pepper-like’ sharp sensation on the eyes which normally results in tears. Oh! Once you do this work, you will experience it. Sometimes the body is already going bad before they bring it but you have to work on it. You asked why we don’t use the goggle and nose masks? Ok, as for Formalin, you are better off not using the nose mask because you can’t breathe well when you have it on. You see, no matter the space and ventilation in the room, like in our case, Formalin doesn’t care about that. Ask anybody who has worked with Formalin in the Morgue before and he will confirm this experience to you.”*

***Sub-theme Two: Exposure to Ergonomic Conditions (Physical Strain):*** Ergonomic conditions (physical strain) were also found to be common sources of exposures affecting majority of the MAs. Poorly designed workstations with inadequate space, strenuous work postures during lifting of dead bodies, and other repetitive movements result in waist, back, neck, and arm pain complaints among the MAs. A number of MAs had experienced dead bodies falling on them while attempting to pull these bodies out of the refrigerator. A 44-yr-old female MA (ECMA2) with over 8 yrs’ experience said: *“I have experienced dead bodies falling on me many times; it’s a common occurrence here. I’m sure we are not the only people that experience this because even at my previous work place, it happened. I experience bodily pains all the time, especially after days when we discharge more bodies.”* Another 32-yr-old male MA (THMA2) with 5 yrs’ experience said: *“Once I was pulling a body from the cabinet and my arm rubbed against the sharp edges of the cabinet and that resulted in bruises. The space in the morgue is so small that you can’t even use the ladder.”*

***Sub-theme Three: Exposure to Extreme Temperature Variation:*** Majority of the MAs experience extreme temperature variations during work. They move in and out of the cold rooms to either deposit or remove dead bodies, often without the appropriate protective

apparel. A 33-yr-old male MA (ECMA1) with over 3 yrs' experience said: *"This is something we experience regularly. I feel a strange sensation in my whole body, and sometimes with headaches, whenever I come out from the cold room, especially on days that we discharge more bodies. I know this may have some effect on my health but there is nothing I can do."* While some MAs acknowledged the potential health effects of this exposure, others do not see the danger. A 36-yr-old male MA (ECMA3) with over 4 yrs' experience believed: *"As for the numbness in the hand, I experience it all the time but I don't think it can do anything to me because it's just like the way we use our domestic fridges."*

**Sub-theme Four: Exposure to Workplace Violence and Psychological Conditions:** The result further indicated that all MAs experienced exposure to workplace violence and psychological conditions like verbal attacks and stigmatisation. For example, unhappy relatives attack MAs when they release bodies to factions or rivalry groups in the family of the deceased, release "wrong" bodies to families, or when the body goes bad. Incidence of stigmatisation and social isolation, especially by nurses, are common experiences of MAs. No security person is assigned and stationed to any mortuary in the metropolis. A 54-yr-old male MA (THMA3) with 14 yrs' experience recounted: *"We suffer stigmatisation all the time, especially from the nurses. Some of them think we are less human than them and unclean to be in the same environment with them. I felt very terrible when a senior nurse asked me if I also have a female partner and whether I am able to have sex with her."* Another 34-yr-old male MA (WRHMA1) with 13 yrs' experience admitted: *"Yes, stigmatisation against us is there but I think it is human nature. Not everyone would like you; you may find people who may like you and others who may not want to even see you at all."*

**Sub-theme Five: Exposure to Noise:** Many of the MAs complained of noise, which usually occurs on Fridays. It comes in the form of wailing, shouting, aggressive dancing and drumming, and honking of car horns by relatives and friends who have come to pick dead bodies. A 43-yr-old male MA (THMA4) with 3 yrs' experience lamented: *"Look at the location of our morgue and the wards around. So, at times the noise can be so loud that the nurses do come and complain bitterly. Sometimes the people would be many that they spill over to the space in front of the administration and wards around. Mostly, it is the youth that make noise during these periods."* However, some MAs found this exposure to be normal and could not be separated from death because it is the way bereaved families expressed their loss. Another 32-yr-old male MA (THMA2) with 5 yrs' experience recounts: *"For me I think the noise is normal; because death and noise are inseparable in our society. Especially when the person dies a painful death at a young age and the family thinks that he was killed."*

**Sub-theme Six: Exposure to Irregular Working Time Arrangements:** The findings further showed that all the MAs experience irregular working time arrangements, they work for 12 hrs daily and the majority of them have not even gone on annual leave since they were recruited. Moreover, most of them have spent between one month to five years on the job while others too spent six years and above.

## 4.2 Theme Three: Safety Practices

This theme produced three sub-themes, including i) hand and personal hygiene, ii) working posture, and iii) use of personal protective equipment (PPE).

**Sub-theme One: Hand Hygiene:** Observation shows that the MAs do not wash their hands regularly during work. The standard handwashing technique, which is found to be effective in crushing infection, is not applied and some do not even use soap when they attempt to do so. A 43-yr-old male MA (THMA4) with 3 yrs' experience remarked: *"We try our best to always wash our hands but the issue is that sometimes the water doesn't flow. I may say that it is the COVID-19 that made them (management) to give us these veronica buckets which you see there. But our main problem is that, water doesn't flow in the morgue regularly. So, we use water hose to connect water from the pipe outside and that is how we have been managing for a long time now. We complained but they (management) don't mind us."* In addition, bathing under running water and with soap after working on a dead body is a standard procedure in the morgue; however, MAs in STM do not observe this. Probably, because these mortuary facilities do not have facilities for bathing and changing over, sometimes they go home in their dresses without bathing. Another 37-yr-old male MA (WRHMA4) with 12 yrs' experience recounts: *"Before the COVID-19 outbreak, we always washed our hands outside the morgue using the pipe over there. Even though I can say that we don't adhere strictly to the standard handwashing protocol, the lack of water in the morgue was the cause. Since the start of the renovation exercise at this place some two years ago, the main line supplying water to working areas in the morgue was affected. We complained and they promised to fix it but that was not done. I am very much aware of the dangers of contracting diseases from poor hand hygiene but in this case, we do not have the water. Hmm.....water is not flowing in here."* Another 34-yr-old male MA (WRHMA1) with 13 yrs' experience said: *"Everything depends on our bosses (management), they have to provide us with the things we need to work with before we can also use them. We usually bath outside, on the grasses over there."*

**Sub-theme Two: Working Posture:** We further observed that the MAs do not assume the right posture when processing dead bodies. They lift, carry, push, or roll dead bodies all the time with awkward postures. Thus, the majority complained of frequent back, neck, waist aches and general body fatigue, but these discomforts heightened on Fridays, when most families come for their bodies. A 32-yr-old male MA (THMA2) with 5 yrs' experience said: *"Hmmm....this one is difficult because, the work requires manpower and you do a lot of lifting, carrying, turning, and pushing at work. You can't do this work if you are not very healthy."*

**Sub-theme Three: Use of Personal Protective Equipment:** The results further revealed that these MAs routinely handle chemicals in processing dead bodies without wearing the right PPE. It is a very common practice among MAs in STM to work in their personal attire, sometimes even without wellington boots and nose masks, encouraging a sub-culture of handling dead cases without regard for the universal precautions. Meanwhile, management of the health facilities appear to find it difficult in enforcing the safety protocols on the MAs. Even though some MAs seem to understand the dangers in

ignoring the safety protocols during work, it was difficult to peer-correct each other. Mortuary attendant (ECMA1) quoted above explained further: *“Truth is only one; we don’t always observe the safety protocols. There were occasions when some of my senior colleagues walked around the mortuary environment barefooted, handle dead bodies with their bare hands, and they won’t listen when you caution them.”*

## 5 Discussion

The MAs reported generally low awareness and knowledge about the Safety Policy Guide of MoH. This was confirmed by their managers. The main sources of hazards in the morgue included exposures to chemical and biological agents, ergonomic conditions (physical strain), extreme temperature variations, workplace violence and psychological conditions, noise, and irregular working time arrangements. Moreover, we found generally a very poor attitude to safety protocols and safety practices among the attendants.

Level of formal education and training (pre-deployment training on specific job functions and post-deployment/routine training) were suggested as prerequisites for participants’ awareness and knowledge about collective worker responsibilities and responsibilities of health managers towards workers under the OHS policy guide (MoH 2010). From the results, gaps in pre and post-deployment training contributed to the low awareness and knowledge among MAs in STM about the OHS Policy Guide. Contrary to provisions of the OHS Policy Guide of MoH, health managers have no clear plan for training MAs, before and after recruitment. This is consistent with findings of a study among MAs in Ibadan which attributed the low level of knowledge to low levels of formal education among the respondents (Adamu and Lawani 2018). Findings of the current study also affirm Loibner et al. (2019) which reported that effective pre and post-deployment training contributed to enhancing the knowledge of workers in the donning and doffing of PPE and general adherence to the universal precautions. It is safe to deduce that level of formal education alone is not enough to guarantee adequate knowledge among MAs, but pre-deployment and post-deployment trainings are also relevant.

The findings again revealed that formaldehyde and fluids from dead bodies were major sources of chemical and biological hazards in the morgue and all the MAs were frequently exposed to them, a situation which has both immediate and long-term health consequences. This is consistent with a previous study among MAs in Nairobi which reported that 71.9% of MAs were frequently exposed to high levels of chemicals and other agents in the morgue (Sirongo 2014). This outcome could be explained as Kaledzi (2020) reported that health managers in Ghana do not provide MAs with adequate protection against exposures in the morgue. This further exposes MAs in Ghana to frequent ergonomic conditions (physical strain) (How Mortuary Men are Recruited in Ghana 2017), as the findings of the current study also revealed. Kaledzi reported that mortuaries in Ghana are increasingly congested with dead bodies, just like prisons, and thus exposing MAs to physical strain.

The majority of MAs in STM frequently experienced extreme temperature variations, a common source of hazard in the morgue. This affirms Adamu and Lawani (2018) who

reported that exposure to frequent transition between hot and cold environments could result in eye infections, muscular spasms, and respiratory infections. Consistent with the current study, Litana and Kapambwe (2017) reported that MAs in Ndola experienced hearing problems due to frequent exposure to extreme noise during work. These will not only affect attendants' physical health but also their psychological health. We found that all the MAs experienced workplace violence and psychological conditions. This confirms a previous study by Douglas and Peterside (2016) which reported that all MAs frequently experienced work-related psychological stress, stigmatisation, and depression.

An irregular working schedule can complicate the health and safety of workers. We found that all MAs in STM experienced irregular working time arrangements, i.e. they work for 12 hrs daily and almost all of them have not gone on annual leave since recruitment. These may adversely affect their health condition especially at a long-term. The current study upholds Bjorvatn (2007) who reported that employees with irregular work schedule and night shifts stand the risk of digestive disorders, disturbed biological rhythm, and eventually physiological disturbances, lower cortisol secretion, increased blood pressure, and heart rate.

Hand hygiene practices among MAs in STM were very poor, as there were inadequate sinks in place. These attendants handle dead bodies with chemicals but do not wash their hands regularly after the procedures. The current study confirms Kannan (2012) reporting that adherence to the universal precautions by MAs was poor at the morgue. Similarly, Douglas and Peterside (2016) found that MAs do not apply universal precautions during work. Therefore, not only are they contaminating their bodies for long periods, but also carry such contaminants into their homes and any place they may go immediately after work.

Right working posture is critical for the immediate and long-term protection of the worker. However, our findings showed that MAs do not practice the right working postures when carrying out activities in the morgue. This may lead to many musculoskeletal conditions. The current study upholds Litana and Kapambwe (2017) reporting that MAs in Zambia frequently experienced physical strain resulting in arm, neck, and back pain. Perhaps, the MAs have not been trained on how to carry out their duties at the appropriate position that will safely guard their health and safety.

We also found that the MAs in STM do not use PPE at work. Lashibi Funeral Home Plans Training for Mortuary Attendants (2019) revealed that health managers in Ghana do not provide MAs with PPE, adequate to sustain a culture of compliance among attendants whose routines include embalming. Meanwhile, the adoption of standard precautions through the use of appropriate PPE would offer good protection and prevent the spread of infection from the deceased body (HPSC 2013). In the absence of adequate and appropriate PPE, the MAs may continue to work without protection, a situation that compromises their health now and in the future.

## 6 Conclusion

**Practical Implication:** The study provided a good understanding of the work practices of MAs in STM, Ghana, using a phenomenological analysis approach. The main sources of health and safety hazards in the morgue included i) exposure to chemicals

and biological agents, ii) ergonomic conditions, iii) extreme temperature variations, iv) workplace violence and psychological conditions, v) noise, and vi) irregular working arrangements. The findings further showed that pre-deployment and post-deployment training are relevant to increasing safe work practices, including personal hygiene and hand hygiene among the attendants. The knowledge carried in this study will draw the attention of MAs and their managers to the main sources of hazards at the morgue, and significantly influence attitudes and safety practices of the MAs.

**Social Implication:** After 11 years into the implementation of the MoH's OHS Policy Guide in Ghana, OHS practices and work conditions of MAs are still very poor, due to i) inadequate supply of PPE, ii) inadequate knowledge about donning and doffing of PPE, iii) poor monitoring and supervision by management, iv) heavy workload, v) environmental factors (temperature), vi) lack of key hygiene facilities (i.e. changing room, washroom, and sinks), and vii) poorly designed work stations. Therefore, the findings: i) exposed gaps in the implementation of the OHS Policy Guide of MoH by health managers in STM, ii) re-directed the attention of health managers to the major health and safety needs of MAs in the STM, and iii) provided a useful framework for possible policy formulation and review in the area of health and safety. Knowledge from this study will influence policy decisions of health managers regarding MAs, and significantly improve work practices and work environments for MAs.

**Originality/Value:** The paucity of studies regarding mortuary attendants in Ghana highlights the novelty of this study. The study unveiled a scary normalisation of hazards such as extreme temperature variations, workplace violence and psychological conditions, and irregular working arrangements by MAs in Ghana. Given provisions of the OHS Safety Policy Guide of the MoH, Ghana, and the SGD 11.2 agenda, which required that cities and human dwellings are made inclusive, safe, robust and sustainable, health managers in STM need to urgently fix all issues affecting the health and safety of MAs.

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# Knowledge, Attitudes and Practices of Grassroots Farmers on Sustainable Environment Activities in Farming Communities of Ghana

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**Abstract. Purpose:** In the quest of making “cities and human settlements inclusive, safe, resilient and sustainable” under specific concerns towards sustaining the natural environment, this paper identifies the educational needs and ecological experiences of grassroots farmers whose activities directly impinge on the natural environment. The paper set forth to find out farmers’ levels of knowledge, attitudes and practices (KAP) on sustainable environment activities (SEA) in farming communities of Ghana and to also determine the relationships among their levels of KAP on SEA.

**Design/Methodology/Approach:** Purposive sampling technique was used to select a farming region and three most dominant farming districts in the Eastern Region of Ghana. The simple random sampling technique was used to sample 400 farmers for the study. A proportionate quota sampling technique was used to select respondents for the study. Data were analysed using mean and standard deviation together with correlation and regression. The results are presented in tables.

**Findings:** The study reveals that grassroots farmers are highly knowledgeable and exhibit highly positive attitudes towards practising specific SEA regularly. Their levels of knowledge, attitude and practices also contribute significantly towards SEA.

**Research Limitation/Implications:** The study focused on farmers who are actively engaged in commercial food, cash crop and livestock production in farming communities of Ghana and 15 communities within three districts in the Eastern Region of Ghana was used as the study area.

**Practical Implication:** The study findings will inform environmental education implementers on the specific levels of practising SEA to regularise environmental education programmes geared towards improving SEA in farming communities.

**Social Implication:** The study findings will disclose to policy-makers the ecological experiences of grassroots farmers required for integration into scientific and theoretical approaches to sustaining the environment.

**Originality/Value:** The study unearths the ecological experiences of grassroots communities and also highlights the relevance of other external factors other than KAP as contributory factors to enhancing SEA for achieving SDG 11.

**Keywords:** Education · Sustainability · Grassroots · Knowledge · Attitudes · Practices

## 1 Introduction

Sustaining environmental resources remain a prime global concern for various reasons including recurring disruptions in the systems of development. Recent quest for development and increased food production for a rapidly increasing population for example have jointly resulted in a dramatic degradation of environmental resources (Zaman et al. 2011; Sharma 2012). Global interventions and policy directives have been championed towards addressing this problem. Typical among them is Agenda 21, a major global action agenda translated and implemented nationally on how to make development socially, economically and environmentally sustainable (Lindner 2019). The Sustainable Development Goals (SDGs), generally referred to as the Global Goals has assumed dominant engagement in recent times. Five out of the 17 SDGs, namely, 6, 12, 13, 14 and 15 directly aim at guaranteeing environmental sustainability. These goals are specifically targeted at ensuring “availability and sustainable management of water and sanitation”, ‘sustainable consumption and production patterns’, taking “actions to combat climate change and its impacts” conserving and “sustainable use of the ocean, sea and marine resources for sustainable development” and protecting, restoring and promoting sustainable use of terrestrial ecosystems, sustainably managing of forests, combating desertification, and halting and reversing “land degradation and halting biodiversity loss” (Sustainable Development Goals Report 2018).

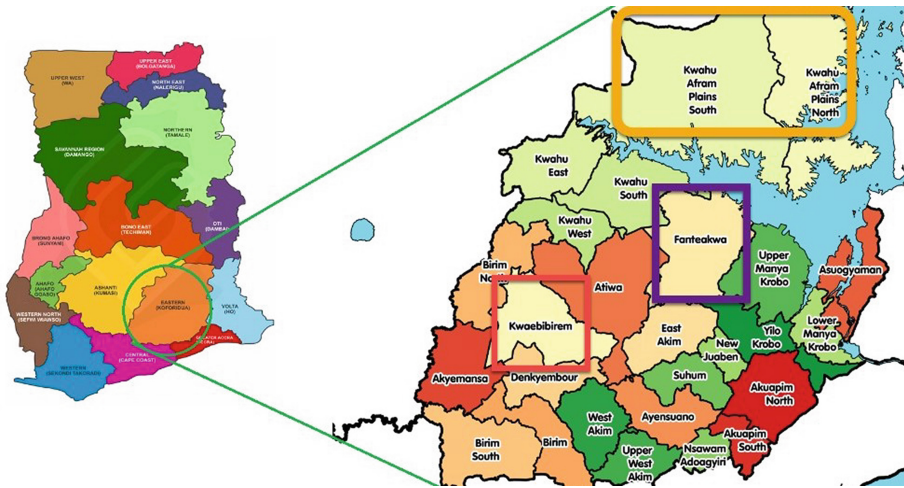
The emergence of these goals is a wake-up call to the entire stakeholders of development in addressing contemporary environmental challenges confronting the world now. It is quite important to note that the SDGs although globally agreed, require nations to apply local strategies and solutions in addressing them (Gassen et al. 2018). Local policies and actions in this regard play a significant role for effective implementation of the SDGs. This implies that a sustainable environment requires context-specific strategies and actions in addressing explicit issues for attaining a trickle-down effect globally.

Indigenous knowledge and experiences acquired by grassroots from their constant interaction with the environment is a major component of local policies needed to spearhead the achievement of the SDGs. Nevertheless, the rural population are generally assumed to be unfriendly to the environment and their ecological experiences are even classified as informal due to the absence of scientific bases (Tisenkopfs and Sumane 2017 and Dutifield 2010). Incorporating grassroots knowledge and experiences into fundamental local policies and actions is a strategic way of managing natural resources while helping to achieve SDG 11: “making cities and human settlements inclusive, safe, resilient and sustainable” (Tume et al. 2019; Sustainable Development Goals Report 2018; Senanayake 2006). On the other hand, neglecting this could derail any environmental sustainability agenda, most especially among developing nations like Ghana whose population and livelihoods are highly dependent on natural resources (Ghana Statistical Service 2013). Identifying farmers’ knowledge, attitudes and practices is a

significant way to determine the educational needs of grassroots as well as their ecological experiences necessary for tapping into empowerment, development and sustainability programmes. This paper, therefore, answers the research question: What is the level of KAP of grassroots farmers on SEA in farming communities of Ghana? The study objectives are to find out the knowledge, attitudes and practices levels of grassroots farmers on SEA as well as determining the relationship among their levels of KAPS on SEA.

**Area and Context of the Study**

Fanteakwa, Kwaebibirem and Afram Plains Districts (Fig. 1).



**Fig. 1.** Map of the Eastern Region depicting the study area

The Eastern Region is one of the administrative regions of Ghana with 2,633,154 as the total population, constituting 10.7% of the national population and a gender distribution pattern of 49 and 50% for males and females respectively (Ghana Statistical Service 2013). The region is situated within the forest and guinea savanna ecological zones, with the forest zone occupying 60%. As a result, it experiences many rainfall patterns which support agriculture, the dominant occupation in the region. The Eastern Region is one of the leading agricultural areas in Ghana with farmers involved in a variety of agricultural activities; food and cash crop production together with livestock raising for both subsistence and commercial purposes (Ministry of Food and Agriculture 2016). Additionally, it is reported that the region is one of the highly degraded areas from human activities like inappropriate agricultural practices (Tesfahunegn 2017; Forest Commission 2012). The Eastern Region is therefore chosen as the study context to reflect the impact of farmers’ KAP on the environment.

## 2 Conceptual and Empirical Review

### Practices of Sustainable Environment Activities

Sustainable environment activity refers to any activity or practice undertaken by a group of people within a defined geographical area towards managing and preserving natural resources for continuous benefits to themselves and generations ahead. Environmental issues although have no boundaries, do require unique actions towards managing them. This is mostly due to the unequal distribution of natural resources across countries and even within the same country. The World Bank (2006) for instance identifies cover cropping as a sustainable environment activity mainly for Ghana transitional zones while crop rotation and application of organic matter are associated with the guinea savannah zones of the same country.

Despite this uniqueness, most farming communities in Ghana are homogenous and can boast of similar resources like forest, farmlands, river bodies, just to mention a few. In effect, activities that sustain natural resources in farming communities of Ghana cut across. Among the most commonly practised SEA are recycling, tree planting, crop rotation, cover cropping, mixed cropping, land fallowing, organic matter application, reduced tillage and buffer stripes (Salas-Zapata et al. 2018; Meije et al. 2015; Wauters and Mathijs 2014; Eyong 2007; World Bank 2006).

Most of these activities are regularly practised in farming communities of Ghana, yet the state of the environment keeps deteriorating at a fast rate. Different writers have attributed this to the neglect of all-inclusive stakeholder involvement in environmental management. Sumiri et al. (2008) for example argue that decision making processes in Malaysia often neglect the opinions of the indigenous people. This is not quite different from what pertains to Ghana. Environmental management, planning and decision-making processes are often done by experts without the active involvement of grassroots practitioners whose activities and livelihoods directly impinge on the environment. In most cases, the highest form of grassroots involvement is through delegation which is not a true representation. Active participation of grassroots is mostly seen at programme implementation stages where they only serve as major sources of labour.

Sustainable environment activities could be enhanced in farming communities when grassroots level practitioners are actively engaged in all aspects of the environmental management processes right from decision making to evaluation stages. By so doing, grassroots knowledge and experiences could be factored into formal management processes. For this reason, Ghai and Vivian (2014) declare that 'local-level-participation' is relevant for avoiding or reversing the degradation of the environment, particularly in instances where international and local policies give recourse to major destructive forces against grassroots environmental actions. Individuals are thus likely to actively participate in actions coming from their own initiatives, hence the need to incorporate local ecological knowledge into environmental management processes.

### Knowledge, Attitudes and Practices of Managing and Sustaining the Environment

Several studies including (Aregay et al. 2017; Ebifa-Othieno et al. 2017; Nabahungu and Visser 2011; Bijani et al. 2017; Borges et al. 2014), particularly KAP surveys have outlined KAP as factors influencing the management and sustainability of environmental



behaviour. These studies reveal contrasting findings on the nature of relationship existing among KAP of managing and sustaining the environment.

Some of these study findings have established significant relationship among KAP of environmental management together with sustainability actions (Aregay et al. 2017; Waiting et al. 2013; Zhou 2011). These findings indicate that the higher the environmental knowledge of a person, the more positive environmental attitudes are exhibited towards practising sustainable environmental activities. Similar studies, however, disprove these findings with contrasting views (Bijani et al. 2017; Ebifa-Othieno et al. 2017; Aini et al. 2006). Findings of these studies on the other hand reveal that being environmentally knowledgeable and having positive environmental attitudes are not always translated into exhibiting sustainable environmental behaviours. In essence, knowledge, attitudes and practices alone cannot determine the performance of environmental actions.

Aini et al. (2006) argued that actions pertaining to environmental sustainability are subjected to both personal values and habits together with other external ones, namely; technology, social policies, laws and community values. Inferable, being environmentally knowledgeable and exhibiting positive environmental attitudes alone cannot fully sustain the environment. A combination of both personal and external factors could rather collectively enhance environmental management and sustainability behaviour.

It is therefore worth noting that these factors (personal and external) are all rooted in formal, non-formal and informal environmental education programmes (Bedural 2018; Aini et al. 2006; Waitling and Zhou 2011; Laurie et al. 2016). Grassroot farmers in Ghana receive non-formal environmental education through agricultural extension services and community outreach programmes by Civil Society Organisations. These farmers also derive ecological knowledge and experiences from their routine community and farming practices. These accumulated experiences end up influencing their personal and external engagement towards managing and sustaining environmental resources informally. It is as a result of this that some scholars identify grassroots knowledge, also referred to as indigenous, local or traditional ecological knowledge as a social capital and an asset of vulnerable communities mostly used for managing and adapting to environmental challenges (Tume et al. 2019; Field et al. 2015; Tisenkopfs and Sumane 2017; Senanayake 2006). Integration of formal and informal ecological knowledge and experiences is a bottom-up approach to addressing environmental issues where indigenous knowledge is upheld. There is therefore a call on regional, national and international organizations to value and incorporate grassroots ecological knowledge into scientific discourse for a common good (Reyes-García and Benyei 2019; Hothongcum et al. 2014).

### 3 Methodology

#### Research Design

A cross-sectional survey was conducted to determine grassroot farmers' levels of KAP on SEA in farming communities of Ghana. The population for the study comprise farmers who are actively engaged in farming and are within the ages of eighteen (18) to sixty (60) years. An estimated population of farmers in the Eastern Region is 724,001 (Ministry of Food and Agriculture 2016).



### Sample and Sampling Techniques

The Eastern Region, one of the dominant farming regions in Ghana was purposively selected for the study. The three most dominant districts identified with the production and commercialization of food crop, cash crop and livestock agricultural activities constituted the study area (Ministry of Food and Agriculture 2016). These comprised Fanteakwa, Kwaebibirem and Afram Plains districts. Due to the uneven nature of the farming communities in the districts, five were randomly selected using the proportionate quota sampling technique. The quota sampling technique was again used to randomly select the required number of respondents for a household survey using a structured questionnaire. The questionnaire was organized into three sections to cater for respondents' levels of KAP of SEA. Their levels of KAP were measured using a 5-point Likert scale that ranged from very low (0–1.4) to very high (4.5–5) for knowledge, strongly disagree (0–1.4) to strongly agree (4.5–5) for attitudes, and never (0–1.4) to always (4.5–5) for practices of SEA. In all, the knowledge levels were composed of eight items while attitudinal and practice levels consisted of thirteen and twelve items, respectively. The researcher conducted a pretest of the instrument to safeguard against errors before collecting the data. Four research assistants were trained to assist in a household survey in fifteen farming communities within the study area<sup>1</sup>. The validity of the questionnaire was established through content and expert validity. Internal consistency of KAP was also tested with Cronbach alpha and the values ranged between .878 and .973.

### Data Analysis

Results of the completed questionnaires were imported into the IBM Statistical Package for the Social Sciences (SPSS) version 24 for data analysis. The data was analysed using descriptive analysis of percentages, means and standard deviation to determine respondents' levels of KAP while correlation and regression were used to establish relations among their levels of KAP. The gender distribution of males was 53% while that of females was 47%. Again, the pattern of distribution on type of farming was 29%, 46% and 25% for a cash crop, food crop and livestock respectively. The findings obtained from the study are analysed and presented in tables.

## 4 Results and Discussion

### Knowledge Levels on Sustainable Environment Activities

Grassroot farmers' knowledge levels on SEA was identified on a 5-point Likert Scale instrument ranging from very low (VL), low (L), neutral (N), high (H) to very high (VH) as presented in Table 1.

<sup>1</sup> Nsogyaso, Asukese No. 2, Forifori, Tease, Maame Krobo, Abodom, Tweapease, Takyiman, Asuom, Kade, Abompe, Saaman, Dwenase, Osino and Begoro.

**Table 1.** Knowledge levels of Grassroot farmers on SEA

Sustainable environment actions	Responses to knowledge levels										Mean	SD
	VL		L		N		H		VH			
	<i>f</i>	%	<i>f</i>	%	<i>f</i>	%	<i>f</i>	%	<i>f</i>	%		
Recycling and re-using waste	38	9.5	37	9.3	15	3.8	121	30.3	189	47.3	3.97	1.318
Tree planting and replacement of cut ones	15	3.8	20	5.0	12	3.0	102	25.5	251	62.8	4.39	1.024
Using manure rather to than fertilizer	33	8.3	18	4.5	18	4.5	84	21.0	247	61.8	4.24	1.238
Using alternative pest control methods rather than chemical ones	52	13.0	41	10.3	35	8.8	99	24.8	173	43.3	3.75	1.429
Gutters and river banks desilting	7	1.8	18	4.5	12	3.0	118	29.5	245	61.3	4.44	.888
Rotating crops at regular intervals	13	3.3	12	3.0	16	4.0	131	32.8	228	57.0	4.37	.941
Land fallowing practices	10	2.5	6	1.5	10	2.5	72	18.0	302	75.5	4.63	.822
Leaving cleared weeds to decompose on lands	12	3.0	9	2.3	9	2.3	57	14.3	313	78.3	4.63	.881
Grand mean	<b>4.3 = High</b>											

Key: VL = very low, L = low, N = neutral, H = high, VH = very high

Table 1 reveals that grassroot farmers are highly knowledgeable on SEA as proven by a grand mean of 4.3 on the five-point Likert Scale. It can also be seen that the farmers highest level of knowledge is on 'land fallowing practices' and 'leaving cleared weeds to decompose on the land (4.63 mean value and .822 and .881 standard deviation values respectively).

### Attitudinal Levels on Sustainable Environment Activities

Respondents' attitudinal levels on SEA was determined on a 5-point Likert scale ranging from strongly disagree to strongly agree as depicted in Table 2. Their scores on the scales used were interpreted as negative attitudes for 'strongly disagree' and 'disagree' while positive and highly positive attitudes represented 'agree and strongly agree' respectively.

Table 2 shows that the grassroots farmers generally exhibited a highly positive attitude towards sustainable environment activities (reflecting 4.5 as grand mean value). Their highest attitudinal level on SEA was displayed on 'Cleared weeds being left on farmlands as compost...' (4.74 mean value and .864 standard deviation value). Their lowest attitudinal level on SEA on the other hand was displayed at 'Enforcing traditional pest control methods rather than chemical pesticides is necessary' (4.18 and 1.064 as

**Table 2.** Grassroot farmers' attitudinal levels on SEA

Attitudes towards sustainable environment activities	Percentages of responses to attitudinal levels										Mean	SD
	SD		D		N		A		SA			
	f	%	f	%	f	%	f	%	f	%		
Encouraging recycling and waste re-use	12	3.0	7	1.8	13	3.3	100	25.0	268	67.0	4.51	.884
Tree planting around surrounding should be compulsory for everyone	7	1.8	12	3.0	12	3.0	91	22.8	278	69.5	4.55	.836
Manure usage as a major form of fertilizer should be encouraged	20	5.0	10	2.5	21	5.3	111	27.8	238	59.5	4.34	1.041
Enforcing traditional pest control methods rather than chemical pesticides is necessary	19	4.8	20	5.0	23	5.8	148	37.0	190	47.5	4.18	1.064
Setting aside two days in a month must for community sanitation activities is necessary	2	.5	3	.8	17	4.3	109	27.3	269	67.3	4.60	.657
Planting different crops together at the same time is a good practice	15	3.8	30	7.5	30	7.5	118	29.5	207	51.8	4.18	1.096
Leaving parts of the farmlands unplanted is a good practice to enable the land regain its strength	10	2.5	9	2.3	10	2.5	67	16.8	304	76.0	4.62	.851
Cleared weeds left on farmlands as compost is a good a practice that needs to be encouraged	8	2.0	4	1.0	8	2.0	58	14.5	322	80.5	4.74	.864
Environmental education and sustainability programmes must be provided on radios and television	2	.5	2	.5	24	6.0	71	17.8	301	75.3	4.67	.658
Every individual must receive sustainable environmental education	3	.8	6	1.5	10	2.5	80	20.0	301	75.3	4.68	.671
Encouraging others to plant trees around their surroundings is a good practice	3	.8	5	1.3	10	2.5	88	22.0	294	73.5	4.66	.663

(continued)

**Table 2.** (continued)

Attitudes towards sustainable environment activities	Percentages of responses to attitudinal levels										Mean	SD
	SD		D		N		A		SA			
	f	%	f	%	f	%	f	%	f	%		
Culprits of environmental laws must be punished severely	5	1.3	4	1.0	10	2.5	79	19.8	302	75.5	4.67	.694
Protecting environmental resources should be a responsibility of every person	16	4.0	2	.5	5	1.3	54	13.5	323	80.8	4.67	.872
Grand mean	<b>4.5 = strongly agree</b>											

Key: SD = strongly disagree, D = disagree, N = neutral, A = agree, SA = strongly agree

mean and standard deviation values respectively). This is a general reflection of the negative attitudes of most Ghanaian farmers on alternative pest control methods at the expense of chemical pesticides. These could stem from the fact that many people lack knowledge of alternative/traditional pest control measure practices. Awareness-raising on this could therefore enhance grassroots farmers’ attitudinal levels of SEA.

**Practice Levels on Sustainable Environment Activities**

Finally, the practice levels of grassroots farmers on SEA is also measured on a 5-point Likert scale ranging from never to always as indicated in Table 3.

**Table 3.** Levels of farmer’s practices on sustainable environment activities

Practices of SEA	Percentages of responses to practice levels										Mean	SD
	N		L		A		H		Al			
	f	%	f	%	f	%	F	%	f	%		
I use compost as a major source of fertilizer	86	21.5	24	6.0	37	9.3	58	14.5	195	48.8	3.63	1.620
I re-use waste (like polythene) for other important activities	79	19.8	32	8.0	45	11.3	95	23.8	149	37.3	3.51	1.532
I plant trees around my environs and any other surroundings	65	16.3	27	6.8	42	10.5	99	24.8	167	41.8	3.69	1.471
I persuade other people to plant trees around their environs	64	16.0	34	8.5	52	13.0	110	27.5	140	35.0	3.57	1.442

(continued)

**Table 3.** (continued)

Practices of SEA	Percentages of responses to practice levels										Mean	SD
	N		L		A		H		Al			
	<i>f</i>	%	<i>f</i>	%	<i>f</i>	%	<i>F</i>	%	<i>f</i>	%		
I use traditional pest control methods other than chemical pesticides	102	25.5	36	9.0	71	17.8	78	19.5	113	28.3	3.16	1.554
I involve myself in communal activities for preserving resources in my community	15	3.8	13	3.3	21	5.3	93	23.3	258	64.5	4.42	.998
I rotate crops and also divide my farmlands into smaller sizes for this practice	31	7.8	14	3.5	38	9.5	101	25.3	216	54.0	4.14	1.207
I practice land fallowing to enable my farmland to regain its fertility	21	5.3	11	2.8	26	6.5	78	19.5	264	66.0	4.38	1.079
I leave cleared weeds on my farmland as a major form of compost	19	4.8	16	4.0	24	6.0	66	16.5	275	68.8	4.41	1.083
I belong to a community environmental protection group and I take part in their activities	155	38.8	39	9.8	21	5.3	45	11.3	140	35.0	2.94	1.779
I go for environmental protection meetings	98	24.6	46	11.5	41	10.3	90	22.5	125	31.3	3.24	1.591
I attend environmental education training programmes	103	25.6	51	12.8	44	11.0	88	22.0	114	28.5	3.15	1.586
Grand mean	<b>3.7 = High</b>											

Key: *N* = never, *L* = low, *A* = average, *H* = high, *Al* = always

These results show that the general level of practising SEA by grassroots farmers is high as confirmed by a grand mean value of 3.7. Their highest level of practising SEA is ‘involving themselves in communal activities for preserving resources in their community (with 4.42 and .998 as mean and standard deviation values). Their lowest level of practising SEA was also exhibited on ‘belonging to a community environmental group and taking part in their activities’ (mean = 2.94 and SD = 1.779).

**Relationship among the Knowledge, Attitudes and Practices of SEA**

To determine the relationships among grassroots farmers’ KAP of SEA, a multiple regression was used to predict the value of the variables. Levels of practices of SEA was used as a dependent variable with knowledge and attitudes levels as independent variables. The result is presented in Table 4 as follows:

**Table 4.** Multiple regression analysis between practice of SEA as dependent variable and knowledge on SEA and attitudes towards SEA as independent variables.

Variable	Unstandardized coefficients		Standardized coefficients	T	Sig.	F	Df	Δ R <sup>2</sup>	Collinearity statistics	
	B	Std. error	β						Collinearity	Tolerance VIF
Practice	-.305	.401		-.762	.447	94.038	3	.416	–	–
Knowledge	.066	.007	.464	9.070	.000				.564	1.774
Attitudes	.404	.088	.234	4.576	.000				.562	1.780

The results indicate that the regression model (Practices, knowledge and attitudes towards SEA) significantly explained (R<sup>2</sup> = 41.6%) practical effect of the variance in the practice of SEA variable at F (P) = .000. The farmers’ knowledge towards practice is higher than their attitudes towards practice. It is also evident that farmers’ knowledge on SEA (β = .464; p ≤ .000) and farmers Attitudes on SEA (β = .234, p ≤ .00) contributes significantly and positively to the variance in the farmers’ practices of SEA. This therefore means that the more knowledgeable a farmer is, the more positive attitudes that farmers also exhibit towards practicing SEA at higher levels.

**4.1 Correlation Analysis**

To further determine the direction of the relationship among KAP, the Pearson Correlation was used to identify the association between these variables and the results are seen in Table 5 as follows:

**Table 5.** Correlation between grassroots farmers’ practice of SEA, knowledge on SEA and attitude towards SEA

		Practice	Knowledge	Attitude
Practice	<i>r</i>	1	.620**	.542**
	<i>Sig.</i>		.000	.000
Knowledge	<i>r</i>	.620**	1	.661**
	<i>sig.</i>	.000		.000
Attitude	<i>r</i>	.542**	.661**	1
	<i>sig</i>	.000	.000	

\*\* Correlation is significant at the 0.05 level (2-tailed)

Table 5 shows a positive statistically linear relationship between practice and knowledge level of farmers on SEA ( $r = .620, p < .05$ ), meaning the higher the knowledge level of farmers on SEA, the more regular their practices of SEA. The results further display a positively modest significant relationship between attitudes of farmers and practices of SEA ( $r = .542, p < 0.05$ ). This means that grassroots farmers with higher levels of environmental attitudes also practice SEA at higher levels and vice versa. The table also indicates a positive statistically significant relationship between farmers’ levels of knowledge and their attitudes towards SEA ( $r = .661, p < .05$ ). Thus, farmers who are highly knowledgeable on SEA also exhibit highly positive attitudes towards SEA. In effect, the knowledge and attitudinal levels of grassroots farmers positively and significantly influence their levels of practising SEA.

## 5 Discussion

### Farmers’ Knowledge Levels on Sustainable Environment Activities

The study reveals that grass-root farmers are highly knowledgeable on SEA. This finding confirms Waitling and Zhou (2011) assertion that concepts and principles are learnt from experiences, education and investigation. In essence, their high knowledge levels on SEA may have emerged from their experiences accumulated from constant practices together with awareness and training programmes acquired from agricultural extension officers. Integration of indigenous ecological knowledge/experiences into formalized scientific ecological knowledge, according to Hothongcum et al. (2014) and Olsson and Folke (2001) is a means of addressing recent complexities and environmental management.

### Farmers’ Attitudinal Levels on Sustainable Environment Activities

The farmers’ exhibition of highly positive attitudes towards SEA supports the fact that the execution of behaviour is positively or negatively evaluated by individuals’ attitudes (Fishbein 2000; Fishbein and Yzer 2003 and Borges et al. 2014). Grassroot farmers’ exhibition of highly positive attitudes in their constant practices, therefore, shows

their concern for environmental management and sustainability. Nevertheless, increasing environmental education on traditional pest control methods could be an added advantage to sustaining environmental resources.

### **Farmers' Practice Levels on Sustainable Environment Activities**

The revelation on the farmers' highest level of practising communal labour reflects what pertains to most rural communities of Ghana. Communal activities popularly referred to as communal labour is a common practice in many farming communities often done to preserve natural resources. Again, their lowest practices in environmental groups activity also confirm the absence of environmental groups in many rural communities of Ghana. Farmers in the 21<sup>st</sup> century thus encounter different environmental challenges and as such engage in multiple sustainable activities for their livelihoods. In essence creating, environmental groups in rural communities could enhance SEA.

### **Relationship Among the Knowledge, Attitudes and Practices of SEA**

The findings that knowledge and attitudinal levels of grassroots farmers positively and significantly influences their levels of practising SEA are consistent with similar studies by notable authors (Zheng et al. 2018; Ahmad et al. 2015; Aregay et al. 2017; Gusti 2016; Waiting et al. 2013; Watling and Zhou 2011). Gusti (2016) study, for example, establish a significant relationship between knowledge and attitudes towards sustainable waste management and highlight that environmental management is best understood through KAP studies.

Despite the revelation of significant relationship among knowledge, attitudes and practices of SEA from the correlation metrics, it is important to emphasize that the high levels of farmers' knowledge (grand mean = 4.3) together with their high levels of attitudes (grand mean = 4.5) did not produce an equivalent high level of practising SEA (grand mean = 3.7). This confirms the idea that a collective integration of environmental knowledge and attitudes with other external factors could promote higher levels of sustainable environmental practices as highlighted by Aini et al. (2006). They found out that Malaysians higher knowledge on sustainability practices were not fully translated into their sustainability practices.

## **6 Conclusion**

The study reveals that grassroots farmers are highly knowledgeable and also exhibit highly positive attitudes towards practising sustainable environmental activities at higher levels in selected farming communities in the Eastern Region of Ghana. It is also evident that grassroots ecological knowledge, attitudes and practices collectively interrelate positively and significantly to produce sustainable environment activities but does not underestimate other external factors. Thus grassroots farmers' degree of practising SEA is dependent on their levels of KAP together with other external factors like policy integration of local and scientific ecological management processes. In conclusion, regular education including enhancement of environmental knowledge through integrated scientific and indigenous ecological knowledge and experiences is a strategic effort for increasing sustainable environmental activities in farming communities towards achieving the SDGs in Ghana.



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# Experimental Investigations of the Flexible Rotor System by Introducing Parametric Excitations into Both Ends of the Rotating Shaft Axially

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**Abstract. Purpose:** It has been shown that it is possible to modify the vibration amplitude by the introduction into one end of the shaft of a rotating flexible rotor system, an axially parametric excitation. This concept drives this study and seeks to introduce excitations into both ends of the shaft theoretically. The purpose of this work is to presents an experimental investigation into the behaviour of a flexible rotor system subjected to an active vibration controller.

**Design/Methodology/Approach:** The equations motion was first solved using the perturbation method of multiple scales. Under principal parametric resonance, the theoretical results revealed an extra decline in the amplitude of the rotor response. Secondly, an experimental test was performed where a test machine with two piezoelectric exciters is mounted on both ends of the shaft. The steady-state feedback was investigated in the presence and absence of a double parametric excitation term.

**Findings:** Findings from the work show a significant decrease in amplitude of rotor response by 23.4% under principal parametric resonance, as well as a convincing agreement between theory and experiment.

**Research Limitation/Implications:** The study performs an analytical investigation of the behaviour of two piezoelectric exciters mounted on both ends of the shaft in a flexible rotor system. The results were verified experimentally. This work does not constrain itself to the numerical verification of the analytical solution, but rather performs experiments.

**Practical Implication:** This study confirms the fact that the amplitude of vibration be can be altered in the presence of an axially parametric excitation that has been introduced into one end of the shaft of a rotating flexible rotor system and establishes the behaviour in the case where excitations are introduced into both ends of the shaft. The literature will be enriched thus far with an active controller of vibration for a flexible rotor system.

**Social Implication:** The knowledge advanced by this research will inform stakeholders in the mechanical engineering fraternity particularly, the manufacturers of a flexible rotor in enhancing their designs for efficiency, sustainability and value for money.

**Originality/Value:** This research gives an understanding of vibration control behaviour in a flexible rotor system. This work is unique as it presents readers with an innovative way of introducing excitations into both ends of the shaft as an active controller of vibration for flexible rotor systems.

**Keywords:** Actuator · Exciter · Flexible rotor system · Parametric excitation · Piezoelectric

## 1 Introduction

### 1.1 Rotor Dynamics Problem

Mass unbalanced forces are one of the main causes of vibration in flexible rotor systems. Forces due to the depositions the machines are subjected to and wear are also important sources of vibration. Achieving perfect balance is virtually impossible. Vibration reduction in the rotor system is critical for safe and efficient operation. It is therefore critical to collaborate with research and product development in the rotary machine industry so as to refashion shaft rotor systems and their frequencies, in the quest to reduce vibration.

### 1.2 Piezoelectric Actuator Solution

Piezoelectric actuators have been used for the stabilization of parametric resonance produced in a cantilever beam and also as an efficient bifurcation control device, which act to shift bifurcation set as well as expand the stable region (Palazzolo et al. 1993; Barrett et al. 1995; Yabuno et al. 2001). Sui and Shi (2012) used an active piezoelectric actuator engine mount to support a vehicle engine while reducing vibrations and force transmitted from the engine to the vehicle structure as well as road surface irregularities. Berardengo et al. (2015) also used shunted piezoelectric actuators with electric impedances consisting of a series of resistance and inductance to passively control vibration in light structures. To actively control vibration in journal bearings, Tuma et al. (2017) used a double assembled linear piezoactuators to actuate the bearing journal position to first damp the vibrations and secondly maintain the preferred position to micrometer-order accuracy. William et al. (2019) studied the possibility of attenuating the vibrations emanating from within a link of a system using active vibration controller with piezoelectric patches as actuators.

### 1.3 Double Piezoelectric Exciter Concept

In Atepor (2008, 2009), the author-controlled vibrations emanating from within a rotor system by designing a piezoelectric exciter together with parametric excitations and incorporated into a flexible rotor-bearing system axially. The idea was to regulate the

response of the rotor’s already existing mass-unbalance vibration. The author also introduced axial excitations into the shaft with the help of a piezoelectric stack actuator to enable him study the interactions between forced vibrations that are caused by rotor unbalance and parametric excitations that are caused by periodic stiffness variations which arise from the actuator’s axial excitations. A workable strategy was recommended. The recommendation was to manipulate intrinsic and prevalent instabilities associated with the flexible rotor-bearing system a manner that will efficiently control the overall performance of the rotor system. To justify this work, a schedule of research was performed. Findings showed a 21.9% decrease in the resonant amplitudes for a forward whirl in the flexible rotor-bearing system. To further lower the inherent vibrations and instabilities associated with the rotor, a theoretical application of double piezoelectric exciters and an intentional insertion of parametric excitations into the flexible rotor-bearing at both ends of the shaft has been explored by a referenced study seen in Atepor (2013). An introduction of double excitation force terms into the governing equations of motion was done theoretically. The famous perturbation method of multiple scales was employed to solve the equations of motion. The steady-state responses were examined for the cases where the double parametric excitation terms were present and absent respectively. Findings suggest a further decline in the rotor response amplitude.

## 2 Theoretical Works

### 2.1 Equations of Motion

Equations (1) to (4) are the equations of motion adapted from Atepor (2008, 2011), and Fig. 1 is the reference frame for a disk on a rotating flexible shaft. A 3-D view of the rotor.

$$\ddot{q}_1 + \hat{c}\dot{q}_1 - \Omega\hat{a}_5\dot{q}_2 + \omega^2q_1 + \hat{b}q_1^3 = \mu d\Omega^2 \sin \Omega t \tag{1}$$

$$\ddot{q}_2 + \hat{c}\dot{q}_2 + \Omega\hat{a}_5\dot{q}_1 + \omega^2q_2 + \hat{b}q_2^3 = \mu d\Omega^2 \cos \Omega t \tag{2}$$

$$\ddot{q}_1 + \hat{c}\dot{q}_1 - \Omega\hat{a}_5\dot{q}_2 + \omega^2q_1 + \hat{b}q_1^3 - \hat{F}_{act}q_1 = \mu d\Omega^2 \sin \Omega t \tag{3}$$

$$\ddot{q}_2 + \hat{c}\dot{q}_2 + \Omega\hat{a}_5\dot{q}_1 + \omega^2q_2 + \hat{b}q_2^3 - \hat{F}_{act}q_2 = \mu d\Omega^2 \cos \Omega t \tag{4}$$

$$\ddot{q}_1 + \hat{c}\dot{q}_1 - \Omega\hat{a}_5\dot{q}_2 + \omega^2q_1 + \hat{b}q_1^3 - 2\hat{F}_{act}q_1 = \mu d\Omega^2 \sin \Omega t \tag{5}$$

$$\ddot{q}_2 + \hat{c}\dot{q}_2 + \Omega\hat{a}_5\dot{q}_1 + \omega^2q_2 + \hat{b}q_2^3 - 2\hat{F}_{act}q_2 = \mu d\Omega^2 \cos \Omega t \tag{6}$$

Equations (1)–(2) and (3)–(4) are illustrates two equations of motion. The former are without parametric excitation force terms and the latter has single parametric excitation force terms present. Equations (5) and (6) are equations with double parametric excitation force terms.

Where,  $\hat{a}_5 = \frac{a_5}{m}$ ,  $\omega^2 = \frac{k}{m}$ ,  $\hat{b} = \frac{b}{m}$ ,  $\hat{c} = \frac{c}{m}$ ,  $\mu = \frac{m_u}{m}$ ,  $\hat{F}_0 = \frac{F_{act}}{m}$ ,  $k$ -linear stiffness coefficient,  $c$ -damping coefficient,  $q_1, q_2$ -displacements,  $\omega$ -natural frequency,  $b$ -nonlinear cubic stiffness coefficient,  $\Omega$ -excitation frequency,  $m_u$ -mass unbalance,  $a_i$ -characteristic equation coefficient,  $F_{act}$ -external applied force,  $F_{act}q_i$  denotes the axial excitation force term (Atepor 2008) and the dots denote differentiation with respect to  $t$ . Parameters used in this work were computed with data sourced from the experimental rig.  $k$  is the radial stiffness of the rotor-bearing which characterises the combined circumferentially-symmetric stiffness of the rotor bearings and shaft.

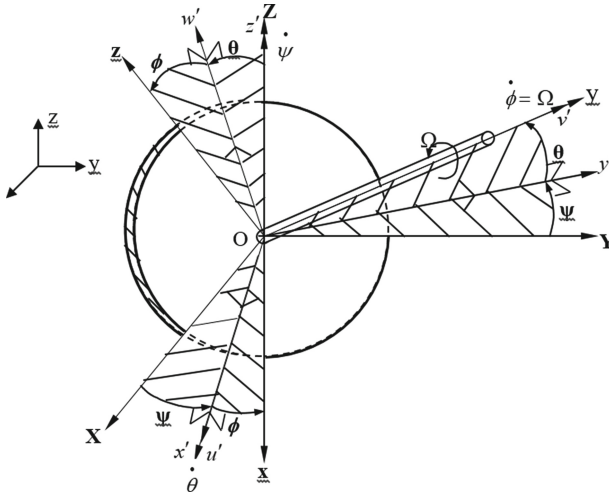


Fig. 1. A 3-D reference frame for a disk on a rotating flexible shaft.

### 2.2 Solutions to the Equations of Motion

As stated earlier, the method of multiple scales is employed to establish an approximate solution for flexible rotor system models with and without parametric excitation terms and given as

$$\begin{aligned} \bar{q}_1 = & 2p \cos\left(\frac{\Omega t}{2\omega}\right) - 2q \sin\left(\frac{\Omega t}{2\omega}\right) + \frac{\hat{b}}{4\omega^2} p^3 \cos\left(\frac{3\Omega t}{2\omega}\right) \\ & - \frac{3\hat{b}}{4\omega^2} p^2 q \sin\left(\frac{3\Omega t}{2\omega}\right) - \frac{3\hat{b}}{4\omega^2} p q^2 \cos\left(\frac{3\Omega t}{2\omega}\right) + \frac{\hat{b}}{4\omega^2} q^3 \sin\left(\frac{3\Omega t}{2\omega}\right) \end{aligned} \tag{7}$$

$$\begin{aligned} \bar{q}_2 = & 2r \cos\left(\frac{\Omega t}{2\omega}\right) - 2s \sin\left(\frac{\Omega t}{2\omega}\right) + \frac{\hat{b}}{4\omega^2} r^3 \cos\left(\frac{3\Omega t}{2\omega}\right) \\ & - \frac{3\hat{b}}{4\omega^2} r^2 s \sin\left(\frac{3\Omega t}{2\omega}\right) - \frac{3\hat{b}}{4\omega^2} r s^2 \cos\left(\frac{3\Omega t}{2\omega}\right) + \frac{\hat{b}}{4\omega^2} s^3 \sin\left(\frac{3\Omega t}{2\omega}\right) \end{aligned} \tag{8}$$

$$\begin{aligned}
\bar{q}_1 = & 2p \cos\left(\frac{\Omega t}{2\omega}\right) - 2q \sin\left(\frac{\Omega t}{2\omega}\right) + \frac{\hat{b}}{4\omega^2} p^3 \cos\left(\frac{3\Omega t}{2\omega}\right) - \frac{3\hat{b}}{4\omega^2} p^2 q \sin\left(\frac{3\Omega t}{2\omega}\right) - \frac{3\hat{b}}{4\omega^2} p q^2 \cos\left(\frac{3\Omega t}{2\omega}\right) \\
& + \frac{\hat{b}}{4\omega^2} q^3 \sin\left(\frac{3\Omega t}{2\omega}\right) - \frac{2\hat{F}_{act} p}{2\Omega_2^2 \omega^2 + 4\Omega_2 \omega} \cos\left(\frac{5\Omega_2 t}{4\omega}\right) + \frac{2\hat{F}_{act} q}{2\Omega_2^2 + 4\Omega_2 \omega} \sin\left(\frac{5\Omega_2 t}{4\omega}\right) \\
& - \frac{2\hat{F}_{act} \Omega_2 \hat{c} k p}{2\Omega_2^2 \omega^2 + 4\Omega_2 \omega^3} \sin\left(\frac{5\Omega_2 t}{4\omega}\right) - \frac{2\hat{F}_{act} \Omega_2 \hat{c} k q}{2\Omega_2^2 \omega^2 + 4\Omega_2 \omega^3} \cos\left(\frac{5\Omega_2 t}{4\omega}\right) + \frac{2\hat{F}_{act} \hat{c} k p}{2\Omega_2^2 \omega + 4\Omega_2 \omega^2} \sin\left(\frac{5\Omega_2 t}{4\omega}\right) \\
& + \frac{2\hat{F}_{act} \Omega_2 \hat{a} s k r}{2\Omega_2^2 \omega^2 + 4\Omega_2 \omega^3} \sin\left(\frac{5\Omega_2 t}{4\omega}\right) - \frac{2\hat{F}_{act} \hat{c} k q}{2\Omega_2^2 \omega + 4\Omega_2 \omega^2} \cos\left(\frac{5\Omega_2 t}{4\omega}\right) + \frac{2\hat{F}_{act} \Omega_2 \hat{a} s k s}{2\Omega_2^2 \omega^2 + 4\Omega_2 \omega^3} \cos\left(\frac{5\Omega_2 t}{4\omega}\right) \\
& + \frac{2\hat{F}_{act} \Omega_2 \hat{a} s k r}{2\Omega_2^2 \omega + 4\Omega_2 \omega^2} \sin\left(\frac{5\Omega_2 t}{4\omega}\right) + \frac{2\hat{F}_{act} \Omega_2 \hat{a} s k s}{2\Omega_2^2 \omega + 4\Omega_2 \omega^2} \cos\left(\frac{5\Omega_2 t}{4\omega}\right) - \frac{2\hat{F}_{act} Q p}{4\Omega_2^2 \omega^2 + 8\Omega_2 \omega^3} \cos\left(\frac{9\Omega_2 t}{4\omega}\right) \\
& + \frac{2\hat{F}_{act} Q q}{4\Omega_2^2 \omega^2 + 8\Omega_2 \omega^3} \sin\left(\frac{9\Omega_2 t}{4\omega}\right)
\end{aligned} \tag{9}$$

$$\begin{aligned}
\bar{q}_2 = & 2r \cos\left(\frac{\Omega t}{2\omega}\right) - 2s \sin\left(\frac{\Omega t}{2\omega}\right) + \frac{\hat{b}}{4\omega^2} r^3 \cos\left(\frac{3\Omega t}{2\omega}\right) - \frac{3\hat{b}}{4\omega^2} r^2 s \sin\left(\frac{3\Omega t}{2\omega}\right) - \frac{3\hat{b}}{4\omega^2} r s^2 \cos\left(\frac{3\Omega t}{2\omega}\right) \\
& + \frac{\hat{b}}{4\omega^2} s^3 \sin\left(\frac{3\Omega t}{2\omega}\right) - \frac{2\hat{F}_{act} r}{2\Omega_2^2 + 4\Omega_2 \omega} \cos\left(\frac{5\Omega_2 t}{4\omega}\right) + \frac{2\hat{F}_{act} s}{2\Omega_2^2 + 4\Omega_2 \omega} \sin\left(\frac{5\Omega_2 t}{4\omega}\right) \\
& - \frac{2\hat{F}_{act} \Omega_2 \hat{c} k r}{2\Omega_2^2 \omega^2 + 4\Omega_2 \omega^3} \sin\left(\frac{5\Omega_2 t}{4\omega}\right) - \frac{2\hat{F}_{act} \Omega_2 \hat{c} k s}{2\Omega_2^2 \omega^2 + 4\Omega_2 \omega^3} \cos\left(\frac{5\Omega_2 t}{4\omega}\right) - \frac{2\hat{F}_{act} \hat{c} k r}{2\Omega_2^2 \omega + 4\Omega_2 \omega^2} \sin\left(\frac{5\Omega_2 t}{4\omega}\right) \\
& - \frac{2\hat{F}_{act} \hat{c} k s}{2\Omega_2^2 \omega + 4\Omega_2 \omega^2} \cos\left(\frac{5\Omega_2 t}{4\omega}\right) - \frac{2\hat{F}_{act} \Omega_2 \hat{a} s k p}{2\Omega_2^2 \omega^2 + 4\Omega_2 \omega^3} \sin\left(\frac{5\Omega_2 t}{4\omega}\right) - \frac{2\hat{F}_{act} \Omega_2 \hat{a} s k q}{2\Omega_2^2 \omega^2 + 4\Omega_2 \omega^3} \cos\left(\frac{5\Omega_2 t}{4\omega}\right) \\
& - \frac{2\hat{F}_{act} \Omega_2 \hat{a} s k p}{2\Omega_2^2 \omega + 4\Omega_2 \omega^2} \sin\left(\frac{5\Omega_2 t}{4\omega}\right) - \frac{2\hat{F}_{act} \Omega_2 \hat{a} s k q}{2\Omega_2^2 \omega + 4\Omega_2 \omega^2} \cos\left(\frac{5\Omega_2 t}{4\omega}\right) - \frac{2\hat{F}_{act} Q r}{4\Omega_2^2 \omega^2 + 8\Omega_2 \omega^3} \cos\left(\frac{9\Omega_2 t}{4\omega}\right) \\
& + \frac{2\hat{F}_{act} Q s}{4\Omega_2^2 \omega^2 + 8\Omega_2 \omega^3} \sin\left(\frac{9\Omega_2 t}{4\omega}\right)
\end{aligned} \tag{10}$$

$$\begin{aligned}
\bar{q}_1 = & 2p \cos\left(\frac{\Omega t}{2\omega}\right) - 2q \sin\left(\frac{\Omega t}{2\omega}\right) + \frac{\hat{b}}{4\omega^2} p^3 \cos\left(\frac{3\Omega t}{2\omega}\right) - \frac{3\hat{b}}{4\omega^2} p^2 q \sin\left(\frac{3\Omega t}{2\omega}\right) - \frac{3\hat{b}}{4\omega^2} p q^2 \cos\left(\frac{3\Omega t}{2\omega}\right) \\
& + \frac{\hat{b}}{4\omega^2} q^3 \sin\left(\frac{3\Omega t}{2\omega}\right) - \frac{4\hat{F}_{act} p}{4\Omega_2^2 + 8\Omega_2 \omega} \cos\left(\frac{5\Omega_2 t}{4\omega}\right) + \frac{4\hat{F}_{act} q}{4\Omega_2^2 + 8\Omega_2 \omega} \sin\left(\frac{5\Omega_2 t}{4\omega}\right) - \frac{4\hat{F}_{act} \Omega_2 \hat{c} j p}{4\Omega_2^2 \omega^2 + 8\Omega_2 \omega^3} \sin\left(\frac{5\Omega_2 t}{4\omega}\right) \\
& - \frac{4\hat{F}_{act} \Omega_2 \hat{c} j q}{4\Omega_2^2 \omega^2 + 8\Omega_2 \omega^3} \cos\left(\frac{5\Omega_2 t}{4\omega}\right) + \frac{4\hat{F}_{act} \hat{c} j p}{4\Omega_2^2 \omega + 8\Omega_2 \omega^2} \sin\left(\frac{5\Omega_2 t}{4\omega}\right) - \frac{4\hat{F}_{act} \hat{c} j q}{4\Omega_2^2 \omega + 8\Omega_2 \omega^2} \cos\left(\frac{5\Omega_2 t}{4\omega}\right) \\
& + \frac{4\hat{F}_{act} \Omega_2 \hat{a} s j r}{4\Omega_2^2 \omega^2 + 8\Omega_2 \omega^3} \sin\left(\frac{5\Omega_2 t}{4\omega}\right) + \frac{4\hat{F}_{act} \Omega_2 \hat{a} s j s}{4\Omega_2^2 \omega^2 + 8\Omega_2 \omega^3} \cos\left(\frac{5\Omega_2 t}{4\omega}\right) + \frac{4\hat{F}_{act} \Omega_2 \hat{a} s j p}{4\Omega_2^2 \omega + 8\Omega_2 \omega^2} \sin\left(\frac{5\Omega_2 t}{4\omega}\right) \\
& + \frac{4\hat{F}_{act} \Omega_2 \hat{a} s j s}{4\Omega_2^2 \omega + 8\Omega_2 \omega^2} \cos\left(\frac{5\Omega_2 t}{4\omega}\right) - \frac{4\hat{F}_{act} L p}{8\Omega_2^2 \omega^2 + 16\Omega_2 \omega^3} \cos\left(\frac{9\Omega_2 t}{4\omega}\right) + \frac{4\hat{F}_{act} L q}{8\Omega_2^2 \omega^2 + 16\Omega_2 \omega^3} \sin\left(\frac{9\Omega_2 t}{4\omega}\right)
\end{aligned} \tag{11}$$

$$\begin{aligned}
\bar{q}_2 = & 2r \cos\left(\frac{\Omega t}{2\omega}\right) - 2s \sin\left(\frac{\Omega t}{2\omega}\right) + \frac{\hat{b}}{4\omega^2} r^3 \cos\left(\frac{3\Omega t}{2\omega}\right) - \frac{3\hat{b}}{4\omega^2} r^2 s \sin\left(\frac{3\Omega t}{2\omega}\right) - \frac{3\hat{b}}{4\omega^2} r s^2 \cos\left(\frac{3\Omega t}{2\omega}\right) \\
& + \frac{\hat{b}}{4\omega^2} s^3 \sin\left(\frac{3\Omega t}{2\omega}\right) - \frac{4\hat{F}_{act} r}{4\Omega_2^2 + 8\Omega_2 \omega} \cos\left(\frac{5\Omega_2 t}{4\omega}\right) + \frac{4\hat{F}_{act} s}{4\Omega_2^2 + 8\Omega_2 \omega} \sin\left(\frac{5\Omega_2 t}{4\omega}\right) - \frac{4\hat{F}_{act} \Omega_2 \hat{c} j r}{4\Omega_2^2 \omega^2 + 8\Omega_2 \omega^3} \sin\left(\frac{5\Omega_2 t}{4\omega}\right) \\
& - \frac{4\hat{F}_{act} \Omega_2 \hat{c} j s}{4\Omega_2^2 \omega^2 + 8\Omega_2 \omega^3} \cos\left(\frac{5\Omega_2 t}{4\omega}\right) - \frac{4\hat{F}_{act} \hat{c} j r}{4\Omega_2^2 \omega + 8\Omega_2 \omega^2} \sin\left(\frac{5\Omega_2 t}{4\omega}\right) - \frac{4\hat{F}_{act} \hat{c} j s}{4\Omega_2^2 \omega + 8\Omega_2 \omega^2} \cos\left(\frac{5\Omega_2 t}{4\omega}\right) \\
& - \frac{4\hat{F}_{act} \Omega_2 \hat{a} s j p}{4\Omega_2^2 \omega^2 + 8\Omega_2 \omega^3} \sin\left(\frac{5\Omega_2 t}{4\omega}\right) - \frac{4\hat{F}_{act} \Omega_2 \hat{a} s j q}{4\Omega_2^2 \omega^2 + 8\Omega_2 \omega^3} \cos\left(\frac{5\Omega_2 t}{4\omega}\right) - \frac{4\hat{F}_{act} \Omega_2 \hat{a} s j p}{4\Omega_2^2 \omega + 8\Omega_2 \omega^2} \sin\left(\frac{5\Omega_2 t}{4\omega}\right) \\
& - \frac{4\hat{F}_{act} \Omega_2 \hat{a} s j q}{4\Omega_2^2 \omega + 8\Omega_2 \omega^2} \cos\left(\frac{5\Omega_2 t}{4\omega}\right) - \frac{4\hat{F}_{act} L r}{8\Omega_2^2 \omega^2 + 16\Omega_2 \omega^3} \cos\left(\frac{9\Omega_2 t}{4\omega}\right) + \frac{4\hat{F}_{act} L s}{8\Omega_2^2 \omega^2 + 16\Omega_2 \omega^3} \sin\left(\frac{9\Omega_2 t}{4\omega}\right)
\end{aligned} \tag{12}$$

where,  $k = \left( \frac{1}{-\frac{\Omega_2^2}{\omega^2} - \frac{2\Omega_2}{\omega}} \right)$ ,  $Q = \left( \frac{1}{-\frac{4\Omega_2^2}{\omega^2} - \frac{4\Omega_2}{\omega}} \right)$ ,  $j = \left( \frac{1}{-\frac{\Omega_2^2}{\omega^2} - \frac{4\Omega_2}{\omega}} \right)$  and  $L = \left( \frac{1}{-\frac{8\Omega_2^2}{\omega^2} - \frac{8\Omega_2}{\omega}} \right)$ .

Full time-domain solutions of Eqs. (1) and (2) which do not have parametric excitation terms are presented in Eqs. (7) and (8), while Eqs. (9) and (10) presents solutions to equations with single parametric excitation terms. Solutions to equations of motion with double parametric excitation terms are presented in Eqs. (11) and (12). Amplitudes are denoted with the variable letters  $p$ ,  $q$ ,  $r$  and  $s$ ,  $\Omega$  is the excitation frequency such that  $\Omega_2 = 2\Omega$  where  $\Omega_2$  denotes the principal parametric resonance frequency.

### 3 Experimental Work

The experiment employs a rotor-kit (built in the Cape Coast Technical University workshop) and piezoelectric exciters developed specifically for the purposes of this study. The kit comes with an electrical drive that served as power for the rotor, a rotor supported by journal bearings and a separate control box from which to select the preferred rotational speed. A solid coupling transmits the torque to the rotor from the electrical motor. Displacement transducers are provided to measure the rotor's movements. A piezoelectric exciter is attached to the rotor kit to serve as an active controller of vibration. A critical component of the exciter unit is a piezoelectric actuator which is supported by a helical compression spring and all are contained in a linear sliding bearing and an aluminum casing. A function generator drives the piezoelectric actuator via a piezoelectric actuator amplifier. To prevent direct contact between the piezoexciter and the shaft and permit free rotation and movement of the shaft end, a small self-aligned ball bearing is fixed between the piezoexciter and the shaft. The rotor's vibration response is then measured with a Polytec Laser Vibrometer, which allows the displacements to be recognized and inspected by a multi-channel data acquisition analyzer. Figures 2, 3 and 4 show the experimental set-up used to activate the flexible rotor system. The foremost principle here is to axially control the rotor vibrations, by using the piezoelectric actuators mounted at the two ends of the shaft.

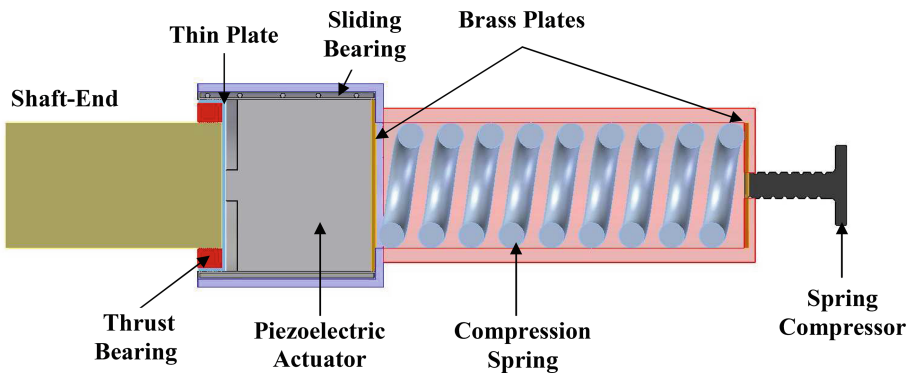


Fig. 2. Schematic of the Piezoelectric Exciter (Atepor 2008)

As stated earlier, the goal has been to design and build a test rig to demonstrate the practicability of active controller of vibration in rotor dynamics using double piezoelectric actuators. Special emphasis is placed on the likelihood of decreasing the amplitude of vibrations of a flexible dynamically unbalanced rotor within acceptable levels. This is accomplished by creating a Piezoexciter that is activated by a high frequency drive. The active Piezoexciter is made up of a sliding bearing that contains a piezoelectric stack actuator and is serially attached to a compression spring. The reaction spring is set up against the actuator, owing to the fact that, the actuator operates only in expansion, with small displacements. The spring compressor adjusts the spring to the requisite length,





**Fig. 3.** The Piezoexciter Test Rig with the two exciters at both ends of the shaft.



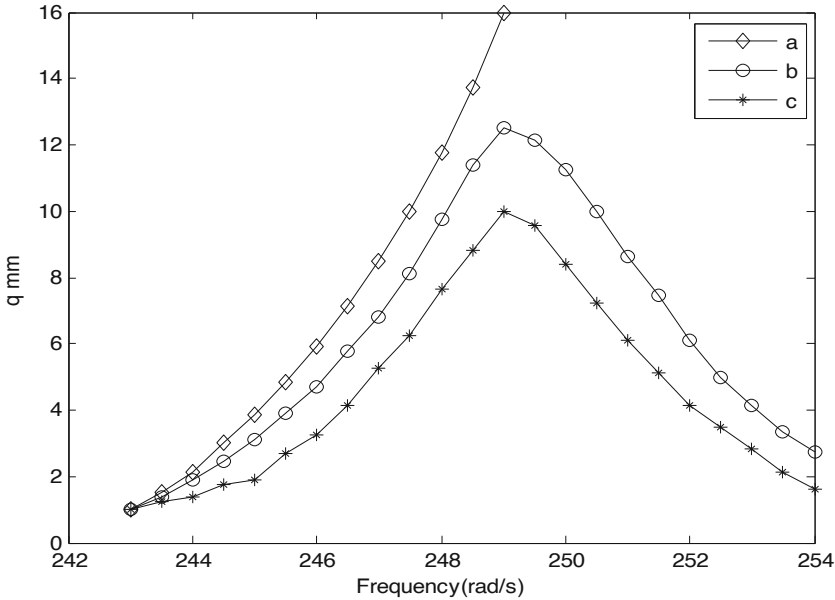
**Fig. 4.** Close up of the exciter assembly

and voltage is applied to the actuator via a piezoelectric voltage amplifier, which generates parametric excitation at twice the rotor system's first whirl frequency. The exciter is operated by a function generator with the help of a high voltage amplifier. The parametric excitation force to be axially introduced to the shaft, are generated by initiating the piezoelectric actuator at twice the excitation frequency of the rotor system.

A laser vibrometer is then used to measure the vibration response of the rotor-bearing system. The response is then analyzed using a multi-channel data acquisition analyzer. The rotor-bearing system and the exciter unit's compression spring are fixed to the first whirl resonance frequency and the requisite length respectively, then the rotor's response is measured. The piezoelectric actuator is then activated, first at a frequency twice the rotor system's first whirl frequency. A series of timed tests were administered, and mean readings were recorded. Sweep tests are then performed around the first whirl frequency, initially without activating the piezoexciter and later, with the exciter activated at the parametric excitation frequency.

## 4 Results and Discussion

### 4.1 Theoretical Results



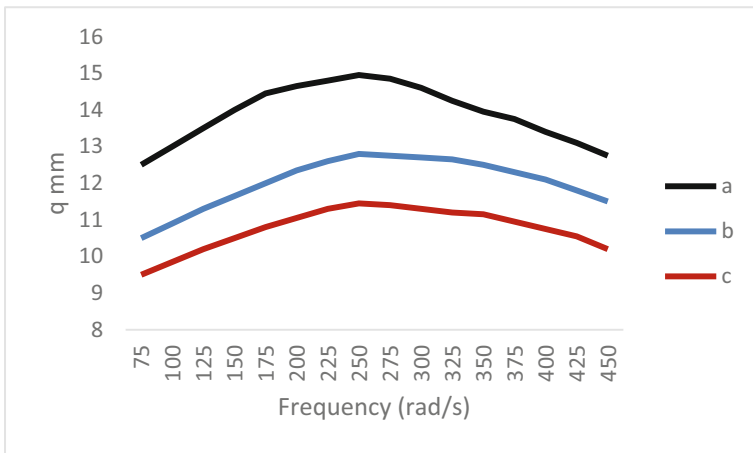
**Fig. 5.** Amplitudes ( $q$ ) of the response as functions of the frequency (rad/s): a-without parametric force term, b-with single parametric force term, c-with double parametric force term.

The theoretical results as presented in Fig. 5. were obtained first obtaining solutions to the governing equations of motion using the perturbation method of multiple scales and the plot generated by using Mathematica™ software. Concerning Fig. 5, and considering plot legend **a**, responses in the first mode of  $q$  show hardening characteristics, jump phenomena and both stable and unstable solutions when the equations of motion contain no parametric force terms. When no parametric force term is present in the equations of motion, responses in the first mode of  $q$  show hardening characteristics, jump phenomena, and both stable and unstable solutions (see Fig. 5a). A 23% decrease in the amplitude is observed when single parametric force terms are included in the equations of motion as can be seen in Fig. 5(b). Elimination of the jump phenomena and stable solutions are also observed. Referencing Fig. 5(c), upon the introduction of double parametric force terms, the same observation was made as seen in Fig. 5(b). However, the amplitude, in this case, was reduced by 60.2%. The further decrease implies stability of the system at a parametric frequency which was actioned by the theoretical introduction of parametric forces at both ends of the shaft.

### 4.2 Experimental Results

To ultimately evaluate the performance of the test rig shown in Fig. 3, the loading condition of the spring of the exciter is set at a length of 25.2 mm (Atepor 2008) where the author in considering the performance of a similar test rig investigated three different loading conditions and arrived at the conclusion that the 25.2 mm compressed length of the spring gives better maximum and minimum spring forces.

The effect of single and double piezoelectric exciter activation was thoroughly investigated. Figure 6(a) displays a 14.95 mm peak amplitude at a 250 rad/s resonance frequency in the absence of the piezoexciter, i.e. the shaft experiences no parametric excitation its speed is varied between 75 rad/s and 450 rad/s inclusive. In Fig. 6(b), activating only one piezoexciter at a parametric frequency of  $\Omega_2 = 500$  rad/s, where  $\Omega_2 = 2\Omega$ , the disk vibration amplitude reduces to 12.8 mm. For the third case, when both piezoexciters are activated at both ends of the shaft at parametric frequencies of 500 rad/s, the disk vibration amplitude reduces to 11.45 mm and this is depicted in Fig. 6(c). In Fig. 6, the collective influence of the existing force vibration and the supplementary parametric excitation in principal parametric resonance occasioned the regulation of the responses of the already existing vibration of the mass unbalance as well as decrement in the critical whirl amplitude. As a recap, the existing force vibration is caused by the mass unbalance and the extra parametric excitation is sanctioned by the piezoexciter. When the parametric excitation is applied to a single end of the shaft, 14.4% decrease in the amplitude is observed, as shown in Fig. 6(b). In the case where both ends of the shaft are exposed to parametric excitations, a further reduction of 23.4% is experienced in the amplitude as shown in Fig. 6(c).



**Fig. 6.** Disc vibration amplitudes (q) as functions of frequency (rad/s) with a spring compression length of 25.2 mm: Experimental results, a-parametric force term absent, b-single parametric force present, c-double parametric force term present.

## 5 Conclusion

The comparison between the theoretical and experimental analyses summarized in this work provides proof of a consistent occurrence, but with a lower percentage reduction for the experimental benchmark than the theoretical consideration, which is primarily due to the assumptions made when the nonlinear equations of motion are analytically solved. The methods used to investigate and identify rotor systems response behavior have all revealed comparable trends in terms of the consequences of introducing double parametric forces. The innovative piezoelectric exciter concepts could be effectively attached to both ends of the shaft of industrial machines, predominantly those installations where axial loading on the rotor is also an inherent part of the control actuation for a very high reduction in vibration amplitude, according to prototypical experimental results from rotor systems.

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# Technical Challenges Associated with Sustainable Land Use Through Vertical Construction

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**Abstract. Purpose:** This study assessed technical challenges associated with sustainable land use through the delivery of vertical constructions as a solution to the urban housing deficit.

**Design/Methodology/Approach:** Quantitative analysis was used which was based on primary data. A total of 120 randomly sampled firms of architects, civil engineers and quantity surveyors who had been involved in high rise construction were targeted. The data obtained from the study were analysed and presented in tables. Descriptive and inferential statistics were used. These include mean, frequency distribution and Mann-Whitney U- test.

**Findings:** Findings revealed that the top ranked technical challenges associated with sustainable land use through vertical construction were availability of skilled labour, time constraints, skill challenge with existing construction technologies, knowledge of existing (skyscraper) technologies and environmental effects.

**Research Limitation/Implications:** The study focused on technical challenges associated with the construction of vertical buildings to land use sustainability.

**Practical Implication:** The knowledge advanced in this study could be used as a means to review construction methodologies/processes to curtail the issues of collapse and abandonment of high-rise constructions.

**Social Implication:** Stakeholders in property development would find the result of this research useful both in optimizing gain and inefficient use of land asset. It would also aid in the adequate preparation of such a construction project, as the likely challenges have been identified.

**Originality/Value:** The novelty of this study also lies in the revealed statistically significant differences which do not exist between the opinions of the respondents in contracting and consultancy organizations except in five variables.

**Keywords:** Challenges · High rise · Technology · Vertical construction

## 1 Introduction

The construction of vertical structures has been justified on sustainability and economy of land use mostly in cities. The concept has also been embraced beyond the economy of land use to include both the fascinating features and attractiveness of arch-structural design (Ede 2014; Chaurasiya and Jamle 2018). In principle, living and working in building scores of storey high makes a great deal of esteem (Aluko 2018). Stakeholders in the construction industry have looked for ideas to solve the pressing issue of land scarcity and environmental sustainability. Some solutions provided in the past have not achieved a success rate of 100%. With the idea of vertical cities, a more feasible solution seems to be on sight. According to Wong (2004), the construction of taller buildings was seen as means of maximizing land use. Vertical construction has been explained by the theory of ‘green skyscraper’ shaped by the writing of Ken Yeang, who proposes the interconnecting measures regarding sustainability features such as; use of energy, water and light.

High rise buildings have also been described as skyscraper. According to Afrin (2009), green skyscraper refers to both the practice and product of creating tall buildings in response to healthy environment and economy of cities. Such construction possesses environmental responsiveness in term of aesthetics, resource efficiency, utility, durability, and comfort throughout the life-cycle of a building. Definitions of green skyscraper vary but the general consensus of the idea involves three main goals (Rachael 2005). These are; providing healthy and sustainable environment, prevention of negative impacts of the environments, and economic implications of buildings in term of reducing operating cost and increasing profitability. There also exist limitless design ideas when it comes to vertical constructions. According to Sev (2009), the morphological characteristics and the top is the most important component consideration in terms of its impression.

The need for vertical construction in Lagos has been more demanding than any city in Africa. Lagos State is the smallest in Nigeria in term of land mass. It has about 92% of its population residing within the metropolis area of the state. The population exceeds 10 million people, with approximately 20,000 persons resides per square kilometre of land. It is the most densely populated State in Nigeria (Ameh and Osegbo 2011). The State alone accounts for about 5 million deficits representing 31% of the estimated national housing deficit of 18 million in Nigeria (Oshodi 2010). In line with these statistics, it could be said that Lagos State might run out of land both for construction and other competing economic uses by government and private individuals if the sustainable approach to land use for construction is not urgently embraced.

While sustainably and economic considerations of vertical construction are justified (Ishaya and Dabo 2010), both the economic and technological challenges of the concept have not been adequately evaluated in the Nigerian construction industry. Research attentions on vertical construction in the Nigerian context have focused mainly on rental values (Ishaya and Dabo 2010), disaster preparedness (Mshelgaru and Olowoyeye 2010), and elsewhere on land use sustainability (Al-Kodmany 2018). The situation at hand in Nigeria is that most of the vertical constructions are suspended, distressed or abandoned. Significant numbers of collapsed buildings are also substantially vertical constructions. While other issues of vertical construction such as supply and acquisition of lands have been viewed within the sociological context of maintaining the community’s cultural

base (Aribigbola 2008), critical technical challenges associated with the construction have not been empirically evaluated.

## 2 Literature Review

Vertical construction is used to describe high rise buildings which is synonymously to tall building and skyscraper (Kim and Lee 2016; Chaurasiya and Jamle 2018). Afrin (2009) defines a high-rise building as one up to 10 and could be more than 50 stories. Most engineers, inspectors, architects and similar professionals in the construction industry define high-rise buildings the same way in terms of height. Some individuals in society could see vertical construction as a wonder idea while some other might find it unreasonable and uncalled for. Vertical construction might even be difficult to afford particularly in developing countries due to technological challenges and weak economy (Afolabi et al. 2019). Notwithstanding, most developed countries are taking their economic advantage and advancement in construction technology to explore the benefits of the concept (Guang-wang and Hua-li 2011).

According to Kim and Lee (2016), the key element technologies of skyscrapers are construction of mega mat foundation meant to deliver the architectural load to the ground, structural system optimization, high-rise building measurement technology, and construction equipment technology, amongst others. For a smooth construction process, it is necessary to have experts who can manage technologies from materials to maintenance and apply them to the work. Mukhtar et al. (2016) concluded that the major issues surrounding the delivery of projects generally in Nigeria include lack of effective finance system, unstable macroeconomic environment, difficulty in accessing land with secured tenure, high cost of building materials, shortages of skilled labour and poor infrastructural facilities. Availability of technology in the developed countries contexts, according to Al-Kodmany (2018), in the 21st-century city has resulted in increasing vertical buildings. Notwithstanding, the construction industry in developing countries generally lack the capacity for indigenous technology (Opawole et al. 2019) and have been very slow in the adoption of new technology (Chan et al. 2018; George 2018). Hence, the developing countries, on the contrary, may be limited in this sustainability approach to land use due to technology and economic challenges. However, the assertion of technical challenges has not received sufficient empirical assessment. This study, therefore, assesses the technical challenges associated with the delivery of vertical construction as a solution to the urban housing deficit to maximize urban land use. The study is expected to provide implications for understanding the technical challenges associated with the construction of vertical buildings while enlightening on the issue of land scarcity.

## 3 Methodology

Both primary and secondary data were used for this study. The sampling frame comprises the construction professionals in the property development organizations including government establishments as well as consulting and contracting outfits in Lagos State, Nigeria. Quantitative descriptive analysis was used which was based on primary data. A total of 120 randomly sampled firms/establishments of architects, civil engineers and

quantity surveyors who had been involved in high rise construction in the study area were surveyed. Data for the analysis were obtained through a structured questionnaire targeted at the organizations’ representatives. The survey questionnaire was designed as a structured multiple-choice type and divided into two parts. The first part helped to gather the profile of the respondents. Information’s obtained include the respondents’ academic and professional qualifications, and their years of experience in the construction industry, among others. The second part relates to questions that seek to further understand the purpose of the study. Likert scale involving rating on a scale of 1–5 was used. On this scale, 5 represents the highest rating while 1 represents the lowest rating available. Seventy-two valid (72) copies were retrieved and used for the analysis. This represented 60% response rate. Tools for data analysis were descriptive and inferential statistics; mean and frequency distribution and Mann- Whitney U-test.

## 4 Findings

### 4.1 Respondents’ Profiles

Table 1 shows the general information of the respondents. About 43.1% of them were from contracting firms, 43.1% were from consultancy firms, while 13.8% had also worked in government organizations. Architects were represented at 16.7%, quantity surveyors were 52.8% (which is the majority) and engineers were 22.2%, while 8.3% of the sample were other professionals. About 16.7% of the respondents held National Diploma, 55.6% held a First degree and 27.8% of had a Masters degree. The results of analysis of the professional affiliations of respondents showed that 15.3% were members of the Nigerian Institute of Architects (NIA), 50.0% were members of the Nigerian Institute of Quantity Surveyors (NIQS), 23.6% were affiliated to Nigerian Society of Engineers (NSE) while 11.1% were affiliated to some other professional bodies. About 25% of the respondents had between 1–5 years of working experience, 33.3% of them have between 6–10 years, 27.8% have between 11–15 years while 2.8% of them have between 16–20 years and 11.1% have above 20 years of experience in the construction industry.

**Table 1.** Profile of respondents

Variables	F	%	
Nature of organization	Contracting firm	31	43.1
	Consultancy firm	31	43.1
	Government	10	13.8
	Others	0	0.0
Professional field of respondent	Architect	12	16.7
	Quantity surveyor	38	52.8

(continued)



**Table 1.** (continued)

Variables		F	%
	Engineers	16	22.2
	Others	6	8.3
Highest academic qualification of respondent	OND/HND	12	16.7
	B.Sc./B. Tech	40	55.6
	M.Sc./M. Tech	20	27.8
Professional affiliation of respondent	NIA	11	15.3
	NIQS	36	50.0
	NSE	17	23.6
	Others	8	11.1

F = frequency

Moreover, 16.7% of the respondents have been involved in 0–5 numbers of projects, 55.6% between 6–10 projects, 20.8% between 11–15 projects and 6.9% between 16–20 projects. About 66.7% have been part of between 0–5 vertical buildings, 18.1% have done between 6–10 vertical buildings, 9.7% have done between 11–15 vertical buildings, 2.8% have done between 16–20 vertical buildings and 2.8% have been involved in above 20 numbers of vertical projects.

## 5 Discussion

### Assessment of Technical Challenges Associated with Vertical Construction

In order to examine the technical challenges associated with vertical construction in the study area, a total of twenty-four (24) factors were modified from various general literature on construction management. The results in Table 2 showed that the mean item score of the factors ranged as  $3.40 \leq \bar{x} \leq 4.76$ , with the adequacy of the skilled labour force ( $\bar{x} = 4.76$ ) ranked first. Other top ranked variables were time constraints ( $\bar{x} = 4.29$ ), skill challenge with existing technologies ( $\bar{x} = 4.11$ ), knowledge of skyscraper technologies ( $\bar{x} = 4.04$ ), competency of subcontractors ( $\bar{x} = 3.96$ ) and environmental effect ( $\bar{x} = 3.93$ ) which ranked in second, third, fourth and fifth position, respectively. On the other hand, neighborhood interference ( $\bar{x} = 3.40$ ), unrealistic expectations ( $\bar{x} = 3.43$ ), unrealistic designs ( $\bar{x} = 3.46$ ), lack of local expertise ( $\bar{x} = 3.61$ ), and slow adoption of innovations ( $\bar{x} = 3.61$ ), stand as the challenges that were reported.

The significance of the high ranking of ‘adequacy of skilled labour’ is attributable to the widespread brain-drain from developing countries to developed countries because of poor remuneration of skilled labour in the developing countries (Thatchenkery and Koizumi 2010). The construction industries in the developing countries have also not been able to develop adequate human capacity index because projects of complex nature from where fresh graduates could learn technical skills are often contracted to foreign

contractors (Afolabi et al. 2019), who often come with their labour force. This factor also explains the inability of the sub-contracting organizations to develop competency that is demanding of vertical construction and agrees with Mukhtar et al. (2016) on the significance of shortages of skilled labour in developing countries. The significance of ‘skill challenge with existing technologies is explained by poor investment in research and development and slow adoption of innovation in most developing countries which were in agreement with (Chan et al. 2018). The results of Whitney U-test showed that except for five (adequacy of safety facilities (p-value = 0.017), errors leading to rework (p-value = 0.000), unrealistic designs (p-value = 0.003), problems with existing technologies (p-value = 0.018), and availability of easy-to-use digital collaboration and mobility tools (p-value = 0.045) among the variables, statistical significant differences do not exist between the opinions of the respondents in contracting and consultancy organizations.

**Table 2.** Technical challenges associated with vertical construction

S/N	Variables	Contracting		Consultancy		Man-Whitney U-test		Total mean	Overall SD	R
		$\bar{x}$	SD	$\bar{x}$	SD	Z-value	P-value			
1	Adequacy of safety facilities	4.0968	1.01176	3.4516	1.09053	-2.389	0.017	3.6944	1.17052	14
2	Errors leading to rework	4.0645	0.57361	3.1935	1.01388	-3.574	0	3.7083	0.89502	13
3	Unrealistic design	4.0323	0.91228	3.1613	1.15749	-2.983	0.003	3.4583	1.18604	22
4	Insufficient detailing of drawings	3.9677	1.016	3.7419	1.29016	-0.497	0.619	3.6528	1.29092	16
5	Availability of skilled labour	4.1613	0.96943	3.8065	1.16674	-1.211	0.226	3.8194	1.16675	9
6	Communication efficiency between professionals	3.8387	1.09839	3.8387	0.86011	-0.367	0.714	3.9167	0.94571	7
7	Steady supply of materials	3.6129	0.88232	3.6129	0.80322	-0.062	0.95	3.6667	0.78722	15
8	Competent subcontractors	4	0.63246	3.8387	0.93441	-0.522	0.602	3.9583	0.75875	5
9	Inaccurate labor and material scheduling	3.8065	0.83344	3.5484	0.96051	-0.535	0.593	3.6111	1.01476	18
10	National Building code restriction	3.6452	0.91464	4.0323	0.65746	-1.89	0.059	3.75	0.86806	12
11	Neighbourhood interference	3.4839	0.85131	3.5161	0.96163	-0.18	0.857	3.4028	0.97374	24
12	Unrealistic expectations	3.4516	1.26065	3.3548	1.17042	-0.272	0.785	3.4306	1.23136	23
13	Adequacy of labour force	3.8065	1.04624	6.0323	6.29012	-0.278	0.781	4.7639	4.30687	1
14	Mobility of labourers and materials within structure	3.5806	1.02548	3.7097	0.93785	-0.552	0.581	3.6111	1.01476	19
15	Time constraints	3.7419	0.96498	7.1935	12.79171	-0.932	0.351	4.2917	8.5059	2
16	Lack of local expertise	3.6452	1.60309	3.5161	1.12163	-0.967	0.333	3.5833	1.37123	21
17	Slow adoption of new technological innovations	3.3871	1.05443	3.6452	0.95038	-1.362	0.173	3.6111	1.00078	20
18	Buildings environmental effect	4	0.85635	3.8387	0.89803	-0.529	0.597	3.9306	0.87736	6
19	Availability of suitable technologies	3.8387	1.12833	3.6774	0.94471	-0.916	0.36	3.8194	0.98333	10

(continued)

**Table 2.** (continued)

S/N	Variables	Contracting		Consultancy		Man-Whitney U-test		Total mean	Overall SD	R
		$\bar{x}$	SD	$\bar{x}$	SD	Z-value	P-value			
20	Skill challenge with existing technologies	4.3226	0.70176	3.8065	0.90992	-2.362	0.018	4.1111	0.81458	3
21	Knowledge of use of existing (skyscraper) technologies on site	3.9032	0.87005	4.129	0.67042	-0.948	0.343	4.0417	0.77709	4
22	Availability of easy-to-use digital collaboration and mobility tools	3.9032	0.83086	3.4194	0.99244	-2.004	0.045	3.6528	0.98094	17
23	Labour productivity downfall	3.9677	0.91228	3.7097	0.97275	-1.019	0.308	3.8056	0.95886	11
24	Availability of new age technological devices like self-heating concrete, drones, etc.	3.871	0.92166	3.8065	1.10813	-0.029	0.977	3.8611	0.99726	8

SD = Standard deviation; Z-Value = Standardized Value; P-Value = Mann-Whitney Value,  $\bar{x}$  = mean score, R = rank

## 6 Conclusion

This study concludes that vertical constructions would be affected by multiple variables of technical challenges. The top ranked challenges, however, were identified as availability of skilled labour force, time constraints, problems with existing technologies, lack of knowledge of existing technologies, reliability of subcontractors, and environmental effect. This research increases the understanding of the various variables which pose challenges to the successful delivery of vertical construction and for which stakeholders must make adequate preparations. Findings could be used as a means to further add to the awareness level on vertical construction and in reviewing construction methodologies and processes to curtail the issues of collapse and abandonment of high-rise constructions. Stakeholders in property development would find the results of this research useful both in optimizing gain and efficient use of land assets through the use of vertical construction. The findings from this research would also aid in the adequate preparation of such a construction project, as the challenges identified could form the basis of improvement for consulting as well as contracting and sub-contracting outfits. Further assessment could extend the study to include the economic challenges of high-rise construction in developing countries and expand the sample size.

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# Determining Food Safety Knowledge, Attitudes and Practices of Chopbar Workers

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**Abstract. Purpose:** Chopbars provide urban and rural communities with easy access to affordable food. However, whether the food produced by these vendors is safe and healthy for human consumption is a big question. Therefore, this study aimed to examine the level of knowledge, attitudes and practices of chopbar workers, and explore the relationship between their knowledge and practices on food safety in the KEEA Municipality.

**Methodology:** Purposive cluster sampling was utilized to select 147 chopbar workers in the Municipality and responded to a researcher-designed questionnaire. Frequency distribution and Goodman-Kruskal's Gamma test were used to analyze the data.

**Findings:** This study revealed that the chopbar workers in the KEEA Municipality have low levels of knowledge on food safety. Most of the chopbar workers had no formal education and this impacted negatively on their level of knowledge. Although the workers had poor knowledge, the majority of them had a positive attitude towards food safety practices, as many of them demonstrated moderate level of food safety practice.

**Research Limitations/Implications:** The study used a closed-ended questionnaire therefore, it constrained the respondents from expressing divergent views, also data collected with structured questionnaires have the problem of bias normally associated with all the studies based on the use of questionnaires and this could not be completely ruled out and likely to affect the extent to which the findings of this study could be generalized.

**Practical Implications:** The knowledge advanced in this study will enable owners and regulatory bodies to improve their monitoring/supervision activities to prevent and reduce negative implications of poor food handling practices at these eating establishments.

**Social Implications:** The study provided data essential for the formulation of guidelines and regulations that will help to improve the safety of food served at chopbars.

**Originality/Value:** The originality of this study lies in the use of the Theory of Planned Behaviour as its theoretical framework and the introduction of leadership as an additional construct to ensure owners, managers/supervisors ensure effective monitoring and supervision.

**Keywords:** Chopbar workers · Food handlers · Food safety · Knowledge · Practice

## 1 Introduction

The adequate supply and access to safe and nourishing food is crucial to the sustenance of life and promoting good health. This is because unsafe food contributes to a myriad of debilitating health conditions such as diarrhoea and cancers as well as denial of basic human right (WHO 2015a). The evolving world and change in the behaviour of consumers have resulted in a greater number of people eating meals prepared outside of their homes. Thus, pushing food producers and handlers to take a greater obligation to guarantee and maintain the safety level of food served for health as well as wellbeing (WHO 2019).

In developing countries, there are fewer processed and packaged foods resulting in the consumption of locally produced food. Therefore, foods eaten outside the home are prepared by street food vendors (FAO/UN 2016). To satisfy the growing demands of consumers, many food production and service outlets such as chopbars, restaurants and canteens emerged serving different varieties of food to the public (Staazt and Hollizgner 2016). Chopbars are traditional catering establishments available in both urban and rural areas in or near markets, transport terminals and roadsides, or small artisanal shops (Alfers and Abban 2011).

The existence of chopbars play a major role in ensuring people in both urban and rural communities have access to an affordable supply of food, to meet their nutritional needs and also sustain life, which is central to the health and wellness of humans. This is also linked to the Sustainable Development Goals (11 i.e. the making of cities safe, resilient and sustainable) by 2030 which is also central to the safety of food (WHO 2015b). The gains derived from the street food occupation encompasses the economies of the local communities since fresh food commodities used by the food vendors are purchased locally, thereby connecting the street food enterprise with the local farms and markets (Rheinlände et al. 2012). According to a study conducted in Accra and Kumasi, the street food enterprise is predicted to offer employment opportunities to about 28%–38% of the population especially women (Nicolò 2012; Otoo et al. 2011), but wholesomeness of the food is questionable.

Studies show that the causes of foodborne illnesses are numerous and cut across geographical boundaries, but the major causes are microbial, chemical and physical hazards (Todd 2014; WHO 2015c). However, food handling practices such as insufficient cooking time, improper holding temperatures of food, contaminated food preparation, serving utensils and improper personal hygiene practices, among others, may plausibly be major avenues to foodborne illness (Food and Drugs Administration 2017). Meanwhile, one of the deadliest factors identified to contribute to foodborne illnesses which are increasingly becoming a public health concern is microbial contamination resulting from improper handling of food by food service employees (Todd et al. 2011; Todd 2014; Hernández-Cortez et al. 2017). These illnesses may have minor or serious effects leading to death in some people. The transmission of foodborne diseases can occur either from person to person or the food serving as a medium for bacterial growth to cause the illness (National Restaurants Association 2010). This confirms the assertion of Kibret and Abera (2012) that improper food handling practices may be more of a problem in the home, institutions and food service establishments in which lack of training, and use of improper techniques, or inexperience may lead to outbreaks of foodborne illness.

In terms of disease prevalence, evidence has revealed that 90% of cholera cases reported globally occur in Africa with 16% of deaths occurring in children younger than five years, which is directly linked to diarrhoeal diseases (WHO 2015; Mokomane et al. 2018). For instance, in South Africa, foodborne illness is of major health concern due to the high HIV/AIDS prevalence in that country. This is because patients who are immunocompromised, a simple foodborne illness, may be potentially fatal to their health (Campbell 2011). In Ghana, diarrhoea diseases have been recognized as one of the major causes of hospital attendance (Akuffo et al. 2017). For example, Larbi et al. (2021) reported a high incidence of diarrhoea cases in low-income communities in Accra. In the Komenda Edina Eguafo Abirem (KEEA) Municipality of the Central Region, statistics available indicate that diarrhoea and typhoid are the most reported diseases at the outpatient departments, with 6,463 and 11,016 recorded cases in the year 2013 respectively (Municipal Health Directorate 2014). This situation is likely to be attributable to lack of adherence to safety standards by chopbar workers and the supervision from regulatory agencies.

This is not to conclude that foods sold at chopbars are the sources of the increase in diseases. In this regard, the food and drugs law in Ghana prohibits the sale of food under insanitary conditions. The regulation specifies people are liable to commit a crime if they prepare, package, transport, supply or exhibit food for sale under unsanitary conditions (FDA 2013). In addition, the law prohibits the manufacture and sale of any food without the supervision of persons with appropriate knowledge and qualification to ensure purity and wholesomeness (FDA). However, the increase in consumer needs and the resultant increase of street food are increasingly posing challenges to the health of consumers and local authorities given the weak control systems in this sector (FAO/UN 2016).

Evidence shows that preparation of food in large quantities increases the likelihood of contamination since many people handle the food and inappropriate handling may be high (Akabanda et al. 2017). Cunha et al. (2014) also argue that, the behaviour of food handlers has an immense effect on food contamination as this can decrease the nutritional and sensory quality of food served. This is because food safety knowledge and handling practices associated with one's upbringing persist through time thereby making it difficult for food handlers to adapt to new changes to maintain the safety of food. The peculiar nature of chopbars also makes it difficult for the regulatory authorities to check their activities as the business springs up and folds up without notification.

This study was hinged on the Theory of Planned Behaviour (TPB) propounded by Ajzen (1980) as an improvement on the TRA. The TPB is selected for this study because of its ability to measure the factors that influence behaviour. The model indicates that the main indicator of an individuals' action is the intent to engage in the behaviour (Fishbein and Ajzen 1975). It is based on three main constructs; subjective norms, attitudes, perceived behavioural control and leadership as an additional construct (Ajzen 1991). Attitude denotes an individual's favourable or unfavourable evaluation of behaviour such as food safety. For, instance an employee's attitude towards safe food practices can be a result of the belief of the effects of food on the health and well-being of the consumer (Akabanda et al. 2017). The model suggests that a person can develop a belief founded on what others expect him/her to do or based on the observation of the action of the relevant people. Hence, employees may acquire favourable attitudes towards safe food

practices, but if managers, supervisors and even customers pressure them not to do so because of time constraints, lack of equipment and shortage of staff, those employees are likely to prepare food with less care.

Perceived behavioural control reflects the workers' beliefs of the availability of resources and opportunities to exhibit safe food practices (Ajzen 1991). For example, in adhering to safe food standards, employees need to be equipped with adequate resources such as knowledge, time, tools/equipment and education/training to increase self-confidence before they can be committed to ensuring safe food practices (Kibret and Abera 2012).

Even though the TPB highlights the need for a positive attitude, acquisition of knowledge/skills by food handlers, provision of tools/equipment, adequate infrastructure and exemplary leadership from managers/supervisors as key in promoting food safety, these factors alone are not enough, without monitoring and supervision. It is important to equally ensure effective monitoring and supervision of the food handlers by owners and regulators as "workers are known to do what is supervised". However, the theory was silent on the need for effective monitoring/supervision which is the gap this study seeks to fill.

Although some data exist on the knowledge, attitude and practices of street food vendors on food safety, still little is known about the level of knowledge of chopbar workers and the effect of their attitude and self-reported practices on the safety of food served to the consuming public. Given that there is an increasing presence of chopbars in rural and urban settings, information relating to the level of knowledge, attitudes, and practices of these food handlers in Ghana is vital for the public. To reduce the risk of foodborne diseases, it is essential we attempt to understand to identify these major food safety deficiencies so as to design strategies and develop policies that can contribute to the safety of food served in these food service outlets. The aim of this study, therefore, are to investigate the knowledge, attitude and practices of chopbar workers in the KEEA Municipality on food safety and the connection between the workers' knowledge on food safety in addition to their practices.

## 2 Materials and Methods

The KEEA Municipality had a total of 92 registered chopbars divided into six zones, each chopbar having an average of four workers (GTA 2019). Using a descriptive survey design, the cluster sampling procedure was employed to select 147 chopbar workers to a proportionate calculation of 65% from each zone. Purposive sampling was then used to select workers who are directly in contact with the food preparation and serving process.

Permission was obtained from the Municipal Environmental Health and Sanitation Unit and the various chopbar owners. The aim of the study was explained to the respondents, assuring them of their anonymity and confidentiality of the data after which verbal informed consent was sought from them. The instrument was administered through personal face-to-face interviews with the respondents on a one-on-one basis.



### 3 Instrument

In order to gather information from the workers, a semi-structured questionnaire was used. The development of the questionnaire was guided by the variables of the study and previous study of Siow and Sani (2014). The variables were categorized into two; research variables (knowledge, attitude and practice) and demographic variables (age, sex, level of education and experience). The questionnaire comprised 40 items segmented into sections A, B, C, and D. Section 'A' measured the background characteristics of the participants. Section 'B' assessed food safety knowledge of the workers with 10 items in a 'Yes' or 'No' and 'I don't know' format. The items in the questionnaire were based on general knowledge on food safety including time and temperature control, cross contamination and personal hygiene. Section 'C' examined the attitude of the workers towards food safety, with eight questions on a four-point Likert scale, ranging from 'strongly agree' to 'strongly disagree'. Section 'D' appraised the frequency of appropriate food safety practices that must be carried out by the chopbar workers. It had 16 items, 12 on a 3-point Likert scale rating ranging from 'always' to 'never', and four items on a multiple choice. To ensure validity and reliability of the instrument, the questionnaire was peer-reviewed and pre-tested using 30 chopbar workers in Cape Coast Metropolis. This is because workers in Cape Coast have similar characteristics with those from KEEA Municipality.

### 4 Data Analysis

Descriptive statistics of frequency distributions and Goodman-Kruskal's Gamma test were used to analyze the data. We classify knowledge, attitude and practice questions using the frequency and percentage counts categorizing the responses into low, moderate and high knowledge. For every correct answer, a score of '1' was given and a score of '0' for every incorrect or unanswered question. Thus, the scores range between 0 and 10 which we converted to 100 points. Meaning that, a score of 0–4 was rated low, 5–7 as moderate and 8–10 as high. Therefore, a score below  $\leq 40\%$  is low whereas 41–59% moderate while  $\geq 60\%$  is high knowledge. The scores for attitude for each worker were determined by totaling the weights obtained by each worker for the eight items used to measure the construct. The scores for food safety attitudes ranged from a minimum of eight to a maximum of 32. A correct answer to 3 or less statements signaled, "negative or poor" attitude towards food safety practices, whereas 5 or more indicated "positive or good" attitude. Proportions of the right responses were calculated and the food safety practices carried out by chopbar workers was determined using a three-point ordinal scale. A score below  $\leq 50\%$  indicates "poor" <50 to >70 "moderate" and  $\geq 70\%$  represents "good" food hygiene practice. To establish the relationship between knowledge and practices on food safety of chopbar workers, Goodman-Kruskal's Gamma test was employed. The Goodman-Kruskal's Gamma test was utilized because the various categories of knowledge levels of food safety and food safety practices were both ordinal in nature.

## 5 Results

The results are presented by knowledge level of the chopbar workers, their attitudes, level of food safety practices in addition to the level of relationship in relation to knowledge and practices. Participants for the study were 147 workers, 86% (n = 126) females and 14% (n = 21) males, with mean age 36.4 (SD = 13.5) years. The youngest of the workers was 16 years old and the oldest 68 years. The workers also had an average of 6.04 (SD = 8) years of working experience. In addition, only 10% (n = 15) of them had some form of training in food preparation, but 90% (n = 132) never participated in any such formal training. The rest of the background information is in Table 1.

**Table 1.** Distribution of chopbar workers by level of education and their knowledge and attitude towards food safety in the KEEA municipality

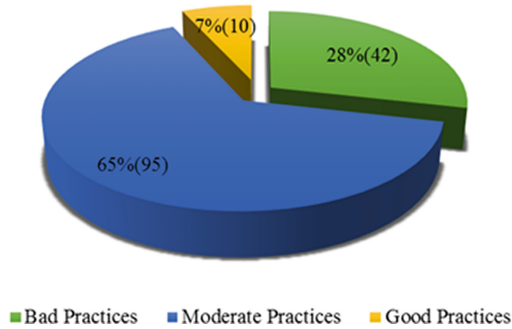
Levels of Education of chopbar workers	F	%
No formal education	39	27
Primary	31	21
JHS	55	37
SHS	19	13
Vocational	3	2
Tertiary	0	0
High knowledge	4	3
Moderate knowledge	79	54
Low knowledge	63	43
Positive attitude	124	84
Negative attitude	23	16
<b>Total</b>	<b>147</b>	<b>100</b>

### Food Safety Knowledge of Chopbar Workers

The results show that the respondents generally have inadequate knowledge on food safety. Thus, only 3% (n = 4) of the workers recorded high knowledge on food safety, with 54% (n = 79) having moderate level of knowledge. However, so much as 43% (n = 63) have low level of knowledge on food safety. The results further indicated that 84% (n = 124) of the chopbar workers had positive attitudes towards food safety (scores greater than 50% but less than 80%) and 16% (n = 23) had negative attitudes (See Table 1).

### Level of Practices of Food Safety by Chopbar Workers

The results showed 65% (n = 95) of the chopbar workers recorded moderate level of food safety practice (their food safety practices scores were greater than or equal to  $\geq 50\%$  but less than  $\leq 80\%$ ). Additionally, whereas about 28% (n = 42) of the workers usually engaged in poor food safety practices, only 7% (n = 10) of the workers' food safety practices are classified as good (See Fig. 1).



**Fig. 1.** Distribution of chopbar workers by levels of safe food practices in the KEEA municipality

### **Relationship Between Chopbar Workers' Food Safety Knowledge and Practices**

Furthermore, the results indicated workers' knowledge on food safety and practices had a low positive correlation ( $r = 0.34$ ;  $p = 0.001$ ). The value of the Goodman-Kruskal's gamma coefficient of 0.4687 with corresponding Asymptotic Standard Error (ASE) of 0.130 and Z-statistic of 3.6054 also suggest that chopbar workers' knowledge on food safety have a statistically (positive) significant association with their level of safe food practices, in the KEEA Municipality.

## **6 Discussion**

This study aimed to examine the level of knowledge on food safety, attitude and practices of chopbar workers in the KEEA Municipality of the Central Region of Ghana, and explore the relation between the workers' knowledge on food safety and their practices in relation to food safety. The findings indicate that close to half of the workers have low levels of knowledge. Perhaps, because the majority did not have any formal training in food preparation and many also are of low educational level. On the contrary, Annor and Baiden (2011) observed that most of their respondents had satisfactory levels of knowledge of food hygiene in Accra, Ghana. In comparison to other studies that have used similar scoring key as this study, knowledge score on food safety in the current study was found to be lower than that of food handlers in Thailand (Cuprasitrit et al. 2011). However, chopbar workers in the KEEA Municipality have higher scores than food service workers from Nigeria and Brazil (Chukuezi 2010; Auad et al. 2019). Also, in contrast to Apanga et al. (2014) knowledge level concerning food safety among chopbar workers in rural Northern Ghana was very high relative to the chopbar workers in KEEA Municipality of Ghana. Tessema et al. (2014) opined that food handlers in Ethiopia have poor knowledge on food handling practices. As can be seen in Table 2, only 52% of the workers in the current study were aware that napkins can spread diseases if not handled properly. This situation can therefore be described as disturbing since the rest of the workers may be spreading foodborne diseases with their napkins. However, majority of these workers expressed the need for every worker to have his or her own napkin while serving food to consumers. Thus, Siow and Sani (2011) asserted that the use of a common napkin by all workers can enhance the transmission of communicable diseases

among the workers and even to their consumers. Therefore, this knowledge becomes critical for high levels of food hygiene practices.

### Attitude of Chopbar Workers Towards Food Safety

Table 3 shows various aspects of food safety on which the attitude of the chopbar workers were assessed. The findings indicate that a little over half of the workers have

**Table 2.** Food safety knowledge of chopbar workers in KEEA municipality

Item	Correct		Wrong		Total	
	No	%	No	%	No	%
Napkins used during food preparation serve as a means of spreading diseases	76	52	71	48	147	100
It is okay for all workers to use the same napkin to dry their hands after hand washing	110	75	37	25	147	100
Hand washing with soap and water before food preparation will increase the chance of foodborne illness	112	76	35	24	147	100
Raw meat that is to be thawed or defrosted should be left in a bowl of water overnight	41	28	106	72	147	100
Frozen food items can be kept out of the refrigerator provided there is ice in them	45	31	102	69	147	100
Food contamination occurs during food preparation	62	42	85	58	147	100
It is okay to touch food with fingers to check whether food is cooked	39	27	108	73	147	100
All food contact surfaces should be washed anytime the type of food or ingredients are changed	88	60	59	40	147	100
It is okay to clean hands with a napkin after breastfeeding before touching food	64	44	83	56	147	100
Wearing of artificial nails is one of the means of transmitting foodborne illness	85	58	62	42	147	100

positive attitudes towards handwashing with soap, with close to half also recording negative attitudes to handwashing with soap and water. The result is however at variance with the findings of Annor and Baiden (2011) that a larger majority of street food vendors in Accra showed a positive attitude to washing hands with soap and water. Again, this may be a result of low levels of formal education and lack of formal training in food preparation, which is more against workers in the current study. Moreover, while Accra is predominantly urban, KEEA Municipality is by far a rural settlement. However, these workers were of the view that training workshops are necessary for restaurant workers rather than chopbar workers. This negative attitude is unfortunate since such training would enhance their knowledge and skills relating to the preparation of food and practice of hygiene as stressed by the theory underpinning this study. Again, the chopbar workers’ attitude towards their responsibility in ensuring food safety by attending training workshops, maintaining sanitation conditions at their workplaces and

**Table 3.** Distribution chopbar workers in the KEEA municipality by attitude level towards specific areas of food safety

Items	Positive		Negative			
	No	%	No	%	No	%
Washing hands without soap is almost good as washing hands with soap and water	97	66	50	34	147	100
It is okay to keep long fingernails provided they are kept clean	76	52	71	48	147	100
Training workshops are necessary for people who work in restaurants, not chopbar workers	91	62	56	38	147	100
It is necessary to have a place purposely set up for workers to wash their hands	30	20	117	80	147	100
Washing my hands with soap and water after urinating is important to me	13	9	134	91	147	100
It is the duty of the municipal assembly to maintain sanitation at my workplace	102	69	45	31	147	100
It is a waste of time and water to always wash hands after breast feeding a baby	102	69	45	31	147	100
Safe food handling requires a lot of work	35	24	112	76	147	100

reserving a place for hand washing for workers can be said to be not encouraging though a high proportion of the respondents showed quite a positive attitude.

### **Level of Food Safety Practices of Chopbar Workers**

The finding further indicated that, while a greater proportion of respondents always used soap and water to wash their hands before handling food, a few others do not do so, even where they practice that, not on regular basis. However, when it comes to specific situations where workers wash their hands, far more than half of them indicated after coughing or sneezing they never wash their hands. In addition, close to half of the workers reported that they clean their hands on their clothes after blowing their nose. This therefore means that an appreciable number of the chopbar workers in the KEEA do not adhere to food safety standards such as frequency of washing hands, except for handwashing before the start of food preparation. It is hygienic that food handlers thoroughly wash their hands after touching their body parts especially after blowing their nostrils. Thus, Nemo et al. (2017), confirmed that most street food vendors in Jimma town in Ethiopia, handle food unhygienically and also do not practice personal hygiene such as handwashing with soap and water after visiting the toilet. This practice may perhaps be a major route for microbial agents to contaminate food.

Furthermore, it is important that chopbar workers wear a cap or hair net when working (good practice), but an overwhelming majority of the workers seldom wear or never use it at all when they are preparing/serving food. This finding agrees with the evidence of Birgen et al. (2020), which identified that most food vendors in Kenya do not cover their hair during the course of food preparation and service. However, our finding is at variance with that of Monney et al. (2013) which indicated that most food vendors in educational institutions in Konongo, used hair protection when preparing and serving food. Probably, the school authorities have appropriate structures and personnel to supervise and monitor the food handlers on their various campuses, something which does not occur in the municipality.

The finding again showed that many of the workers would suspend work immediately if they get injured such as a cut or bruise on their fingers/hands. This is to prevent their blood from contaminating the food product, in accordance with the FDA (2017) code of conduct for food service workers, to prevent transfer of infectious microbial agents for example as *Streptococcus A* and *Staphylococcus aureus* from the wound of an infected person to equipment or food. In addition, FAO/PAHO (2017) suggests that any person with signs of illness must be prevented from handling food, and must not come into contact with other people, until declared healthy. Nevertheless, the few workers who do work with injured hands may be contaminating the food.

However, FDA (2013) code of conduct for food handlers' bars food handlers from handling food and money at the same time. Evidence in this research again showed close to one-third of the workers always store cooked and uncooked food items together in the same place in their refrigerators. Meanwhile, Haraminac (2014) opined that food storage should follow the "first in first out" (FIFO) method. The order of purchase and storage should be recorded for stock rotation, to prevent rot, resulting in wastage, or eventual use of food when no longer appropriate for consumption thus, exposing consumers to risk. This practice helps to ensure that food items do not keep too long to spoil before they are used. Since they turn to lose their nutritional and organoleptic properties when

decay sets in. Yet, street food handlers have limited means of storage due to lack of refrigerators or deep freezers (FAO 2016) (Table 4).

**Table 4.** Food safety practices of chopbar workers in the KEEA municipality

Food safety practices	Good practices		Poor practices			
	No	%	No	%	No	%
I wash my hands after coughing or sneezing	46	31	101	69	147	100
I clean my hands on my clothes after blowing my nose	75	51	72	49	147	100
I wash hands with soap and water before handling food	13	92	12	8	147	100
I use the same napkin for cooking and cleaning surfaces provided it is clean	65	44	82	56	147	100
I wash my Napkins every day after food preparation	121	82	26	18	147	100
I wear a cap or hairnet when working	44	30	103	70	147	100
I wear clean clothes or uniforms when preparing or serving food	61	41	86	59	147	100
I eat when preparing or serving food	74	50	73	50	147	100
When I have a cut/bruise on my hands/fingers when preparing food, I stop food for someone to continue	73	50	74	50	147	100
I dispose of rubbish every morning or evening	135	92	12	8	147	100
I wash cooking utensils immediately after use	120	82	27	18	147	100
I handle cooked food with bare hands	10	7	137	93	147	100
I store raw and cooked food items together at the same place in the refrigerator	57	39	90	61	147	100
I check the expiry dates on packaged foods before using them	56	38	91	62	147	100
I use food items when in store on first-in first-out basis	76	52	71	48	147	100
I seek information on food safety	23	16	124	84	147	100

### **Relationship Between Food Safety Knowledge and Practice**

The finding further revealed a positively low association between knowledge and practices of food safety among chopbar workers in the KEEA Municipality. This suggests that chopbar workers with high food safety knowledge are likely to observe safe food handling practices, all other things being equal. Even though the relationship is positive and weak, it lends some evidence to support that knowledge increases with practice. The finding of this study agrees with the findings of Cuprasitrit et al. (2011) which found a significant link in the level of knowledge on the safety of food and practices among food vendors on the street in the Ratchathewi district of Bangkok. Accordingly, increases in the knowledge level of food handlers via training, formal education and others are likely avenues to promoting food safety practices among the workers. In a similar vein, Monney et al. (2013) found a significant association between food vendors' training on critical food hygiene issues are correlated with key food handling practices such as hygiene of hand and keeping food away from contaminants such as flies, dust as well as medical examination. However, Apanga et al. (2014) explained that vendors of street food in parts of the Northern Region of Ghana have good knowledge on issues of food safety but that did not improve their level of hygienic practices. Additionally, evidence showed knowledge level of street food workers on food safety in the Ejisu Municipality of the Ashanti Region was not associated with their educational level (Addo-Tham et al. 2020).

## **7 Limitations**

Though this study produced findings from a rural developing area where there is a sporadic cholera outbreak, there are still limitations on the generalization. Firstly, the questionnaire used for the study was close-ended therefore, it constrained the respondents from expressing divergent views. Secondly, data was collected with structured questionnaires so the problem of bias normally associated with all the studies based on the use of questionnaires could not be completely ruled out. Therefore, these problems are likely to affect the extent to which the findings of this study could be generalized. Lastly, some of the respondents were reluctant to answer some of the questions, for the fear that the researchers might be workers of the Municipal Assembly who have come to assess their food safety practices and penalize them.

## **8 Conclusion**

The study revealed that the chopbar workers in the KEEA Municipality have low levels of knowledge on food safety. Most of the chopbar workers had no formal education and this impacted negatively on their level of knowledge. Although the workers had poor knowledge, the majority of them had positive attitude towards food safety practices, as many of them demonstrated a moderate level of food safety practice. Therefore, chopbar workers are likely not to adhere to measures to enhance the safety of food and this could expose a number of these food handlers to poor food safety practices likely to compromise the health and wellbeing of consumers. It is believed that the perennial cholera outbreak in the municipality is linked to low levels of food safety knowledge



and practices among these food handlers. The study also provided data essential for the formulation of guidelines and regulations in enhancing the safety levels of food served at chopbars. Moreover, we believe that if the knowledge of the chopbar workers is increased, food safety practices are equally likely to be promoted. Thus, formal training in food preparation, including food safety and personal hygiene, is important to uplift the food safety practices of these workers.

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# Resilience to Food Insecurity in Central Tanzania: Absorptive, Adaptive, and Transformative Analysis

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**Abstract. Purpose:** This paper provides a critical analysis on absorptive, adaptive, and transformative resilience among agro-pastoral communities in Chamwino and Chemba Districts in central Tanzania.

**Design/Methodology/Approach:** A cross-sectional design was employed whereby secondary and primary data were collected from 333 randomly selected household heads through; survey, focus group discussions, key informant interviews, and observation methods. Both descriptive and One-way analysis of variance (ANOVA) were used.

**Findings:** Findings illustrate that Mean absorptive, adaptive, and transformative resilience indices were 51.477, 46.794, and 55.242, respectively, and the differences between them were statistically significant at  $p = 0.000$ . Chemba District was reported to have higher aggregated resilience Mean index of 53.511 than Chamwino which had 48.883, and the difference were statistically significant at  $p = 0.000$ .

**Research Limitation/Implication:** The study focused on absorptive, adaptive and transformative resilience attributes employed by agro-pastoral communities in Dodoma region, central Tanzania the study focused mainly on two districts out of seven districts occupied by agro-pastoral communities.

**Social Implication:** It is imperative for various stakeholders including development practitioners, policy and decision-makers to employ different interventions especially transformative attributes in addressing food insecurity for attaining sustainable community development.

**Originality:** The uniqueness of this study also lies on resilience mechanisms to food insecurity among agro-pastoral communities in central Tanzania where communities in Chamwino and Chemba Districts were the bases; it cultivates all the attributes based on the context of the agro-pastoral communities in the study area.

**Keywords:** Absorptive · Adaptive · Transformative · Resilience · Food insecurity

## 1 Introduction

Chamwino and Chemba Districts are found in Dodoma region are characterized by uneven distribution of rainfall, manifested through prolonged dry spells and flash floods. The magnitude, frequency and severity of food insecurity hazards in districts have been reported several times (URT 2014). In addition, crop failures and low livestock production and productivity have been reported to occur in the communities where majorities are agro-pastoralist (Faustine 2016; Elia 2015; Liwenga 2003; URT 2014). Despite the situation of food insecurity in Chamwino and Chemba Districts, majorities of the agro-pastoral communities are able to persist without external assistance. It is not clearly known as to why agro-pastoral communities become resilient in spite of the shocks and stress resulted from food insecurity. This paper provides an understanding of the resilience to food insecurity practiced by agro-pastoral communities of Chamwino and Chemba Districts in central Tanzania basing on absorptive, adaptive and transformative as proposed by different scholars Msuya (2015); Constans et al. (2014); Béné et al. (2018); Ansah et al. (2019). The findings will provide the right direction towards creating stable and resilient communities to food insecurity. The aim of this paper is to understand the resilience mechanisms practiced by agro-pastoral communities of Chamwino and Chemba districts in Central Tanzania. The paper was guided by three objectives which are:-to examine absorptive, adaptive and transformative resilience mechanisms employed by agro-pastoral communities of Chamwino and Chemba Districts in Central Tanzania; to determine the resilience magnitudes by Districts among agro-pastoral communities Districts in Central Tanzania and to analyze the levels of resilience mechanisms employed by agro-pastoral communities of Chamwino and Chemba Districts in Central Tanzania.

### Theories Underpinning the Study

**Resilience Theory:** The theory was proposed by Béné, Godfrey, Newsham and Davie (2012), the theory explaining resilience as a promising concept for understanding how households cope with shocks and stressors, trying to streamline its use in their regular programming, targeting and measurement activities. Béné et al. (2012), explained resilience as the capacity with three key attributes which characterize the set of necessary actions that any system exposed to shocks need to undertake. The actions include what need to be done to help the system absorb a shock when it occurs; what needs to be done for the system to transform so that it is no longer prone to similar shocks Constans & Barret (2013). In connections to that, the theory mentioned the three key attributes as absorptive, adaptive and transformative. Absorptive attributes refers to ability of the system to minimize its exposure to shocks, but also having the mechanisms to recovery quickly when shocks actualize. While adaptive measures the ability to make informed choices about alternative livelihood strategies based on changing conditions. Transformative attribute focusing to the system level conditions that are necessary for changing the basic configurations of the system to create long-term resilience.

## 2 Methodology

### Research Design Stated

A cross-sectional research design was used to collect data. A mixed research approaches

of qualitative and quantitative data were used to allow triangulation of results as well as generating new insights to the analysis of the resilience to food insecurity.

### Population

According to the Tanzania census of 2012, the average household in the wards of Fufu and Makorongo in Chamwino and Chemba Districts were estimated to be 1500 households. Thus 3000 households in both wards were selected. According to the census of 2012 the agro-pastoral households were estimated to be 65–67% of the total households (URT 2014). This makes 2000 agro-pastoral households as the target population.

### Sampling Techniques

Both non probability and Probability sampling techniques were used in the study. For non-probability sampling purposive sampling was used and simple random sampling was used for probability sampling.

### Sample Size

By using Yamane (1967) formula to compute the sample size, the targeted agro-pastoral sample populations were 2000 households.

$$n = \frac{N}{1 + N(e)^2} \quad (1)$$

Applying this formula to the population of 2000 agro-pastoral households of Fufu and Makorongo wards in Chamwino and Chemba Districts,

$$\text{sample size} = \frac{2000}{1+2000(0.05)^2} = 333.33. \text{ Therefore, the sample size was 333.}$$

### Data Analysis

The approach adopted was characterized by the steps taken to generate the resilience mean index scores of each attribute. According to (Béné et al. 2012) these attributes are absorptive (AB) adaptive (AD), and transformative (TR). Each attribute had their mechanisms where respondents had to choose them independently. These mechanisms were measured in terms of 1 or 0 (“on” or “off”) where number one (1) was for the chosen mechanism and number zero (0) was for not chosen. After there, scores were summed and converted into indices where resilience mean indices were obtained from each attribute. After getting the resilience mean indices of Absorptive (ABMI), Adaptive (ADMI) and Transformative (TRMI) a commutative application of the total scores of each attributes were done to get the total Aggregated Mean Resilience Index (AGMRI) as per Alinovi et al. (2008).

$$\text{AGMRI} = \text{Summation of } (AB_i, AD_i, TR_i, )$$

## 3 Findings and Discussion

### Employed Resilience and Its Levels

This section presents the findings and discussion based on the three important elements of

resilience in which analysis is based on absorptive, adaptive and transformative. Absorptive mechanisms (ABM) employed by agro-pastoral communities includes using savings to buy food, consume reserved foods, consume edible wild plants, consume edible wild animals, sell nonproductive assets, harvesting crops early, delaying debt repayments and borrowing money from relatives and friends to buy foods. Adaptive mechanisms (ADM) utilized were selling of livestock to buy food, lend money from financial institutions, doing petty trading to generate income to buy food, planting drought resistant crops, changing income generating activities, selling part of land to obtain income and practicing controlled harvesting of edible wild plants. The Transformative mechanisms (TRM) employed entails:- adopting conservation agriculture, livelihoods diversifications, preservation of harvested edible wild foods, joining community-based savings and credit associations and asking for government donor/assistance.

Results from Table 1 indicate that absorptive resilience index (ABRMIL) level was 51.477 while the Mean adaptive resilience index level (ADRMIL) was 46.79 and the Mean transformative resilience index level (TRMIL) was 55.242. From the findings the TRMI was the highest followed by ABRMI and ADRMI. The findings implied that most of the respondents use transformative resilience mechanism as the main alternative to bounce back shocks and stress resulted by food insecurity in the study area. The findings are similar to those of Ansah et al. (2019), Elia and Ema (2017) and Matunga (2016) who argued that, communities in Chamwino and Chemba Districts have different strategies to prizefight hunger, they find themselves engaging on preservation of harvested edible wild foods as alternative to stresses resulted by food insecurity. Moreover, Faustine (2016) reported that communities in Chamwino Districts have been developing resilience mechanisms to address food insecurity by joining community-based savings and credit associations like SACCOSS and VICOBA in order to get income as the substitute to transform food insecurity. However, results from the one way ANOVA showed that the differences between the Mean resilient indices were found to be statistically significant at  $p = 0.000$  and the total AGRMI was 50.731. This implied that more than half (50%) of the total community's in the study area depends on resilience mechanisms as the survival strategies in meeting their dairy livelihoods particularly in terms of food.

**Table 1.** Mean resilience indices levels (MRIL)

Resilience indexes	n	Mean	Std. error mean	Std. deviation	Sign
Absorptive	333	51.477	0.4943	9.021	
Adaptive	333	46.794	0.5152	9.401	.000**
Transformative	333	55.242	0.4847	8.846	
Aggregated	333	50.731	0.4139	7.554	

Note: \*\* significant at 5% level

Sources: Survey Data, 2019

### 3.1 Mean Resilience Indices Magnitude by Districts

#### 3.1.1 Mean Absorptive Resilience Index

Results from one-way ANOVA test as indicated in Table 2 show that Chemba District has higher absorptive resilience index (ABRI) of 56.212 than Chamwino District which has 48.278. The results imply that agro-pastoral communities in Chemba Districts practice more absorptive resilience mechanisms compared to those of Chamwino District. Some of the mentioned absorptive mechanisms included consumption of wild grains like Egyptian grasses (*Dactyloctenium aegyptium*) or “*helaa*” in Sandawe language. These wild foods enable them to buffer themselves against shocks hence persisting under adversative condition of food insecurity. The findings are similar to those by Bene et al. (2012); Tesfaham (2017) and Smith and Frankenberger (2018) who connoted that communities with high absorptive resilience dimensions are more likely to moderate the impacts of food insecurity by reducing the amounts of food to consume or consume edible wild plants.

**Table 2.** Mean absorptive resilience index by districts

Resilience	District	n	Mean	Std. deviation	Std. error	Sig.
Absorptive	Chamwino	200	48.278	9.829	.695	
	Chemba	133	56.212	4.574	.369	0.000**
	Total	333	51.447	9.020	.4943	

Note: \*\* significant at 5% level

Sources: Survey Data, 2019

From Table 2 results of One way ANOVA test showed that the differences in Mean Absorptive index between Chemba and Chamwino Districts was statistically significant at  $p = 0.000$ . This connotes that, communities in the study area use absorptive resilience mechanism as immediate solution to struggle against shocks or stress of food insecurity. The findings were supported by the interview at Makorongo village a Village Chairperson who noted that (Fig. 1);

*“We normally eat helaa Egyptian grass (Dactyloctenium aegyptium) during food scarcity”.*

Absorptive resilience mechanism enable the agro-pastoral households to bounce back after stress and shocks caused by food insecurity. Focus Group Discussions conducted in Suli and Fufu villages revealed the importance of absorptive resilience as narrated in the following:

*“We normally face food insecurity in our villages but we are certain that we cannot die .of hunger. We normally consume some edible wild plants, vegetables and fruits when hunger persists. Some of them are available during rainy season while others are obtainable during dry season. The traditional common foods we consume include:- Ngole (Vitex mombassae), Umbuswa (Flocourtia indica), Ukoma*



Egyptian grass (*Dactyloctenium aegyptium*) in Gogo language called “*hungo*” while in Sandawe language is called “*hela*” this is one of the most drought-resistant African grasses as it can quickly grow when first rains start and mature earlier than other crops like maize, sorghum, finger millet etc. Due to its short durations to maturity it has rapid growth and high ability to produce seed each wet season. It has been used as food during chronic food insecurity.



**Fig. 1.** About Egyptian grasses (*Dactyloctenium aegyptium*) Source: Survey Data, 2019

(*Grewia bicolor*), *Nh'ubalu* (*Vitex diversifolia*), *Mgwelu*, *Nh'inh'a*, *Ngomwa*, *Udawi*, *Mluze*, *Ukwata*, *Mahikwi*, *Ng'anga*, *Tukula*, *Ihungo*, *Ng'anga*, *Nh'afuta*)”.

### 3.1.2 Mean Adaptive Resilience Index

The study further analyzed the Mean adaptive resilience indexes by districts. The findings in Table 3 show that, Chamwino District has higher Mean adaptive resilience index of 47.349 while that of Chemba District is 45.960. The findings denote that the agro-pastoral communities in Chamwino District have relatively better performance of incremental adjustments to the impacts of food insecurity including shifting to drought resistant crops and starting income generating activities compared to that of Chemba District. However, the One way ANOVA test shows that the differences in Mean adaptive resilience indices between Chemba and Chamwino Districts were not statistically significant ( $p = 0.18$ ). The findings are in line with Kalumanga et al. (2020) that communities in Chamwino Districts utilize adaptive including planting of drought resistant crops to mitigate the impacts of food insecurity.

**Table 3.** Mean adaptive resilience index by districts

Resilience	District	n	Mean	Std. deviation	Std. error	Sig.
Adaptive	Chamwino	200	47.349	10.064	.712	
	Chemba	133	45.960	8.271	.717	0.18
	Total	333	46.794	9.401	.515	

Note: \*\* significant at 5% level

Sources: Survey Data, 2019

### 3.1.3 Mean Transformative Resilience Index

The Mean transformative resilience indices by districts are as shown in Table 4.

**Table 4.** Mean transformative resilience index by districts

Resilience	District	n	Mean	Std. deviation	Std. error	Sig.
Transformative	Chamwino	200	51.878	7.124	.504	
	Chemba	133	60.301	8.795	.763	0.000**
	Total	333	55.242	8.846	.485	

Note: \*\* significant at 5% level

Sources: Survey Data, 2019

Results in Table 4 revealed that, Chemba District exhibited higher Mean transformative index (MTRI) of 60.301 compared to that of Chamwino which is 55.242 the differences between them are statistically significant at  $p = 0.000$  as per One way ANOVA test. Based on the findings, it is clearly shown that in Chemba District agro-pastoral communities are relatively better in practicing transformative mechanisms as the ways to bounce back from shocks and stress resulted from food insecurity than in Chamwino District. This is because the communities have been creating more fundamentally new systems including adoption of new crops, which serve different purposes. For example, roselle crop (*Hibiscus sabdariffa*) is used to prepare local brews as alternative source of income for food. These findings concur with those by Frankenberger and Nelson (2012); Hassan (2013) who reported that most communities in Africa adopt livelihood diversifications as an open gate to improve their living especially during shocks and stress caused by food insecurity.

The findings were confirmed during Focus Group Discussion conducted with participants in Khubunko village, as described,

*“We have discovered an alternative crop called “Choya” in Swahili language. The crop is helping us to diversify our livelihoods by preparing local brew known as “Udo” which we sell and get money for our living. Generally, most of the households at Khubunko are cultivating this crop as cash crop nowadays”.* (See Fig. 2)



**Fig. 2.** Women at Khubunko village selling local brews known as “Udo” prepared from Choya (*Hibiscus sabdariffa*) as seen from right hand side.

### 3.1.4 Mean Aggregate Resilience Index by District

The study further analyzed the Mean aggregate resilience based on the district wise. The findings in Table 5 depict that, Chemba District has the highest AGRMI of 53.511 than Chamwino District, which has AGRMI of 48.883.

**Table 5.** Mean aggregated resilience index by districts

Resilience	District	n	Mean	Std. deviation	Std. error	Sig.
Aggregated	Chamwino	200	48.883	8.466	.598	
	Chemba	133	53.511	4.748	.412	0.000**
	Total	333	50.731	7.554	.414	

Note: \*\* significant at 5% level

Sources: Survey Data, 2019

As such, the higher the aggregated resilience mechanisms the higher the ability to mitigate shocks and stress resulted by food insecurity. One way ANOVA test shows that the difference in Mean aggregated resilience mechanisms between districts were found to be statistically significant at  $p = 0.000$ . The findings were similar to those of (Béné et al. 2018) and d’Errico, DiGiuseppe (2018) who proposed that, for the community to have stable resilience need to curb all levels of resilience, which include absorptive, adaptive and transformative dimensions. In that regard, agro-pastoral communities of Chemba District are more likely to bounce back quickly from stress and shocks resulting from food insecurity than their counterparts in Chamwino Districts due to high Mean aggregated resilience index.

## 4 Conclusion and Recommendations

This paper analyzed the three elements of resilience to food insecurity in agro-pastoral communities in central Tanzania. These include absorptive, adaptive and transformative

resilience mechanisms based on how and what agro-pastoral communities do to maintain their livelihoods in terms of food insecurity during the adverse situation. The findings revealed that, although resilience is a complex concept yet agro-pastoral communities in central Tanzania practice absorptive, adaptive and transformative resilience in different levels. However, the transformative component revealed to be the most applicable for the community to move out of food insecurity incidences. These include, adopting conservation agriculture, livelihoods diversification, and preservation of harvested edible wild food, joining community-based savings and credit associations and asking for government donor/assistance. Therefore, the study suggest that, stakeholders including policy makers have to consider seriously the resilience elements particularly the transformative components as potential alternatives for agro-pastoral communities in central Tanzania and global at large. This is imperative for stakeholders to come up with the appropriate interventions designed for agro-pastoral communities to traffic food insecurity for their life sustenance. This will also help to create sustainable communities as stipulated in sustainable development goal number eleven.

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# Ujamaa: It's Implementation in Fishing in Mwanza, Tanzania 1960s–1980s

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**Abstract. Purpose:** This paper advances an understanding of *ujamaa* policy as a policy guideline that operated in various sectors of production. It informs that the implementation of the policy was extended to sectors other than agriculture. In achieving this goal there is one objective which is to demonstrate the relevance of *ujamaa* policy in the fisheries sector.

**Methodology:** The production of this paper employed a qualitative approach which was based on the review of documentary publications by various scholars as well as the conduct of interviews and survey of archival documents.

**Findings:** Findings revealed that the policy of *ujamaa* was not only implemented in agriculture but also in the fisheries sector where the government undertook several initiatives to promote the development of *ujamaa* fishing.

**Research Limitation:** This study focused on the implementation of *ujamaa* policy in the fishing sector from the 1960s to 1980s. The study concentrated mainly in five districts of Mwanza region which represented more than thirty districts where *ujamaa* fishing villages were established.

**Practical Implication:** The information generated from this study would inform scholars researching on *ujamaa* policy on the relevance of *ujamaa* in the fishing sector.

**Social Implication:** The knowledge advanced in this study would help policy-makers to design policies that would match the country's economy to avoid the weaknesses which led to the failure of *ujamaa* policy in the 1980s.

**Value:** the uniqueness of this study lies in its attempt to divert the perception of most scholars by examining the relevance of *ujamaa* policy in fishing.

**Keywords:** Fishing · Fisherfolks · Fishing policy · Mwanza region · Ujamaa

## 1 Introduction

The adoption of the policy of *ujamaa* in the 1960s was principally meant to provide a guide to the social-economic and political development of Tanzania. Its applicability in various sectors of production was viewed as the best practice through which its goal of promoting socio-economic development would be achieved. However, a bulk



of studies on the subject matter of *ujamaa* have been conducted to delineate the policy of *ujamaa* and its applicability in the sector of agriculture at the expense of other sectors of production. There is, for example, a lack of serious attention on the applicability of the policy of *ujamaa* in the fisheries sector. It is because of this deficiency that this study was conducted to look at the implementation of the policy of *ujamaa* in the fishing sector. This study, which is based on the fourth chapter of my Ph.D thesis, has one major objective which sought to analyze the Tanzanian policy of *ujamaa* and its relevance in the fisheries sector in Mwanza, Tanzania. It sought to divert the focus of the *ujamaa* policy on agriculture by showing how the policy was also applicable in other sectors of production like fishing.

*Ujamaa* is a Swahili word that was initially adopted by Julius Nyerere, the first President of Tanzania, in 1962 referring to socialism and family-hood. It signified the traditional kinship communalism which was practised in many rural communities in Africa. The policy was adopted as a roadmap to guide the socio-political and economic development of post-independence Tanzania. In general terms, the expression *ujamaa* in Nyerere's perspective advocated for freedom, unity, equality, as well as respect for human dignity and human rights. The latter was, in Nyerere's perspective, viewed as the foundation for human rights (Sanga and Pagnucco 2020, p. 16). The adoption of the *ujamaa* policy was accompanied by the formation of communal villages where individuals had to live and work collectively for the common good to build a self-reliant national economy (Lal 2015, p. 210). Since its inception in the early 1960s, its core attribute has been to emphasize cooperative socialist rural production focusing on agriculture as the basis for national development (Lal 2012, p. 212). Ideally, the policy was aimed at eliminating exploitative structures and emphasize individuals' loyalties to a sovereign African government.

The policy of *ujamaa*, as highlighted in the preceding section, was primarily intended to promote cooperative peasant production as opposed to individualistic farming. Various government agencies which were charged with the task of organizing the rural people to abide by the principles of *ujamaa* tended to stress the implementation of *ujamaa* policy in the sector of agriculture. The department of community development which was assigned the task of managing issues related to *ujamaa* confined itself to the promotion of the *ujamaa* economy in the villages by targeting the improvement of income of a farmer. In the course of implementing this objective, the department encouraged the people to initiate cooperative farming in *ujamaa* villages (TNA-File No. D.3/43/5).

## 2 Research Methodology

The production of this paper employed a qualitative approach which was based on the review of documentary publications by various scholars as well as the conduct of interviews and survey of archival documents. The data collection employed the use of both primary and secondary sources of data. The primary sources of information included archival research which was conducted at the Tanzania National Archives in Dar es Salaam and Dodoma regions. From archival research, information was obtained from fishing surveys, district annual reports, provincial annual reports, District Commissioners' correspondences, and other public documents. Archival materials were accessed

and identified through printed or published guides, indexes, finding aids, subject-based research guides, and catalogues. The oral interview was also used to collect information from respondents in Mwanza. The research was conducted between June and August 2019. There is no specific sample population since the sample size was based on data saturation.

### 3 Discussion of Findings

Findings revealed that the application of *ujamaa* policy in the fisheries sector in the late 1960s was triggered by the need of the government to bring fishermen together so that it would be easy to provide them with moral and material support. Under this attempt, the government sought to enable fishermen to boost their production through the use of modern fishing gear so that they would benefit from their labour. Under the policy of *ujamaa*, fishing was designed to respond to socialist ideology and a state-run economy. The implementation of the policy of *ujamaa* was carried out through the establishment of various *ujamaa* fishing villages and the encouragement of *ujamaa* cooperative fishing. Under this arrangement, the various government agencies would work hand in hand with staff in the Fisheries Division to support the welfare of fishermen. The formation of *ujamaa* fishing villages was preceded by the establishment of *ujamaa* village fishing units which were later to be transformed into *Ujamaa* Fishing Villages (UFV). Therefore, the formation of *ujamaa* village fishing units was regarded as the first step toward the establishment of *Ujamaa* Fishing Villages. Under the early stages of promoting *ujamaa* fishing, the Fisheries Division organized some villages in the Lake Victoria regions into *Ujamaa* Village Fishing Units (UVFU). The initial effort under this attempt was taken in Ukerewe District in the Mwanza region where eight villages were merged to form a single unit under the name Bukindo project. Such an attempt was undertaken under the premise that the earlier villages could not work under the principles of *ujamaa* (TNA-File No. R.20/4).

The idea of the government, through the Fisheries Division, was to transform some of the matured UVFUs into UFVs and consumer cooperatives in the future. As a matter of achieving this goal, in 1969 the government of Tanzania, through the Fisheries Division, allocated 560,000/- Tanzania shillings. In the same year, three village fishing units were established in Mwanza, including Luchebele, Ukerewe, and Masanza 1 fishing units (TNA- File No. F.2/9). The latter village was also used as a training center where the local fishermen received training on the better and modern methods of fishing. To facilitate the functioning of village fishing units, the government equipped each village fishing unit with better fishing equipment, fish storage facilities, fish receiving stations, and knowledgeable staff. The latter was supposed to offer training to the villagers concerning various issues related to the use of modern fishing gear as well as better methods of processing and selling fish (TNA- File No. C.3/1). A total amount of 196,000/- Tanzanian shillings was allocated by the government to facilitate the intended training (URT 1981).

The typical *ujamaa* fishing villages were officially started in 1970 and at the end of the Second Five Years Development Plan; there were a total of 28 of them across the country. Each *ujamaa* fishing village was supposed to have a fish receiving station. The aim of establishing *ujamaa* fishing villages was to facilitate the easy dissemination of



modern fishing techniques to the fishermen who were involved in cooperative fishing to boost their fishing capacity and income (URT 1976). Fishermen along Lake Victoria responded by forming *ujamaa* fishing villages in different fish landing beaches. In 1970, twelve fishermen in Missungwi Districts in the Mwanza region joined their efforts and formed an *ujamaa* fishing village with which they agreed to conduct fishing activities together. In their association, they agreed that each member had to contribute an entrance fee of 25 Tshs in addition to 150 Tshs which was to be paid as a share for every member. By August 1970, their business had earned them a total of 3100/50 Tshs. The government was inspired by their successes such that it encouraged other fishermen in Missungwi to form *ujamaa* fishing villages. Furthermore, the government prohibited individuals in Missungwi District to engage in the selling of fish. This was done purposely to discourage individualistic tendencies in favour of cooperative fishing (TNA- File No. F.2/9). In 1971, fishermen at Katunguru in Sengerema District in the Mwanza region also joined their efforts to form an *ujamaa* fishing village and started conducting fishing activities in cooperation. The government, through the Fisheries Division, supported their initiatives by providing five fishing nets which they used to improve their catches (TNA- File No. F.30/1).

The implementation of the policy of *ujamaa* in fishing succeeded in some cases as it was reported to have improved the volume of fish. In the Mwanza region, for example, *ujamaa* fishing was reported to have increased the volume of fish from 21,473 tons worth 17,934,000 Tshs in 1974 to 29,832 tons worth 31,205,000 Tshs in 1975 (URT 1975). The *ujamaa* fishing also succeeded in several *ujamaa* villages along with Lake Victoria, including Bukindo. This was one of the famous *ujamaa* fishing villages in Ukerewe District which was formed following the merging of eight fishing villages. In this area, fishing was carried out by using a 35-foot trawler boat. In 1978, villagers caught a total of 10,186.8 kg worth 28,378/35 Tshs for 43 days. These were caught between January and May and between October and December. Between June and September 1978, fishing activities were not carried out due to technical problems which faced the boat engine (TNA- File No. R.20/4). In Buyanja fishing village the residents conducted fishing activities for 34 days and managed to obtain 373 Tshs as savings. Elsewhere in Bukiko the villagers obtained a profit of 162.20 Tshs after conducting fishing for 34 days.

Igogo *ujamaa* fishing village which was established in Nyamagana District in the Mwanza region also flourished under the principles of *ujamaa* fishing. Fishermen in this village received various kinds of training which were offered by the Nyegezi fisheries training college located in Nyamagana District. The training they received was related to the mending of fishing nets and operating fishing boats. After receiving training, they started carrying out fishing activities in cooperation with the Tanzania Fisheries Company (TAFICO) which offered technical support to fishermen. In 1978, Igogo *ujamaa* fishing village used a 35 ft. fishing boat to catch 11,574.2 kilos of fish worth 32,516.90 Tsh for 65 days (TNA- File No. R.20/4). In 1983, Igogo *ujamaa* Fishing village caught a total of 105.3 tons of different species of fish worth 157,920/- compared with 191.0 tons of fish worth 299,501/50 in the year 1982 (URT 1975). The major challenge which is believed to have hindered fish production in 1983 was a shortage of fishing nets, which forced some fishermen to abandon fishing activities entirely. The economic crisis of the

1980s which affected various sectors of production did not spare the fishing industry. It is reported that most fishnet factories were affected by the shortage of raw materials; thus, they failed to produce fishing nets that could meet the demands of fishermen (URT 1983/1984). The two fishnet factories which existed during that time, the Ubungu and Mwanza fishnet factories could only produce 30% of the total requirements in the country (URT 1986/1987). As a consequence, some fishing boats abandoned fishing activities and started transporting crops (TNA- File No. F.2/9).

#### **4 The Government's Initiatives to Promote the Development of *Ujamaa* Fishing**

The post-independence government played a significant role to promote the development of *ujamaa* fishing in Tanzania and the Mwanza region in particular. In the first place, the government through the Ministry of Natural Resources and Tourism made several efforts to expand boat building industries to increase the number of fishing boats that were to be supplied to *ujamaa* fishing villages. In the 1972/1973 financial year, a total of 58 new fishing boats were constructed, including 12 with inboard engines and 46 with outboard engines (URT 1973/1974). Later in 1974, the Tanzania Fishing Corporation (TAFICO) was established, among other things, to enhance the development of boat building industries which was marred by a shortage of technicians and craftsmen. In the same year, the Mwanza Boat Building Yard, which had been established in 1961, was strengthened and handed over to TAFICO. The primary objective was to make it more effective to the extent that it would manufacture many boats that would be supplied to *ujamaa* fishing villages at an affordable price (TNA- File No. F.2/9). The establishment of TAFICO was, in that respect, meant to ensure that an experienced workforce was available for the development of the boat building industry. The TAFICO sought to work in cooperation with other boat builders to attain self-sufficiency in the construction of modern fishing boats in the country (URT 1976).

In the move to facilitate the development of *ujamaa* fishing, the government introduced *ujamaa* fisheries competitions in 1975/76. The competition involved various *ujamaa* fishing villages from the district to the national level. Among the criteria that were considered in the fisheries competitions were the number of people who were involved in fishing, the volume of fish caught by a particular *ujamaa* fishing village, and the fish preservation techniques which were employed by *ujamaa* fishing villages. Other issues which were considered in the competition included the quantity of fishing gear and how they were preserved by the fishing villages; the extent to which the fishing villages collected fisheries statistics; the extent to which the villagers made initiatives to manufacture their gear instead of waiting for government assistance; and the division of labour in the village. This looked at the extent to which the villagers assigned themselves different tasks in situations where there was a shortage of fishing gear. It required that the people who could not engage in fishing because of the shortage of fishing gear be assigned other activities rather than staying idle (TNA- File No. D.3/159). Apart from the fisheries competition, the government also devised the Natural Resources Development Plan whose main objective was to improve fisheries in *ujamaa* villages bordering Lake

Victoria. The plan provided modern boats and other fishing gear to enable fishermen to catch more fish to increase their revenues (TNA- File No. D3/45).

Moreover, to encourage the formation of *ujamaa* fishing villages especially in areas where fishermen were still fishing independently, the government decided to provide support to fishermen who were willing to work jointly. In Bugula *ujamaa* fishing village, for example, the government provided one hundred fishing nets and one fishing boat to 23 fishermen who had joined to form an *ujamaa* fishing village. In other areas of Ukerewe District efforts to encourage fishermen to form *ujamaa* fishing villages started in the early 1970s at a slower pace. More efforts were made in 1973 when the former Prime Minister of Tanzania Mr. Kawawa visited Ukerewe District on May 29, 1973, to encourage the people of Ukerewe to form different *ujamaa* fishing villages. He informed the people of Ukerewe that through combined efforts, they would place themselves in a better position of meeting the cost of modern fishing gear and earn moral and material support from various government and non-government agencies (TNA- File No. F.2/9). In response to the call of the Prime Minister, fishermen from seven *ujamaa* villages in Ukerewe District organized themselves to conduct fishing activities in collaboration. These include Bukindo, Nakasasa, Bagaile, Musozi, Kagunguli, Bulamba and Nakisilila. They formed the *Ujamaa* Fishing Cooperative Union which sought to carry out a fishing program worth around 254,878/= Tanzanian shillings. The major constraint that daunted the functioning of the cooperative was the lack of financial muscle to execute the program, having only 7,000 Tshs at its disposal and owning fishing gear worth 40,100 Tshs (TNA-File No. F.2/9).

Likewise, the government through the FD provided support to fishermen who had organized themselves to work together in the Ukara Division of Ukerewe District. The beneficiaries of the government support were Bukiko and Busanya fishing villages which obtained three powered fishing boats and 120 fishing nets (TNA- File No. F.2/9). In the same vein, the Mwanza Regional Development Fund allocated 5,500 Tanzanian shillings to buy a motorized boat to fishermen in Bugorola *ujamaa* fishing village. All these were carried out in line with the government policy which encouraged people to settle in organized *ujamaa* villages so that they could be supported by the government (TNA- File No. C.5/79). To make sure that *ujamaa* fishing villages persisted and that they continued operating, the government played a significant role in making sure that markets were readily available for the fish products. For the case of Lake Victoria, the Nyanza Fishing and Processing Company, which was based in Mwanza town, was designated to purchase fish caught by *ujamaa* villages and private individuals. It was also involved in catching fish as well as in manufacturing fish concentrates for animal feed (TNA- File No. C5/84).

## 5 Challenges that Faced the Implementation of *Ujamaa* Policy in Fishing

Despite the achievements observed in some *ujamaa* fishing villages, the general performance of fishing in most *ujamaa* villages was deterred by several challenges which hindered the effective implementation of the policy of *ujamaa* over time. In the first place, some *ujamaa* fishing villages failed to collect reliable fisheries statistics to indicate the amount of fish caught and the income accrued by fishermen. Most of these villages were

those which had not yet established themselves to the fullest strength, conducting fishing at a very low scale. They include Buyanja, Bukiko, and Busere which conducted *ujamaa* fishing in the Ukara Division, in Ukerewe District. A similar situation was observed at Kayenze in Ilemela District. In this area, there were some villages that were involved in the buying and selling of fish but they failed to keep records for the revenues which were obtained (TNA- File No. R.20/4). The failure of collecting fisheries statistics was, in some cases, responsible for the reported decline of fish catches in the Mwanza region. In the year 1977/1978, for example, the harvest of fish was reported to have declined from 26,869 tons to 26,557 tons due to a reported failure of some villages and fish collection centers to collect fish statistics. Nkome center, for example, managed to record statistics for three months only, whereas Nyakaliro center recorded statistics for four months. The rest of the months went without any recorded statistics (TNA- File No. R.20/4).

Some villages which had been registered as *ujamaa* Fishing Villages eventually stopped conducting *ujamaa* fishing altogether. The Mwanza region annual report for 1983 reported that only the four fishing villages of Irenze, Kahumulo, Igogo, and Nyakaliro maintained the practice of *ujamaa* fishing. Many other villages had stopped the practice of *ujamaa* fishing (TNA- File No. F.2/9). In some *ujamaa* fishing villages like Luchebele, found in Nyamagana District, poor leadership was reportedly responsible for the malfunction of the practice of *ujamaa* fishing. In this fishing village, a lack of trustworthiness among the *ujamaa* leaders lowered the morale of the villagers and, consequently, their desire to practice *ujamaa* fishing. Julius John, a retired fisherman at Luchebele landing beach, pointed out how some unfaithful leaders hastened the collapse of *ujamaa* fishing at Luchebele. He affirmed that, in the early 1980s, such leaders in cooperation with other unfaithful fishermen started using the village's properties for their gains, leaving the fishing village in a paralyzed state. Financial and material supports, including 220,000 Tanzanian shillings which were provided by the government to facilitate the development of *ujamaa* fishing at Luchebele ended up in vain (TNA- File No. C10/23). As a consequence, most villagers stopped engaging in *ujamaa* fishing, something which led to the collapse of *ujamaa* fishing at Luchebele (Interview with Julius John 2019). In line with this view, an anonymous respondent established that the village's fishing boat which had been offered by the government remained unrepaired due to the greed of corrupt leaders who ruined the village properties. The buildings which had been used for official matters at Luchebele fishing village were later returned to the government (Interview with an Anonymous Respondent 2019).

Financial constraints were also reported to have been a major stumbling block for the successful implementation of the *ujamaa* policy in fishing. The government was eager to make sure that *ujamaa* fishing villages were established in every part of the country where fishing was taking place. The government was, therefore, supposed to invest heavily to achieve the establishment of *ujamaa* fishing villages. In that regard, the government had to make sure that people organized under *ujamaa* fishing villages were granted moral and material support which would enable them to perform their cooperative undertakings. With these obligations, it became almost impossible for the government to fulfill the demands of *ujamaa* fishing villages. Given such a situation, the government acknowledged that financial constraints weakened its position to purchase and supply modern fishing implements to *ujamaa* villages. As a result, the morale of

fishermen to organize themselves into *ujamaa* fishing villages declined (Hansard 1968). As a result, *ujamaa* fishing dwindled at Luchelele, and fishermen started organizing themselves independently (Interview with Gerald Funga 2019).

Lack of diesel and spare parts was another common problem for most *ujamaa* fishing villages. In 1975, for example, several villages reportedly abandoned the conduct of *ujamaa* fishing due to the shortage of working tools. These included Nakasasa, Kabingo, Nebuye, Nabweko, Serema, Kiyozu, Bugula, and Gallu, both of them located in Ukerewe District (URT 1975). In 1978, a shortage of diesel, seine nets, and spare parts was reported to have contributed to the decline in the catches of fish (URT 1984/1985). It was during this period when the oil price shock hit the entire world, leading to a serious global economic crisis. Many African countries including Tanzania were seriously affected following the sharp upsurge of oil prices (Mendes and Mario 2019, p. 2239). Some villages which were affected by the shortage of diesel and spare parts include Nyakaliro, which witnessed a decline of tilapia catches from 114 tons in 1977 to 90 tons in 1978; in Ukerewe, the catch for tilapia decreased from 116 tons to 77 tons in the same year (TNA- File No. R.20/4). The same case was observed in Igogo *ujamaa* fishing village located in Nyamagana District, where the total catch of fish dropped from 191 tons in 1982 to 105.3 tons in 1983 due to the shortage of diesel and spare parts (TNA- File No. F.2/9). The shortage of spare parts did not just affect fishermen; it affected the fisheries department as well. The Ministry of Natural Resources and Tourism which was the overseer of the fisheries sector admitted that there was a serious shortage of spare parts from the late 1970s. Such a state of affairs affected the functioning of the ministry which failed to conduct patrols on the oceans as well as on the lakes. In the early 1980s, the ministry responsible for fisheries was reported to have not a single boat for surveillance (URT 1983/1984). The ruling *Chama Cha Mapinduzi* documented the shortage of petrol and spare parts as a serious challenge for the development of the fishing industry. It revealed that the lack of spare parts and diesel led the country to catch less than half of its capacity in 1977. The seminar for the members of the General National Council of *Chama Cha Mapinduzi* held in August 1984, emphasized providing diesel, spare parts, fishing nets, and canoes to artisanal fishermen so that they could boost production (Chama Cha Mapinduzi 1984).

Lack of training on the use of modern fishing gear affected the implementation of *ujamaa* fishing in some of the villages. Before the establishment of *ujamaa* fishing villages, most fishermen were accustomed to the use of traditional fishing gear which operated in line with the local customs. The establishment of *ujamaa* fishing villages, which was accompanied by the introduction of modern fishing techniques, brought in new challenges in the fisheries sector. The government's endeavour of introducing modern fishing gear to various *ujamaa* fishing villages was aimed at enabling fishermen to maximize their catch and profit. However, most fishermen who were at ease with traditional fishing gear found it difficult to comprehend the newly introduced techniques. To address this challenge, the staff of the fisheries department had to provide special practical training to orient fishermen stationed in *ujamaa* fishing villages on the proper use of modern methods and practices of fishing (TNA- File No. D3/146). In Ukerewe District, for example, the staff of the Fisheries Division taught the people of Bukiko and Bugula *ujamaa* villages how to use a 25 ft. fishing boat by the use of beach seines.

Similar training was provided to the people of Igogo *ujamaa* village in Nyamagana District (TNA- File No. R.20/4). Fishermen in *ujamaa* villages were also taught how to manufacture modern canoes. (Modern Agriculture 1970). It was very unfortunate that the number of staff from the fisheries department was very much limited to such an extent that some fishermen were left unattended (TNA- File No. R.20/4).

Some *ujamaa* villages were not willing to venture into fishing activities because they regarded them as secondary to other economic activities such as agriculture. Their belief was reinforced by government messaging, which laid more emphasis on the development of agricultural *ujamaa* villages. Fishermen believed that the government had not done its best to assist the development of *ujamaa* fishing villages as was the case with *ujamaa* agricultural villages. Such a state of affairs discouraged the development of *ujamaa* fishing in some areas. A good example comes from Gallu village which was located in Ukerewe District. Despite being located near Lake Victoria, its people preferred farming to fishing. The people of Gallu have long engaged in the cultivation of annual crops like maize, cotton, vegetables, and bananas. However, none of these crops had a promising future in terms of creating an independent economy for the village. They sought to diversify their agricultural economy and supplement it with the fishing industry. The people of Gallu village, which was established in 1966, started engaging in fishing activities in the early 1970s when the government started showing some little interest in fishing after realizing that agriculture could not satisfy the village's economic aspirations (TNA- File No. C20/35).

The spread of diseases such as dysentery and cholera appeared to be one of the stumbling blocks which affected the implementation of the *ujamaa* policy in fishing. The diseases, which mostly affected the villages stationed along with Lake Victoria, were very much pronounced in the 1980s. The Mwanza regional report on cholera disease which was released in December 1984 informed the migration of fishermen from one district to the other to have been responsible for the spread of cholera in different parts bordering Lake Victoria. According to the report, the very first district to get infected by cholera was Sengerema District which witnessed the outbreak of the disease in November 1984. Other districts which were infected in the Mwanza region include Mwanza, Geita, and Ukerewe where the most affected villages included Nansio, Bukondo, Rubya, Kagunguli, Ukara, and Irugwa (TNA- File No. M.10/35). The outbreak of cholera necessitated the closure of various fish landing beaches where *ujamaa* fishing villages had been established. In an attempt to contain the spread of cholera, various fishing camps, which were also believed to have been the cause for the cholera explosion, were closed. As a consequence, there was a serious decline in fish catches as reported in the 1984/85 budget speech of the Minister for Land, Natural Resources and Tourism (URT 1984/1985).

## 6 Conclusion

This paper has emerged as a challenge to most scholars who have tended to conceptualize the policy of *ujamaa* within the context of promoting Tanzania's rural transformation based on collective farming. The writer's interest was stimulated by the fact that most of the existing studies on the subject matter of *ujamaa* have tended to associate the policy

with collective rural agricultural production at the expense of other sectors of production. It's no wonder that the position of the earlier scholars might have been dictated by the belief that agriculture formed the basis of Tanzania's economy. Despite this belief, it is worth understanding that the implementation of the policy of *ujamaa* in other sectors is recognized. It is under this premise that the writing of this article has tended to shift the focus by demonstrating how the policy of *ujamaa*, which was designed to remedy the socio-political and economic ills of the colonial period, was implemented in other sectors of production, particularly fishing. The article has demonstrated how the policy of *ujamaa* brought fishermen together by encouraging the formation of *ujamaa* fishing villages under which fishermen conducted collective fishing as a means of augmenting their production. Based on this paper, scholars should take serious consideration on describing the policy of *ujamaa* beyond the scope of rural agricultural production. They should strive to contextualize *ujamaa* policy not only within the parameters of promoting collective rural agricultural production but also within the context of the diverse sectors of production.

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Interview with Julius John held at Sweya Landing Beach on 25th June 2019

Interview with an Anonymous Respondent held at Sweya Landing Beach on 25th June 2019

Interview with Gerald Funga held at Luchelele landing Beach on 27th June 2019





# Financial Performance of Firms Before and After Listing on Dar es Salaam Stock Exchange, Tanzania

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**Abstract. Purpose:** This paper measured and compared the financial performance of 17 firms before and after listing on Dar es Salaam Stock Exchange (DSE). It's started by measuring financial performance using financial ratios which included Return on Sales (ROS), Return on Asset (ROA), Return on Equity (ROE) and Liquidity Ratio (LR).

**Methodology:** The paper applied descriptive research design and Student paired t-test. The study test the null hypothesis stated that there is no difference in firm financial performance before and after listing ( $H_0: \mu_1 = \mu_2$ ).

**Findings:** The paper results showed that ROS and LR have a positive increase after firm listing and their difference were statistically significant at 1%. These findings are useful to investors in stock exchanges market in developing economies in general and DSE in particular.

**Research Implications:** The paper focused to the financial performance among firms before and after listing on Dar es Salaam Stock Exchange. It proved that after listing the financial performance of firms improves compared to before listing.

**Practical Implication:** This has implications for the attraction of investment from both local and foreign investors because indicators for a good performance after listing increase the confidence of shareholders as they become more assured of the future financial performance of listed firms.

**Social Implication:** The knowledge advanced by this study will help policy-makers, regulators of stock exchange market, investors monitoring and governance of listed firms.

**Originality:** The paper provided evidence that listed firms have improved financial performance after listing. This study being quite different from previous researchers' arguments and Agency cost theory arguments highlighted poor financial performance once the firm list at stock exchange.

**Keywords:** Financial performance · Firms · Listing · DSE

## 1 Introduction

Practically, once a firm reaches at a certain stage of growth all internal sources of capital raising are exhausted. The only option is to issue shares or listing with an Initial Public

Offering (IPO) as a way of acquiring more capital (Ernest & Young 2018). Listing reduces private ownership and brings the respective firms under market discipline (Ghonyan 2017, Kumbhakar and Sarkar 2003). This phenomenon creates an opportunity for the general public to become shareholders of the firm and share profit and risks (Pastusiak et al. 2016). Moreover, out of their accumulated capital more value in absolute term increase to shareholders once firm listing and further issuing share through bonus and rights issues which lead to capital expansion of a firm without acquiring additional debt (Norman 2011).

Firms benefits after listing, in this process periodic financial report and sound corporate governance becomes mandatory (Klynveld Peat Marwick Goerdeler [KPMG] 2015, Ritter and Welch 2002). Hence, investors gain confidence due to strict regulations of stock exchange prior to listing and firms' automatically gains integrity and projects confidence to investors. Furthermore, listing improve wealth and liquidity base for firms and increase employee motivation (KPMG 2008). Moreover, due to the publicity and recognition gained through market activities, listed firms are in good position to increase their operations locally and globally (Hung et al. 2017, Loughran and Ritter 2002).

Nevertheless, listing enable shareholders to share profits and losses achieved by firm through dividends distributed annually. Furthermore, public firms must file reports (annually, semiannually, and quarterly) to the regulatory authority so as to fulfill regulations for their listing. However, due to this process firms incur additional costs such as auditors 'fees for consultancy, management's time, and publication cost, whereas information disclosed by firms could be beneficial to their competitors (Van Tan and Trinh 2019, Wabwire et al. 2013).

In the case of Tanzania, the Capital Markets and Security Authority (CMSA) was established in 1994 to promote and regulate securities business in the Tanzania under the Capital Markets and Security Act of 1994. By August, 2021 the Dar es Salaam Stock Exchange (DSE) is the only formal trading place for securities in Tanzania which was formed in 1996 and began operations in 1998 (DSE 2017). By then listed firms were very few however, in the past the DSE has undergone major transformations where its level of activities increased which enabled local and foreign firms to own shares. Firms can also raise additional funds for expansion by producing a prospectus which provide information about price of the shares, operations strategies and future prospects. DSE is comprised of 28 listed firms where, only 21 domestic firms are traded with a trading turnover of about TZS 35,711.09 million and a total domestic market capitalization of approximately TZS 20,129.69 billion (DSE 2019). Apart from shares, Government bonds and corporate bonds are also traded on the DSE and these bring an opportunity to compare firm's financial performance before and after listing.

Theoretically, firms perform well after listing due to accountability and transparency of management in the absence of agency cost problem (Jensen and Meckling 1976). Several studies conducted both in developed and developing economies shows that firms improve their financial performance after listing (Shukla and Shaw 2018, Kinyua et al. 2013, Bessler and Seim 2012, Krishnan et al. 2011) while other studies show firms underperform after listing (Ferreira 2017, Mungure 2017, Mittal and Mayur 2012, Ahmad-Zaluki 2008, Wang 2005, Shiah-Hou 2005). For developing countries especially Tanzania, still there are few studies on financial performance of firms after listing. Munisi

(2017) concentrated on before and after IPO using only one ratio; profitability and Pulkeria (2014) focused on impact of IPO on share price rather than financial performance of firm after listing. Both studies ignored liquidity ratio as a measure of financial performance, even though it is practically known that, firm may underperform but having high liquidity ratio enable firm to cover short term obligations (Le et al. 2020, Kuria 2014, Kinyua et al. 2013). Given the raising number of firms listed on DSE in the recent past, it is important to undertake an analysis on financial performance of firms before and after listing. This study focused on profitability and liquidity ratio in comparing the financial performance of firms before and after listing. Therefore, the differences of results found in developed and developing countries together with some missing important financial performance measures like liquidity ratio, hence justifies for further studies to be taken on the subject matter.

The study objective is to measure and compare the financial performance of firms before and after listing. Specifically the study intends to examine the difference in financial performance of listed firms in DSE before and after listing.

The study hypothesis was;

$H_o$  : There is no difference in financial performance of listed firms on DSE before and after listing ( $H_o : \mu_1 = \mu_2$ ).

## 2 Literature Review

### 2.1 Concept of Performance

Performance is defined as the ability of a firm to gain and manage its scarce resources in a way of gaining competitive advantage (Bist et al. 2017, Omondi and Muturi 2013). Performance of the firm can be measured differently but there are two common ways which are; accounting measures (financial ratios) and market measures (Mutende et al. 2017, Gentry and Shen 2010, Tayeh et al. 2015, Al-Matari et al. 2014). However, researchers from developed economies are interested with market measures, due to stock market are characterized with, high degree of efficiency and high liquidity base making the stock price to reflect the available information (Munisi and Randøy 2013, Ghosh and Revilla 2007, Malkiel 2003). In this case, for developing economies like Tanzania accounting measures (financial) are recommended by many researchers as the appropriate measure of firm performance due to the nature of the market (high degree of inefficiency) (Munisi 2017, Nwosa and Oseni 2011).

### 2.2 Theoretical Underpinnings

Normally, firm first prefer to utilize internal funds followed by debt then external equity (listing) (Donaldson 1961). Then, after listing, managerial ownership declines which lead to agency problem (agency theory). Agency theory by Jensen and Meckling (1976), which state that, principals (investors) hire agents (managers) to run business on their behalf which results to conflict of interest between investors and managers. Conflict of interest results when managers' start doing things for their self-benefit hence, poor performance of firm is expected. After listing, the performance of the firm may increase as ownership increases further. The theory is appropriate to this study as it shows why firm opt listing and their expected outcome.

### 2.3 Empirical Review

According to Kurtaran and Bünyamin (2008) study examined post-issue operating performance of IPOs in an emerging market from Istanbul Stock Exchange for the period of eighty years (1992–2000). The variables of interest were post issue performance and management ownership. The findings showed that there is a strong positive relationship for the tested variables. Also, the study tested price earnings ratio and market to book ratio to post issue and found that there is decline in both ratios. The authors focused only on market value ratios and ignored other ratios such as profitability and liquidity ratio.

Moreover, Alanazi and Liu (2013) conducted a study on 52 IPO firms performance in the region of Gulf Cooperating Council for a period of seven years (2003–2010) by using panel data model. The study used return on sales, return on asset and sales to asset as variables of interest. The results showed that decline in performance is associated with firm transition from private to public due to rise of agency cost. This study considered only profitability ratios as measures of performance while ignoring other ratios like liquidity ratio.

Furthermore, Batool (2018) used panel data from 2006 to 2011 for 15 firms listed in Pakistani to analyze long run performance of Initial Public Offering (IPO). The variables investigated were profitability, age, size, leverage and returns on IPO. The results showed a positive significance on profitability and firm size in the long run performance of IPO, while age and leverage were negatively associated with IPO performance in long run. The study gave more emphasize on profitability ratio, leverage, and ignoring liquidity ratio.

Also, Munisi (2017) conducted a study on financial performance of IPO among listed companies on Dar es Salaam stock Exchange using mean score of financial performance ratio for five years for ten companies only. The end results showed that, there was a significant increase in post IPO performance for some measures. The study gave more importance on profitability ratio for only ten companies while this study on top of profitability ratio also liquidity ratio was analyzed by considering data from 17 listed firms for six years.

Finally, Pulkeria (2014) assessed the effect of IPO on share price among companies listed on Dar es Salaam Stock exchange from 2008 to 2013, the study used share price as dependent variable as well as IPO announcement and IPO selling as independent variables. The findings illustrate that both IPO announcement and IPO selling have no significant impact on share price. The study considered share price as the only performance measure while ignoring profitability and liquidity ratio.

Therefore, the above studies have shown both theories to be relevant and empirically relating to firms listing. The theory clarifies more why firms issue IPO through listing and why some firms perform better while others underperform after listing. The empirical reviews show gaps and contradiction on methodology and findings respectively. Therefore, this study seeks to bridge the gaps by including both profitability and liquidity as financial performance measures.

### 3 Research Methodology

#### 3.1 Research Design, Data Type and Sources

The study adopted descriptive research design where by mean (measure of central tendency) was used to compare changes of financial performance measures of firms before and after listing. This design was adopted because it helps in describing the financial performance of the firms before and after listing. The study relied on secondary sources in measuring and comparing financial performance of firms' that have issued IPOs. The study used profitability and liquidity ratio to measure and compares performance of firm data before and after going public, where before listing data was collected from Capital Market and Security Authority (CMSA) and after listing data was collected from DSE for analysis. CMSA is a regulator of security market in Tanzania with the responsibility of ordering firms to submit three years minimum accounting audited (prospectus) before a firm listed and keeping them for other user's reference. Whereas, DSE is a market where investors (large and small) can trade securities and publish both quarterly and annual financial reports for general market and individually listed firms.

#### 3.2 Population, Sampling Technique and Sample Size

The study is conducted in DSE between 1998 to 2018, where most of IPO took place; the basis of choosing 1998 is the year where stock exchange start operation. There are 28 firms listed at the DSE where by 21 listed are domestic firms while 7 are foreign firms (DSE 2018). The selection of time frame and how many years to include before and after IPO depends on objective of the study, circumstances and data availability (Alanazi and Liu 2013). The target population of this study comprises of only traded and exposed firms to the public for the first time when engaged IPO (domestic firms) with at least six years (three years before listing and three years after listing) as used by (Shukla and Shaw 2018, Alanazi et al. 2011, Kuria 2014) and firms with missing required data have been excluded from the study. Due to this criterion 11 firms were dropped from the study, 7 are foreign firms which are not traded locally and 4 firms are domestic traded but missing either data of three years before listing or after listing (DSE 2017). Hence this criterion resulted in a sample of 17 firms that have issued IPO through listing.

#### 3.3 Data Analysis Techniques

Meanwhile, Student Paired-t test was used to examine mean difference of financial performance measures before and after indicators by accepting or rejecting the  $H_0$ . STATA 14 statistical software was used to carry out all statistical test and data analysis.

#### 3.4 Measurement of Variables

Moreover, for developing economies like Tanzania, financial ratios are recommended by many researchers as the appropriate measure of firm financial performance due to the nature of the market (high degree of inefficiency) (Munisi 2017, Nwosa and Oseni 2011). Therefore, this study also used; return on sales, return on asset, return on equity

and liquidity ratio as financial ratios for analysis measuring financial performance of firms as used by other studies such as; Hung et al. (2017), Kinyua et al. (2013), Alanazi et al. (2011), and Kuria (2014) (Table 1).

**Table 1.** Operational definition of variables.

Variable name	Measurement method
Return on Sales (ROS)	The ratio shows how successful a firm create profits from its sales revenue. Normally obtained profit before interest and tax divided by sales revenue * 100
Return on Asset (ROA)	The ratio illustrates how firm's management is using its assets to generate profit. It is computed by taking profit before interest and tax divided by total asset * 100
Return on Equity (ROE)	The ratio indicates firm management success or failure at maximizing The return to shareholders based on their investment in the firm. It is calculated as profit before interest and tax divided by shareholder's fund * 100
Liquidity Ratio (LR)	Is the ratio of current assets of a firm to current liabilities. It is mostly used to test liquidity of a firm to meet its short-term liabilities with its short-term assets

Note\* represents multiplication.

## 4 Results and Discussions

### 4.1 Descriptive Statistics

Table 2 results shows Return on Sales (ROS) increased by 15.72% after the firm listing from 8.49% to 24.21%. This implies that, there is an increase of profit by 15.72% out of sales when firm listing. The study results are similar to Kinyua et al. (2013), Shukla and Shaw (2018) findings that, ROS increases after firm listing. Additionally, there was minimal increase of Return on Asset (ROA) by 1.59% from 12.64% to 14.23% average performance from before and after listing respectively. This implies that, after listing firms' utilization of assets to generate profit increases by 1.59%. This result is contrary to Alanazi *et al.* (2011) study results on financial performance of Saudi Arabia IPO showing deterioration of ROA after listing however, the deterioration was very minimal. While Batool (2018) study in the long run performance of IPO in Pakistani found that ROA increased after firm listing.

**Table 2.** Descriptive statistics showing comparison of firm financial performance measures

Before listing					After listing					
Variable	Obs	Mean	Std. Dev	Min	Max	Obs	Mean	Std. Dev	Min	Max
ROS	51	8.49	31.61	-120.53	48.39	51	24.21	31.29	-94.69	94.69
ROA	51	12.64	16.12	-16.71	49.42	51	14.23	22.44	-63.61	58.66
ROE	51	26.56	18.53	-7.18	64.86	51	15.12	63.43	-303.19	96.2
LR	51	1.57	1.39	.09	8.26	51	5.39	7.65	.21	33.98

Additionally, Return on Equity (ROE) results showed a huge decrease of 11.44% from 26.56% to 15.12% on average ROE before and after listing respectively. This happens due to after listing firm increases both number of shares and amount of equity while profit remain the same as before listing (firm failed to utilize available equity by 11.44% to generate profit). These results are similar to Pastusiak et al. (2016) study on Company profitability before and after IPO in Poland stock exchange where results showed that ROE fall after firm going public.

Finally, the result on Liquidity Ratio (LR) showed an increase of 3.82 from 1.57 to 5.39 average liquidity ratio before and after firm listing respectively. This illustrate that, after listing firm ability to cover short term liability out of asset increase by 3.82. This result in line with Kinyua et al. (2013) study on Initial Public Offering Performance of listed Companies.

Furthermore, for mean difference in financial performance measures before and after listing Student paired t test was used. Student paired t test assumes: Scores (variables test) are continuous numerical, the data are selected from population, observations are dependent and paired, and test variable (scores) difference are normal distributed in each group. By central limit theorem, if data is  $> 30$  assume data is normal so can proceed with t test (Fuad et al. 2015). This study observation was 51 which was greater than the minimum required observation of 30 for a normal distribution condition hence, the study data is normally distributed basing on central limit theorem.

## 4.2 Student Paired T-test Statistics Results

Table 3, shows mean difference in firm financial performance measures before and after listing at 1% significant level. The P-value of ROS (0.0000) was less than 0.01 (1% significant level), meaning that there is sufficient evidence to reject null hypothesis ( $H_0$ : There is no difference in financial performance of listed firms in DSE before and after listing). Hence, accept alternative hypothesis, as resulted from listed firms having a good public image due to increased ownership which ensure high revenue and profit at given level of cost. This result are similar to Iman and Ghodrattollah (2014), Shukla and Shaw (2018), but contradict with studies of Alanazi et al. (2011), Huang and Song (2005) which indicated that difference on ROS before and after listing are not statistically significant.

However, the mean difference in financial performance of ROA increases (positively) after listing, the P-value of ROA (0.4665) is greater than 0.01(1% significant level)

**Table 3.** Mean difference of firm financial performance measures before and after listing

Variable	Mean difference	t-stat	DF	P-value	Conf-Interval (CI)
ROS	15.72	4.51	50	0.0000***	6.378282, 25.06646
ROA	1.58	0.73	50	0.4665	-4.196891, 7.365399
ROE	-11.44	-1.28	50	0.2081	-35.47511, 12.58629
LR	3.82	3.62	50	0.0007***	.9966327, 6.642328

Note: \*\*\* significant at 1% level

therefore, no sufficient evidence to reject null hypothesis ( $H_0$ : There is no difference in financial performance of listed firms on DSE before and after listing). Also, this result resembles Alanazi and Liu (2013), Bhatia and Singh (2009) studies which portrayed that transition period were triggering factor.

Additionally, the mean difference in financial performance of ROE decreased (negatively) after listing, with P-value = 0.2081 which is greater than 0.01 (1% significant level). Thus, no sufficient evidence to reject null hypothesis ( $H_0$ : There is no difference in financial performance of listed firms on DSE before and after going public). Same findings were noted by Bhatia and Singh (2009) and Pastusiak et al. (2016) although their mean difference was found to increase (positively).

Finally, for LR, the P-value (0.0007) was less than 0.01 (1% significant level), meaning, there is sufficient evidence to reject null hypothesis ( $H_0$ : There is no difference in financial performance of listed firms on DSE before and after listing) hence, accept alternative hypothesis. Therefore, after IPO firms' ability to cover short term liabilities increase due to high liquidity base from shares sold to the public. This result contradicts with Ahmad-Zaluki (2008), Mittal and Mayur (2012) study results that showed mean difference in financial performance was statistically insignificant while this study results were similar to Kinyua et al. (2013), Hamidah and Muhammad (2018) study result, where liquidity was statistically significant.

### 4.3 Implications of Theory and Related Studies

The study used agency theory illustrating that, firm initially may underperform due to agency cost as a result of conflict between investors (principal) and managers (agent) leading to unnecessary expenditure which are unfavorable to shareholders. However, firms perform better as ownership increase. The results hold true to the theory as after IPO firms may create good public image and managerial structure resulting to high liquidity base which later on lead to high ROS, ROA, and ROE.

Furthermore, the findings confirmed that agency theory through good public image and managerial structure lead ROS and LR to be statistically significant. The results were also confirmed by studies of Iman and Ghodratollah (2014), Shukla and Shaw (2018) finding that, high ROS depends more on good public image and managerial structure. Likewise, Kinyua et al. (2013), Hamidah and Muhammad (2018), supported the current study finding, where liquidity ratio was found to be significant after listing due to high liquidity base originated from good managerial structure and public image. Therefore, the current study finds the applied theory being relevant and statistically justified, hence having a positive implication on its applicability.



## 5 Conclusion and Policy Implications

In this paper ROS, ROA, ROE and LR were used as firm financial Performance measures. However, ROS was statistically significant due to firms having a good public image resulting to increased ownership which ensure high revenue and profit. Also liquidity ratio was found to be statistically significant, liquidity of a firm improved after listing due to profits received by firms after selling shares to the public. These findings are useful to investors in stock exchanges market in developing economies in general and DSE in particular. The findings have policy implication for roles of the regulators of stock exchange market, investors monitoring and governance of listed firms, as results indicate that, after listing the financial performance of firms improves compared to before listing. This has implication for attraction of investment from both local and foreign investors because indicators for good performance after listing increase the confidence of shareholders as they become more assured on future financial performance of listed firms.

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# The Covid-19 Outbreak and The Disruption of Women-Headed Families' Livelihood in Dar es Salaam, Tanzania

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**Abstract. Purpose:** This study entailed to assess the impact of strategies employed by the government of Tanzania in combating the spread of COVID 19 on the livelihood of women vendors in Dar es Salaam.

**Design/Methodology/Approach:** The study employed qualitative methodology with an ethnographic research design. A sample of 100 street vendors was obtained from ten top streets used by women vendors who are also family breadwinners. Through in-depth interviews with street vendor's data were obtained and analyzed by the use of content analysis.

**Findings:** It was established that a number of Women Street vendors' livelihood means were shuttered by the government measures as more vendors were forced to make losses, close their business, disorganize their other economic activities, welcome family conflicts and above all live on a single meal.

**Research Limitation/Implications:** the study only focused on how the government efforts to combat COVID 19 affected the livelihood of informal business persons specifically women vendors who also happen to be heads of their families. Economic and social effects were studied.

**Practical Implication:** knowledge advanced in this study will inform leaders that during pandemics, not only formal economic activities are affected, even the informal ones especially those headed by women are badly shattered.

**Social Implication:** From this study, policymakers will understand the importance of formulating policies to harness the informal sector. It will inform them of the importance of creating better policies for proper disaster management and revamping victims immediately.

**Originality/Value:** while many studies in the Tanzanian context focused on the effect of the pandemic on education and formal economy, this study has focused on the informal economy with women vendors being considered as a case in point.

**Keywords:** COVID-19 · Livelihood · Resilience · Women vendors · Women-headed families

## 1 Introduction

It is globally accepted that there are various family structural changes recent moments. It has widely been observed that, single parent families and female supported families are increasing day after a day (Drago et al. 2005). The changing nature of affairs shows that, women currently are more into entrepreneurship and are the most bread earners of different families (Martins 2006).

In the US, a considerable number of children live in women-headed families (Tucker & Lowell 2016). Such households are much more likely to be caught in poverty, despite the fact that women in these families have either fulltime jobs or were in the informal sector. In 2012, 23% of children lived in households headed by women (single mothers) (Freeman 2017) and out of whom, more than 40% of children living in female headed families were poor (Hoffert 2016; Tucker & Lowell 2016).

In Sub Saharan Africa, the number of women headed families is increasing rapidly in almost every country. For instance by 2011, there were 46% of female-headed families in Botswana. In South Africa, the number has been on increase since 2011. It shows that, the number increased from 31.2% to 39.4% and then to 41.36% in 2009, 2011 and 2015 respectively (Mabelane et al. 2019). In the Tanzanian context, studies indicate that by 2010 to 2020, the number of female headed families was between 24–33% showing an increase from 18.6% in 1992 (Indexmundi 2018; Sakamoto 2011). Thus, the increase in the number of female headed families has resulted in many children raised in these same families across Africa (Lesetedi 2018).

The escalating level of divorce resulting from domestic gender-based violence against women, cohabitation, desertion, death of fathers, the need for freedom from female-based violence suffered for a long time economic changes, economic downturns, social pressure, and out of wedlock pregnancies have been attributed to such families. However, data indicate that, desertion, and divorce are the greatest cause of increase in women headed households (Kpoor 2014; Katapa 2005). Such families are vulnerable to poverty, food insecurity and other threats (Sakamoto 2011).

The extreme level of poverty among women-headed families affect children in terms of education, health and relationships with others and expose these families to social and economic threats. Because mothers in these families strive to ensure their families stand, they end up in the informal sector and other low paying subsistence jobs to help them as a means of earning income to cope with poverty threats (Sakamoto 2011), although such jobs do not successfully provide them with enough income (Defina 2008). Women engage in such subsistence activities due to the absence of other secure means of livelihood (WIEGO 2019).

Women in the informal sector are mainly involved in street vending activities and constitute around 50–90% of vendors with most of them vending raw, cooked, and processed foods and other related products (Chen 2001). A study by Njaya (2014) on street food entrepreneurs in Harare, Zimbabwe, showed that women dominate in street food vending. In Tanzania, a study by Marras (2018) indicate that women account for 80–90% of all food vendor '*mama lishe/mama ntilie*'. This is because the business is viable to most women, requires low education and start-up capital (Milanzi 2011).

By the end of 2019, a virus (Corona) which later became known as COVID -19 was discovered in Wuhan, China. It led to the outbreak of a deadly Global pandemic causing severe acute human respiratory complications. The pandemic spread and has since then affect the entire world (ECA 2020). The pandemic has infected over 173 million people and resulted to around 3.7 million deaths worldwide so far (Worldometer 2021). The first case in Tanzania was identified in mid- March 2020 and followed by other 480 infection cases in wave one (WHO 2020). This was followed by other cases in wave two, however the number was not established (WHO 2020).

Through protective measures taken by different countries in the world, that include total and partial lockdown, curfew and closing of some sectors, paralyzed different countries' economies with those in the informal sector being adversely affected. In Tanzania, the closure of educational institutions across the country, the prohibition of congestions as a measure to obtain social distance, posed a great challenge to the informal sectors especially food vendors dominated by women most of whom are single mothers and heads of their families. Such measures led to a decrease in the number people in centers where food vendors work from. On the other hand, restricting of vending activities through guidelines such as social distancing meant minimal sales and jeopardized the livelihoods of this group of women who have a great burden of servicing their loans, minimized their social life, trust, affected their physical assets and increased the burden of providing for their families in terms of food paying house rent, and keeping their life going.

This study therefore, intended to examine the extent at which the livelihood of women-headed families have been affected by the outbreak of COVID-19 pandemic, challenges experienced by women heads of the family during the COVID-19 pandemic period and scrutinize the way women-heads of families coped with challenges they experience during the corona pandemic period. The study intends to recommend possible policy strategies through which the government can enact to support informal sectors during catastrophic periods.

This study was guided by the multi-layered social resilience framework (Obrist et al. 2010). The framework draws from ecological (Carpenter and Walker 2001), psychological (Luthar and Zelazo 2003) and socio-anthropological approaches (Bourdieu 1984), as well as from the sustainable livelihoods framework of the UK Department for International Development (DfID 2000). In this study, social resilience means the ability of actors to cope with an affecting emergency/threats resulting from the COVID-19 pandemic "reactive capacities" and to search for and create options as "proactive capacities" in order to develop competencies of coping with the threats.

## 2 Materials and Methods

### 2.1 Research Design

The study was qualitative in nature utilizing an ethnographic design being. The study intended to use the design as it involved studying people and their life experiences as a result of the COVID-19 pandemic. Similarly, there was a need to capture women vendors' views deeply regarding the topic under the study. Qualitative strategies provide better answers to how COVID-19 affected women vendors and how they managed to cope with

the situation (Goodrick 2014; Tzeng and Yin 2014). The study was conducted in Dar es Salaam due to the fact that, the city is a growing business hub which is densely populated as compared to any city in the country. Thus, this population attracts more vendors from different parts of the country because they capitalize on the available population. Thus, there are very many food street vendors in Dar es Salaam as compared to other cities in Tanzania.

## **2.2 Research Instruments**

The study collected data through interviews, researchers' experience and observation. With regards to interview, open ended questions were set and administered to respondents. However, this was done after a pilot study was carried to find out if they collect the intended information. These questions focused on the effect of the pandemic to their livelihood and how they managed to cope with the situation. Researchers ensured that they administered all questions to all participants and that the same set of questions were asked to them all except when more clarifications were needed. In the same vein, the researcher devoted much of his time to observe vendors' operations since the eruption of the pandemic and afterwards. This helped the researcher to live with and understand difficulties women headed street vending ventures.

## **2.3 Case Selection Criteria**

The study employed 100 women street vendors who were heads of their own families in different streets of Dar es Salaam. These were selected by the means of snow-ball technique, where the first respondent was spotted by the researcher and she referred the researcher to other women vendors who were also heads of their own families. This exercise was done to all streets and data saturation was arrived at after interviewing 100 respondents. The sampled persons were included in this study because of their vast knowledge in the topic. These were approached and requested to participate in the study. Those who consented were asked questions regarding the topic. Due to the fact that the study was conducted during their working hours, participants were allowed to attend their customers in the middle of the interview. On the maximum, the interview was about 40 min long.

## **2.4 Data Analysis**

In order to ensure that the researcher obtains valid findings, all participants were asked the same questions, and responses were properly recorded. Swahili was used for all conversations and interviews. Thus, Swahili transcriptions were translated into English by a qualified translator, typed and saved as text format. MAXQDA 10 was used to analyze data. At first data were arranged, coded and repeating themes identified as directed by Denscombe (2010). These were then used as main themes in the findings. These were presented in the findings section along with important quotations.



**2.5 Findings and Discussion**

This section presents findings regarding the extent to which COVID 19 pandemic has affected the livelihood of women vendors who are also heads of families, challenges experienced and resilient strategies employed by these vendors. The study provides a demographic overview of the respondents before presenting findings as per each objective.

**Demographic Characteristics of Respondents**

Based on the demographic characteristics as presented in Table 1, it is indicated that with regards to age, a great number of women were in between 19 to 60 years of age. This presents the reality that it is the same age under which women are faced with a number of obligations to take care of. It was also spotted that even at 60 and above, there were respondents who were vending and still were heads of their own homesteads with mouths to feed. Regarding, the level of education, while a reasonable number (23) of respondents revealed that they had never had any formal education. Most of these were above 50 years of age. This is attributed to the state of affairs in the past where access to education was a great problem to women. Surprising facts indicated t that there were university graduates suggesting that due to limited chances in formal employment some graduates have opted for street food vending. Data further indicated that, most respondents were working in the city centre (61) with a reasonable number of them having between 4 to 6 dependents. It is further revealed that food vending employs a reasonable number of women vendors. In this study out of 100 vendors 85 of them were food vendors dealing with both raw and cooked food items with 91 of them depending on the same business for their family survival.

**Table 1.** Demographic distribution of Women Vendors

Item	Description	Frequency
Age	Under 18 years	4
	19–40 years	47
	41–60 years	39
	60+ years	10
<b>Total</b>		<b>100</b>
Education	No formal education	23
	Primary	51
	Secondary	14
	Tech and Voc. Education	4
	Tertiary education	8
<b>Total</b>		<b>100</b>

*(continued)*



**Table 1.** (continued)

Item	Description	Frequency
Location	City centre	61
	City suburbs	39
<b>Total</b>		<b>100</b>
No. of dependents	Below 3 dependents	24
	4–6 dependents	64
	7+ dependents	12
<b>Total</b>		<b>100</b>
Type of business	Cooked food	47
	Fruits and vegetables	39
	Beverages	9
	Other businesses	6
<b>Total</b>		<b>100</b>
Number of business owned	One business	91
	More than one business	9
<b>Total</b>		<b>100</b>

## 2.6 The Effect of COVID 19 Pandemic on the Livelihood of Women Vendors Who Are also Heads of Families

Under this objective the researcher used the multi-layered social resilience framework in discussing the effect of the pandemic to women livelihood strategies. However, in this study, the study concentrates on economic and social effects. These are discussed in the subsequent section.

### Economic Effects of COVID-19 Pandemic on the Livelihood of Women Vendors

On the economic aspect, the study revealed that the pandemic caused three great effects including, decrease in income, limited number of customers served, and blockage of other income generating channels as well as crippling the ability of servicing the loan.

With the inset of the pandemic, the government closed schools and discouraged people to move. This meant that there were limited movements among individuals in different parts of the country and the Dar es Salaam city in particular. Bearing in the mind that street vendors are dependent on the continuous movement of people, it meant that vendors' customer base was cut short. In the same manner, due to the fact that vendors stage their products and businesses around areas with a high concentration of people (natural markets), the inset of the pandemic and the government reactions on discouraging movements, controlling the urban public transport and closing other

important offices meant nothing but another disaster to women street vendors and their entire families.

### ***Decrease in the Number of Customers Served***

The situation resulted in a continuous decrease in the number of people moving around the city. In reality these are the major customers that street vendors normally provide their services to. For example, women food vendors who work around bus stands and terminals, markets, schools, college and universities were the first to lose a great bunch of customers. This was followed by a number of other people who restricted their movements and decided to work from home. For others, they decided to move out of the city. All these meant harm and threat to women street vendors. For women vendors who sell perishable items (which most of them do) were forced to incur losses because they used to display items for the entire day or two but could not be sold out. For food vendors, they ended up spilling large quantities of food because they had no one to sell them to. This situation crippled their financial status as well as their capital base. During an interview with one vendor she said:

My son, this disaster is not only going to kill those who succumb the virus, but the cascading effects will kill most of us. Imagine, I normally sell food around this college but no students are here. I used to cook up to 10 Kg of rice and other types of food. But today I have cooked 5 Kg and I have only served a single customer. The evening is nearly sweeping in, where do you think I will take this whole food? What will I do with it? The same happened yesterday, my kids are waiting for me to go home with household requirements. Will I manage? (Woman vendor 21, Bibi Titi Mohammed Street, 2020).

The quotation indicates that while vendors are trying to ensure that they sell their products, there is no one to sell the products to. But still these vendors are worried of how they are going to run their families if they keep incurring losses on a daily basis. While cementing on the same, another vendor remarked, “*We have been incurring losses on a daily basis ever since the presidential order was issued in March 2020. I don’t remember selling more than 10,000 TZS. In this situation, how shall I make it keeping up my family? Will I be in the position to stand again if I keep incurring losses on a daily basis?*”.

The remarked posed more questions than the required answers. This was caused by mixed feelings these vendors had with regard to the situation against a number of mouths they have to feed and provide for in their homes.

### ***Low Income Inflow***

Customer base is always a principal aspect in any business be it big or small. The customer base determines the cash inflow and profit margins of the business. However, with regard to the situation that existed during the COVID 19 pandemic, the closure of offices, congested places and academic institutions lead to a decrease in the number of customers served by street vendors. This ultimately led to a drastic fall in the cash inflow of most women street vendors. The fall in cash inflow was interpreted as losses and a hindrance to the growth of women headed micro businesses (vending ventures). The limited cash inflow meant nothing but limited ability of providing for the family

but above all payment of house rent for most of the families whose mothers were street vendors. The situation was elaborated more by one of the street vendor in Buguruni. She said;

The reality is that most of our families suffered a lot during the period when the government closed important offices and areas that attracted a concentration of people. We could not sell all of our displayed items, and at times we could not sell even a single shilling because there is no one to sell to. Some of our items perished and caused losses. But in the evening you have to go home with food for the entire family. Moreover, at the end of the month, you need to pay for rent. While there is no cash inflow in the business but you need to spend money right from the morning up to evening in terms of fare, food for yourself, the family and other important items (Woman vendor 14, Buguruni market, 2020).

The quotation entails that the period was marked with limited cash inflow among women vendors which caused suffering and distress among families and women themselves. This was more expanded by another vendors who said, *“I have never experienced hard times of the kind. I had all the required commodities but there was no one to sell to. My family ended up suffering during the entire period”*.

### ***Blockage of Other Sources of Income***

It is a reality beyond doubts that in the current moments street vending has been a strategy to most women. Cooked and raw food vending selling and distribution of Fresh fruits and Vegetables (FFV) attract more women than other ventures. However, most women do not have a single venture. While vending, they engage in merry go round groups, use their profits to buy different products and sell them to others and much more. The onset of the pandemic and associated government measures, all opportunities of securing additional income among street vendors were blocked. For instance due to the pandemic there was limited money circulation and thus the merry go round groups could not be run any more. Similarly, due to the fact that there was no money circulation, no customers and the likes, this meant that, no extra profits could be obtained to buy other commodities to circulate to other women. The situation was elaborated as follows:

I knew I had an extended family to look after, so I decided to be wise and creative. On a daily basis, I used around 60% of my profits to buy commodities and circulate them at night to other neighboring women. This gave me extra income. But still the merry go around group was also like a source of income to me because I used to receive a certain huge amount of cash during critical moments. I could use money for school fees, rent and other important requirements. But after the onset of COVID 19 all my extra income was blocked. I had no one to sell my products to no one had money. But on the other hand I also fell short of capital because I could no longer get profits with which I could buy these products (Woman vendor 66, Kivukoni, 2020)

Findings indicate that women vendors' economic opportunities were shuttered during the pandemic and during when government restrictions were active. While the situation caused more problems to women themselves, but the effect was severely felt by families

to which their income meant food, shelter, clothing, school fees and much more. These findings are in line with the study of other scholars (Mburu 2020; Haldevang 2020; Price 2020; Wegerif 2020) which among other things they reported that in the informal sector, the pandemic brought about losses in several ventures, limited inflow of income but more specifically suffering of families whose major economic source was from the informal sector. Haldevang (2020) further urges that vendors and other people in the informal sector were in the dilemma as to whether they close their ventures and observe government directives or risk their families dying of hunger. The same situation was witnessed in Dar es Salaam but women, looking at the mouths they had to feed, ended up opening their ventures as a means of collecting something that would save the family since no support was expected from anyone.

## **2.7 Social Effects of COVID-19 Pandemic on the Livelihood of Women Vendors**

Social life is also of paramount importance among people. It adds value to people's lives. It involves how interacts with others and make use of them in running his/her life. The inset of the pandemic and the associated aftermaths affected women vendors lives in the following ways;

### ***Disorganization and Dissolution of Merry Go Round Groups***

In most cases tend to socialize than men. They make use of their presence as a means to creating connection, positive relationship among themselves and collective opportunity sharing. The merry go round groups are created as a means of attaining social solidarity and cohesion. However, during the inset of the pandemic, a number of people ceased opening their ventures. This ultimately affected the way in which they shared their opportunities. They ended up closing the group and hence their social cohesion lost in the entire period.

### ***Misunderstanding Among Business Persons***

It was also revealed that during the moment when the pandemic was at the peak and government standard operating procedures active no business was taking place. This means limited customers and income. For those who had taken loans in their SACCOS failed to service their loans which ended up creating misunderstandings among women vendors. One of the women narrated,

“ ... I had applied and received a loan of 1.5 million TZS (Approximately 700 USD) before the inset of the pandemic. The money was not productive as I thought. There was no business, I had to take care of my kids and mother but still, I had to service the loan. There is no way I could handle all that in the absence of the business. I ended up defaulting to pay the loan which led to misunderstanding between me and my group members (Woman vendor, Mnazi mmoja, 2020).

The findings are in line with the multi-layered social resilience framework (Obrist et al. 2010) which explains that distressing a situation brings about economic, social physical and psychological effect. Hence the inset of the COVID 19 pandemic was expected to come along with social effects to women vendors and their families in general.

## 2.8 Challenges Faced by Women Vendors During the COVID 19 Pandemic

While the previous data presented the effect of the pandemic to women vendors in Dar es Salaam, it has not displayed what were the challenges associated or resulting from both economic and social effects. In this paragraph a list of associated challenges will be presented with regard to the collected data from respondents. It was reported that due to the onset of the pandemic customers lost trust in women vendors and their products. This is because of the nature in which the pandemic spreads. It was further reported that limited number of washing materials was yet another challenge. In this vendors were required to incur extra costs of acquiring such materials and they could not get assistance because they were considered to be working in unauthorized places. From the economic perspectives, vendors were challenged when it came to access to financial assistance. No financial organization was interested in providing such assistance because their businesses were considered more risky hence low possibility of loan repayment. Family stability and upkeep was yet another challenge for women street vendors who are again heads of their families. Considering the fact that there was no healthy business taking place, these women had limited amount of savings to run their families for the entire period when the pandemic was at the peak. Moreover, realities indicate that a reasonable number of vendors have subsistence economies. Hence, a greatest number of street vendors' families lacked and suffered a lot during the entire period of the pandemic.

Considering the entire situation, Price (2020) and Wegerif (2020) earlier presented that economic related suffering, business slow down and limited access to finance challenged many informal business ventures during and even after the first wave of the Pandemic. Suggesting that at some point and in some countries, the economic stability has not been achieved as a result of the COVID 19 pandemic in these countries.

### Resilience Strategies Employed by Vendors During the Pandemic

While the pandemic posed economic and social effects and challenges to women vendors and their families, they never failed to take initiatives after having failed to receive assistance from authorities. These strategies were geared towards ensuring that their families survive during the pandemic despite the hard moments they are passing through. Among these strategies include the following;

#### *Minimizing the Expenditure Pattern of the Family*

It was revealed that most women decided to cut down their expenditure so that they ensure the survival of their families. Expenditure was limited to essential and basic needs like food. It was also revealed that even food was limited at a single meal for the entire day. As expressed by one of the respondent. *"I had to cut down breakfast and dinner. We only ate once at around 1600 h. This served as lunch and supper"*. Another reported, *"I cut down TV subscriptions, internet bundles on my phone and expensive foods. We remained with posho or rice and beans"*. Quotations indicate that women had to ensure that their families survive in the hardest moment irrespective of the prevailing challenges.

#### *Sending Part Or the Entire Family in the Village*

Data indicate that during the pandemic and the harsh fangs associated to it, women vendors decided to lower the burden of dependents by sending some members in the village.

Due to the reality that most vendors are immigrants to the Dar es Salaam metropolitan, in hardest moments they normally go back to their origin. This is what happened during the pandemic. The researcher was shown around twenty ventures which were locked as a result of their owners deciding to go back to villages as a result of economic hardships. During the interview, another woman was recorded saying that; *“I decided to take my children to my mother, so that I hustle on my own. Without doing that, it would be hard for me to pass through the hard moment”*.

### ***Using the Available Savings in Terms of Money and Food***

Data indicate that while the pandemic hit severely, people decided to use their savings to run their lives. Although the initial aim of savings was for something else, it had to be used to rescue the prevailing situation. This was validated by a vendor who reported that she had to use all the money she has saved for buying doors for her new house under construction. Another said that the food she had in her store was enough to sustain her entire family for about four to six months. Apart from using their savings in terms of cash and food, it was further recorded that families, friends, parents and guardians were reached for assistance to cope with the hard situation that was prevailing in the city.

Findings indicate that despite hard moments, people had to search for alternative means and situations to ensure that life continues despite the prevailing challenges. These findings are in line with the suggestions of multi-layered social resilience framework (Obriest et al. 2010). Despite the fact that resilience strategies are on an individual and family levels alone, they however indicate the importance of being resilient during critical moments.

## **3 Conclusion**

Economically, COVID-19 has rendered the women vendors unable to participate in livelihood activities, due to closure of various social economic activities and customers' fear to shop in the crowded places. Consequently, the pandemic has further rendered them little abilities to meet daily needs and needs of their families. It should be noted that, while women vendors were struggling to make ends meet for them but behind were children and other dependents under their care. While it has been discovered that women vendors were strongly hit by the outcomes of the pandemic, they were left with a single option to save themselves and their families with their own initiative. No assistance was provided from any organization as a means of ensuring that women and their families are safe during the pandemic. The study recommends the government of Tanzania through the prime ministers' office to be active during emergencies by providing assistance to the most affected and vulnerable groups. This will minimize the rate at which vulnerable families suffer. Secondly, the study recommends the government to think of providing stimulus package to all groups of people including women vendors. This is due to the fact that while the formal sector was affected, the informal was adversely affected but very few took heed in discovering the effect they experienced. The study recommends that because the threat still lives, then there should be improvement of hygiene status at vendors' living and working places mainly in urban informal settlements, improvement of hygiene and PPE utilization in public transport, ensure access to social protection and

health insurance as well as access to relevant COVID-19 related information. Others are ensuring accessibility of Personal Protective Equipment (PPE) to the vendors, extension of relevant economic stimulus packages and programmes to informal sectors and finally, mitigation strategies should be gender sensitive.

**Declaration of Conflict of Interest.** Authors wish to declare that they have no any conflict of interest with regard to this study.

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# Learning from Stable Street Vendors' Groups: Lessons from WAMBOMA in Dar es Salaam, Tanzania

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**Abstract. Purpose:** This study intended to analyse a group of street vendors situated in the city of Dar es salaam, their practices and how they have for a long period of time managed to overcome challenges faced by the group.

**Methodology:** The study was qualitative in nature and a case study design was employed and the WAMBOMA group was the studied case. Data were collected from the top leaders of the group who were sampled purposively by the means of in depth interviews. Obtained data were subjected to MAXQDA 10 for analysis from which useful themes and content were extracted.

**Findings:** It was established that, organization, unity, strong leadership, and self-awareness have led WAMBOMA to their current success. Moreover, the nature of the business model employed by WAMBOMA was observed to be peculiar as compared to the model used by other normal street vendors.

**Research Limitation:** The study mainly focused on the operations and practices of WAMBOMA towards alleviating challenges facing street vendors along Zanaki Street. Being a case study, a single union of vendors along Zanaki Street (WAMBOMA) was studied.

**Practical Implication:** Knowledge obtained from this study will inform urban authorities on how best unions of street vendors can be used to solve issues of disorganization, crimes, and dirtiness among others.

**Social Implication:** The study informs policy makers at the local government level on how best street vendors once untied and well organised can be of great importance. Thus calling for reviewing policies to accommodate street vending as a licit economic activity.

**Value:** The novelty of this works lies on how social unions of marginalized yet “illegal” groups can create a difference in business and social arrangement contrary to the expectations of many.

**Keywords:** WAMBOMA · Street vendors · Business strategies · Urban authorities

## 1 Introduction

The presence of street vendors in urban setting in the world has been an undisputed fact. The venture has been described as a fact that cannot be denied and is there to stay (Hussain 2011). Street vendors include both moving and stationed persons doing small business for their personal survival. Such persons do not possess permanently built structures (NASVI) and their proliferation has been attributed to the decrease in employment opportunities in Sub Saharan Africa (Bahai 2014) increased population (Cohen 2004) inability of authorities to absorb the massive number of rural migrants into the formal sector (Bahai 2014) and the increase in the number of rural urban migrants. More to this, the influx of excessive imports in most developing countries has also contributed to the proliferation as such imports including second hand clothes have opened opportunities of employment to poor urban dwellers.

In developing countries, the existence of political social and economic upheavals has escalated Rural Urban Migration which has in turn led to the concentration of population in urban settings (Munishi 2019; Munishi 2013). The concentration of unemployed population has been attributed to the expansion of the informal business especially along urban streets (Brown 2006). The informal sector is currently thought to include a reasonable number of individuals all over the Sub Saharan Africa and estimated to account for over 60% of the entire employment in the region (Kirumirah and Munishi 2021; Dell'Anno et al. 2018) with Tanzania, being among the top five countries with the largest informal sector in the region (Dell'Anno et al. 2018).

In Tanzania, following the country's economic quagmire in the late 70s to early 90s, the number of people working in the formal economy dropped from 84% to 36% from 1978 to 1991 respectively. Despite local by laws that illegalised informal economic activities, street vending inclusive, the economic situation encouraged it. The 1983 Human resources Deployment Act established street vending trading licenses. The SDP which had earlier identified street vending as a problem, later recommended harnessing it after the Bankruptcy of Dar es salaam City Council in 1996. However, the venture exists by living in a legal vacuum outside and beyond the law (Goldie 2002) and their denial by the authorities who regard them as a threat and a source of increasing informal activities in the economy, invading the city spaces and a serious source of pollution and increased crime.

In reality, street vending provides products and services to the needy people conveniently and at a reasonable price (Bahai 2014; Kirumirah 2021) and their services cater for both the middle and lower class individuals. The venture also offers employment to the jobless young boys and girls around urban areas (Mramba 2015; IFRA 2016). Street vending is not only a living phenomenon in the Sub Saharan Africa (SSA). It has been witnessed in even developed countries like USA, Japan, China, among others. The middle economic countries, most of which are from Asia, have also been experiencing an influx in the number of street vendors (Meneses-Reyes and Caballero-Juarez 2014; Munoz 2018; Hummel 2017; Mahadevia and Vyas 2012).

Experience indicates that street vendors in urban settings have been faced by a number of legal, political, and economic challenges. For instance, street vending has been considered a nuisance and has thus been running in legal vacuum (Nakibuuka 2015). Furthermore, they have been vulnerable to various challenges including, lack of

legal status and right to vend, lack of space or poor location, restriction on licensing, cost of regulation, harassment, bribes, confiscation and eviction that always accompanied with blood shed, lack of services and lack of representation (Mitullah 2004; Munishi and Casmir 2019; WIEGO n.d.) contrary to their basic right to the city as proposed by Henri Lefebvre in 1968 (King and Blake 2018). They have also been associated to selling contaminated items, polluting the environment, theft and lawlessness, destruction of social amenities, congestion in roads and conflict with business owners in urban settings by most urban authorities and these have been the bases from which urban authorities evict vendors time and again.

The escalating state of mistreatment of street vendors by urban authorities attracted the presence of many local and international organizations whose actions have supported the existence of street vendors in urban settings. Organizations like the Commission for Legal Empowerment of the Poor recognize the importance of street vendors in the urban economy and agitate for their equality in accessing and using the available open spaces (UNDP 2008), The International Labour Organization agitates for more improvement in street vendors activities to make it a more decent work, the National Association of Street vendors in India (NASVI), Women in Informal Employment Globalization and Organization (WIEGO) all put their efforts together to end the unpleasant situation.

In the Tanzanian context, several organizations have been in place to fight for the rights of street vendors. The Shirikisho la Wamachinga Tanzania, Umoja wa Wamachinga Tanzania, VIBINDO and Kivulini have been actively working to ensure legalization of street vending business. However, due to personal interests, these organizations have been working in isolation and have not achieved the goal. In the Dar es Salaam context, the Wauza Mboga na Matunda (WAMBOMA) group has been actively fighting to solve all problems related to street vendors as articulated by urban authorities. A number of studies have discussed about the presence of the group as just a living street vendors' association (Lyons and Brown 2007), its operations and joining instructions (Benit-Gbaffou 2015) and as a regionally recognized association for informal traders (Babere 2013). However, none of them has focused on how the organization has solved a number of challenges articulated by urban authorities. The organization has set a number of solutions to several challenges articulated by urban authorities and have been an example that can be emulated elsewhere in the country. Thus, this study entails to expose how WAMBOMA group has managed to set themselves higher to the currently articulated challenges of poor quality products, dirtiness, pollution, lawlessness, blocking the traffic, destruction of amenities, conflict with formal business owners among others. The study intends to respond to the question has the organization been able to solve such challenges and place themselves to a better position among other vendors and in the eyes of urban authorities? And what has contributed to their success for all that period of time?

## 2 The WAMBOMA Group

It was formed by street vendors as a cooperative for fruits and vegetables sellers in 1997 and was registered the following year (Benit-Gbaffou 2015). The organization was intended to safeguard vendors' rights by improving positive relationship between street vendors, the city council and property owners in managing and running business taking

place around Zanaki Street. Despite the fact that the available rules, regulations and by-laws formulated by Ilala Municipal Council do not allow street vending operations, but these vendors have been at the fore front to ensure that they survive in these streets and are given rights to manage these streets. Thus, cleanliness, security and storage facilities are well managed by vendors through their group. The WAMBOMA group has also become a social welfare group that provides social support among members during social related problems (Bahai 2014; Benit-Gbaffou 2015).

## 2.1 Methodology

The study adopted a purely qualitative approach with a case study design. The approach and design were used due to their abilities to allow the research to interact with the respondents freely and capture their views. Being the biggest business hub in the country (Malefakis 2019), where the case is found, the study was carried in Dar es salaam. Researchers adopted the use of open ended questions in form of In Depth Interview. The intended population of 10 respondents was sampled purposively in the sense that only 5 leaders and five oldest individuals working in the sampled case were interviewed. With regards to the oldest vendors, snow ball method was used to sample them in the sense that the first was identified by leaders and the others were pin pointed by the preceding respondent.

The data collected from different respondents through interviews were summarized and grouped according to contents they possess. Important contents were coded and obtained from the texts. Researchers used Qualitative content analysis in analyzing data as instructed by Denscombe (2010). Along with analyzed data, important quotations were also included.

## 3 Findings and Discussion

While it has been widely documented that there has been an antagonism between urban authorities and street vendors all over Dar es Salaam, this study reveals the truth on how the street vendors' union at Zanaki Street (WAMBOMA) has paved a way in solving the antipathy. The findings presented in this part are generated from responses given by leaders and oldest business operators. The responses are aimed at dissolving each account raised by urban authority as a reason of evicting street vendors. Such reasons are centred on contaminated products, dirtiness, poor quality products, pollution, lawlessness, conflicts with other formal businesses and residents, destruction of amenities, and blocking the free flow of traffic.

### 3.1 Selling of Poor Quality and Contaminated Products

This was one of the basis from which urban authorities have been always evicting street vendors from time and again and have been accusing them of endangering peoples' health. However, as a means of solving this, most street vendors have been encouraged by their leaders to consider three things as very important these include, sourcing vegetables

and fresh fruits from reliable sources, sorting the best, and displaying them by using metallic cages and shelves.

All vendors have been obtaining their products from different areas. While some are obtained from different regions of the country, some are sourced offshores like how other supermarkets do. Here one of the leader was quoted saying; “*We normally import some of the fruits we sell here just like other supermarkets do. How then are authorities accusing us of selling poor quality products?*” this indicates that most of what they import is treated and is of better quality compared to other product.

With regard to sorting products, it was reported by all interviewed informants that even though some products are obtained offshores, some reach here with damages so have to be sorted out. And for those obtained in the country, due to poor technology, most of them are never sorted. The chairperson narrated

*We normally ensure that all of products we sell are of high quality. The moment we receive them from our suppliers we have to sort them to ensure no poor quality product is displayed and sold to customers. Because of this, that is why we normally sell our products at a relatively high price than other markets. (Chairman WAMBOMA, June, 2021).*

Such a quotation indicates that apart from selling all products at high price, they sell high quality products contrary to the urban authority accusations of selling rotten and poor quality products. The same is in line with Nnkya (2006) who clarifies that vendors at Zanaki Street sell imported fruits and vegetable of the higher grades as compared to other areas.

With regards to contamination of products sold by street vendors, it was revealed by informants that street vendors at Zanaki Street have always wanted to make a difference. In the past, vendors used boxes and wooden pallets to display their products. However, in the late 2000s they started using aluminium and metallic shelves in which products are placed and displayed to customers. On this one of the leaders said, “*...we advised our people to create shelves from which they will display their products. This was done to ensure that none of our products are displayed on the ground. Again this helped to create more space for vendors who had more products to sell*’ (Fig. 1).

The three important practices have been among the important ones that have in one way or the other silenced authorities with regards to selling of poor and contaminated products. Generalizing this, a trader said,

*In reality, we have done a lot to preserve the quality of what we sell. Considering the fact that everyone who buys our products will first wash them as those obtained in the supermarkets, what we have always done has been showing that we care about our customers’ health. Because the moment we damage their health is the moment we lower our customer base.*

### 3.2 Dirtiness and Pollution

This was another challenge that urban authorities in Dar es Salaam accused street vendors around the Zanaki Street. In reality, urban authorities used to accuse street vendors of



**Fig. 1.** (L-R) Traders arranging products in shelves. Earlier wooden pallets used to display products. Photos: Courtesy of African image library.

littering garbage in the streets which at the end would block water channels and tunnels. Further they were accused of polluting the environment by displaying their products where they were not allowed and making unnecessary noises in the course of selling their products. At different moments, these vendors were evicted at different moments. As a result of this, WAMBOMA leaders decided to make arrangements with private garbage collection companies. In this regard the Green Waste Pro was engaged to make cleanliness and collect all garbage produced by vendors the entire day. The activity was to be done on a daily basis without excluding weekends. Expounding about this, the chairman said,

*City authority leaders were very much concerned with dirtiness and would evict us almost on a weekly basis. We decided to ensure that all garbage produced by vendors and our customers are cleaned and collected and dumped in a specific dumping site. We contracted the Green Waste Pro who had to do the cleaning from 21:00 just immediately after closing our businesses. We, at first used to pay them on daily basis, then we changed the mode of payment to weekly and at last we would pay them monthly. By doing this we ensured that none of our waste products blocks water trenches, channels and tunnels (Chairman WAMBOMA, June, 2021).*

Such statements indicate that vendors in collaboration with their leaders were able to contract a private garbage collection company to cater for cleanliness of their working place. Cementing this, one of the traders said, *as a means of ensuring that we minimise clashes with authorities, we decided to contribute some money to ensure that our area is cleaned, and no garbage is littered around the place.* Such an initiative was of tremendous importance as it in one way or the other silenced authorities on dirtiness. Findings are in line with those obtained by Lyon and Brown (2008) who indicate that in the past vendors used to hire women to clean the place. This implies that WAMBOMA were not just littering but were also maintaining safety and cleanliness of the city. The same was presented by Benit-Gbaffou (2015).



### 3.3 Lawlessness, Crimes and Conflicts with Other Formal Businesses and Residents

It has been a norm by various researchers to report that street vendors are associated to lawlessness and crimes by authorities. This was also a case to Zanaki Street vendors who were accused by Dar es Salaam City council and Ilala Municipal authority of contributing to increased crime rates and escalating conflicts between formal business owners and residents. In order to end this, vendors through WAMBOMA held different discussions with formal business owners and residents and came with a conclusion that as vendors use spaces outside shops, vendors will provide security services to formal business operators during the day and at night vendors will employ watchmen to care of both vendors' products and shops. In another way, vendors agreed with formal business owners that, vendors will only sell what is not sold in shops but what accompanies what is sold in shops or supplying fruits and vegetables needed by hoteliers. Clarifying the situation, one leaders remarked,

*We currently have no any conflict with either formal business persons or residents. While using the space in front of formal shops, our presence provides security to those shops during the day and at night the watchmen that guard our products do the same to shops (Trader, June 2021).*

In the similar vein, the issue of security crime and lawlessness attracted more arguments from other respondents. One of them while talking about crimes commented that,

*Every one of us is a security guard to his products and the neighbours'. We have agreed to one another that no unknown person to all of us should be allowed to sit in the area for more than five minutes. When we suspect a person with ill intentions, we use security guards to arrest them and we have done so several times. But still, our presence in the area has been a blessing to all tenants in those flats. We supply them with all they need at a reasonable price and they have become our close friends (Trader, June, 2021)*

Supplementing on this the vice chairperson said, "...it was in the past that we used to quarrel with shop owners and other residents. But since we sorted our difference we support one another. It is just scratch my back and I scratch yours practice".

Such quotations indicate that currently street vendors, formal business operators and residents are in harmony and are depending on one another in terms of security and provision of relatively cheap products. But still, the presence of street vendors has contributed to maintaining security thereby arresting the rate of crime around Zanaki Street. In this aspect, Benit-Gbaffou (2015) reports that it is through street vendors' union of WAMBOMA that night watchmen are employed to ensure that they watch over vendors' items as well as shops around the area.

### 3.4 Blocking the Free Flow of Traffic

For a long period, authorities have maintained that street vendors are a cause of traffic congestion as they display their products along in the streets. This was also a case with

street vendors along Zanaki Street. Due to the fact that WAMBOMA was in mutual relationship with shop owners, vendors along Zanaki Street decided to extend their products behind leaving the street free for the flow of motor and pedestrians. All this was done to ensure that that authorities do not get any reason of chasing them away. One of the respondents was quoted saying: *“When we realized that vendors were operating in the streets and were blocking the free flow of traffic, we requested shop owners to allow us extend our products behind which they did. Since then none of us occupies the street”*

When supporting this, the WAMBOMA chairperson said

*Realizing that occupying street is not only an issue to traffic congestion, it is also a risk to us as poses a risk of accidents, we had to find a solution. Because we had earlier discussions with shop owners on the issue of security, when we presented to them that of accident risk, they allowed us to use pavements. This has been also a move to silence urban authorities that have based on this to suppress our existence.*

Such quotations and available pictures are available, indicate that currently vendors are operating along the pavements and not in the street as they were before. The picture below presents this reality (Fig. 2).

The researcher upon discovering all the facts, decided to find out what has contributed to their success. The researcher though of such because the case was extraordinary in comparison to other areas where vendors have operated for a long period of time a case being Makorobo area in Mwanza City. Leaders alongside their sampled vendors cited the following;



**Fig. 2.** Street vendors displaying their products on the street pavements (Photo: Courtesy of nasirpage9)



### 3.5 Strong Leadership

It was revealed that since its establishment, the union has been led by different leaders but all of them have been strong in dealing with vendors' affairs. Anything concerning vendors has been considered of utmost importance by leaders. One of the interviewee said, "... *our leaders know what they are doing and are really strong in ensuring that we are all in the same rail*". The reality is in harmony with Lyons and Brown (2008) who also maintained that WAMBOMA leadership has been strong and has led them to where they are.

### 3.6 Unity

This has been among the contributing factor to vendors' success. Had it not been for unity they would not have survived since then. Bearing the reality that most of the members are Luguru (ethnic tribe from Morogoro, Tanzania) they have considered themselves as brothers. The same spirit has been perpetrated by their leaders. In case of misunderstandings, it is solved quickly to unravel the situation. One of the leader maintained the same stance by saying, "... *we are all brothers, so there is nothing that should separate us. Our unity is our strength*". This is similar to what was maintained by Lyons and Brown (2008) that leaders were active in ensuring that conflicts among members are resolved as a means of maintaining their unity. Benit-Gbaffou (2015) also reported that leaders ensured that unity among members is maintained by quickly solving misunderstandings between them.

### 3.7 Strong Network

Findings presented indicate that while WAMBOMA group has been active and successful in ensuring that they appear in the way they are, strong connection and social networks have been associated to this success. It was revealed that doing business in the city needs a lot of social connections which these leaders had. They at times negotiated with authorities on ejection orders, needs and requirements, as well as regulatory processes. One of the respondent said, "*while we had connection with customers, our leaders were in good terms with municipal and city authorities, police and other leaders at the top*". All this was meant to ensure that we are not disturbed at all. In line with other findings by other scholars (Nnkya 2006; Lyons and Brown 2007; Bahai 2014; Benit-Gbaffou 2015) which present that the union leaders have been in touch and communication with authorities to ensure that vendors are never evicted.

Further details present that WAMBOMA's success has been also a product of self-awareness and Organization. Because of being self-aware, vendors maintained peace and regulatory requirements as presented to them by their leaders and have also maintained their organization bearing in mind that without which they are not going to stay any longer as they have.

## 4 Conclusions

The fact that eviction has been reported to be a common challenge facing street vendors cannot be ignored. Vendors have been evicted on the ground of littering garbage, blocking

traffic flow, selling low quality products that endanger peoples' health and increasing the rate of crimes. However, street vendors' union (WAMBOMA) has turned the table around. Through using their cooperative union, they have been in a better position of rectifying all vices the city authority has been blaming them of. They have truly decided to make vending free from all vices marred and ascribed to the activity. To them, the city can be co habited by all individuals of different calibre for earning their livelihood. It can be concluded that while in some other parts of the country street vending is regarded a burden, it is to them a descent economic activity that supports their life and can be done with people of different dignities, selling high quality products, orderly and without littering garbage in the city as claimed by different authorities. In this regard, a number of lessons are drawn from this group as presented below.

There is a need for urban authorities to strengthen its efforts in ensuring that street vendors are unionised. This will facilitate easy coordination of vending activities and will act as a bridge between urban authorities and vendors there by ensuring mutual understanding. The presence of mutual understanding ensures that the city is used by all for their livelihood.

Street vending is not a disorganized business but authorities disorganize it. In the situation when vendors are given permission to vend with a number of principles to adhere to, they will ensure that the business is done in a cool calm and conducive environment. But because authorities have not used the presence of vendors as a strength, they end up making vendors disorganized and hence operate in the way they do.

Street vending is an opportunity that can be used to serve all classes of people including the middle and low income earners. This based on the state that vendors have the ability of segmenting their customers and provide services according to their economic status and needs.

Street vendors contain a pool of individuals that can be used as a network of preventing crimes in the city. This is rooted from the reality that as vendors use formal business openings, they provide security assistance to formal business owners.

Since the WAMBOMA group at Zanaki Street stands to be an outstanding example, their organization and operations can be considered a case study by the city authority and emulated to other streets within the city or other urban centres in the country.

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# Enhancement of an Electromechanically Excited Spinning Pendulum by Means of a PPF Controller

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**Abstract. Purpose:** This study aims to enhance the performance of the nonlinear dynamic behaviours of an electromechanically excited pendulum with spinning support subjected to simultaneous resonances.

**Design/Methodology/Approach:** A positive position feedback controller otherwise known as a PPF controller is applied to control chaos. This control method is aimed at modifying bifurcations in the spinning support pendulum setup. The dynamics 2 software of Nusse and Yorke is employed for the numerical simulations. The PPF control method is used to keep the system's rotational solutions stable while avoiding chaos and period doubling.

**Findings:** The results show that period doubling bifurcation and bifurcation leading to chaos can be prevented and a solution for stable rotation is attainable. The PPF controller method presented in this work enables a desired rotational solution of the system to be sustained over a wide range of amplitudes and excitation frequencies.

**Research Limitation/Implications:** Many chaos control methods exist. This paper is limited to the application of a PPF controller as a means to control chaos to consequently alter bifurcations in the spinning support pendulum to enhance its performance.

**Practical Implication:** Results from the studies confirm that the PPF is a sustainable active controller that can control bifurcations leading to chaos effectively and efficiently and enhances the performance of the spinning support pendulum excited by an electromechanical device. This implies that the electromechanical may be applicable for scavenging green energy.

**Social Implication:** The applications of the electromechanical device proposed in this research may be used as a green energy scavenger. This encourages alternative energy use and is an eye-opener for industry players and policymakers to make sustainable devices/designs and policies respectively to protect the environment.

**Originality/Value:** No work has been reported in the literature on the study of stability and bifurcation to chaos control of spinning support pendulum with electromechanical excitation using PPF controller. This work gives a novel approach to avoiding bifurcations that destabilize the spinning motion of devices which ultimately possess the opportunity for scavenging large quantities of energy using a stable spinning support pendulum.

**Keywords:** Spinning pendulum · Positive position feedback · Control · Bifurcation · Chaos

## 1 Introduction

Spinning support pendulums are pendulums whose support rotates at a constant speed. The nonlinear oscillations of such pendulums are dependent on time that can either be the rotational speed or the support's non-dimensional form. Practical applications of the spinning support pendulum model include but not limited to quantum mechanics, electronics, solid state physics, fly-ball governors, vibration absorbers, nonlinear optics and quite recently renewable energy, that is green energy harvesting (Abdel-Rahman 1983; Koch and Leven 1985; Wiercigroch 2010; Lai et al. 2011). Although the mathematical expression of the spinning support pendulum is simple and understandable, it contains phenomena such as simple periodic oscillations, large amplitude oscillations, instabilities, bifurcations, and complex chaos, most of which inhibit the satisfactory performance of the system.

To overcome the above-mentioned problems associated with the rotating pendulum many scientists have proposed several control methods (El-Ganaini et al. 2013). However, most of these proposed methods are either not very effective, cost effective or compact. Lighter and effective systems are being sought, thus the need for control methods that make the models compact and light. Therefore, researchers perceive controllers to either reduce or eliminate these phenomena and enhance the performance of the dynamic system to attain stability. There are frequently issues with the movement control of various electromechanical systems in practice. In most cases, it is advised to design the control law, preferably with feedback, in order to form desirable modes (Sablina et al. 2016).

For many years, bifurcation and chaotic control theories and techniques have been extensively researched. Szemplinska-Stupnicka et al. (2000) and Szemplinska-Stupnicka and Tyrkiel (2002) numerically studied universal bifurcations, boundaries of fractal basin and the coexistence of rotating solutions. Xu et al. (2005) and Horton et al. (2011) have carried out extensive simulations of various types of rotations, as well as oscillations and chaos.

Although different authors have discovered and studied these rotations, it is worthy of note that, their existence spans a narrow range of parameter and there are many system bifurcations that destabilize this type of motion. It therefore suffices that bifurcation control could be useful in preserving spinning solutions. The idea of bifurcation control is based on altering the nonlinear system of interest in the quest to produce a desired dynamic behaviour through the development and application of a controller (Wen et al. 2006; Xiao and Cao 2009).

Various types of controllers have been developed to suppress and modify vibrations in oscillating systems. One of such is the PPF controller that has found wide applications for vibration reduction in a wide range of linear and nonlinear dynamical systems, demonstrating its feasibility and efficiency in practice. The PPF controller have been used for oscillations control of a nonlinear dynamic model closer to the internal and primary

resonance cases (El-Ganaini et al. 2013). Several other authors used PPF controllers to analyze nonlinear behaviours and to reduce oscillations in various systems (Omidi et al. 2016; El-Sayed and Bauomy 2015; Abdelhafez and Nassar 2016; Niu et al. 2018; Amer et al. 2019).

This paper is devoted to the application of PPF active controller to control bifurcations leading to chaos and to enhance the performance of the spinning support pendulum excited by an electromechanical device having in mind its application to scavenging for green energy. It is evident that no work has been reported in literature on the study of stability and bifurcation to chaos control of spinning support pendulum with electromechanical excitation using PPF controller. The main objective is to prevent bifurcations, which disrupt the spinning motion. The fascination with these rotational solutions stems from the concept of scavenging large quantities of energy using a stable spinning support pendulum.

Section 2 deals with the mathematical representation of the excited pendulum and in Sect. 3, the bifurcation to chaos controller is used to alleviate unstable rotating orbits rooted in chaotic attractors and to extend the range of stability of existing periodic orbits by avoiding bifurcations to chaos and period doubling bifurcations.

## 2 Mathematical Representation of the Excited Pendulum

The excited spinning support pendulum system is shown in Fig. 1. The assembly consist of a rod of length  $l$  negligible mass fixed to a ball of mass  $m$  at one end and the other end is attached to a spinning support driven by an electrical device vertically. The spinning pendulum- electromechanical excitation system is a modified form of what is investigated in Sze-Hong et al. (2014). Three major components make up the electrical device and

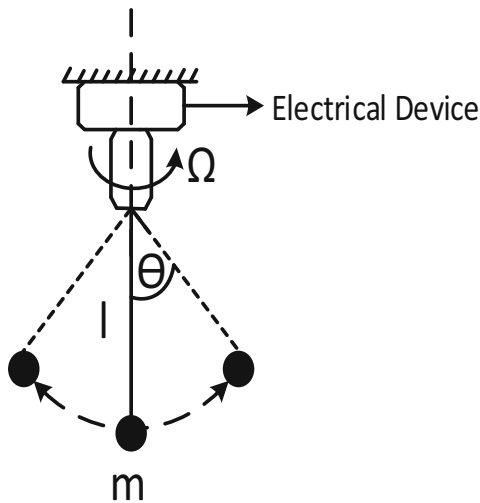


Fig. 1. Pendulum oscillation with a spinning support.

they are the capacitance,  $C$ , inductance,  $L$  and resistor,  $R$ . An externally supplied time dependent voltage powers the electrical circuit (Sze-Hong et al. 2014)

$$V(t) = V_0 \sin(\Omega t), \tag{1}$$

$$\ddot{V}(t) = -V_0\Omega^2 \sin(\Omega t) \tag{2}$$

Where,  $V_0$  denotes the amplitude and  $\Omega$  represents the frequency of the alternating current power supply. The mechanical energy of the system at any given time are stated as

$$T = \frac{1}{2}m\left(l^2\dot{\theta}^2 \cos^2 \theta + l^2\dot{\theta}^2 \sin^2 \theta + \dot{V}(t)^2 - 2l\dot{\theta}\dot{V}(t) \sin \theta\right) \tag{3}$$

$$U = mgl(1 - \cos \theta) - mgV(t) \tag{4}$$

Applying Lagrange’s equation for generalized coordinate,  $\theta$ , in the form of Eq. (5) to Eqs. (3) and (4) and after rearranging and writing compactly leads to Eq. (6).

$$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{\theta}}\right) - \frac{\partial T}{\partial \theta} + \frac{\partial U}{\partial \theta} - Q_\theta = 0 \tag{5}$$

Where,  $Q_\theta$  is the generalized force.

$$\ddot{\theta} + (g - \ddot{V}(t))\frac{\sin \theta}{l} = 0 \tag{6}$$

Substituting Eq. (2) into Eq. (6) and adding a linear viscous damping term for more realism leads to

$$\ddot{\theta} + 2\xi\omega\dot{\theta} + \left(\omega^2 + \frac{V_0\Omega^2}{l} \cos \Omega t\right) \sin \theta = 0 \tag{7}$$

Where,  $\omega = \sqrt{g/l}$ ,  $\xi$  is the damping coefficient and  $g = 9.81 \text{ m/s}^2$ . Equation (7) governs the spinning support pendulum oscillation. For large swing angles,  $\sin \theta \neq 0$ , the Maclaurin series for  $\sin \theta$  may be used and we truncate the series after  $0(\theta^3)$ , Eq. (7) therefore becomes

$$\ddot{\theta} + 2\xi\omega\dot{\theta} + \omega^2\theta - \frac{\omega^2\theta^3}{6} - \frac{V_0\Omega^2}{l} \cos \Omega t.\theta + \frac{V_0\Omega^2}{6l} \cos \Omega t.\theta^3 = 0 \tag{8}$$

According to control law, a second-order nonlinear controller is introduced and coupled to the pendulum spinning support model of Eq. (8) and ordered by a small approximation parameter  $\epsilon$  resulting in the suggested governing closed loop system equations

$$\ddot{\theta} + 2\xi\omega\dot{\theta} + \omega^2\theta - \frac{\omega^2\theta^3}{6} - \frac{V_0\Omega^2}{l} \cos \Omega t.\theta + \frac{V_0\Omega^2}{6l} \cos \Omega t.\theta^3 = \mu F_P \tag{9}$$

$$x + 2\xi_1\omega_1\dot{x} + \omega_1^2x = \mu_1 F_f \tag{10}$$

Where, Eq. (10) is the equation of the dynamics controller,  $\mu$  is the parameter of control signals sign,  $\mu_1$  is the parameter of feedback signals sign for the controller,  $\xi_1$  is the controller damping coefficient and  $\omega_1$  is the natural frequency of the controller. The control signals sign is selected such that  $F_P = x$  and the feedback signals sign as  $F_f = \theta$ . The closed-loop system equation is presented in in Fig. 2 as a block diagram.



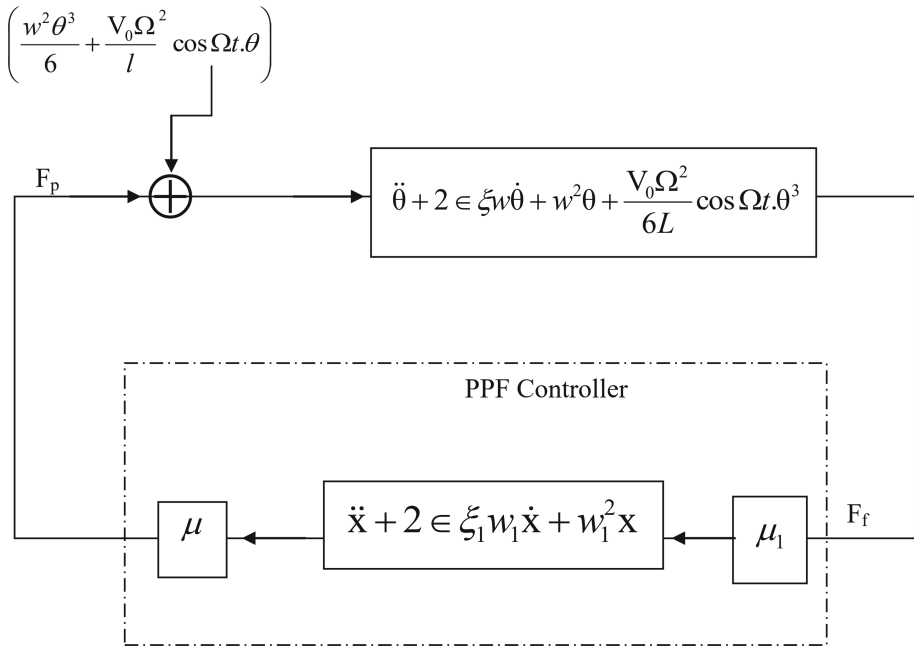


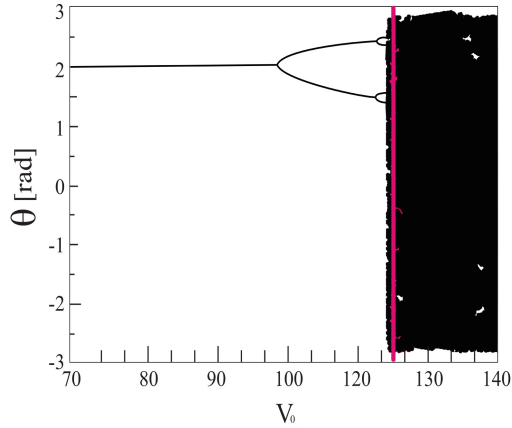
Fig. 2. A diagram of the closed-loop system.

### 3 Numerical Results

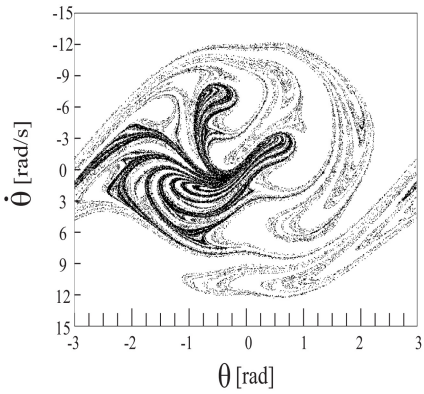
Numerical results of the ordinary differential Eqs. (9) and (10) are examined in this section. The Dynamics 2 software is used in this study as the computational basis for qualitative bifurcation assessments and to obtain the bifurcation set that expresses the boundary of the stable and unstable motions, with and without the control parameters of the governing equations. For the numerical calculations, if not indicated otherwise, the parameters are set to experimentally pragmatic values as follows,  $m = 1 \text{ kg}$ ,  $l = 0.25 \text{ m}$ ,  $\mu = 2.0$ ,  $\mu_1 = 2.0$ ,  $\omega = 6.6 \text{ rad/s}$ ,  $\omega_1 = 6.6 \text{ rad/s}$ ,  $\Omega = 13.2 \text{ rad/s}$ ,  $\xi = 0.04$ ,  $\xi_1 = 0.004$  and  $V_0 = 70 \text{ V}$ .

#### 3.1 Bifurcation Diagrams

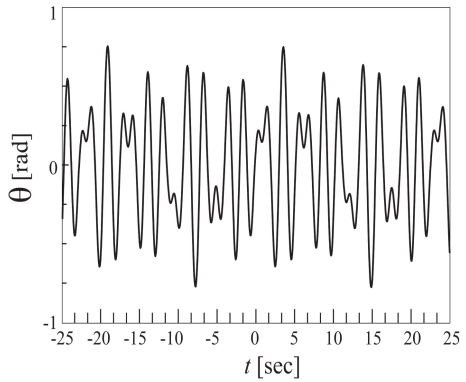
Bifurcation diagrams for the angular position  $\theta$  are considered for increased voltage amplitude  $V_0$  with initial value of  $V_0 = 70 \text{ V}$ , to provide a high-level overview of the dynamical system without and then with a PPF controller. For the uncontrolled system's behaviour, Fig. 3(a) shows a bifurcation diagram of period one to period doubling to period four leading to chaotic region calculated for  $\Omega = 13.2 \text{ rad/s}$ . A point at  $V_0 = 125 \text{ V}$  is picked in the chaotic region for further analysis leading to the chaotic attractor's Poincaré section as can be seen in Fig. 3(b) with its corresponding time plot in Fig. 3(c). The system dynamics analysis reveals that the spinning support pendulum may present a variety of solutions. From Fig. 3 the system's behaviour includes periodic, quasi-periodic, and chaotic responses when not controlled. As a result, bifurcation control



(a)



(b)



(c)

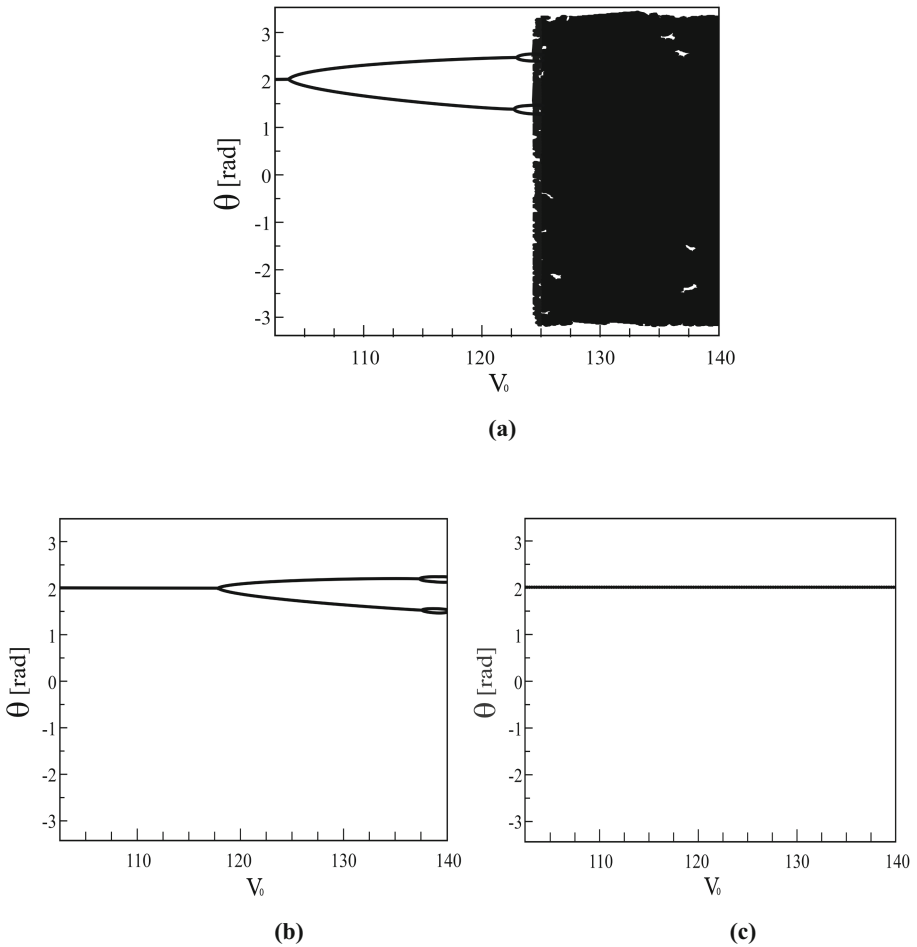
**Fig. 3.** (a) Bifurcation diagram for the uncontrolled system, (b) Poincaré section for the uncontrolled system at  $V_0 = 125$  V and (c) time plot for the uncontrolled system at  $V_0 = 125$  V.

is critical when considering the use of this pendulum in some applications and it is especially important to maintain a period one spinning orbit while escaping any form of unwanted bifurcation. A fascinating alternative is to stabilize a spinning solution placed in a chaotic attractor. With reference to the foregoing, bifurcation and chaotic control techniques will be employed.

### 3.2 Chaos Control

For the system to function in stable spinning mode, an avoidance of the qualitative changes in system response must be ensured across the entire parameter range. If chaos control methods are used, system bifurcations can be avoided (De Paula et al. 2012). The system's behaviour is studied when the PPF controller is activated. The learning stage of this control method is when what to be controlled is recognized and section of the control parameters are made.

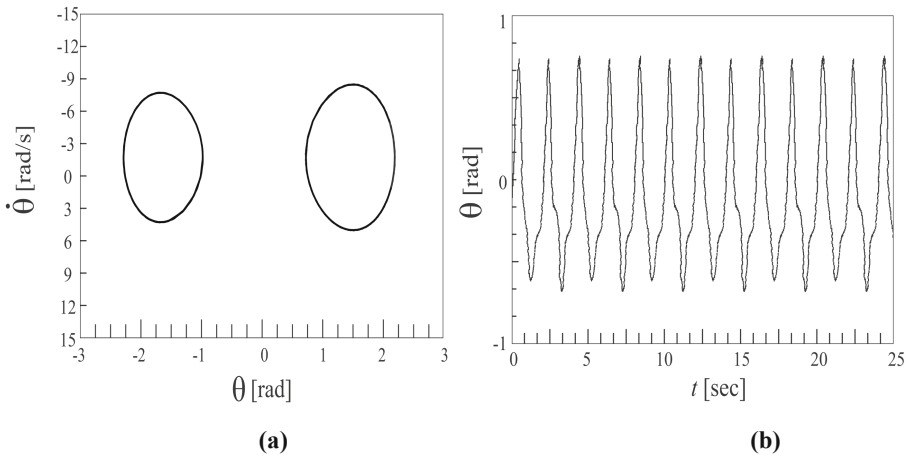
The bifurcation diagrams of the displacement of the pendulum at  $V_0 = 100$  V without control action can be referred from Fig. 4(a) and with control action seen in Figs. 4(b) and 4(c). In the latter figures, the bifurcation calculations are performed considering different



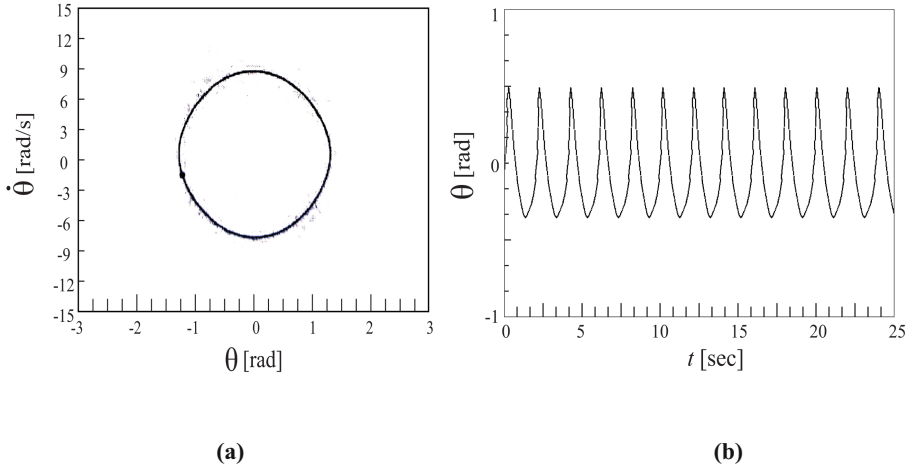
**Fig. 4.** (a) Bifurcation plot for the uncontrolled system at  $V_0 = 100$  V, (b) Bifurcation plot for the controlled system at  $V_0 = 100$  V,  $\mu = \mu_1 = 2.0$  and (c) Bifurcation plot for the controlled system at  $V_0 = 100$  V,  $\mu = \mu_1 = 2.5$ .

sets of control parameters:  $\mu = \mu_1 = 2.0$  and  $\mu = \mu_1 = 2.5$  respectively. Note that these parameters were selected after an extensive study of the system's behaviours. Observing Figs. 4(b) and 4(c) shows that bifurcation leading to chaos is avoided in both cases but that of Fig. 4(c) is more efficient to maintain the period one response. When bifurcation control is performed using different values of  $\mu$  and  $\mu_1$ , larger values of the  $\mu$  and  $\mu_1$  result in a more effective control, implying that the rotational solution's stability is maintained over a wider range of  $V_0$  and the period two motion observed in Fig. 4(b) becomes stable period one motion. This is illustrated in Fig. 4(c), where the period one rotational orbit stays stable during the entire range of  $V_0$  for  $\mu = \mu_1 = 2.5$ . It is crucial to highlight that the periodic orbits shown in Figs. 4(b) and 4(c) are obtained by stabilizing the original system's unstable periodic orbits. As a result, changing the parameter  $V_0$  causes a alteration in the response. This is accounted for by the control system.

Further analysis of the system at some excitation levels in Figs. 4(b) and 4(c) results in the plots in Figs. 5 and 6. Figures 5 and 6 show the Poincaré maps and time plots for the selected sets of control parameters of  $V_0 = 100$  V,  $\mu = \mu_1 = 2.0$  and  $V_0 = 100$  V,  $\mu = \mu_1 = 2.5$  displaying period two and stable periodic motions corresponding to their bifurcation diagrams in Figs. 4(b) and 4(c) respectively.



**Fig. 5.** (a) Poincaré map and (b) Time plot for the controlled system at  $V_0 = 100$  V,  $\mu = \mu_1 = 2.0$



**Fig. 6.** (a) Poincaré map and (b) Time plot for the controlled system at  $V_0 = 100$  V,  $\mu = \mu_1 = 2.5$

## 4 Conclusion

This work gives the analysis and bifurcation to chaos control of a spinning support pendulum system. The electromechanically excited system is coupled with a positive position feedback (PPF) controller to examine the system's stability to make it more effective in its practical applications, which include green energy scavenging. This concept necessitates that the system's spinning periodic response be maintained over a wide range of parameters. The bifurcation to chaos PPF controller is used in the stabilization of preferred rotational orbits for parameter values that are initially unstable. Once the controller parameters are properly tuned or selected, period doubling bifurcation is prevented, bifurcation to chaos is prevented and a stable spinning solution is maintained.

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# Efficiency Determinants in Tanzanian Private Hospitals: An Application of Tobit Model

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**Abstract. Purpose:** The study investigates sources of performance of private hospitals in Tanzania, the study also Investigates the direction and level of causality relationship between environmental factors and performance of hospitals.

**Design/Methodology:** The study used medical staff and number of beds as inputs while outpatient visits, admissions, post-admission days, outpatients' surgeries as well as the number of births were used as outputs in Data Envelopment Analysis (DEA) to measure efficiency. Data were extracted from the hospital annual report from the year 2002 to 2013. Tobit model was employed to measure factors that determine efficiency, where hospitals efficiency scores were treated as dependent variables while the environmental variables were used as the independent variables.

**Findings:** Findings revealed that Public Private Partnerships (PPP) and health insurance have positive causal relationships with hospitals efficiency while the Average length of stay, percentage of emergency room visits and percentage of births were found to have negative causal relationships with hospitals efficiency. In terms of the significance of causality, the Percent of emergency, percent of birth, number of beds and occupancy rate were significantly explaining the latent dependent variable of the model, the four variables were also found to have a positive causal relationship with the latent variable of the model.

**Research Limitations/Implications:** the study period covers the year 2002–2013 which seems appears not to include recent years, simply because of some missing data (information) in the recent year's hospital reports. The study also focuses only on the 17 hospitals out of 90 hospitals which are private not for profit hospitals in Tanzania. Hence, the future similar research will focus on the remaining 73 hospitals and try to use the most recent data going beyond the year 2013.

**Practical Implications:** knowledge derived from the findings of this study will inform the hospitals' administrators, owners on the factors that significantly determine the efficiency of their hospitals in the country.

**Social Implications:** contribution from this study will also tell what should be done in terms of review of health sector policy to make sure that scarce healthcare resources are efficiently utilized to realize Sustainable Development Goals relating to sustainable improvement in the economy.

**Originality/Value:** the study included environmental as possible factors that may determine the performance of hospitals such inclusion of which will inform hospitals administrators how the said significant factors should be handled and policymakers to revisit existing health policies for effective management of health facilities.

**Keywords:** Determinants · Efficiency · Hospitals · Public private partnerships · Tanzania

## 1 Introduction

After World War two, most of the Governments in developed and developing economies solely entrusted both production and delivery of public services to the public sector, example of such public services included transportation, health, education, defence, water, energy, telecommunication, etc. The public sector or public sector agencies entrusted are government's departments or state-owned enterprises (Grimsey and Lewis 2002; Harris 2003). The influence of this was the results of perceived market failure and imperfection associated with non-rivalry and non-excludability features of pure public services (public good). Initially, these features discouraged the private sector to invest in public services delivery as they may not be able to guarantee the return on their investment.

However, due to inefficiency experienced in this traditional approach many governments both in developed and developing economies have been giving away the traditional approach and adapting the new direction that encourages the private sector involvement in the provision of public services (including healthcare services). In the health sector particularly, literature contends that health service delivery using the traditional approach has proved to be indefensible as the sector mandated with provision of health services normally characterized by insufficient investments, inadequate budget, inefficient resource utilization, poor pricing policies, corruptions, overstaffing, mismanagement, and stagnation (Harris 2003; Rwelamira 2004). Due to increasing pressure demanding quality health care, many governments have been encouraging private counterparts to increase investment in the health sector to cover the gap. Due to dynamic performance in many economies, it is obvious that resources utilization for the health care system sector is not abundantly and constantly available. According to Eke and Oburota (2019) healthcare system comprises of different components, out of those health facilities constitute the major parts within the system and it consumes a larger part of the resources dedicated to the health system both in developing and developed economies. Wastage of resources is a serious challenge in the healthcare system of different countries, for example, according to the World Health Organization (WHO) it is estimated that on average, 20–40% of global total health spending is wasted (Asbu et al. 2020). According to Asbu et al. (2020) the need for increasing efficiency of health systems has drawn the interest of many researchers due to rapid growth in health expenditure fueled by both internal and external factors, for example, advancement in health technology and increasing expectations of the population regarding the quality healthcare. Literature has shown that technical inefficiency in health facilities continues to grow in different countries regardless of the level of the country's economic development, for example, WHO (2014) report that Globally almost US\$ 300 billion is lost annually on issues relating to the inefficiency of hospitals. Therefore, it is quite imperative to investigate factors that determine the hospital inefficiency hence recommends interventions to improve the efficiency of health facilities and entire health systems in general. The main objective of



this paper is to examine factors that determine the efficiency of private hospitals in Tanzania. Specifically, the study aims to: examine factors that are significant in determining the technical efficiency of private hospitals in Tanzania; and determine the causality relationship between environmental factors and the technical efficiency of hospitals.

The study is significant since the ongoing exponential growth of inefficiency in the health system and the projection of rising future trends have attracted the interest of many researchers, hospitals managers, and policymakers on what effective measures could contain health costs (World Health Report 2010). Though several measures have been applied to improve efficiency in health systems (Jacobs et al. 2006) in different countries, it is obvious that the most effective measures could yield good result after establishing the sources of technical inefficiency in the health systems. The remaining part of this paper organized as follows; Sect. 2 contains literatures regarding technical efficiency of hospitals in different countries. Section 3 covers the research techniques used in the study as well variables and data source, findings and discussion of the hospitals efficiency results, as well as discussion on findings, are presented in Sect. 4. Conclusion and recommendations are covered in section regarding Sect. 5. Due to the ongoing shortage of healthcare resources hospital managers or administrators need to establish the determinants of hospitals performance in order to ensure efficient utilization of healthcare resources (Bwana and Gwahula 2015), however, it is more important to determine the sources of (in)efficiency in order to have effective policy which ensure the best use of resources.

## 2 Review of Literature

There is exponential increase in the number of studies on hospitals technical efficiency in recent decades, the aim being the assessment of relative hospitals performance given the available scarce resources (Jacobs 2001). According to Li et al. (2014) a hospital is said to be technically efficient if an increase in output requires a decrease in at least one other output, or an increase in at least one input. Alternatively, a reduction in any input must require an increase in at least one other input or a decrease in at least one output. It should also be borne in mind that in the hospitals' resources include patients, physicians or plants (Kim and McCue 2008). This study is built on the *Resources Dependency Theory (RDT)*, the RDT advocates that the organization viability will dependent on the extent to which it can explore and utilizes the resources from the environment in which it is situated. According to Mudambi and Pedersen (2007) organization that can obtain the resources from the environment in which it operates exhibits greater power and can enhance its viability. In view of the RTD hospitals which can utilize resources (inputs) efficiently will manifest viability compared to those which cannot utilize the resources efficiently. However, the sources or determinants of efficiency could be rooted either from within or outside the organization. Therefore the gap that this study tries to bridge is how the environmental variables could determine hospitals efficiency in Tanzanian. From the study by Bhat and Jain (2006), increase in the hospitals patients leads to high occupancy rate which is an indication of the efficiency. Therefore, access to the six explanatory variables that are employed in this study is expected to have an impact on the efficiency of private hospitals in Tanzania. For example, from previous study by

Chang and Lan (2010) we predict the average length of stay (ALOS) to have positive association (positive coefficient) with hospitals' inefficiency due to the fact that as the hospital's ALOS increases the more resources are likely to be used to the same patients, and that would cause hospitals' technical inefficiency.

Cheng et al. (2015) stressed that the size of hospital as well as average length of stay (ALOS) are negatively related with hospitals efficiency, while the occupancy rate, bed-to-nurse ratio, and nurse-to-physician ratio are positively related with hospitals efficiency. From the previous study by Chang (2006) we predict that introduction of health insurance in Tanzania to have positive association with the hospitals efficiency; this is mainly caused by the fact that hospitals feel incentive to increase the hospitals outputs which are derived from demand from patients under the insurance cover. As far as health insurance is concerned there is another school of thought arguing that health insurance sometimes may have negative causal relationship with hospitals efficiency since hospitals can raise the prices of health services and fail to monitor the cost control hence lead to technical inefficiency. As far as Public-private partnership (PPP) status is concerned we expect PPP status to have positive causal relationship to the hospitals efficiency. PPP in healthcare in Tanzania relates to the autonomy and contribution of resources; that is as hospital engage in the PPP arrangements more resources (financial, medical equipment and human) are expected from the government therefore if no direct government involvement in operation then autonomy makes the hospitals technically efficiency to increase. Like in other countries, Contracting of health services is one of the major tools being used to enhance the performance of health services delivery in Tanzania, where the government (public and private sector) signed a service contract through which the risk, resources, objectives and rewards will be shared between the two parties (Bwana 2017). From the previous studies, the remaining explanatory variables (percentage of birth, percentage of emergency room visits and percent of minor surgery) are expected to have a positive causal relationship with the hospitals' technical inefficiency. The geographic boundaries of the sample involved in this study supported the assumptions that all hospitals involved were homogeneous with respect to environmental variables exogenous to the study, such as location (as most of these hospitals are situated in rural areas), demographic and professional personnel shifts, change in demand, utilization and reimbursement/payment procedures from the government or health insurance companies, wage rate and other resources costs and the general state of the economy.

### 3 Methodology

This study investigates determinants of efficiency using panel data extracted from 17 private hospitals over 12 years. The data was extracted from hospitals' annual reports over the year 2002 to 2013. The sample was drawn from a population of 90 private not-for profit hospitals in the country. We use a non-parametric approach known as Data envelopment analysis (DEA) to measure hospitals' efficiency and later on adopted a second stage of DEA to measure determinants of hospitals efficiency. The use of DEA (a non-parametric technique) was built on the ground that the sample was drawn from the population that did were not normally distributed, and literature also contended that the model is appropriate for measuring efficiency of not for profit firms. We tested the

normality of the independent variables using the Shapiro -Wilk W test. The statistic is positive and less than or equal to one, being close to one indicating normality.

We tested the Null hypothesis (Ho): that outcome was drawn from the population that follows normal distribution, against the Alternative hypothesis (H1): outcome was not drawn the population that doesn't follow the normal distribution. We rejected the null hypothesis at 5% level of significance since the p-value in all four variables was less than 5%, Shapiro-Wilk W was performed using STATA 10. Cooper and Schindler (2006) argued that a tool is said to be valid if it measures what it wishes to measure. To test reliability, from the Inputs and outputs used in the study the standardized tools was developed and used to test the alpha using SPSS 21 and found the reliability coefficient of 0.77 which was fairly enough. To attain high validity researcher had discussions with several experts from a similar area of study to test research instruments in a pilot study.

### 3.1 Sampling Techniques and Variables Selection

The aim of sampling is to obtain the representative group from the population such that the study can be conducted on the sample, and produce the accurate generalization about the population (Neuman 2006). Mapping of the non-for profit hospitals in Tanzania is under five zones, namely eastern, western, northern, southern, lake and central zone. From stratified sampling technique, each zone was treated as stratum and was represented by at least two or more hospitals. The main reason for adoption of stratified sampling was to make sure the study is more inclusive and have representative from each zone. Computation of hospitals efficiency requires inputs and outputs; inputs in health healthcare consist of labor, capital assets and/or other operational expenses. Labour is the main inputs category, is measured by the number of hours per patient per day by skill mix (this group include medical staff (such as doctors, nurses) and non-medical staff (such as administrators). Capital assets, mainly defined as plants, equipment and support technology, due to variations in the accounting practices of hospitals, number of beds in the units are used as the proxy measure to capture unit level of capital assets (Ozcan 2008). On the other hand, hospitals outputs depend on the appropriateness to the evaluation of the hospital's efficiency and easy availability of the data/information. The number of outpatients' visits has been consistently used as a measure of outpatient output. Similarly, the number of admissions and post admissions days (inpatients days-admissions) have been used as a measure of inpatient outputs (Rosko and Mutter 2010; Nedelea 2012). Therefore, outputs employed in this study include *outpatient visits, admissions, post-admission days, outpatients' surgeries as well as births.*

### 3.2 Data Envelopment Analysis (DEA) and Tobit Model

Data envelopment analysis (DEA) is a non-parametric technique which examines and establishes the 'best practice' frontier that is built empirically from the observed inputs and outputs and then each decision-making units is compared with its peers. DEA is the preferred method of efficiency analysis in the non-profit sector (Coelli et al. 1998), this makes the method more relevant to this study since this study we are focusing on the private not-for profit hospitals. Therefore, it is essentially designed to measure the relative efficiency of DMUs in an environment where there is the existence of multiple

inputs-outputs and no clear specific objective approach of aggregating either inputs or outputs into a meaningful index of productive efficiency (Ozcan 2008). Since the study involves two stage of DEA, variables used in measuring efficiency in the first stage of DEA are categorized into inputs and outputs, whereby Inputs variables are those that define resources used to produce outputs. Generally, DEA inputs in healthcare studies involve variables representing labour, capital assets and/or other operating expenses (Bwana 2015).

Generally, efficiency result is sensitive to the influence of outliers and measurement errors. In this part we present the analysis of the robustness of the efficiency scores using the Jackknife (Zere et al. 2006; Uslu and Pharm 2008; Pharm 2010). Jackknifing process involves the removal of efficient hospitals one at a time from the analysis, hence new efficiency measures are recalculated. The efficiency ranking of the model before removal of efficiency hospitals and after removal is compared. The similarity between the models is then tested using the spearman *Rank Correlation Coefficients*. If the correlation coefficient is zero (0) it implies no correlation between the rankings, meaning ranking between the models should vary. Indicating efficient hospitals are influential to the efficiency scores of other hospitals. The value of 1 or -1 implies the influence of outliers on hospitals' efficiency does not exist. Jackknifing was conducted on a year by year on average technical efficiency (CRS) and pure technical efficiency (VRS). The result indicates that the value of spearman rank order correlation coefficient of technical efficiency (CRS) was above 0.846 and for pure technical efficiency (VRS) was ranging between 0.6503 to 0.83322 which is significantly different from zero at 5 percent level of significance. This implies that efficient hospitals did not have serious influence on the efficiency of other hospitals. Since there was absence of linearity and most of these independent variables were not normally distributed we conducted further testing. Gujarat and Porter (2010) argued that heteroscedasticity can be tested using the white test, where the observed *chi-square* is compared with calculated one using  $N * R^2$ , where the N - is number of observation and  $R^2$  is R square. The rule of thumb if calculated is less than the observed chi square heteroscedasticity is not a problem in the model. From the data analysis (using SPSS 21) we found the chi square equals to 2162.92. Therefore, Chi square observed = 2162.96 Calculated  $N * R^2 = (408) (0.259) = 105.672$ . Therefore, due to absence of normality in the dependent variables, absence of linearity in the variables we used Tobit model to estimate determinants of hospitals technical efficiency, in the first stage we employed traditional DEA method to compute hospitals technical efficiencies. In the second stage to DEA, technical efficiency scores from first stage are regressed upon the environmental variables. Since the dependent variables (efficiency scores) in the regression are limited applying censored regression is useful (Sherman 2004; Chang 2006). The DEA model provides estimates for the technical efficiency scores in order to benchmark hospital performance. However, for the practitioners it is important to determine what are the causes/influencing factors that are significant in explaining inefficiency performance. In order to know factors that are significant in explaining the inefficiency performance *Tobit model* is relevant and explained as follows:

$$Y_i = X_i\beta + u_i \quad \text{if } X_i\beta + u_i > 0 = 0 \quad X_i\beta + u_i \leq 0$$

$$t = 1, 2, \dots, N$$

where  $N$  is the number of observations,  $Y_t$  is the dependent variables,  $X$  is the vector of independent variables,  $\beta$  is the vector of unknown coefficients and  $u$  is the independently distributed error term assumed to be normal with zero mean and constant variance  $\sigma^2$  following the study by Zere (2000), Kirigia and Azbu (2013), Greene (1993) we transformed the DEA efficiency score into inefficiency scores, left censored at zero using:

$$\text{Inefficiency score} = \left( \frac{1}{DEA} - 1 \right).$$

It is argued that the procedure helps in normalizing the DEA distribution and has convenience in the calculation. From the literature and previous studies variables that related to hospitals and that might have explanatory impact on the hospitals inefficiency were identified as: *percent of emergency room visit, percent of outpatient surgeries, percent of births, percent of NHIF/CHF admissions, ALOS, BED, OCC and PPP status*. Therefore, we summarize and establish the following Tobit Regression model:

$$Y_t = \beta_0 + \beta_1\alpha_1 + \beta_2\alpha_2 + \beta_3\alpha_3 + \beta_4\alpha_4 + \beta_5\alpha_5 + \beta_6\alpha_6 + \beta_7\alpha_7 + \beta_8\alpha_8 + \mu_t$$

Where  $Y_t$  - is the efficient score of private hospital  $t$ , computed based on the BCC Model under the VRS assumption,  $\alpha_1$ - is the percent of emergency room visits;  $\alpha_2$  - percentage of minor surgery (outpatient surgery);  $\alpha_3$ - percent of births;  $\alpha_4$ - percent of admission under the health insurance cover;  $\alpha_5$  - average length of stay;  $\alpha_6$  - Occupancy rate;  $\alpha_7$  - Number of bed per hospital,  $\alpha_8$ - public-private partnership status and  $u_t$  is the independently distributed error term assumed to be normal with zero mean and constant variance  $\sigma^2$ .ry.

## 4 Findings and Discussion

### 4.1 Robustness Consideration

Spearman correlation is a non-parametric measure of the strength/degree as well as the direction of the association between the two quantitative variables. It is normally measured as the ordinal scale. It is denoted by the symbol  $r_s$  (rho). Based on the fact that we are using the two stage of DEA (non-parametric analysis), we applied the spearman’s correlation to test for the strength and direction of association between inputs, outputs and explanatory variables in the Tobit regression model. Ruggiero and Vitaliano (1999), Coelli et al. (2005) argued that when using two-stage approach to DEA, the output variables and explanatory variables should be uncorrelated. Therefore, the correlation analysis was performed between the environmental variables and correlation between environmental variables along with inputs and outputs. The results showed that there is no strong correlation between the environmental variable, result also revealed that there is no strong correlation between explanatory variables and hospitals inputs and outputs

meaning that the requirement has been satisfied. As Uslu and Linh (2008) argued when the correlation is tested and result shows no strong correlation between the environmental variables as well as inputs and outputs, it is unlikely that the regression model will have multi collinearity.

**4.2 Determinants of Hospitals Efficiency**

Regarding the Public private partnerships (PPP) status finding revealed that as the hospitals engage in Public Private Partnership (PPP) its expected technical inefficiency decreased by 0.0167933 units, meaning negative causal relationship (Table 1). This implies that PPP coefficient assumes the negative sign, similar to our prediction that hospitals engagement into Public Private Partnership (PPP) would decrease the hospitals technical inefficiency. Nature of the PPP financing of health care in Tanzania, is much of sharing of resources (such as human resources, financial, hospitals equipment etc.), therefore hospitals’ administrators (and owners) have autonomy on the hospital’s operating activities. In line with such findings, our prediction has also been built on the assumption that as the organization becomes more autonomous (free from government direct influence), the more it is likely to be efficient (for example pricing of the products, resource utilization). Study conducted in Vietnam, Chang (2006) found that, as the hospitals become more autonomous (freedom from government influence) the more they become efficient, this is in line with findings revealed in this study. When compared to study by Nedelea (2012) which was conducted in USA, hospitals’ conversion was found to have positive and significant in explaining the inefficiency of hospitals. Unlike in this study where findings revealed that PPP have negative causal relationship to technical inefficiency though it is not significant in explaining hospitals inefficiency.

**Table 1.** Summary statistics of inputs and outputs variables

Variables	Observations	Mean	Standard deviations	Min	Max
Percentage surgery	204	.004118	0.0059641	0	0.0267676
Percent of minor surgery	204	.0508364	0.0977904	0	0.967153
Percent of birth	204	.3019791	0.3175442	0.182927	3.627186
Nhif/chf	204	.1169265	0.0200108	0.08	0.139
PPP or not	204	.7254902	0.4473648	0	1
ALOS	204	6.364461	2.064317	2.4	19.7
Number of beds	204	192.951	79.36203	40	527
Occupancy rate	204	0.8109672	0.835486	0.0558302	5.523699
Technical efficiency	204	1.150203	0.873158	0	3.589704

Findings revealed that the introduction of National Health Insurance (NHIF) or Community Health Fund (CHF) in financing of health services has a negative causal relationship with the hospital's inefficiency. Health insurance gives the new pattern of healthcare financing in Tanzania. In the study by Chang (2006) it was found that health insurance had positive causal relationship with hospitals' efficiency in Vietnam. It supports finding in this study, possible reason is the increase of outputs of health services motivated by increased in demand from the patients covered by insurance. The findings also conforms with the findings in a study by Hu et al. (2012) where it was revealed that social insurance reforms relate positively with overall hospitals technical efficiency in China. The result of positive causal relationship of average length of stay (ALOS) with the expected hospitals inefficiency in this study support the study by Chang (2006), where it was found that ALOS had negative causal relationship with the efficiency of public hospitals in Vietnam. In a similar study by Chang and Lan (2010) it was also found that ALOS has negative causal relationship with the hospitals efficiency in Taiwan, which also conforms to finding in this study. The argument is that as the ALOS increase it implies excess medical care given to same patients, which induce waste of healthcare resources, therefore both government and private owners should find how to discourage increase in ALOS and motivate competitive healthcare delivery.

The result of this study shows that percent of the emergency room significantly explain the negative causal relationship with expected hospitals efficiency (positively relate with hospitals technical efficiency). The logic is that as the percent of patients visiting emergency room increases resources would be used carelessly to serve life of patients. Coefficient percent of emergency room was relatively large compared to coefficient of other explanatory variables, which signify the amount of the impact it has on the hospitals inefficiency compared to other significant explanatory variables. When compared to previous studies, findings in this study supports result from Nedelea (2012) where it was found that percentage of emergency room visit had positive causal relationship with expected inefficiency of CAH hospitals in USA, unlike this study, in the study by Nedelea percentage of emergency room visit was insignificant. As far as percent of birth is concerned, exhibits positive causal relationship and significantly explaining the expected hospitals' technical inefficiency of private hospitals in Tanzania. The result is contrary to the finding in the study by Nedelea (2012) where the variable was not significant in explaining the hospitals' inefficiency. The possible reason for the difference is that in Tanzania, birth rate is high and the child delivery services is normally subsidized by the government which sometimes provide inadequate resources for primary health programs. This may lead to the change in use of available scarce resources (usage rate). Unlike percentage of birth, the percentage of minor surgery shows negative causal relationship with the expected hospitals inefficiency, but not significantly explains the latent dependent variable of the model (technical inefficiency). The result supports the study by Nedelea (2012) where the percentage of minor surgery had negative causal relationship with the hospitals inefficiency; however it was not significantly explaining the hospitals inefficiency in both studies.

Table 2 shows percentage of emergency, percent of birth, average length of stay and PPP status have negative coefficient of correlation to the dependent variable which is the hospitals technical efficiency. This implies negative causal relationship with the latent



**Table 2.** Output for the tobit model analysis

Variables	Coeff	Std error	t	p >  t	95% [confide interval]	
Percentage surgery	46.94901	11.66711	4.02	0.000	23.93982	69.9582
Percent of minor surgery	-0.8394007	0.441815	-1.90	0.509	-1.710715	0.0399139
Percent of birth	1.0119613	0.327464	3.11	0.002	0.3738083	1.665419
Nhif/chf	-1.600048	2.27938	-0.70	0.484	-6.095306	2.895211
PPP or not	-0.0169133	0.1039404	-0.16	0.871	-0.2218984	0.1880718
ALOS	0.0307499	0.018705	1.64	0.102	-0.0061408	0.0676405
Number of beds	0.0027312	0.0006086	4.49	0.000	0.4173041	0.0039312
Occupancy rate	-0.3106108	0.540698	-5.78	0.000	-0.4173041	-0.2040376
Cons	0.280715	0.2857026	0.98	0.327	-0.282731	0.8441609
Sigma	0.5053104	0.0410818			0.4242993	0.5863375

Source: Bwana (2015)

Summary obs: 9 left sencored observations at technical  $eff \leq 0$   
 Tobit regression

Log likelihood = -129.38384 LR Chi2(8) = 97.32  
 Prob>Chi2 = 0.0000  
 Pseudo R2 = 0.2733

94 Unsencored observations

101 Right sencored at technical  $eff \geq 1$

variable of the model. Specifically, the result shows regression coefficient of 46.94901, -0.8394007, 1.019613, -1.600048, -0.0169133, 0.0307499, 0.0027312, -0.03106708 for percent of emergency room visit, percent of minor surgery, percent of births, percent of NHIF admission, PPP status, ALOS, Beds and occupancy rate. It was also observed that positive coefficients were very low indicating very weak causal relationship between the variables and latent independent variables of the model, with exception of the percentage of emergency which has the coefficient of 46.95. The regression result shows that presence of the significant causality between the latent dependent variables of the model with the *Percent of emergency, percent of birth, number of beds and occupancy rate*, the four variables were significantly explaining the latent dependent variable of the model (hospitals technical inefficiency), the four variables were also found to have the positive causal relationship with the latent variable of the model. For example, it was observed that one-unit increase in percent of emergency room visit would lead to an increase in hospital’s expected inefficiency score by 46.945 units, holding other variables in the model constant. Coefficient of percent of birth also has assumed the positive sign, this is also conforming to our prediction that as the percent of birth increases the it



may lead to hospitals' inefficiency since some birth admission requires special attention and may need more than expected resources, this may lead to hospitals technical inefficiency. One-unit increase in percent of births would lead to an increase in hospital's expected inefficiency by 1.019613 units, holding other variables in the model constant. On the other hand, number of beds per hospitals assumed the positive sign, one-unit increase in number of beds would lead to an increase of expected technical inefficiency by 0.0027312 units. The result of occupancy rate assumed the negative sign, It was observed that one percentage increase in occupancy rate would lead to a decrease of technical inefficiency by 0.3106708 units.

Percent of NHIF/CHF of admission has negative causal relationship on the hospital technical inefficiency, for example one-unit increase in percent of NHIF/CHF admission would lead to a decrease of expected inefficiency by 1.600048 units, given that all other variables in the model are held constant. The average length of stay (ALOS) was one of the explanatory variables found to have positive causal relationship with the latent dependent variable of the model (technical inefficiency). For example, one-unit increase in the (length of stay) ALOS would lead to an increase in the expected technical inefficiency of CDHs by 0.0307499 holding other variables constant. PPP status assumed the negative causal relationship with the latent variable of the model, one-unit increase in the PPP activities would lead to the decrease of the expected technical inefficiency of CDHs by 0.0169133 other variables being constant. Percent of minor surgery was found to have negative causal relationship with latent variable of the model, one-unit increase in percent of minor surgery would lead to decrease in expected technical inefficiency by 0.8394007 holding other variables of the model constant.

## 5 Conclusion and Implications

This study aims to examine factors that determine technical efficiency of private hospitals in Tanzania, the study uses efficiency scores (dependent variables) obtained from the first stage of DEA model and environmental variables (independent variables such as *percent of emergency room visits; percentage of minor surgery (outpatient surgery); percentage of births; percent of admission under the health insurance cover; average length of stay (ALOS); Occupancy rate; Number of bed per hospital, public-private partnership status*) in a Tobit regression model to determine factors that affect hospitals efficiency. The study concludes that extent of autonomy in delivering of healthcare services without being interfered and extent of healthcare services offered under insurance cover have positive causal relationships with technical efficiency of private hospitals. On the other hand, extend of resources spent on the emergency room visits, extent to which more resources are spent to one patient (measured by average length of stay) as well as number of birth have negative causal relationships to technical efficiency of private hospitals in Tanzania. The regression result shows that presence of the significant causality between the latent dependent variables of the model with the *Percent of emergency, percent of birth, number of beds and occupancy rate* the four variables were significantly explaining the latent dependent variable of the model (hospitals technical inefficiency), the four variables were also found to have the positive causal relationship with the latent variable of the model. Practical implications is that an increase in percent of emergency

room visit would lead to an increase in hospital's expected inefficiency, holding other variables in the model constant, this is exactly the same to our initial predictions. We predicted that the increase in the percent of emergency would have disturbed the usage rate of hospitals scarce resources, and hence lead to technical inefficiency. Therefore, this study recommends that resources in the emergency room need proper management as mishandling of such resources may have a significant negative impact on the performance of hospitals. Coefficient of percent of birth also has assumed positive sign, this is also conforming to our prediction that as the percent of birth increases the it may lead to hospitals' inefficiency since some birth admission requires special attention and may need more than expected resources, this may lead to hospitals technical inefficiency. On the other hand, number of beds per hospitals assumed the positive sign, this is the same as our prediction that as the hospitals' number of bed increases while the admitted patients is the same or decrease then the hospitals can experience technical inefficiency since many bed will remain unoccupied. The result of occupancy rate assumed the negative sign, this also is similar to our prediction that an increase in occupancy rate shows the utilization of the hospitals assets (Bed and FTEs), therefore it would lead to decrease in hospitals technical inefficiency. The introduction of national health insurance has negative causal relationship on the hospital technical inefficiency. These findings also imply that number of beds and occupancy rate may have implications on the early discharge of patients since the number of beds is fixed in the hospitals, if not properly handled this may affect the quality of healthcare in the health system.

This study recommends that since the percentage of emergency visit was negatively relating to hospitals technical inefficiency, hospitals administrators are urged to adopt policy that allows resources mobility particularly when emergency room visit is at peak so as to encourage efficient utilization of the available resources. Since increase in number of beds positively relate with the hospitals inefficiency, the study recommends existing bends should be fully utilized to maintained or increase hospitals occupancy rate which is an indicator of hospitals efficiency. The study further recommends that, future research should focus on the factors that determine performance in public hospitals to provide the platform for comparison between private hospitals and public hospitals.

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# Engine Performance Evaluation Using Biodiesel Blends: Comparative Testing Using Mixed Edible Oils, Mixed Non-edible Oils, and Petroleum Diesel

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**Abstract. Purpose:** This study examines an engine's performance using biodiesels produced from mixed edible oils (coconut and palm) and mixed non-edible oils (Desert Date and Neem) blended with petroleum diesel.

**Design:** The biodiesel was blended with petroleum diesel, and its properties were determined in the laboratory. After that, an engine test was conducted by applying different loads on a four-stroke diesel engine. The engine performance measured mechanical efficiency, brake specific fuel consumption, thermal efficiency, and exhaust temperature. Furthermore, a gas analyser was utilised to measure emissions.

**Findings:** The results indicate that the biodiesel blends CPB20 (diesel, coconut, and palm oil) and DNB20 (diesel desert date and neem oil) had lower emissions, better fuel characteristics, and engine performance compared to petroleum diesel (D2).

**Research Limitation/Implication:** The study was limited to only a four-stroke diesel engine during the engine test experiment at the laboratory.

**Practical Implication:** Biodiesel production from blending mixed edible oils (coconut and palm) and mixed non-edible oils (Desert Date and Neem) are potential fuel substitutes for diesel engines utilised in Ghana. This could contribute to Ghana's Renewable Energy Masterplan, which encourages and promotes liquid biofuels blending from locally available crops.

**Social Implication:** The findings advanced in this study would prompt decision-makers to consider facilitating investment in biodiesel production from mixed non-edible oils (Desert Date and Neem) to help improve air quality and reduce greenhouse gas emissions.

**Originality/Value:** This study innovation provides an in-depth investigation and comparison (based on fuel characterisation and full engine tests) of mixed edible plant oils (coconut and palm) and mixed non-edible plant oils (Desert Date and Neem) biodiesel blends.

**Keywords:** Alternative fuel · Blends · Edible oils · Engine tests · Non-edible oils

## 1 Introduction

The global economy's expansion necessitates the development of renewable energy sources capable of replacing petroleum fuels. The current petroleum-based economy is unsustainable due to its environmental consequences, economic reliance, and lack of energy security. Biodiesel is regarded as a potentially viable replacement fuel for diesel engines. Biodiesel can be produced from edible and non-edible plants, and these fuels have been highlighted as biodegradable, renewable, less harmful, and reducing reliance on petroleum-based fuels. However, the primary impediments to biodiesel derived from edible plant oils and fats are food production constraints, cost, and availability (Maina 2014).

Currently, non-edible plant biodiesel feedstocks are abundant in developing nations, including Ghana, and more cost-effective than food oils (Demirbas 2008). The use of edible and non-edible plant biodiesel is limited due to unfavourable physical qualities, such as viscosity, which is around 10–20 times that of petroleum diesel. These characteristics result in insufficient atomisation of the fuel, inefficient combustion, and the formation of carbon deposits (Mishra and Ha 2016). The efficient blending of fuels avoids these problems and improves the fuel's performance in an engine (Jaichandar and Annamalai 2011). Thus, this study proposes a blend of mixed edible plant oil biodiesel and mixed non-edible plant oil biodiesel with petroleum diesel to test the engine performance. Several notable studies have revealed that B20 (a blend of 20% biodiesel and 80% petroleum diesel) is a potential substitute for petroleum diesel since it emits fewer carbon monoxide (CO), carbon dioxide (CO<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>) emissions, smoke density, and is as viscous as petroleum fuel (Gad et al. 2018; Al Dawody and Bhatti 2014; Phadatare and Raheman 2004; Ghaley et al. 2010; Mensah et al. 2013; Maina 2014; Chavan et al. 2014). The reasons above limit this study test to only mixed oil blends of B20 (20% Biodiesel + 80% Diesel). Engine performance testing using biodiesel derived from fresh mixed edible and non-edible plant oils is relatively new and less explored. However, previous studies focused on the use of mixed waste oils and pure unmixed oils. At the moment, no study has highlighted an in-depth investigation and comparison (based on fuel characterisation and full engine tests) of mixed edible plant oils (from coconut and palm) and mixed non-edible plant oils (from Desert Date and Neem) biodiesel blends.

The study objectives are (1) to assess the performance of diesel engines by utilising biodiesel produced from mixed edible and mixed non-edible plant oils and (2) to investigate the impacts of blending mixed edible and mixed non-edible plant oil biodiesels with that of petroleum diesel. The study findings are pertinent to policymakers, investors, and decision-makers towards developing biodiesel as a replacement for diesel engines in developing countries for sustainable development.

## 2 Materials and Method

### 2.1 Engine Testing

The experimental testing was conducted with a four-stroke diesel engine. The diesel engine's specifications are listed in Table 1. Figure 1 illustrates the engine testing components' linkages. The component was set up, and the technique was adopted from Maina

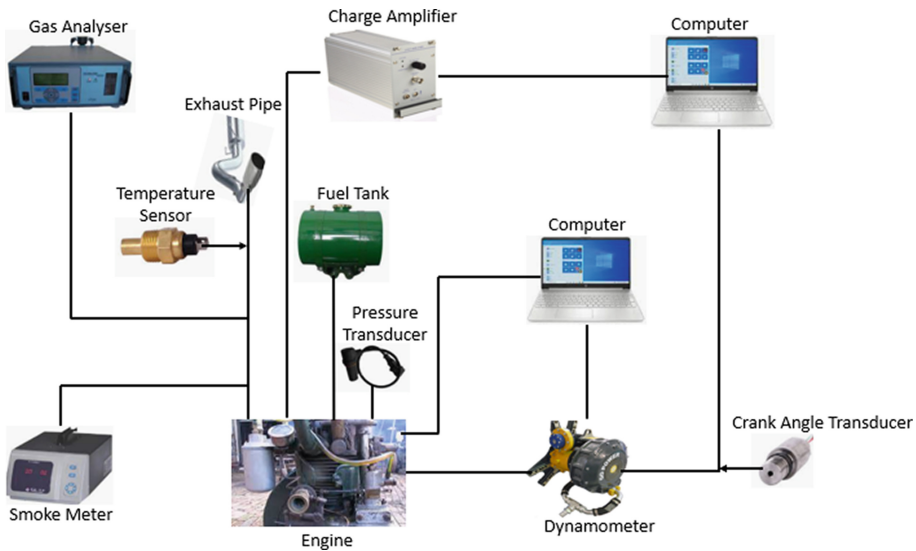
(2014). The engine was connected to a dynamometer to create brake load, whereas a computer regulated the engine’s throttling and dynamometer configuration. Inside one of the piston cylinders, a pressure transducer was mounted. The charge amplifier amplified the cylinder pressure signals from the pressure transducer and coupled them to the computer to obtain data. Externally, the crank angle transducer activated the data acquisition system approximately 1,024 times each revolution. Fuel was introduced via a flow metering device installed in a fuel tank. Throughout the fuel switching, the fuel tank was drained of the engine fuel, new fuel was added till the fuel filter became filled, and the engine was restarted and left running for some time to clean the fuel lines and stabilise. Thereafter, a gas analyser was utilised to measure carbon dioxide, carbon monoxide, total hydrocarbons, and nitrogen oxide emissions from the engine exhaust pipe. A smoke metre was linked to the engine exhaust pipe to measure smoke emissions.

The two biodiesels are produced from (1) Mixed edible plant oils of Coconut and Palm and (2) Mixed non-edible plant oils of Desert Date and Neem through transesterification with alcohol in the presence of potassium hydroxide (KOH) as a catalyst. The biodiesels were volumetrically blended with petroleum diesel to produce the following blends.:

- 80% diesel + 20% mixed coconut and palm oil biodiesel = CPB20
- 80% diesel + 20% mixed desert date and neem oil biodiesel = DNB20

**Table 1.** Engine test specification

Manufacturer	Victor diesel engine
Engine	Number 42
Type	Single cylinder, 4 stroke, vertical compression, air-cooled, fixed throttle
Cylinder Bore	80 mm
Torque arm	10 mm
Stroke	100 mm
Swept volume	0.5 L
Fuel	Diesel
Maximum speed	1500 rpm
Brake power	2.982 kW at 1500 rpm



**Fig. 1.** Engine test layout

### 3 Results and Discussion

#### 3.1 Physico-chemical Properties Characteristics of Biodiesel-Petroleum Diesel Blends

Table 2 shows the physicochemical characteristics of the tested biodiesel blends. It can be observed that CPB20 and DNB20 blends exhibited a lower density than petroleum diesel, though their density differences are small. Similarly, CPB20 and DNB20 blend cetane numbers are far higher than petroleum diesel. This implies that CPB20 and DNB20 are more likely to auto-ignite when compared to petroleum diesel. In light of this, a higher cetane number of biodiesel blends could be attributed to the biodiesel chemical composition, which increases the fuel's capacity to auto-ignite and combust efficiently (Mensah et al. 2013). Also, the biodiesel blends' sulphur content was significantly lower than petroleum diesel, with values of 0.91 ppm for CPB20, 0.07 ppm for DNB20, and 45 ppm for petroleum diesel. The results also show that the viscosity of the blends outshines that of petroleum diesel. Likewise, the blended pour point temperature is significantly lower and comparable to that of petroleum diesel. Moreover, the blended carbon residues are far lower than diesel. The carbon residues normally form at high temperatures form a carbon deposit and give the fuel the tendency to develop carbonaceous deposits. However, there is a weak relationship involving carbon residue and the performance of diesel engines (Mensah et al. 2013). Furthermore, how diesel engines burn their fuel and how much deposit accumulates on the engine can influence engine loading and tuning, as well as fuel ignition properties (Kittiwake Developments 2013).

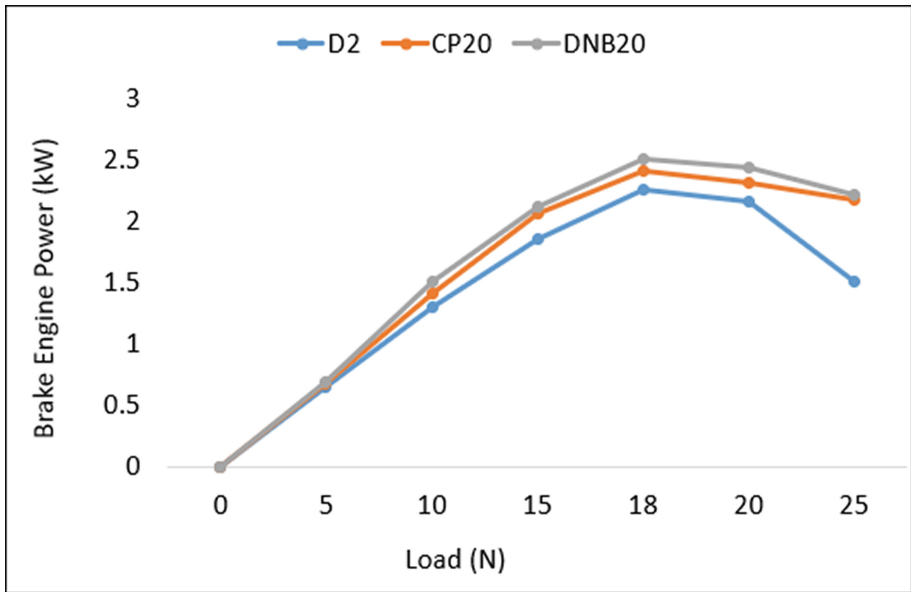


**Table 2.** Comparison of CPB20 and DNB20 biodiesel and petroleum diesel

Fuel type	Density at STP (Kg/m <sup>3</sup> )	Viscosity mm <sup>2</sup> /s (cSt)	Calorific value (KJ/Kg)	Cetane number	Sulphur content	Carbon residue (%wt)	Pour point (°C)
Diesel fuel	860	4.1	45316	4.2	45	0.35	-6
CPB20	824	3.93	44130	51.8	0.91	0.027	-9
DNB20	847	3.81	44011	65.8	0.07	0.016	-6

### 3.2 Brake Power of Engine

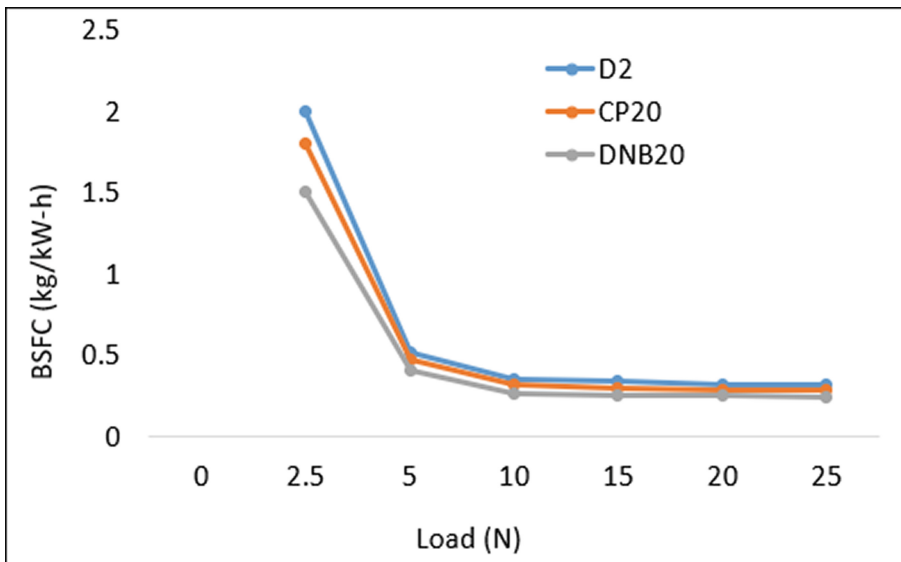
Figure 2 depicts the fuel’s impact on engine brake power as a function of load. It can be observed that the engine’s brake power surges with load, reaches a maximum at a certain point, and then gradually decreases with a greater load. In fact, this is the general performance of a brake power engine. Also, it can be observed that CP20 and DNB20 exhibited a higher brake engine power than petroleum diesel (D2) for all the loads, contrary to the findings of many other researchers. This might be due to the calorific values of the blends being very close to those of the standard diesel and diesel blends having a very high cetane number. The blend from the mixed non-edible biodiesel (DNB20) gives the highest brake power. Generally, a fuel heating value affects the power of an engine.



**Fig. 2.** Fuel impact on brake power at different loads

### 3.3 Engine Brake Specific Fuel Consumption

Figure 3 represents the fuel impact on brake specific fuel (BSF) consumption at different loads. Under low load, the amount of fuel that provides enough torque to drive the engine is high, resulting in a high fuel consumption rate. However, at higher loads, torque requirement is low, resulting in reduced fuel consumption, and this tendency is similar to the findings of Jaichanda and Annamalai (2011). In comparison to petroleum diesel, the DNB20 blend has the lowest BSFC by a difference of 25.2%, followed by the CPB20 blend with a difference of 9.6%. These differences might be attributed to the enhanced fuel usage caused by the high oxygen gas level in the mixed oil biodiesel blends.



**Fig. 3.** Fuel impact on brake specific fuel consumption at different loads

### 3.4 Exhaust Gas Temperature

Figure 4 depicts the connection between exhaust gas temperature and load. Generally, the exhaust gas temperature increases with load and determines an engine's combustion efficiency (Pramod and Sivanesan 2019). The exhaust temperatures are lower for the CPB20 and DNB20 mixed blends, with the mixed non-edible biodiesel blend (DNB20) having the lowest compared with the CPB20 and pure petroleum diesel. Thus, the DNB20 blend will perform better by giving a higher thermal efficiency than the CPB20 blend and the petroleum diesel.

### 3.5 Thermal Efficiency

Thermal efficiency is a key measure of how effectively the chemical energy stored in the input fuel is transformed to useful output. Figure 5 demonstrates that the thermal efficiency of all fuels started rising as the load increased. The thermal efficiency of the mixed oil biodiesel blends was greater compared to diesel fuel. This finding agrees with the findings of Pramod and Sivanesan (2019) and Agarwal and Das (2001). The results show high thermal efficiency of nearly 27% (for petroleum fuel) and nearly 29% and 31% for CPB20 and DNB20, respectively. This improved thermal efficiency of the biodiesel fuels could be attributed to the better lubricity, coupled with a high concentration of oxygen in the fuel, which facilitates incomplete combustion (Mensah et al. 2013).

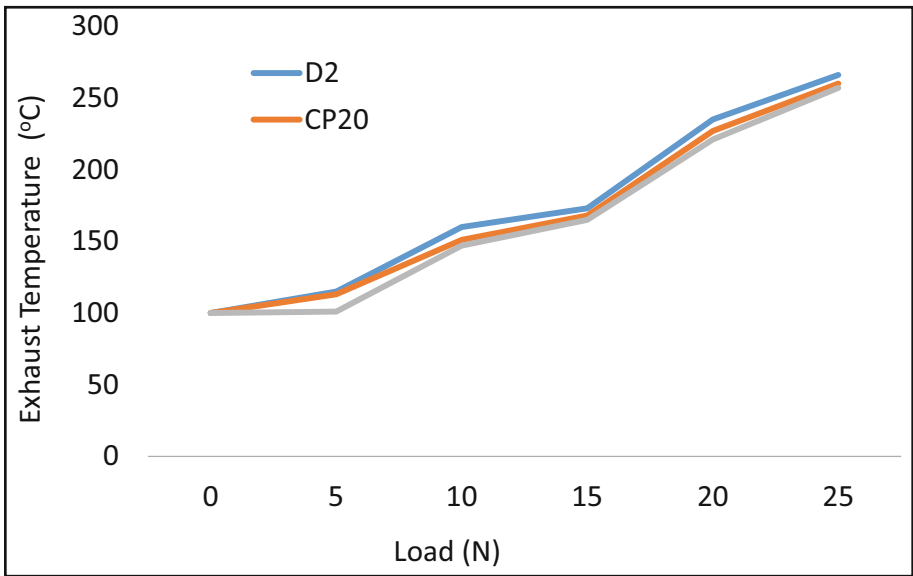


Fig. 4. Fuel impact on exhaust gas temperature at different loads

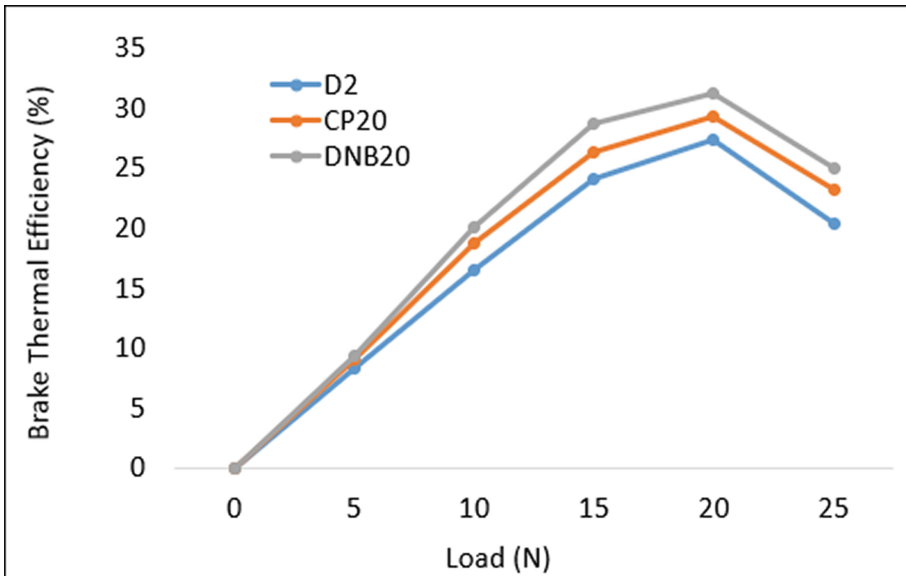


Fig. 5. Fuel impact on brake thermal efficiency at different loads

## 4 Conclusion

From the experiments conducted on the diesel engine and tests for some fuel properties to compare biodiesels from mixed edible plant oils and mixed non-edible plant oils with petroleum diesel, the following results were obtained:

- CPB20 (diesel, coconut, and palm oil) and DNB20 (diesel desert date and neem oil) biodiesel blends brake power and thermal efficiencies are high, but the exhaust temperatures are low.
- Break specific fuel consumption for the two blends was lower than petroleum diesel.

Thus, it can be concluded that blends of CPB20 (diesel, coconut, and palm oil) and DNB20 (diesel desert date and neem oil) could be utilised as alternative fuels in diesel engines and that their viscosities are similar to that of petroleum diesel, with the DNB20 producing the best of all the results.

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# Colonialism and the Criminalization of Traditional Fishing in Mwanza, 1890–1960

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**Abstract. Purpose:** This paper develops an understanding of the colonial policies and their influence on the criminalization of traditional fishing in Mwanza, Tanzania. In an attempt to achieve this goal, the two objectives are the need of the colonialists to replace the indigenous species of fish which were branded trash fish, they need to transform fishing from a traditional undertaking into a commercial undertaking.

**Methodology:** This study employed a qualitative approach which employed both primary and secondary sources of data. The primary source of data involved interviews and archival research. The sample size for this study was based on data saturation.

**Findings:** Findings revealed that the introduction of colonial policies criminalized traditional fishing because the local people were forced to abide by the new regulations which limited their fishing practices.

**Research limitation:** The study focused on colonial policies as key determinants to the criminalization of fishing in Mwanza, Tanzania. Therefore the study concentrated on the Mwanza region, representing other regions where fishing activities take place.

**Practical implication:** The information generated from this study would inform the local fishing communities of the background factors which influenced the establishment of several regulations which hindered their participation in fishing.

**Social implication:** The knowledge advanced in this study would help policy-makers in the fisheries sector to design the policies in such a way that the policies do not hinder the local communities to participate in fishing.

**Originality/Value:** The uniqueness of this study lies in its historical narration of criminalization of traditional fishing.

**Keywords:** Colonial rule · Fishing · Illegal fishing · Lake Victoria · Nile perch

## 1 Introduction

For quite several years, fishing has acted as a subsistence activity for the local people in Mwanza and other areas bordering Lake Victoria. Traditional fishing practices guided by the local chiefs under customary regulations served as an important tool to

achieve the aforesaid goal. However, this goal was deterred by the colonial policies which transformed fishing from a traditional undertaking into a commercial activity leading to the adoption of new regulations to guide commercial fishing. As a result, the implementation of colonial policies and the new regulations ended up excluding traditional fishermen from the fishing industry through criminalizing the traditional fishing practices. In response to this scenario, this study explored how colonial policies acted as a catalyst for the criminalization of traditional fishing practices. This study, which is based on the third chapter of my Ph.D. thesis, is guided by one major objective which sought to examine the influence of colonial policies on the criminalization of traditional fishing practices in Mwanza, Tanzania.

The concept of illegal fishing, as it has been described during the colonial period, is believed to have been invented by colonial rule through a set of various policies. The notion was almost non-existent before the establishment of colonial rule in the early 1890s. During that time, the idea of illegal fishing had a very narrow scope as it excluded most aspects of fishing under traditional fishing practices. Most fishing practices which were branded illegal during the colonial rule were traditionally permissible under the overseers of the local chiefs and the customary regulations. Evidently, before the establishment of colonial rule, the scope of “illegal fishing” was hardly defined beyond the observation of the customary regulations. Whatever malpractices related to traditional fishing were limited to customary restrictions and cultural taboos which guided the conduct of fishing activities along various fish landing beaches. Therefore, the local communities living along Lake Victoria were bound to observe the local norms which were put in place to ensure the proper conduct of fishing in the lake (Fulgencio 2009). The local chiefs could, therefore, set principles that were to be followed by the local fishermen to ensure that sustainability in fishing was maintained (Opondo 2011). They could as well punish those who contravened the customary regulations (Opondo 2016).

The customary regulations also acted as the major custodian of fishing in the absence of formal legal procedures. Ideally, the local fishermen had free access to the lake provided that they acted upon the local norms. Those who contravened the customary regulations were punished to pay compensation for the damage they caused. The establishment of colonial rule in the 1890s changed the general atmosphere surrounding the fishing industry in the area bordering Lake Victoria. Colonialism advocated for the establishment of new policies which broadened the scope and the horizon of illegal fishing. The implementation of these policies, which were administered by the colonial personnel, ended up criminalizing several traditional fishing practices which contradicted the colonial interests. In due course, the local fishermen were forced to abandon some traditional fishing practices and abide by the colonial regulations. Although in most countries customary regulations co-existed with colonial practices; the colonialists tended to discourage the customary laws which happened to threaten their interests.

## 2 Research Methodology

This study employed a qualitative approach under which the researcher employed both primary and secondary sources of data. The primary source of data involved interviews and archival research which was conducted in the Tanzania National Archives in Dar es

Salaam and Dodoma, Tanzania. Archival sources were accessed and identified through printed or published guides, indexes, finding aids, subject-based research guides, and catalogs. The secondary sources of data involved the documentary publications done by other researchers. The sample size for this study was based on data saturation.

### 3 Fish Taboos as Management Tools to the Local Fishing Communities

Taboo in an African context is referred to as a dangerous behavior that is forbidden to a particular society to serve various social significances. It is viewed as something which is concerned with social mechanisms of compliance which carry ritual significance with specific and restrictive behaviour in dangerous conditions (Essel 2018, p. 373). Omobola (2013, p. 222) has presented taboos as a historical construct in the sense that they were initiated from early man's initiatives to describe nature and his survival, to propitiate fate and invite fortune; to evade evils he could not recognize and to pry into the forthcoming events. Historically, the origin of taboos differs from one place to the other depending on the socio-cultural practices of a particular society. Anthropological explanations believe that taboos originated from cultural experience (Fershtman et al. 2011, p. 140). Among the Igbo society of Nigeria, for example, taboos are believed to have originated from conflicts, whereby some communities that were invaded adopted new names and developed totems and taboos to honour the spiritual forces that are believed to have saved them during the intrusions (Orij 2009). In many traditional African societies, taboos have been used to provide a set of instructions that serve as moral guidance in a particular society to guarantee a harmonious environment in that particular society (Omobola 2013, p. 223). Its violation, therefore, signified an offence against ancestors and the Supreme Being which would, in turn, result in various misfortunes such as crop failures in farmland; poor catches in the lakes, sickness, hunting accidents, famine, drought, and epidemic to mention just a few (Dosu 2017).

To traditional fishing, taboos are referred to as the spiritual-temporal rules that were used to oversee and control fisheries resource use by members of a respective fishing community (Fulgencio 2009). The taboos and other social-cultural beliefs were practiced in several socio-economic and cultural sectors of human societies. In the fishing sector, taboos have occupied a central position in most traditional African societies from the pre-colonial period to the post-independence era. They have been viewed as conservation tools given that they have been used to promote the sustainable exploitation of fish resources. Among the Luo society in neighbouring Kenya, the use of strong-smelling soap for bathing was considered taboo on the ground that it polluted the water sources leading to the death of fish resources (Opondo 2016, p. 206). On the Kenyan part of Lake Victoria, taboos were reported to have been common around the sacred trees which were believed to be the residences of the spirits. In these areas fishing activities were strictly prohibited. The situation was more or less the same along the Mgingo Island which was believed to have been inhabited by unsympathetic spirits. As such, from the pre-colonial period the area was left unoccupied by fishermen and no any fishing activities took place therein. Fishermen were not allowed to either step their feet on the island or to utter a word if they happened to see any creature nearby Mgingo (Geheb 1997). Fishermen



and the surrounding communities considered the area to be the dwelling place for the ghost spirits. In addition, the island was believed to have been occupied by nightmares, unpredictable weather, and the beasts that used to conquer the island at midnight (*The Guardian*, Sunday 9<sup>th</sup> August 2009). A somewhat similar situation was observed on the Tanzanian side of the lake in islands like Nyiregenge, Lutilwa Mugabo, and Ukara, where dangerous ghosts were believed to have settled in those areas (*The Guardian*, Sunday 9<sup>th</sup> August 2009).

In other Tanzanian parts bordering Lake Victoria taboos related to fishing have been observed on several fish landing beaches. The fishing communities in Bukoba believed in *Mugasha*, the spirit of water and fish, which was regarded by many as the hero of fishermen. All fishermen who adored *Mugasha* had to invoke him and provide offerings to him before and after carrying out fishing activities, otherwise, it was believed, they would most likely fail to catch fish and at the same time face terrible weather conditions in the lake. Offerings were mostly made in small houses stationed on the coast of the lake to serve that purpose (TNA- File No. 1/EQN). *Mugasha* was believed to be the custodian of the lake and all its belongings. In the most recent past, the elders in Bukoba maintained a belief that heavy storms were caused by the angry *Mugasha*. Thus, whenever damaging storms happened, some clan elders carried out ritual practices to calm *Mugasha*. However, to a younger generation of fishermen, such practices have been rarely observed. *Mugasha* was believed to possess spiritual powers which enabled him to control the wind, rain, and thunderstorms (TNA- File No. 1/EQN). In Buganda, such powers were vested in *Mukasa*, who was the god of the lake and fishermen. Fishermen used to pray to *Mukasa* to ensure maximum catches and calm weather during all their encounters in the lake (Schoenbrun 2018, p. 401).

The socio-cultural beliefs and taboos associated with fishing were as well observed in areas other than Lake Victoria. In Ghana, for instance, the Jamestown fishing community was reported to practice several taboos that were associated with fishing. The most common taboo to this fishing community prohibited fishing activities on Tuesdays on the ground that the violators would encounter a serious misfortune and eventually lost their lives. Fishermen in this community believed that their fishing activities were directly influenced by various beliefs and taboos in the sense that when the taboos and beliefs were observed fishermen obtained high catches and they were guaranteed protection from various misfortunes (Dosu 2017). Another taboo related to fishing was observed among the people of Busua fishing village in Ghana where people used to perform annual rituals by offering the sacrifice of a monkey to honour and give thanks to *Nana Bokwa*, the island god of Busua, for guaranteeing security and protection to fishermen and the general public of Busua. A group of elders collaborated with the traditional priests and the principal fisherman to perform the annual ceremony (Adjei and Bright 2019, p. 12).

## 4 Discussion of Findings

### 4.1 Colonial Policies and the Criminalization of Traditional Fishing

Findings for this study revealed that the establishment of colonial rule in the early 1890s transformed the general conduct of traditional fishing in the area bordering Lake Victoria. This was because the policy measures which were introduced by the colonial

regime sharply contradicted the interest of the local fishermen as they were guided by a series of customary regulations. The local fishermen conducted their fishing activities traditionally by the use of traditional fishing gear. Before colonial intrusion, fishing was largely conducted for subsistence purposes to meet the demands of the local fishermen. The arrival of the colonialists turned things around as they sought to transform the fishing industry from a traditional activity to a commercial sector oriented to capitalist demands. The colonialists believed that Lake Victoria was underutilized and, therefore, they introduced several policy measures which were intended to make Lake Victoria fishing more productive. Among the policies which they introduced include those which were related to the mesh size control, gear restriction, the introduction of new species of fish, the introduction of modern fishing gear, the control of the size of fish to be caught, to mention just a few. The adoption of these policies, as they will be described underneath, redefined the conceptualization of fishing. The locals were obliged to perceive fishing in a different way contrary to the way they used to conceptualize it prior to colonial intrusion. It was during this time when the concept of illegal fishing was expanded to include a set of pre-colonial traditional fishing practices which were viewed as detrimental to the fish resources.

The period after the introduction of colonial rule witnessed the adoption of several legislations which were put in place by the colonial government to administer the fishing industry. The adoption of the new legislations placed in jeopardy many pre-colonial traditional fishing practices which were permissible according to customary norms. The new policies criminalized several traditional fishing practices (TNA- File No. 39167/1). The initial colonial legislation to manage the Lake Victoria fisheries was the Fish Protection Ordinance of 1908 which came with the introduction of gillnets as a replacement to the traditional gear. With this Ordinance, the local communities were restricted to get involved in fishing activities in several ways. In the first place, the law banned the use of small mesh size nets and sanctioned the Governor of the colonies to impose charges, register boats, issue licenses, and determine the time of fishing (Opondo 2011, p. 123). The two rules which were published under this Ordinance, the Victoria Nyanza Fish Protection Rules of 1914 and the Victoria Nyanza Fish Protection Rules of 1919 were applied to the entire area of Lake Victoria. The former rule required all individuals who were involved in commercial fishing through fish trade or barter system to be registered on an annual basis. Moreover, by this rule, all licensed fishermen were required to register their fishing gear including boats and nets (TNA- File No. 992). This provision affected the local trading patterns which were grounded on the barter system as it stipulated an aspect of licensing as mandatory. The local fisher folks could, in that respect, no longer conduct fishing activities freely as they used to do before the colonial regulations were effected. The imposition of fees and the registration of boats also implied that the participation of the local fishermen in fishing was placed under stringent control.

The establishment of the mesh-size regulations was another colonial policy intervention through which the traditional fishing practices were criminalized. In 1931, the colonial governments of Tanganyika, Kenya, and Uganda reached an agreement to establish rules which would enable them to protect the fishing industry on Lake Victoria. The primary interest of the colonial government was the protection of tilapia species which

appeared to be the most valuable species during the colonial period. The colonial government was nervous that the continued catch of small tilapia would, more likely, result in their disappearance in the future. Therefore, in October 1931, it was officially declared illegal for any person to catch fish in Lake Victoria by the use of a fishing net with a mesh size that was below 5 inches (TNA- File No. 10465/190). In the course of implementing this regulation, a person found guilty of this offence was liable to a penalty not exceeding 2,000 shillings, or a six months imprisonment, or both fine and imprisonment (TNA- File No. 992 Vol. II). Consequently, the establishment of this regulation, which ended up criminalizing the traditional fishing gear, denied the local fishermen their natural right of accessing some fish species which formed part of their basic diet. With this regulation, for example, the locals were denied access to species like *Haplochromis* and *Ningu* which are naturally small in size and they could easily be caught by the use of 2-inch to 3-inch mesh nets. In Mwanza, a 3-inch mesh size net, which had been commonly used to catch small-sized fish locally known as *Ningu* for local consumption was banned (TNA- File No. 992 Vol. VII). Following this criminalization, the fishing nets which were in use before the introduction of colonial rule were placed under siege and they could only be used behind closed doors.

In 1949, the colonial government established the Lake Victoria Fisheries Ordinance of 1949 as another tool to manage the Lake Victoria fisheries. Like its predecessor, this legislation sought to control the registration of fishing gear and the licensing of fishermen. Moreover, it banned the taking of juvenile fish, the introduction of new species into Lake Victoria, the pollution of Lake Victoria, and the use of explosives and poisonous substances. The major aim for the adoption of this regulation, as articulated by the colonial officials, was to make sure that fish breeding grounds, as well as fish resources, were protected to give rise to sustainable commercial fishing. Section 3(1) of this ordinance provided for the registration of all the boats, vessels, nets, and other equipment that was to be used in Lake Victoria fishing. Every individual who possessed a fishing boat was, by this regulation, supposed to pay a registration fee amounting to five shillings to obtain a certificate of registration. The issuing of certificates of registration free of charge to natives who owned canoes was left under the discretion of the Chief Fisheries Officer. Section 4 (1) called upon all those who wished to take part in fishing to secure a fishing license from the Assistant Fisheries Officer after paying two shillings and fifty cents as a license fee (TNA- File No. 992/B). The adoption of this regulation criminalized several indigenous fishing practices as it required those involved in fishing to secure the certificate of registration and to abstain from taking the immature fish. Although the Chief Fisheries Officer was given the discretionary power to issue certificates of registration free of charge to natives, most of the local fishermen remained unlicensed and, therefore, ended up conducting fishing activities illegally.

The Lake Victoria Fishery Ordinance of 1949 also criminalized the catch, possession, selling, trading, as well as the bartering of any tilapia which was below eleven inches. This prohibition was triggered by the desire of the colonial government to promote commercial fishing. The local fishermen were, in that respect, obliged to withdraw from the catch of tilapia and direct their attention to the catch of other indigenous species of fish that had little commercial value. They were, as well, denied an opportunity to practice their customary barter system of exchanging fish products with other commodities from

the non-fishing communities. The local fishing communities which previously depended on tilapia as one of their primary sources of protein food were placed at risk of facing malnutrition (TNA- File No. 992/C Vol. I). In addition, the non-fishing communities who had their agricultural products ready for exchange with tilapia from the fishing communities could not, under this prohibition, obtain their favoured protein fish. This was because the local fishermen could no longer catch tilapia below eleven inches as they used to do before.

The criminalization of traditional fishing was well-engineered by the establishment of the closed season which was effected through colonial legislation. The closed season was the period when people were not allowed to engage in any sort of activities related to fishing. The banning of fishing activities during the closed seasons was effected when Section 14 (b) of the Lake Victoria Fisheries Ordinance of 1949 empowered the colonial administrator to determine the closed seasons and prohibited places. During this period, the taking, killing, or injuring of any fish was prohibited in Lake Victoria. The Ordinance also prohibited the buying, selling, exposing for selling, and possession of any fish that had been taken from Lake Victoria during any closed season or closed period (TNA- File No. 992 Vol. IV). In 1950, the power of determining the closed season was shifted from the administrator to the Lake Victoria Fisheries Board (LVFB). Those who failed to observe the closed seasons were deemed guilty of an offence against this Ordinance (TNA- File No. 39167/1). Like the other regulations, the establishment of closed seasons turned the local fishermen into the victims of this course of action as they could no longer exercise their free will as far as fishing was concerned. The imposition of the closed season was a serious burden to the communities which survived entirely on fishing activities as it denied them their primary means of survival. Although the closed seasons existed even during the pre-colonial period, their implementation and objectives varied from those of the colonial period. The closed seasons imposed by the clan elders during the pre-colonial period were set up during the farming seasons between January and May when fishermen stopped fishing and invested their labour-power in agriculture which served as an alternative means of earning subsistence needs (Interview with Patrick Dede, July 2019). In contrast, the closed seasons imposed during colonial rule did not take into consideration the periodization of the farming season. The major reason for the establishment of the closed season during colonial rule was to protect and conserve commercial species of fish, especially tilapia, to serve the commercial interests of the colonial government at the expense of the subsistence needs of the local people.

The introduction of new species of fish also played a decisive role in the criminalization of traditional fishing along with Lake Victoria. Having been influenced by the desire to enhance commercial fishing and improve the lake's productivity, the colonialists believed that Lake Victoria was underutilized for being occupied by small species of fish with little commercial significance. Therefore, they sought to boost Lake Victoria fishing by introducing new species of fish (Aura et al. 2020, p. 1). As a matter of implementing this course of action, in the early 1950s, the British colonial government introduced four species of tilapia following the agreement that was reached during the 9<sup>th</sup> meeting of the Lake Victoria Fisheries Board which was held in Nairobi (TNA- File No. F.2/6). Initially, the fishing nets which ranged from 2.5 inches to 4.5 inches were used to catch the newly introduced tilapia species (TNA- File No. 992/C Vol. I). Despite

the introduction of tilapia, the general trend of the production of fish in Lake Victoria remained low. As such the Nile perch was introduced in the mid-1950s to supplement the so-called trash fish which were dominant in Lake Victoria. The introduction of the new species of tilapia and the Nile perch intensified the criminalization of traditional fishing as it facilitated the adoption of new regulations that were designed to protect the introduced species. The prohibition of the 2-inch set-net was, for example, passed for the sake of protecting commercial and locally-dietary-preferred tilapia (*ngege*), which, according to various colonial reports, was on the verge of decline. As if that was not enough, the Lake Victoria Fisheries Regulation of 1953 identified a tilapia below the lengths of 25 cm to be immature and banned its catch in the Smith's Sound in Lake Victoria. In other areas of Lake Victoria, a tilapia whose length was below the length of 27cm was declared immature to be taken, killed, or injured (TNA- File No. F2/5). Any act involving the catch of undersized fish, as defined by the colonial regulations, was branded criminal. By this regulation, the local fishermen could no longer exercise freely their natural freedom of accessing fish which formed part of their basic diet.

The criminalization of traditional fishing practices was also facilitated by the introduction of what was referred to as the modern fishing gear by the colonial government. The colonialists believed that Lake Victoria had abundant fish resources which were underexploited due to the use of traditional fishing gear. Besides, they claimed that some traditional fishing techniques were detrimental to the fish resources. In November 1928, the Provincial Commissioner for Mwanza described two traditional fish traps, the weir and the lobster pot, as destructive because they captured immature fish, hence threatening the sustainability of the fishing industry (TNA- File No. 992 Vol. II). Therefore, they sought to introduce new fishing techniques which, in their view, would make Lake Victoria fishing more productive and sustainable in an attempt to promote the development of commercial fishing. Although the traditional fishing gear suited the demands and interests of the local communities, they did not attract any attention to the colonial government as they were believed to cater to the subsistence needs of the local community. In consequence, in 1905, gillnets were introduced in the Kavirondo Gulf in Kenya before they were later introduced on the Tanzanian part of Lake Victoria in Mwanza in 1908 (TNA- File No. F2/5). In the early part of the 20<sup>th</sup> century, the Europeans introduced European flax gill-net of the 5-inch mesh before they later introduced the sailing dhow and trawlers (TNA- File No. 10465/19). To make the matter worse, the colonialists introduced seine nets which ended up replacing the *usambo* traditional fishing techniques that had been commonly used along with Lake Victoria. The newly introduced fishing gear shared one common characteristic; they appeared to be somewhat expensive to be accessed by the local fishermen. The cost of a single sailing dhow was, for example, reported to have been £50 (Graham, 1927–1928). The local fishermen who were obliged to abandon some of their traditional fishing gear in favour of the newly introduced gear could hardly afford the expenses of the latter. As such, they turned to be the victims of the new developments. Their continued secrecy attachment to their traditional fishing gear changed their status from being referred to as traditional fishermen to being referred to as illegal fishermen.

To make sure that the colonial regulations were executed and interpreted, the colonial government established colonial legal instruments for settling various legal questions along the area bordering Lake Victoria. It established several courts of law that, among other issues, were charged with the responsibility of administering the fisheries regulations. Along with Lake Victoria, several courts were established to deal with the offences that violated the colonial regulations including those which were related to fisheries. In Ukerewe District, for example, the courts that were established in 1951 to deal with offences that contravened the colonial regulations include Bukindo 'A', Bukindo 'I', Nansio 'I', Ilangara 'I' and Ukara 'I'. In Musoma District several courts were also established including Ushashi, Majita, Mugango, and Bukwaya. These were given jurisdiction under cap.73 to deal with offences against the Lake Victoria Fisheries Regulation. A number of courts were as well established in Mwanza, including Mwanza, Bugenej, Bukumbi, Urima, Usukuma, Nassa, Masanza I and Masanza II, Missungwi, and Mbarika. There was also the Court of Appeal including the Court of the Mwanza Federation and the Court of the Chief of Urima (TNA- File No. 992/B). The Local Native Courts were initially not granted jurisdiction over the offences against the Lake Victoria Fisheries Act of 1950 and Regulations of 1951. Although African courts were later said to have jurisdiction to try offences under the Lake Victoria Fisheries Act and Regulations, in practice, they ended up dealing with trivial issues related to fishing. Moreover, the jurisdiction of the Local Native Courts was not extended to the non-African population (TNA- File No. 992/C Vol. I). The establishment of colonial legal instruments intensified the criminalization of fishing as it weakened the customary regulations that were used to address various local confrontations during the pre-colonial period. The clan leaders who were in charge of various local affairs had their roles replaced by colonial personnel who took charge of various administrative matters of the colony.

## 5 Conclusion

The conceptualization of illegal fishing as far as the Lake Victoria fishery is concerned attracts serious attention from scholars. From a historical point of view, the concept of illegal fishing could be traced from the early 1890s when colonial rule was established. Before that time the concept was almost non-existence. What existed was some sort of customary regulations involving a set of customs, beliefs, and practices agreed upon as the guiding principles of the indigenous fishing practices. There was non-existence of specific laws laid down to stipulate what was legal and what was illegal. Local fishermen were free to conduct fishing activities along various landing beaches in agreement with the customary regulations. The establishment of colonial rule in the early 1890s changed the general morphology of traditional fishing practices as it came along with policies and regulations which criminalized several aspects of traditional fishing. The local rulers, who were the custodians of the customary regulations within their localities, lost control of fishing and their powers and mandate were subordinated to the colonial regulations which took charge of all matters related to fisheries management. The local fishermen along Lake Victoria turned to be the major victims of the new policies as they were required to register their fishing gear and obtain fishing licenses. Besides, they were forced to abandon their traditional fishing gears which were declared detrimental to

fisheries resources. The implementation of colonial policies detached fishing activities from the local communities as it banned the catch of immature fish, the catching of fish during closed seasons, and the use of small mesh size nets and the seine nets which formed an important aspect of traditional fishing practices.

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# The Political Economy of Cluster Development Initiatives in Tanzania: Institutional Framework and Emerging Challenges

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**Abstract. Purpose:** This article aimed to examine the political economy of Cluster Development Initiatives on the institutional framework for CDIs in Tanzania context basing on the contractual arrangements of key actors, policy strategies, collaboration and institutional challenges under the guidance of the new institutional economic theory.

**Design/Methodology/Approach:** The research used a cross-sectional design with a mixed approach through simple random sampling techniques to obtain 150 SMEs owners in the cluster of the regions of Singida, Mbeya and Morogoro. Interview, observation, survey and review of documents were used to get the required information. The quantitative and qualitative information were analyzed by descriptive statistics, ANOVA as well as analysis of the themes consecutively.

**Findings:** It was found that the contractual arrangements of key actors were based on funding, training, technical expertise and linking clusters to various stakeholders. The difference in collaboration was not significant as well as significant with P value = 0.097 and P value = 0.000 across regions and clusters respectively. Low government commitment, inadequate funding and low collaboration among cluster members were the major institutional challenges as there was inadequate political and institutional support to realize the intended objectives.

**Research limitation:** The study focused on SMEs in clusters in the regions of Singida, Mbeya and Morogoro in Tanzania where CDIs were largely implemented.

**Practical Implication:** The knowledge advanced by this study will help CDIs implementers and other stakeholders on the nature of political and institutional support, the collaboration of key stakeholders and the major institutional challenges.

**Social Implication:** The knowledge advanced by this study will help policy-makers to adjust SME development policies to provide special attention to CDIs issues as well as strengthen project capacity write up to attract funds.

**Originality/Value:** The novelty of this study is on informing about the political economy of Cluster Development Initiatives particularly on the contractual arrangements of key actors, policy strategies, collaboration and institutional challenges under the guidance of the new institutional economic theory in Tanzania.



**Keywords:** Political economy · Cluster development initiatives · Institutional framework · Challenges · New institutional economic theory

## 1 Introduction

The Political Economy of Cluster Development Initiatives has been an issue of global concern to policymakers, implementers and the scholar community. Political economy contemplates how the political institutions, political environment and the economic system affect each other. In this regard, the structures of a country's government institutions such as organizations, policies, guidelines, laws are the 'political architecture' of the economic sphere especially on programs of the business environment and other related interventions (Donor Committee for Enterprise Development 2011; Michael and John 2019; Alkahtani et al. 2020). To this, the new institutional economic theory unveil the role of political institutions that, collaboration among individuals, firms and other supporting institutions can have a greater impact on decisions than an individual contrary to what neoclassical economic theory assumes (North 2000; Obiska-Wajda 2016). In the same vein, Cluster Development Initiatives 'philosophy' relies on the fundamental tenets of the combination of different activities and collaboration of several members for shared advantage (Stamp 2013; Yoshino 2011).

In a mixed economy, CDIs are the state interventions through its institutions to shield SMEs against market forces (Zoaka et al. 2017). Through this SMEs can adjust quickly and develop appropriate responses. These adaptive measures form a situation through which specialized SMEs initiate and strengthen their capacity to strive for major services, international markets as well as supplying other segments of industries (Arslan 2020; Gudda et al. 2013). The Tanzania government adopted CDIs in 2000s with a triple helix model which involves the government institutions, SMEs owners and the academia/research institutions to solve various SMEs constraints and create enabling business environment. However, the literature on the political economy of cluster development initiatives is scanty. Some scholars link political economy with SMEs in the context of increasing government revenue, poverty reduction strategy and sustaining urban politics (Moges 2013; Alkahtani et al. 2020; Westman et al. 2020) while others focus on the impact of political institutions in terms of policies to SMEs performance (Figal-Garone et al. 2015; Lehmann and Menter 2017; Aboal et al. 2020). Another group, rely on the role of political institutions in creating business environment only (Ngo and Miao 2020; Michael and John 2019). Different from this literature, this paper draws the link of political economy to cluster development initiatives by examining institutional framework for CDIs in Tanzania context specifically on the contractual arrangements of key actors, policy strategies, collaboration and major institutional challenges under the guidance of the new institutional economic theory.

## 2 Theory Underpinning the Study

This research was underpinned by the New Institutional Economic theory (NIET). NIET highlights the importance of initiating and strengthening networks, collaboration as

well as linkages of institutions (North 2000; Obiska-Wajda 2016). The major issue to be responded by this research in the context of this theory is on the ways through which political institutions shape the implementation of CDIs for creating enabling business environment for SMEs through contractual arrangements of institutions, policy strategies in place and the emerging institutional challenges.

### **3 Methodology**

The study employed cross section design with a mixed approach which involved collection of both quantitative and qualitative data once at a location. The selection of the design was due to its economical in terms of time serving in obtaining data (Cresswell 2014). The research was done in the regions of Mbeya, Morogoro and Singida. This was simply because CDIs were in those regions for a couple of years (Msuya 2011). The owners of SMEs clusters from the regions of Singida, Mbeya and Morogoro formed the study population whereby 150 SMEs owners were sampled. Random proportionate technique of selection was employed to get respondents from each cluster in the study area. Purposeful sampling technique was employed to obtain key informants from MIT, SIDO, COSTECH and SME cluster leaders. The first hand data were obtained using survey though a tool of questionnaire. Also, the interview guides were used in the interview of the key informants. Observation method using observation guide was also utilized. The secondary data were obtained through documentary review of several reports such as the Tanzania SME Development policy of 2003, A Twenty four years and Nine Months report on National Entrepreneurship Development Fund-NEDF (1994–2019), SIDO Industrial Cluster Development Strategy, 2017 and SIDO Report on Supporting Industrialization in Tanzania using Cluster Development Approach, 2017. The qualitative data were analyzed by paying attention on the themes in line with examining the institutional framework for CDIs. The quantitative information was analyzed by SPSS software. For each response on the level of collaboration in five point likert scale were converted into categorical data then the index was summed up and the mean was calculated and compared by One way ANOVA across the regions and clusters so as to obtain the statistical difference of collaboration of key actors.

### **4 Findings and Discussion**

This part provides the results and discussion on the institutional framework of CDIs in the triple helix configuration, by identifying the key actors, contractual arrangements, policy strategies, collaboration of institutions in the implementation of CDs and the institutional challenges as follows;

### **5 Contractual Arrangements and Policy Strategies**

Information from documentary review revealed that, the government institutions which were key actors in the implementation of CDIs activities are the Small Industries Development Organization (SIDO) under the Ministry of Industries and Trade (MIT) and the

Tanzania Commission for Science and Technology (COSTECH). Tanzania SME Development policy of 2003 has been implemented in MIT by SIDO which is a machinery mandated by the government to organize, promote and provide all forms of services required in SMEs including CDIs. SIDO was responsible for provision of advice initiating industries, selection of technology, context economic viability, fixing and repairing machines, searching and diversifying markets for produced goods (MIT 2003).

Moreover, CDIs were part of the execution of the 2003 SME Development Policy of Tanzania as elaborated in its fifth chapter in section 5.2 to 5.5 which comprises issues on construction of different physical structures, various services for initiating and consolidation of businesses, ways to obtain fund and the institutions for initiating and strengthening SMEs (MIT 2003: 16–23). The researcher observed that, through SMEs policy strategies the policy document sets the policy strategies to be implemented for all SMEs it does not provide specific strategies for CDIs. The findings implies that, the policy is unsuited for the implementation of CDIs since it does not set specific strategies for CDIs but treats SMEs in clusters under CDIs same as those operate outside of the cluster. The findings tally with Donor Committee for Enterprise Development (2011) which underlines that, policy implementers manage to create enabling business environment only if there proper policy strategies determined by the political economy of the country. In addition Goodluck et al. (2016) emphasizes that, it is vital for governments to recognize the significance of setting a national policy framework for SME development that addresses comprehensively the SMEs' size, nature of operations and competitive challenges.

Documentary review also revealed that, COSTECH has been responsible for overseeing research in science and technology; however in the year 2010 it chipped in implementation of CDIs with the focus on establishing collaboration between academic/R&D institutions, entrepreneurs (SMEs owners) and government authorities in a so-called Triple Helix configuration. Through this configuration, SMEs owners were expected to obtain support from research and higher education institutions to do science and technology supported innovations as part of technology support and capacity building in various business aspects as part of implementation of CDIs. SIDO and COSTECH signed a Memorandum of understanding as CDIs implementing partners.

Again, these key actors also signed a Memorandum of Understanding (MoU) with SMEs in clusters as well as Södertörn University of Sweden under the School of Natural Sciences, Technology and Environmental Studies. Since then they have been implementing projects known as Innovation Systems and Cluster Development Programme-Tanzania (ISCP-TZ) which was a preparatory project accomplished in 2015 and another project in progress known as Fostering Innovation for Socio-Economic Development expected to be accomplished in 2021 which have been funded by Swedish International Development Agency- SIDA. SIDO and COSTECH have been collaborating in funding, trainings, technical expertise and linking SMEs in clusters to various stakeholders for smooth SMEs business operations. Therefore, MIT remained as the overseer of the overall implementation of CDIs and overarching policy making and initiating legislations. The findings imply that, there has been a framework for implementation of CDIs in the triple helix configuration through contractual arrangement of government institutions, SMEs owners and academic/ research institutions. These ensures that, there mutually

agreed defined roles and responsibilities of each party based on the law. The results agree with the new institutional economic theory that places more weight on the significance of institutions in improving and guiding decision making to enhance performance of the organizations rather than an individual based on rational choice and decision (North 2000; Obiska-Wajda 2016).

## 6 Collaboration of Key Actors in Implementation of Cluster Development Initiatives

In examining the implementation status of CDIs, it was important for the study to understand how and to what extent the key actors (SIDO and COSTECH) collaborated in implementation of CDIs. This aimed at building understanding on the level of interaction of key actors in implementation of CDIs across regions and clusters.

**Table 1.** Collaboration of key actors in CDIs implementation across regions

Regions	Collaboration (Mean)	F- value	P value
Singida	2.905	2.566	0.097
Mbeya	2.953		
Morogoro	3.062		
Overall mean	2.986		

**Source:** Survey Data, 2019

**Table 2.** Collaboration of key actors in CDIs implementation across clusters

Cluster	Collaboration (mean)	F value	P value
Mtinko Sunflower oil processing	3.559	17.455	0.000
SIMUSOP	2.250		
Mbeya Rice group	3.145		
Mbeya Sunflower oil processing	2.761		
Morogoro Engineering	2.750		
Morogoro Food processing	3.205		
Morogoro grain Milling	3.233		
Overall mean	2.986		

**Source:** Survey Data, 2019.

Results of one way ANOVA referring Table 1 show that, the total average score of the mean on collaboration over the regions read 2.986 with the region of Singida

scoring the mean of 2.905, Mbeya region scoring the mean of 2.953 as well as Morogoro region scoring the mean of 3.062. The difference in collaboration over the regions was insignificant statistically at P value of 0.097.

Results of one way ANOVA referring Table 2 show that, the total average mean scoring of collaboration over the clusters read 2.986 whereby Mtinko sunflower oil processing cluster had collaboration mean score of 3.559, SIMUSOP had collaboration mean score of 2.250, the rice group cluster of Mbeya scoring collaboration mean of 3.145, Mbeya sunflower oil processing had collaboration mean score of 2.761, Morogoro engineering cluster had collaboration mean score of 2.750, the food processing cluster of Morogoro scored collaboration mean of 3.205, Morogoro grain milling cluster had collaboration mean score of 3.233. The difference in collaboration of key actors across clusters was statistically significant with P value of 0.000.

From the results in Table 1, collaboration of key actors was relatively higher in Morogoro region with mean score above the overall average mean score while Mbeya and Singida regions were below the average mean score across regions but the difference in collaboration over the regions read statistically insignificant at P value of 0.097. This revealed that collaboration of key actors across regions was similar and depended much on the nature of cluster activities operated in a particular region. Interview with one of COSTECH official testified:

*“Through our collaborative effort with SIDO, we have managed to conduct several trainings and provide technical expertise to cluster members in various issues like technology and marketing. Also various stakeholders some of which are Banks, SIDA, MIVARF, JICA, TCCIA, LGAs, Academic/ Research institutions have been linked to clusters to provide various supports from time to time depending on their interests, capacity and projects at hand.”* (In depth interview, August, 2019).

The findings reveal that, there was collaboration of key actors (SIDO and COSTECH) which mostly based on training and technical expertise as well as linking clusters to various stakeholders as compared to funding across regions in the study area. This was mainly contributed by the fact that, large parts of funds for implementation of CDIs were derived from projects funded by linked institutions to SMEs in the clusters. The findings imply that, key actors collaboration under CDIs created an environment for various stakeholders to participate so as to form a synergy required for improving SMEs business operations. These findings are supported by the new institutional economic theory which insists on key actors to ensure conducive terms and conditions to all cluster stakeholders and diversification of the linkages among SMEs in clusters and supportive institutions such as educational institutions such as universities and donors that may play an educational role, promoting R&D, innovation and funding various cluster activities (Stamp 2013; North 2000; Obiska-Wajda 2016).

## **7 Institutional Challenges for Implementation of Cluster Development Initiatives**

The study was interested to understand the challenges on the institutional framework for implementation of CDIs as follows;

Results in Table 3 show that, among of the challenges majorities of the respondents (29%) reported low government commitment while some of the respondents (12%) reported low engagement of academic/research institutions. On the other hand, other respondents (16.8%) reported inadequate funding for CDIs while some of the respondents (9.4%) reported poor infrastructure and some of the respondents (14.2%) reported weak coordination of CDIs stakeholders. Moreover, some of the respondents (14.8%) reported low collaboration among cluster members while other respondents (3.8%) reported inadequate expertise support.

**Table 3.** Respondents distribution on institutional challenges for implementing CDIs

Challenge	Frequency	Percentage
Low government commitment on CDIs	161	29
Low engagement of academic/Research institutions	67	12
Inadequate funding for CDIs	93	16.8
Inadequate infrastructure	52	9.4
Weak coordination of CDIs stakeholders	79	14.2
Low collaboration among cluster members	82	14.8
Inadequate expertise support	21	3.8
Total	555	100

**Note:** Results are in Multiple Responses

**Source:** Survey Data, 2019

From the results, low government commitment on CDIs, inadequate funding for CDIs and low collaboration among cluster members were identified to be the main challenges that faced the overall institutional framework for implementation of CDIs over the regions. The research revealed that, there was low government commitment on CDIs accounting for 29%. This was manifested by the absence of a strategy for CDIs implementation at the Ministry of Industries and Trade. Interview with one of the officials at the ministry confirmed:

*“Ministry of Industry and Trade acknowledges the existence and operations of CDIs in various regions of Tanzania but currently it has no specific strategy for implementing CDIs. As the overseer on implementation of SME Development policy of 2003, it therefore, mandates this responsibility to provide all forms of services needed by SMEs to SIDO. From the Business Development Services provided by SIDO in collaboration with the Directorate of SMEs at the ministry, all SMEs are eligible to receive the supports in which those under CDIs are also inclusive.”* (In depth interview, August, 2019).

The findings imply that, at the ministry level CDIs had been undertaken without having a specific national strategy describing the directions on how it should be carried out in terms of modalities, approaches, monitoring and evaluation techniques and

the resources which were required or committed for implementation. The literature on political economy of SMEs and business environment reform points out that, lack of a strategy which acts as the road map on CDIs implementation is a clear indication of low government commitment because, the strategy enables coordination of various programs as well as budget implications since in most cases it is implemented as a dynamic long-term process (Ngo and Miao 2020; Michael and John 2019; Alkahtani et al. 2020; Donahue et al. 2018).

On the other hand, documentary review revealed that, it was only in the year 2016 majorities of professional staff at all SIDO regional offices were sensitized to CDIs in details based on the draft strategy for cluster development which was prepared at SIDO headquarter under technical assistance of JICA then in February, 2017 SIDO adopted it for guidance purposes on implementation of CDIs. However, mainstreaming of CDIs concept into the national and Local Government Authorities (LGAs) had not been sufficiently done. The findings imply that, it is challenging to mainstream a CDIs strategy at national and local government levels without amendment of the policy since the current SMEs Development policy does not provide specific strategies to be implemented to SMEs in clusters under CDIs. On contrary it provides general strategies for both SMEs in clusters and outside clusters this jeopardizes the implementation of CDIs. The findings are supported by Zoaka et al. (2017) who argues that, the existing governments' political institutions impact positively or negatively on various interventions. Therefore, CDIs implementation is determined by the existing SMEs Development policy.

On the other hand, inadequate funding for CDIs was reported as one of the main challenges accounting for 16.8%. A documentary review from SIDO indicated that, from financial year 2014/2015 to 2017/2018 there was no any fund provided by the government to SIDO for developing NEDF. This was due to the fact that, the government allocated fund in the respective financial year budget but it was not delivered for implementation of the plans. This limited the financial capacity of SIDO to support SMEs in clusters via NEDF loan scheme. It was further reported that, the fund for capital support provided by SIDO to SMEs via different loan schemes national wide from 2014/2015 to 2018/2019 was TZS.28, 503 billion in which SMEs in clusters were inclusive. This implies that, SIDO had no specific budget from the government for implementation of CDIs. This further imply that, there was heavy reliance on donor funded projects for most of CDIs activities which appealed in building and strengthening project write up capacity for obtaining funds through various competitive project grants for implementation of CDIs.

However, low collaboration among cluster members which accounted 14.8% was among the main challenges identified. The framework for implementation of CDIs aimed at enhancing collaboration among cluster members through their leadership. Collaboration in CDIs meant the readiness of cluster members to engage fully in various joint actions depending with the nature of the cluster such as collective marketing and sales of products, collective sources of raw materials to enhance mutual cooperation and complementarity among them. Interview with cluster leader revealed that, some SMEs owners were still reluctant for mutual cooperation due to lack of trust and being unclear with the concept of CDIs.

It was further observed that, in most of SMEs in clusters production processes were still performed in isolated working premises. These situations led to some cluster members to be unwilling to commit their individual resources for attaining unified plans through various joint actions. These in turn promoted competition rather than co-optation in various business activities among SMEs owners over the regions. This implies that, CDIs implementation did not sufficiently enable mutual collaboration of SMEs owners as a result, it was difficult for most of them to build common vision for their clusters, taking on board some shared short term plans and strategies, common learning from their past experiences and adopt new strategies to move forward as well as crafting long term plans for their future business endeavors.

## 8 Conclusion

The contribution of this research is on informing about the political economy of CDIs under the guidance of the new institutional economic theory which elaborates the collaboration of various institutions in the triple helix configuration. The knowledge advanced by this study will help CDIs implementers and other stakeholders on the nature of political and institutional support, collaboration of key actors and the major institutional challenges. It was concluded that, the institutional framework for CDIs implementation is not sufficiently supportive to realize the CDIs intended objectives. Nevertheless, low government commitment, inadequate funding and low collaboration among cluster members were the major institutional challenges. It is recommended that, policy makers and other stakeholders make SME policy amendments to provide special attention on CDIs issues as well as strengthen capacity for project write up to attract fund.

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# Adoption of Sustainability Practices by Textiles Firms: Implications for Competitiveness

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**Abstract. Purpose:** The study aims to provide domestic textiles firms with a clear direction to fully adopt and implement sustainability concepts and practices to build a competitive edge against their offshore counterparts.

**Design/Methodology/approach:** Using the Triple Bottom Line (TBL) paradigm, the study employed extensive literature based on the findings of a qualitative study to analyze the firms' sustainability strategies.

**Findings:** Theoretical evidence on sustainability, coupled with the global trend of sustainable practices among textile firms, suggest critical gaps exist concerning domestic textiles firms' application of sustainable design and production practices.

**Research Limitation/ Implications:** The published data may need proper testing through field investigation to verify validity and reliability.

**Practical Implication:** Addressing sustainability challenges and optimizing the Triple Bottom Line (TBL) brings a variety of opportunities and concerns for businesses interested in engaging in sustainable operations.

**Social Implication:** The competitiveness and long-term capability of textile companies are dependent on labour. Firms must assist current and future generations' abilities to maintain a safe and healthy environment.

**Originality/Value:** This paper intends to offer an integrated and consistent measurement of sustainability in textile firms through the TBL.

**Keywords:** Sustainability practices · Offshore and domestic firms · Textiles industry · Competitiveness · Triple bottom line

## 1 Introduction

Textile firms are considered the largest, oldest technologically complex, indispensable, and most global industry in the world that satisfies people's most basic needs (Karthik and Gopalakrishnan, 2014; Muthu 2017). It forms a significant part of production, trade, and employment in many developing countries (Keane and Willem 2008). In many nations, the textile sector has been a substantial supplier, and it plays a crucial part in the global economic integration of developing and industrializing countries. The success of these businesses in the segment could have a significant impact on growth and

development and, consequently, serve as a catalyst for economic growth, among other factors (Gyambea-Amoako 2019). The sector is a powerful greenhouse gas, amounting to 10% of total carbon footprint, nation's second threat to humanity after petroleum sector, (AfDB 2019; Sharma and Narula 2020). Textile production emissions, approximated at 1.2 billion tons per year, outweigh the entire air pollution from international routes and marine shipping, and the situation is not improving. According to the United Nations Framework Convention on Climate Change, textile industry emissions are expected to increase by more than 60% by 2030. (Sharma and Narula 2020). The textile sector processes and utilizes a lot of water (80 to 150 L) and other chemicals to obtain 1 kg of cloth, (Rahman Bhuiyan et al. 2016). China, the largest textile manufacturer globally (Kabir et al. 2019), produces approximately 54% of all textiles produced worldwide. It produces about 25,000 tons of wastewater each year, all of which must be cleansed before being released into the atmosphere.

The textile and fashion industries have enormous economic revolution potential. According to Gbolarumi et al. (2021) the worldwide textile sector is worth USD 3 trillion per year and accounts for 2% of global GDP (GDP). African countries can capitalize on this potential while minimizing negative environmental and climate change consequences. One major topic everyone discusses, but no one seems to have the complete answer, is sustainability. Irrespective of what industry one is in, one has perhaps overheard the word "sustainability" at least a couple of times. Organisations worldwide are coming up with five-year plans to go 100% green (Cole and Aitken 2019). Historically, industrialisation has ignored environmental issues and has been one of the most significant sources of pollution and led to unsustainable production modes. A sustainable manufacturing system is an unavoidable consideration for textile firms. (Kishawy et al. (2018).

Ramos (2019) opines that there is a growing need for businesses to consider sustainability initiatives across their whole value chain within many sectors of the economy. The desire to address sustainability stems mostly from increased awareness among important stakeholders, including investors, large-scale customers, employees, and non-governmental organizations. The importance of design and its value in the manufacturing firm is growing (Deutz et al. 2013). The new industrial epoch delivers a complete technological guarantee, based on the ground breaking green design innovation. Construction of complex specialized factories with automation, informatization, and intellectualization improves production's long-term viability (Liu et al. 2019). A genuine company interest in operational efficiency and cost reduction is another element (Ramos 2019). Sustainability (Ramos 2019; Jamali 2006) is an operational method for a manufacturing organization that emphasizes long-term viability in environmental, economic, and social dimensions that does not negatively affect future generations' possibilities. Ramos further said that converting that description into a framework for distinct and meaningful operations is a difficulty for most organizations. Textile firms can translate sustainability into their production practices considering the environmental, social, and economic issues to compete with the global trends.

According to Rosen and Kishawy (2012); Kishawy et al. (2018), Production decision-makers and designers that accept sustainability, concentrate, and create a sustainable culture in their businesses are more likely to improve design and manufacturing. More

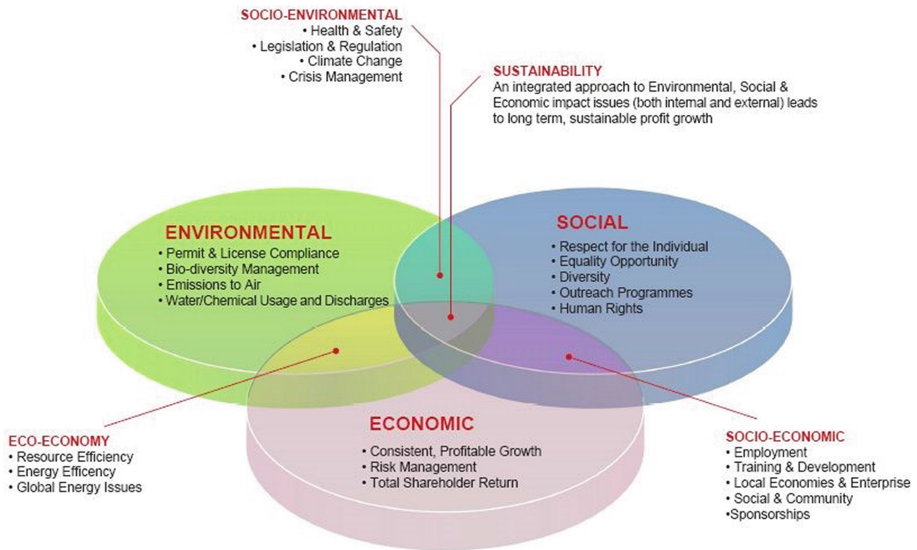
thorough study and collaboration, according to the report, are required to better understand sustainability in production and design, as well as technology transfers and application of sustainability. Kootstra (2009) added that effective design is a crucial enabler of competitiveness for many companies and alluded that it is the most potent differentiation tool companies can use to stand out among their competitors. Businesses are becoming increasingly aware of their impact on the environment and society, as well as their potential contribution to achieving long-term development goals. Companies are implementing sustainable solutions due to growing demand from different stakeholders (Hąbek et al. 2018). Customers are getting more concerned about the environmental impact of the things they buy, according to Kolodziej (2015). The relevance of corporate social responsibility is gradually being recognized by most political agencies and communities. The information above highlights the importance of operational sustainability and how sustainable design and production may be achieved inside manufacturing companies.

The 2030 Agenda for Sustainable Development highlights the worldwide political resolve to build a sustainable future based on long-term environmental conservation (Swain and Sweet, 2021). Resource and energy efficiency, long-term infrastructure, and availability to essential services are all promoted by sustainable production practices. Its execution would facilitate the achievement of overall development goals, as well as the reduction of future economic, environmental, and social costs, improvement in competitiveness and poverty reduction.

### 1.1 Sustainability in the Textile Industry

Du Pisani (2006), awareness of sustainability in managing organizations first appeared in the 1930s. The term “sustainability” refers to an operational approach that emphasizes the long-term viability of environmental, economic, and social components while minimizing the detrimental influence on future generations’ chances, (Ramos, 2019). The article further said, converting that description into a framework for distinct, meaningful activities is a barrier for most businesses. Environmental management systems, ISO 14001:2015 in its background also corroborated this and adduced that maintaining a balance between the economy, environment, and society is vital to providing the needs of the present without putting at risk the future generations’ ability to meet their needs. Sustainable development can be achieved by balancing the three pillars of sustainability. The concept of sustainable development has played a pivotal role in policy-making since the Brundtland Report in 1987 (Chang et al. 2017). The overarching objective of sustainable development is long-term economic and environmental stability (Kumar et al. 2017). This could be accomplished by integrating economic, environmental, and social issues in the decision-making process (see Fig. 1:1). According to Liu, Hsu, and Lin, the emphasis of enterprises’ sustainable development plans and key indicators must shift to economic, social, and environmental factors (2019).

Literature from various authors suggest that the social and economic pillars are less discussed than the environmental sustainability when it comes to sustainability in the textiles and clothing industry. This is corroborated by Seuring and Muller (2008), who examined the limits of 191 papers on sustainability management and found that social factors of sustainable development are frequently overlooked. The other two dimensions



**Fig. 1.** New business models sustainable development. *Source:* (Drimmelen, 2013; <http://greenprintsurvival.wordpress.com>)

of sustainable development are equally significant and must be taken into account in order for the textile sector to be sustainable.

### ***Economic sustainability***

The economic pillar of sustainability, which is also known as the governance pillar, is where most firms believe they are on solid ground since they believe that being successful means the business is long-term. The pillar, though, is not solely about profit (Beattie 2019, June 16), the economic pillar's activities include compliance, good governance, and risk assessment, to name a few. The board of directors and management are primarily concerned with aligning shareholder interests with those of the company's community, value chains, and end-user consumers. Investors, in this case, may want to know that the company employs those accurate and transparent accounting methods and that stakeholders voting rights on critical issues are considered. Investors may also want assurances from companies that they have policies that prohibits conflicts of interest in board member selection, does not rely on political contributions to receive overly favourable treatment, and does not engage in illegal practices (Beattie 2019, June 16). The article further adduces that policies such as abandoning fossil fuels or chemical fertilizers are extreme measures that companies depend on the economic pillar.

### ***Environmental Sustainability***

According to the Environmental Management Systems ISO 14001:2015 standard, environmental challenges such as pollution, inefficient resource use, poor waste management, climate change, habitat destruction, and biodiversity loss have become more severe. As a result public hopes for sustainable growth, openness, and accountability have grown. Businesses have no choice but to take a systematic approach to environmental management by developing environmental management systems in order to contribute to the

environmental pillar of sustainability. This pillar is concerned with the physical features of environmental life-support systems such as the water, soil and the atmosphere and considered the most important. Many firms are working to reduce their carbon footprints, packaging waste, water use, and overall environmental impact. (Beattie 2019, June 16). Reducing raw material use and having a positive impact on the environment can cut total spending and have a favourable financing impact on the organization. (Muthu 2017). The maintenance of the life-support system, or environmental sustainability, is the most important requirement for social sustainability (Goodland and Daly 1995; Khalili 2011).

### ***Social Sustainability***

Meeting present societal needs without causing harm or posing potential threats to future generations is the goal of social sustainability (Sarmadi 2013). As a result, it promotes a healthy future by laying a solid foundation without risking current societal requirements (Annappoorani 2017). Social sustainability tackles poverty and human growth and requires the cooperation and consent of workers, stakeholders, and society in its operations (Muthu 2017; Sharma and Narula, 2020). The strategies may include good neighbourliness, better community relationship and employee wellbeing. Businesses emphasis on staff retention and engagement strategies, such as more flexible scheduling, learning and development opportunities, and increased maternity and paternity benefits. Companies have devised approaches that promote their community involvement, such as sponsorships, scholarships, and investment in local public activities, Beattie (June 16th, 2019). Do businesses need to be aware of their suppliers on the global social scale; are there child labour practices in the company? Has management provided a safe and healthy working condition that prevents injuries and ill health? Are workers being treated fairly and paid fairly? Many huge retailers have struggled with this, and the public has expressed their outrage. The Bangladesh factory collapse catastrophe, for example, has highlighted previously unrecognized hazards in procuring from the cheapest provider (Goodland and Daly 1995; Khalili 2011).

This paper reviews and assesses the extent of the adoption of sustainability practices by domestic textiles firms vis-à-vis their offshore counterparts based on an intensive literature approach. The aim is to make pragmatic recommendations to improve the competitiveness of domestic textile firms.

## **2 Methodology**

This research used a historical research design. Extensive literature studies focused on theoretical and empirical topics were conducted to gather the information for this study. Using the Triple Bottom Line concept, data from theoretical and empirical evaluations were used to analyze domestic textile production processes.

### **2.1 Triple Bottom Line**

Elkington 1998, as cited in (Uniamikogbo and Amos, 2016), described sustainable growth using the triple bottom line to achieve profitability, integrity of the planet, and social equality simultaneously, a decade after the Brundtland Commission Report. The

TBL, popularly called the 3Ps, seeks to attain equitable balance of social (people), environmental (planet), and economic (profit) sustainability components. Its approach to business models is a relatively well-understood concept (Joyce and Paquin 2016). Taking care of these challenges of sustainability and maximizing the Triple Bottom Line (Sharma and Narula 2020; Joyce and Paquin 2016; Akenji & Bengtsson 2014) gives a variety of opportunities and concerns for businesses to engage in sustainable activities.

The product needs to be profitable to be sustainable and consider environmental and social impacts during its lifetime. Melissa and Lenita (2006) as cited in (Chang et al. 2017), by presenting data to back up the idea that applying the TBL can help businesses become more competitive. Some studies, on the other hand, question TBL's utility. Milne and Gray, (2012) Uniamikogbo, Amos, (2016), for example, claimed that TBL reports have little to do with what sustainability is all about and that reconciling the tension between sustainability and the requirement to make a profit is unachievable. However, empirical evidence has proven that TBL operationalises sustainability in the businesses and therefore recommends it for organisations who prioritise sustainability to build a competitive edge against their competitors, hence the justification for its use for this study.

### 3 Results and Discussion

A review of sustainability theories and practices by textiles firms and their implications for competitiveness is presented and discussed.

#### 3.1 Sustainability in the Textile Industry: Implication for Competitiveness

A sustainable product, according to Fletcher (2009), is made in a way that has the fewest possible negative environmental consequences, such as employing one of best use of energy like water and energy, and recovering raw materials as much as possible by recycling or recovering heat from industrial effluents. Gardetti and Torres (2017) in the textile firm, sustainability is defined as inexhaustible materials, waste and water use minimisation across the supply chain, and lowering chemical pollution. Sustainability, according to Hethorn & Ulasewicz (2008), means that no harm is done to people or the environment as a result of the development and use of a thing or process, and that if implemented, the thing or process can improve the well-being of those who interact with it as well as the environment in which it is made and used. In this study, sustainability in the textile sector will be defined as the application of the 6Rs to improve people's and the planet's well-being while also generating a significant profit for the company.

#### 3.2 Offshore Textiles Firms Employing Sustainable Principles

Various sustainability measures taken by offshore textiles enterprises to improve their environmental, social, and economic achievement are presented in this empirical review (Gardetti and Torres 2017). A study by Hasanbeigi and Prize (2012) reviewed and summarized the various energy-efficient technologies and measures at each the stages of textile production: Use of high speed carding machines, the use of lightweight bobbins



in ring-frame at the spinning stage; Electric heating systems for yarn polishing at the weaving stage was replaced with steam heating systems; Heat is recovered from hot rinse water, washing and rinsing water are reused at the wet processing stage; The use of a lighter carbon-reinforced spinning pot rather than a steel-reinforced spinning pot, as well as pressure regulator systems with variable speed in cleaning motors during the fibre production process. In less than a year, these changes culminated in a significant decrease in the company's overall energy consumption and related CO<sub>2</sub> emissions.

The Owner & Managing Director, Bengal Technology & Engineering Associates, shared his experience selling technologically advanced machinery to the textile industry and observed that modern machinery is used for quality products and cost optimisation (Textile Focus, December 25 2018). The article further explained that ten years back in Bangladesh, the industry owners used cheap obsolete machines that resulted in high energy and water consumption, high chemical usage, and environmental pollution.

In China, previously 2.5 tons of freshwater was used for printing and dyeing 100 m of cloth but has now reduced to 1.8 tons for the same length of cloth, while the water return rate has increased from 15% to more than 30% (Environment and Trade Hub, 2017).

Obsolete machinery requires 300 L of water to dye 1 kg of cloth, but modern machinery can dye the same with only 50 L of water. There was pressure from many brands for the toxic-free textile industry. 99.9% of chemicals used in Bangladesh are Alkylphenol ethoxylates (APEO), Alcohol phenol oxylates (APO), AZO free, and all the chemicals and dyestuff are using the same label (Textile Focus, December 25, 2018).

In Turkey, the firm's total water use fell by 40.2%, while wastewater generation fell by 43.4%. Total energy usage and CO<sub>2</sub> emissions for the company have fallen by 17.1% and 13.5%, respectively. Simultaneously, overall salt (NaCl) usage fell by 46.0 percent, (Alkaya & Demirer, 2014).

Sharma and Narula (2020) assessed the drivers and constraints for textile firms in India to pursue sustainability, as well as the influence on their adoption of sustainable business practices.. The authors concluded that, the textile firm's efficiency is hindered by the use of antiquated machinery and technology. Firms with significant government support are determined to offer cash resources to prevent environmental deterioration, as seen by the effect of regulatory pressure. Certification and standardization assist firms in venturing into new segments of the market, expanding their global and domestic operations, and maintaining a competitive position and increasing market share. GOTS, SMETA (SEDEX Member Ethical Trade Audit), and BCI (Better Cotton Initiative) textile standards were also disclosed by firm managers during the manufacturing process. These guidelines establish internationally recognized criteria for determining whether or not a cloth is organic. The standards and certifications enable textile producers to market their biodegradable fabrics with a single certification that is recognized across all major markets, expanding the business and improving profitability. One key future research area identified is the role of environmental and social certifications and how these deployment of sustainable practices are influenced. It is evident that while global textiles firms make the application of standardization and certification in their operations, an utmost priority to accrued the benefit thereof, such initiatives have been very challenging for domestic textile firms to implement.



Other studies have shown that offshores companies have tackled environmental concerns through the use of green certifications from standard bodies like as ISO 14001, GOTS (Global Organic Textile Standards), GRI (Global Reporting Initiative), ecolabels, and Oeko-Tex 100, (Almeida et al. 2015). Green product and process innovation, which considers production technology, product qualities, and materials are utilized (Niinimäki and Hassi 2011; Al-Mulali, Saboori, and Ozturk, 2015), are among the others. As a result, hazardous ingredients and procedures used in textile and apparel manufacture are restricted, putting governmental pressure on firms.

To establish an alternate energy source, waste generated during cotton ginning is used. Another notable breakthrough by several research organizations, which has been used by textile mills, is the collecting of willow dust and the manufacture of biogas (Vishnoi 2013). Zabaniotou and Andreou (2010) as cited in (Sharma and Narula, 2020) reported on the use of waste generated during cotton ginning to develop an alternative energy source for lowering Greenhouse Gas (GHG) emissions. Schaltegger et al. (2016) found that expanding into various eco-friendly markets and redeveloping products to be more ecologically sensitive, reduced environmental impacts. This was accomplished by use of less pesticides and inorganic fertilizers, as well as social benefits like reduced pesticide-related health risks and improved working conditions. The offshore textile factories on the other hand, have installed modern high-speed systems, particularly CAD/CAM, digital design software, screen engravers, image plotters, and shuttleless loom machines, etc., to make their operations sustainable (Kolodziej 2015; Hąbek and Lavios Villahoz 2018). Most offshore textiles firms are significantly practising sustainable production, grounded on the TBL framework (3Ps), making them more competitive in the global textiles market.

### 3.3 Practices by Domestic Textiles Firms

Ghana had gained tremendous benefits from textiles in terms of employment, production, and revenue generation, according to Howard (2013). MoTI 2004 (as cited in Howard 2013; Quartey 2006), the industry employed 25,000 people in 1977 and 1994, with a total output of 129 million yards of cloth and 179.7 million USD in exported textiles. However, revenue from textile exports had dropped to \$7.4 million, and overall employment in the business had fallen to 2,961 persons in 2005, with total output of 39 million yards, showing a substantial downturn in the industry. Most of the leading manufacturers and their associated factories have closed down. Ghana's textile productivity and output capacity level is half of china's because they are ill-equipped to pose any real competitive challenge (Korley 2011).

According to Ghana News Agency, the government of Ghana has implemented interventions through stimulus packages for various sustainability practices by chosen textile enterprises, with the goal of making the Ghanaian textile industry more sustainable and competitive (Ghana News Agency, June 19). The article references Akosombo Industrial Company Limited (AICL), which has embarked on retooling its plant for improvement and overall operational efficiency. Critical machinery for textiles production, which was nearly twenty years old and obsolete, was utterly replaced in March 2019 with state-of-the-art machines such as digital screen engravers, image plotters. With these improvements in machinery, it is expected that AICL will increase its production from under

one million yards in 2018 to five million in 2019. According to the Factory Manager at AICL, the company is also introducing cost-saving measures to regain competitiveness by installing new and efficient Biomass Boilers that would reduce the energy cost of the factory by 50 percent (Ghana News Agency 2019, July 4). These practices by the local textiles firms are in line with the agenda for sustainable practices.

Studies on the Ghanaian textile industry mainly focus on the operational challenges and prospects from the fibre stage to the final consumer (Howard 2013, Adikorley 2013; Korley 2011). It seems probable that none of the studies explicitly focused on sustainable design and production in Ghana's textile industries. Hence, there is little or no empirical knowledge on sustainable design and production practices in the local textile industry, which affects the competitiveness and profitability of the industry (Howard 2013; Korley 2011, p.21; GNA 2019).

Furthermore, the Director-General of the Ghana Standards Authority (GSA) confirms that, the lack of adherence to standards is a major impediment to Ghanaian enterprises assessing the African Growth and Opportunity Act (AGOA) (Ghana Standards Authority 2018, January 22). This suggests that compliance to standards is compromised by Ghanaian textiles firms, which affects their competitiveness globally. More so, studies have shown that the obsolete nature of the machinery, (Howard, 2011; Korley, 2011; Ghana News Agency, 2019a, 2019b) used by the Ghana textile industry has resulted in the inability of the industry to build a competitive edge to produce at an optimal level to achieve economy of scale; hence, their inability to compete with imported textile products due to high prices of their products.

### 3.4 Conclusion and Recommendations

Despite the fact that there is extensive theoretical evidence on sustainability and a global trend toward sustainable practices among textile companies, critical gaps in the use of sustainable design and production processes by domestic textile companies have been identified. This has made the domestic textiles firms disadvantageous to their offshore counterparts, who prioritise sustainability as a critical engine for the growth of their firms. A lack of research into the social dimensions of the triple bottom line in SSCM was discovered by Köksal et al. (2017). As a result, significant empirical study, particularly at the supplier level in poor nations, is required to close this gap. Domestic textiles firms must apply all three elements of sustainability, which aim to achieve a balance between the social (people), environmental (planet), and economic (profit) dimensions of sustainability in equal harmony, to gain a competitive advantage over their offshore counterparts in terms of profitability and long-term development.

Low-cost bio-based textile processes that employ advanced technology and apparatus could pave the way for next-generation sustainable textile technologies. The following are some of the recommendations made by the report for stakeholders to consider:

The usage of bio or nature-based materials in the textile production line is strongly encouraged. When compared to synthetic chemicals and auxiliaries, these materials are safe, biodegradable, and produce fewer emissions. Bio-polishing, enzymatic de-sizing, and bio-scouring should be used extensively in the textile industries, as they require less energy and time and thus reduce production cost (Rahman Bhuiyan et al. 2016). Textile

producers can also combine a small proportion of synthetic dyes with many natural dyes to ensure an environmentally sustainable yet economically viable dyeing operation.

The use of modern high-speed systems, particularly CAD/CAM, such as digital design software and screen engravers, image plotters, and shuttleless loom machines, are recommended to save time, reduce labour, and cut down production costs. Introduction of cost-saving measures to regain competitiveness by installing new and efficient Biomass Boilers to reduce energy cost and Greenhouse Gas (GHG) emissions. For instance, developing in the textile production process, the use of bio or nature-based resources is strongly encouraged. These materials are safer, biodegradable, and discharge fewer pollutants than synthetic chemicals and auxiliaries. In the textile industry, bio-polishing, enzymatic de-sizing, and bio-scouring should be utilized extensively because they demand less energy and time, lowering manufacturing costs (Rahman Bhuiyan et al. 2016). Textile manufacturers can also blend a modest percentage of synthetic dyes with a large number of natural dyes to provide a dyeing process that is both environmentally friendly and profitable alternative energy source from waste generated during cotton ginning. Textile companies will profit both economically and environmentally.

Adoption of worldwide recognized standards and certifications such as GOTS, SMETA, and BCI for production to ensure the natural state of textiles, including environmental, economic, and social sustainability, is highly recommended to domestic textiles firms. Textile manufacturers may sell their organic fabrics with a single certification that is recognised in all key markets, thus, expanding their businesses and improving overall profitability.

Recent technical advancements have reduced production costs and reduced environmental effect by recycling process input and waste to be reused. Membrane filtration, biological therapy, oxidation, and crystallization are all examples of this. These are suggested for consideration and implementation by domestic textile firms.

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# The Influence of Cluster Development Initiatives on Small and Medium Enterprises Performance in Tanzania

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**Abstract. Purpose:** This research article aimed to examine the influence of Cluster Development Initiatives on SMEs performance in the regions of Mbeya, Morogoro and Singida -Tanzania, explicitly on technological, training, networking, capital, marketing and working premises.

**Design/Methodology/Approach:** This research employed a cross-sectional research design with a mixed approach whereby 150 SMEs owners were randomly selected from clusters. Survey, interview, observation and review of documents were employed to obtain information. The quantitative information was analyzed by SPSS using multiple linear regression models whereas qualitative data were analyzed using thematic analysis.

**Findings:** The findings revealed that, there was positive significant influence of training, networking and marketing supports on SMEs performance at  $\beta = 0.039$  (P value = 0.027),  $\beta = 0.079$  (P value = 0.000) and  $\beta = 0.036$  (P value = 0.031) respectively. On the other hand, there was negative significant influence of capital and working premises support on SMEs performance at  $\beta = -0.076$  (P value = 0.000) and  $\beta = -0.043$  (P value = 0.000) respectively.

**Research limitation:** The study focused on SMEs in clusters of the regions of Singida, Mbeya and Morogoro in Tanzania where Cluster Development Initiatives were mostly implemented. The research considered financial information of SMEs in clusters from 2015 to 2018.

**Practical Implication:** The knowledge advanced by this study will help CDIs implementers and other stakeholders to understand the supports that significantly influence SMEs performance.

**Social Implication:** The knowledge advanced by this study will help policymakers to adjust capital support policies for SMEs in clusters to match with diverse contexts of SMEs activities including the provision of modern machines on a credit basis. Also, working premises support to focus on ensuring SMEs work at common locations.

**Originality/Value:** The novelty of this study bases on informing the influence of each CDIs supports on SMEs performance combining both financial and non-financial aspects in Tanzania.

**Keyword:** Cluster development · Influence · Initiatives · Small and medium enterprises · Performance



## 1 Introduction

The Development of Cluster Initiatives have acquired a special position in today's globalized economy. This emanates from the fact that, the complementary networks established form situations for the easier and effective appliance of support initiatives to SMEs for expansion of production, markets and initiate progress (UNIDO 2006; Zeng 2008; Fayaz et al. 2020). In this stand point, it helps to improve SMEs performance (Pratono 2018; Mlotshwa and Galawe 2020).

Recognizing these potentials, some CDIs were established in the early 1990s and flourished towards the end of 2000s implemented by the European Union (EU) and UNIDO in Europe, Africa and Latin America to support a range of clusters across diverse sectors (UNIDO 2009; UNIDO 2015). Since then, most developed and developing countries including Tanzania adopted CDIs with diverse objectives, scope and methodologies to enhance SMEs performance (UNIDO 2006; Diyamett and Komba 2008). However, less is known on the influence of Cluster Development Initiatives on SMEs performance to inform policy interventions.

Although the literature on Cluster Development Initiatives and SMEs performance world-wide is plentiful, in the developing world and particularly in Tanzania it is scanty. Some literature tends to link SMEs performance as the outcome of independent business entities efforts without any influence of government interventions (Tundui andTundui 2013; Mason et al. 2015; Adesanya et al. 2018; Majukwa et al. 2020). Therefore, their major concern is to understand how SMEs owners can independently use their resources in terms of skills, technology, capital and others to enhance SMEs performance. This does not inform policy intervention for better management of public services but rather, it is an orientation for business administration which identifies the necessary resources worthy for an entrepreneur to acquire and how they can be used to enhance SMEs performance.

Yet, within this kind of literature, others simply focused at implementation of Cluster Development Initiatives to support SMEs (Msuya 2011; Ali 2012; Jankowiak 2017; Francis et al. 2021). These focused on the role played by governments in implementation of CDIs, the kind of supports provided, progress and status of implementation. Also, methodologically other studies focused on the influence of some aspects like training and networks on either financial or non-financial SMEs performance only (Adesanya et al. 2018; Gunawan et al. 2013).

Unlike this literature, the present article examines the influence of CDIs (technological, training, networking, capital, marketing and working premises) on SMEs performance combining both financial and non-financial aspects in SMEs clusters of Singida, Mbeya and Morogoro in Tanzania.

## 2 Theories Underpinning the Study

Resource Based Theory underpinned this study. The theory clarifies the manner through which numerous resources like fiscal, technology, physical and human are necessary to enhance SMEs performance (Eisenhardt and Martin 2000; Barney 1991; Wernerfelt 1995). Supports of Cluster Development Initiatives in capital, networking, marketing,



technology, training as well as working premises lead to SMEs performance both in financial and non-financial aspects. An inquiry to be responded by this paper under this theory is; what influence each acquired resource under CDIs has on SMEs performance for context specific policy recommendations based on each support in Tanzania and other parts of the world.

### 3 Methodology

The study employed cross section design with a mixed approach which involved collection of both quantitative and qualitative data once at a place. The selection of the design was due to its fastness and time serving in obtaining data (Cresswell 2014). The research was done in the regions of Mbeya, Morogoro and Singida. This was simply because CDIs existed in the regions for a substantial number of years (Msuya 2011). The owners of SMEs clusters from the regions of Singida, Mbeya and Morogoro formed the study population whereby 150 SMEs owners were sampled. Random proportionate technique of selection was employed to get respondents from each cluster in the study area. Purposeful sampling technique was employed to obtain key informants from MIT, SIDO, COSTECH and SME clusters. The first hand data were obtained using survey through a tool of questionnaire. Also, the interview guides were used in the interview of the key informants. Observation method using observation guide was also employed. The secondary data were obtained through documentary review of several reports about CDIs. The qualitative data were analyzed by paying attention on the themes and quantitative information was analyzed by SPSS software. The analysis was as follows;

SMEs performance which is the depended variable was measured in two aspects (financial and non-financial). Financial aspect comprised of Return on Investment (ROI), capital and sales while non-financial aspect comprised of perceived level of technology, level of collaboration and level of linkages. The dependent variable was obtained as follows. Firstly, for each variable in which CDIs supports were provided an element received in each support a respondent scored one (1) if received and scored zero (0) if did not receive. Secondly, the total sum of the received elements under each support were summed up and converted into an index relative to the total number of support elements to form an index of each support. Thirdly, the total sum of index of each support were summed up and converted into an index relative to the total number of supports which were six (6) in which this summated index formed the dependent variable.

Moreover, the dependent variable was obtained under the following steps. Firstly, perceived level of capital, sales, technology, collaboration and linkages which were in five points likert scale were transformed into three levels that is 1-low, 2-moderate and 3-high. Secondly, Return On Investment (ROI) of SMEs in clusters for each year from the year 2015 to 2018 was calculated using the formula here under:

$$ROI = \text{Net profit/Initial investment} \times 100 \text{ (the higher the better)} \dots \quad (1)$$

Then the summation of ROI for SMEs in clusters from the year 2015 to 2018 was done. Thirdly, the mean and the standard deviation of the summation of ROI were calculated, which were 66 and 29 respectively. This was purposely done so as to categorize SMEs in clusters in three levels of ROI performance in which mean (66) plus one standard

deviation (29) was categorized as high performance (95) and mean minus one standard deviation (37) was categorized as low performance whereby SMEs with ROI between 37 and 95 were categorized in moderate performance. Fourthly, SMEs in clusters were assigned index scores in three levels of performance depending with their ROI as 1- low (ROI from 37 and below, 2- Moderate (ROI above 37 and below 95) and 3- high (ROI from 95 and above). Fifthly, the index scores assigned in each SMEs were summated relative to the total number of expected score (3) making the possible scores on overall SME performance to be 18 (3 per each support), then the six variables which comprised SME performance in both financial and non-financial aspects were added and divided by 18 to convert into SME performance index in continuous data to form the dependent variable. Inferential statistics (multiple linear regression) model analyzed the influence of the independent variable to the dependent variable as set in the equation;

$$Y_i = \hat{\beta}_0 + \hat{\beta}_1 x_{1i} + \hat{\beta}_2 x_{2i} + \dots + \hat{\beta}_p x_{pi} + \varepsilon_i \dots \quad (2)$$

Whereas:

$Y_i$  = SME performance (Dependent Variable)

$X_1$  = Technological support

$X_2$  = Training support

$X_3$  = Networking support

$X_4$  = Capital support

$X_5$  = Marketing support

$X_6$  = Working premises support

$\varepsilon_1$  = Error term

$\beta_i$  =  $j^{\text{th}}$  parameter coefficient of the predictor variable (it indicates the variations in dependent variable value per unit change of independent variable value when other variables remain constant).

## 4 Findings and Discussion

The research paper examined the influence of CDIs (technological, training, networking, capital, marketing and working premises) on SMEs performance (financial and non-financial). Table 1 and 2 show the model summary and results.

Results of the model summary in Table 1 indicate that, the predictor variable was CDIs, coefficient of relationship (R) was 0.235, coefficient of determination ( $R^2$ ) was 0.55, standard error was 0.015 with an F value of 10.20 and P value = 0.001. Results imply that, a regression model had a possibility of less than 0.001 to provide the incorrect prediction. Hence, the regression model employed was an appropriate (model) prediction to explain the influence of CDIs on SMEs performance in the study. Moreover, the relationship between CDIs and SMEs performance was positive ( $R = 0.235$ ) whereby 55% of SMEs performance was influenced by all the predictor variables (technological, training, networking, capital, marketing and working premises supports) under CDIs presented in the model.

Results of Multiple linear regression model in Table 2 indicate that, there was positive insignificant influence of technological support on SMEs performance at  $\beta = 0.004$  (P value = 0.795). Also, results show that, there were positive significant influence of

**Table 1.** Multiple linear regression model summary

Variable	R	R <sup>2</sup>	F-value	Std error	P value
CDIs	0.235	0.55	10.20	0.015	0.001

**Source:** Survey Data, 2019

training, networking and marketing supports on SMEs performance at  $\beta = 0.039$  (P value = 0.027),  $\beta = 0.079$  (P value = 0.000) and  $\beta = 0.036$  (P value = 0.031) respectively. On the other hand, results show that, there was negative significant influence of capital and working premises supports on SMEs performance at  $\beta = -0.076$  (P value = 0.000) and  $\beta = -0.043$  (P value = 0.000) respectively.

**Table 2.** Multiple linear regression for the influence of CDIs on SMEs performance

Variable	Unstandardized coefficients		Standardized coefficients	t value	P value
	$\beta$	Std. error	Beta		
Technological support	0.004	0.016	0.010	0.260	0.795
Training support	0.039	.018	0.089	2.218	0.027
Networking support	0.079	.017	0.157	4.765	0.000
Capital support	-0.076	0.020	-0.134	-3.832	0.000
Marketing support	0.036	0.016	0.071	2.163	0.031
Working premises	-0.043	0.012	-0.108	-3.562	0.000

**Note:** Statistically significant at P value < 0.05.

**Source:** Survey Data, 2019

From multiple linear regression results, positive insignificant influence of technological support on SMEs performance suggests that, technological support through CDIs was inadequately implemented to significantly influence SMEs performance in the study area. This was supported by an interview with one of cluster leaders that:

*“Technological support mostly based on technological expertise on machines specification, ordering and where to obtain them with few inter-firm technological learning and study tour for technological learning and adoption as well as provision of machines and equipments to SMEs.”* (Interview in July, 2019).

The findings imply that, technological support under CDIs could not enhance adequate use and adoption of modern machines for improving production process and quality of the products. These contributed into the failure of technological support to significantly influence SMEs performance in the study area.

Moreover, positive significant influence of training, networking and marketing supports on SMEs performance suggested that, the more training, networking and marketing supports were provided through CDIs the more SMEs performance was reflected in clusters. This was supported in an interview that:

*“...Training provided diverse skills required by SMEs owners such as business record keeping, bankable business plans, modern processing and preservation methods and the like. On the other hand, networking provided linkage to various institutions such as academic and research institutions, donors and other development partners, LGAs, financial institutions which provided important services and business supports to SMEs owners in clusters. Moreover, marketing support under CDIs provided linkage to more retail and whole sale customers especially through SIDO annual exhibitions, Nanenane, Sabasaba and some international trade fairs like Dar es Salaam International Trade Fair (DITF)...”* (Interview in July, 2019).

The findings suggest that, the kind of training, networking and marketing supports implemented through CDIs in the study area should be maintained as they had positive significant influence on SMEs performance. The results tally with the resource based theory which acknowledges on highly diverse networking, training and marketing supports to provide a diverse and convenient blending of resources in terms of skills, expertise, experience, customers, service providers and business supporters that bring about SMEs performance (Eisenhardt and Martin 2000; Barney 1991; Wernerfelt 1995).

Furthermore, negative significant influence of capital support on SMEs performance implies that, the more SMEs relied on capital support through CDIs the more their performance decreased significantly. The findings do not suggest that capital support through CDIs was not important. However, it emphasizes that the packages, conditions and size of capital support were not desirable to positively influence SMEs performance in the study area. Information from documentary review supported that, capital support under CDIs was provided mostly through fund from linked financial institutions like banks and SIDO loans i.e. CGS, NEDF and RRF. These loan packages provided small amount of fund (small loan size) to enable significant expansion of business activities, delays due to long processes in which some SMEs could secure fund out of the required season as well as high interest rates.

Also, collaterals were required for the financial organizations which were linked to SMEs in clusters in which most of SMEs especially the sunflower oil processing cluster of Mtinko in the regions of Singida could not qualify. Therefore, the findings suggest that, heavy reliance on this capital support by SMEs owners had significant negative influence to their SMEs performance. From the findings, it can be deduced that, the forms and conditions of capital support through CDIs were insufficient to enhance SMEs performance in the study area. Therefore, this implies that, there is a serious need to review capital support in terms of its reliability, adequacy and appropriateness to match with various cluster contexts in which SMEs operated. Similarly, it has also been pointed out that, procedures for SMEs accessing fund should be flexible and considerate to widely accommodate diverse settings of business operations in order to have positive significant

influence on SMEs performance (Cheruiyot 2020; Ng'umbi et al. 2020, Andoh and Nunoo 2011; Ong'olo and Awino 2013).

Further still, negative significance influence of working premises support on SMEs performance suggest that, the more SMEs continued to operate under working premises support provided through CDIs, the more their performance decreased. This reveals that, the available working premises support negatively influenced SMEs performance and the influence was significant simply because majorities of SMEs in the study area were observed to operate in isolated working premises since out of seven clusters in the regions of Singida, Mbeya and Morogoro only two clusters in the region of Mbeya SMEs operated in working premises at a common location at Mwanjelwa SIDO Industrial area.

However, sunflower oil processing cluster of Mtinko and food processing cluster of Morogoro had common facilities. Nevertheless, it was observed that, most of SMEs owners in these clusters continued to operate their activities in isolated working premises, simply because the common facility provided could not accommodate all SMEs owners' activities at a common location. Also, inadequate machines and other facilities were observed at the common facility of Morogoro food processing cluster located at Kihonda in Morogoro region. This discouraged mutual collaboration for joint actions in various business activities among SMEs owners, limited diffusion of technology through apprenticeship of workers, sharing of expertise knowledge and business experience and increased production cost.

In addition, it also discouraged engaging whole sellers due to lack of an economy of scale as SMEs owners were so dispersed in various locations, this culminated into an increase of competition than cooptation among SMEs owners in clusters. These conditions observed provide explanation for the available working premises support under CDIs to have negative significant influence on SMEs performance in the study area. The findings suggest that, working premises support through CDIs should be improved especially on ensuring common location and proximity of SMEs owners in clusters to address the adverse conditions which negatively influenced SMEs performance in the study area. Similarly, other studies also witnessed that, common location and proximity of working premises help to solve a number of constraints which negatively influence SMEs performance (Ali 2012; Martin and Sunley 2003; Foghani et al. 2017).

## 5 Conclusion

This research paper contributes to enlighten on the influence of the acquired resources through CDIs (technological, capital, marketing, training, networking as well as working premises) on SMEs performance combining both financial and non-financial aspects. The knowledge advanced by this study will help CDIs implementers and other stakeholders to understand the supports that significantly influence SMEs performance. From the above results, it is concluded that the existing situations, terms and conditions on working premises and capital supports were not favourable for SMEs performance. It was recommended that capital support policies for SMEs in clusters should be adjusted to match with diverse contexts of SMEs activities including the provision of modern machines on a credit basis. Also, working premises support should typically focus on ensuring SMEs work at common locations.

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# A Decision Support System for Evaluating Cooking Fuels for Sustainable Development in Ghana

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**Abstract. Purpose:** This study assesses fuels comprising firewood, charcoal, kerosene, liquefied petroleum gas (LPG), pellet/briquette, biogas, and solar suitable for sustainable cooking in Ghana.

**Design:** The study employed 5 different MCDM methods to evaluate the cooking fuels based on 14 selected decision-making criteria which emanate from technical, economic, environmental, and socio-political aspects. The Criteria Importance through Intercriteria Correlation (CRITIC) Method was applied to compute criteria weights. Subsequently, the results were integrated into the Technique of Order Preference Similarity to the Ideal Solution (TOPSIS) and Multi-Objective Optimisation on the Basis of Ratio Analysis (MOORA) methods to rank the cooking fuels.

**Findings:** The findings show that the final rankings for the cooking fuels are as follows: biogas > pellet/briquette > solar > LPG > kerosene > charcoal > firewood. This indicates that biogas is the best cooking fuel among the others suitable for achieving sustainable development in Ghana.

**Research Limitation/Implication:** The study was limited by identifying enough experts in cooking fuels for data collection. However, the study concentrated on responses received from twenty experts for decision-making.

**Practical Implication:** The knowledge advanced in this study suggests that biogas performs better and could replace existing LPG for cooking in both rural and urban communities. Likewise, firewood and charcoal could be phased out or replaced with a pellet/briquette for cooking.

**Social Implication:** The study findings are vital to policymakers towards promoting clean fuels to consolidate efforts towards achieving sustainable development in Ghana.

**Originality/Value:** This study's innovation uses 5 different MCDM frameworks to assess the resilience of cooking fuels in the Ghanaian context to make highly informed decisions.

**Keywords:** Clean energy · Cooking fuels · Decision making · Sustainable development · Ghana



## 1 Introduction

Cooking is an essential component of life. It is an activity that unites families and has cultural and social significance worldwide. Clean cookstoves and fuels can save lives, improve livelihoods, empower women, and reduce pollution. Also, through sustained effort and focused deployment, clean cooking can directly help achieve 10 of the 17 Sustainable Development Goals (SDGs) and establish a supportive framework for the full implementation of Agenda 2030 (UNDP 2015).

Polluting fuels for cooking have been a global concern, especially in developing countries over the decades. Presently, household air pollution (HAP) from burning fuel is one of the most severe environmental health threats facing the world (WHO 2018a). Nearly 3 billion people use harmful open fire stoves that rely on kerosene, biomass, or coal for cooking. Cooking with inefficient, polluting stoves, solid fuels, and kerosene causes roughly 4 million premature deaths annually. Household air pollution contributes to non-communicable diseases like stroke, heart disease, and lung cancer. Nearly 50% of all pneumonia deaths in children under five years are caused by particulate matter (soot) inhaled due to HAP (WHO 2018b). In Ghana, air pollution is a major risk influence on premature death. Each year, the cumulative impact of HAP results in nearly 23,000 deaths. Moreover, HAP caused by cooking with polluting fuels results in over 14,000 premature deaths annually (WHO 2018b). For instance, HAP from cooking with polluting fuels is believed to have been responsible for 7,796 adult deaths from stroke and 4,238 infant deaths from respiratory illnesses in 2012 (WHO 2018b).

Petroleum products (47.6%), biomass (firewood and charcoal) (37.4%), and electricity (15%) accounted for Ghana's total energy consumption in 2019 (Energy Commission 2020). Solid fuels continue to be the predominant form of energy for cooking in Ghanaian households. About 76% of households primarily cook using polluting fuels and technologies (mainly firewood, 41.3%, and charcoal, 31.5%). The primary use of polluting fuels for cooking is exceptionally high in rural areas of Ghana (94%) (Ghana Statistical Service 2014). Approximately 25.1% of all households in Ghana use liquified petroleum gas (LPG) for cooking. Nevertheless, the proportion of the population using electricity is low at 0.3% (Energy Commission 2020). The low use of electricity for cooking might be due to accessibility, reliability, and high tariffs.

Multicriteria decision making (MCDM) has already been utilised successfully in renewable energy planning and resource allocation to disseminate numerous energy choices (Pohekar and Ramachandran 2004). Wimmer et al. (2015) highlighted several instances wherein MCDM was utilised to make energy planning decisions. Consequently, MCDM methods are tremendously beneficial, particularly in decision-making for sustainable energy due to their capacity to integrate many criteria.

The global transition to clean and efficient fuels, including solar, biogas, liquified petroleum gas (LPG), and briquettes and pellets for cooking and heating, has attracted the interest of researchers. This has incited researchers to use several approaches to ascertain the resilience of cooking fuels in several countries, including Ghana. For instance, Nlom and Karimov (2015) explored households' likelihood of transitioning from firewood to kerosene and LPG in northern Cameroon. A probity model was utilised to develop cooking patterns and fuel options. The results indicate that the study area has the prospect of transitioning from traditional fuels to clean fuels. Karimu (2015) applied

an MNP regression model to study major influences on Ghana's modern, solid and traditional fuel preferences. The author indicated that education, income, urban location, and infrastructure access influenced households' preference of cooking fuel, including fuelwood, charcoal, and LPG. Alem et al. (2016) examined the factors of household cooking fuel preference and energy transition in urbanised Ethiopia. It was observed that fuel choice is influenced by household financial status, alternative fuel costs, and education. The findings also suggested the utilisation of several fuels. Hou et al. (2016) investigated the conditions, transition, and factors influencing fuel choice for domestic cooking in China. The study showed a significant difference in the use of commercial cooking fuels between rural and urban households. Moreover, farmers' markets, education background, coal prices, and female labour participation influence household choices.

Emagbetere et al. (2016) assessed the fuel sources used in households for cooking in Ikeja, Nigeria. The findings indicated that LPG obtained the ultimate choice for household energy, followed by electricity, kerosene, charcoal, and firewood. Tewari et al. (2017) used MOORA and VIKOR methods to select the most sustainable cooking in India's context. The selection of the cooking fuels was based on only six criteria. The findings indicate that electrical induction is the best fuel, followed by PNG and LPG, respectively. Vaccari et al. (2017) evaluated cooking technologies suitable for Logone Valley, located between Chad and Cameroon. The results suggest that the Centrafrican stove is the best suitable cooking technology for Logone Valley compared to the ceramic stove, parabolic solar cooker, biodigester, LPG stove, and rice husk stove.

Ozoh et al. (2018) investigated the prevalence of kerosene, LPG, and other cooking fuels in a populous area in Lagos, Nigeria. It was seen that kerosene is utilised as a cooking fuel in practically all households, while LPG usage is minimal, mostly utilised by only one-fifth of the households. Atieno et al. (2018) assessed the degree of energy poverty in low-income households in Kisumu City, Kenya. It was observed that preferences are connected to attributes of energy sources assessed by current users and non-users. Masoud et al. (2020) investigated the sustainability of Ghanaian cooking fuels. The authors employed regression analysis to examine the fuel selection relationship. The findings indicate that price, availability, location, and household size significantly impact the selection of cooking fuels in Ghana. Also, the findings revealed that solar energy for cooking is the most sustainable alternative for Ghanaian households, followed by biogas and LPG. Likewise, charcoal and firewood had the least sustainability ratings.

This study objective is to evaluate fuels including firewood, charcoal, kerosene, LPG, biogas, briquette/pellet, and solar for cooking in Ghana. The innovation in this study uses the MCDA framework for making highly informed decisions in the Ghanaian context. Also, 14 different selected criteria are employed for assessing the cooking fuels. It is believed that the study findings would alert policymakers and decision-makers towards promoting clean fuels to consolidate efforts towards achieving sustainable development in Ghana.

## 2 Materials and Method

### 2.1 Selection of Cooking Fuels and Criteria

In this study, the cooking fuels recognised for evaluation are firewood, charcoal, kerosene, liquified petroleum gas (LPG), biogas, briquette/briquette, and solar. However, evaluating the cooking fuels is heavily reliant on relevant raw data for decision making. Also, the raw data depends on specific relevant criteria associated with cooking fuels for sustainable development. Firstly, literature review and personal interviews were conducted to identify pertinent criteria associated with evaluating cooking fuels for socio-economic and sustainable development across the world. After that, a comprehensive questionnaire was constructed and distributed to experts with significant knowledge of cooking fuels to identify each criterion’s importance. The respondents were asked to indicate the preference of each criterion for each cooking fuel on a 10-point Likert scale, where 10 is the highest and 1 is the lowest. The experts were asked to range from 1 to 10 the importance of each cooking fuel based on the 14 selected criteria. Table 1 presents selected criteria for prioritising cooking fuels. The beneficial attributes have higher values as the best in decision-making.

### 2.2 Cronbach’s Alpha - Survey Questionnaire Reliability Test

Twenty (20) experts invited responded to the questionnaires. Table 2 summarises the key experts’ profiles. The reliability and consistency of the collated data from the questionnaires were investigated using the Cronbach alpha reliability test. Equation (1) was used to perform the reliability test:

$$a = \frac{m}{m - 1} \left[ 1 - \frac{\sum k_y^2}{k_x^2} \right] \tag{1}$$

where, m denotes the number of test items;  $\sum k_y^2$  denotes the sum of the item variance;  $k_x^2$  denotes total score variance.

The Cronbach’s alpha test was performed for each criterion. The findings indicate that the total Cronbach’s alpha value for all questions is far greater than 0.7, proving the reliability of obtained data from the questionnaire. Table 3 summarises data extracted from the questionnaires to form a decision matrix for MCDM analysis. This data emanates from scores awarded by the 20 experts. The scores were summed up to obtain consistent data in the range of 1–200 to form the decision matrix.

**Table 1.** Selected criteria for evaluating cooking fuels

Criteria	Attribute	Explanation/Significance
Resource availability	Beneficial	Ease in finding the resources for fuel production

*(continued)*

**Table 1.** (continued)

Criteria	Attribute	Explanation/Significance
Efficiency	Beneficial	Fuel efficacy during cooking. This depicts how efficiently its primary energy sources are converted for cooking and heating
Resource reliability	Beneficial	Ease of depending on the resource to produce reliable fuel
Safety	Beneficial	The hazards such as fatal accidents involved in using the fuel
Production process maturity	Beneficial	The complexity involved in producing the fuel
Job creation	Non-beneficial	Job creation demonstrates the potential for job creation associated with the deployment of fuel technology
Social-cultural acceptance	Beneficial	The public and society are ready to accept the fuel for cooking
Compatible with national energy policy	Beneficial	The fuel deployment and contribution to Ghana's Renewable Energy Masterplan
Ease of storage	Beneficial	The effortless associated with storing the fuel for later use
Market maturity	Beneficial	A ready market and awareness about the use of the fuel
Capital cost	Beneficial	The cost of purchasing the fuel (\$/kg) for use
Fuel cost	Non-beneficial	The initial investment cost for producing the fuel. It comprises expenditure to establish technology, including the costs of land, equipment, wages, installation, and infrastructure
Impact on human health	Non-beneficial	Negative impact on human health from fuel usage
Emissions	Non-beneficial	The amount of CO <sub>2</sub> , CO, NO <sub>x</sub> , and SO <sub>x</sub> emissions produced by burning the fuel

**2.3 Multicriteria Decision Making (MCDM) Methods**

Figure 1 displays the proposed study approach utilised to achieve the study goal. This study employed three different decision-making approaches to evaluate the cooking fuels suitable for sustainable development. The Critic method is used to compute criteria weights. After that, the Technique of Order Preference Similarity to the Ideal Solution (TOPSIS) and Multi-Objective Optimisation on the Basis of Ratio Analysis (MOORA) methods were utilised to rank the cooking fuels. The ranking results from the decision-making methods are compared to validate and justify the selected cooking fuel.

**Table 2.** Decision matrix extracted for MCDM analysis

Criteria	Cooking fuels						
	Firewood	Charcoal	Kerosene	LPG	Biogas	Pellet/ Briquette	Solar
Resource availability	134	129	58	93	140	125	131
Efficiency	63	72	163	164	120	104	63
Resource reliability	51	68	59	62	143	101	136
Safety	55	103	102	116	122	123	124
Production process maturity	57	67	90	137	143	135	144
Emissions	164	142	116	72	56	67	29
Job creation	36	73	84	104	126	136	123
Social-cultural acceptance	82	105	110	132	134	132	132
Compatible with national energy policy	37	62	77	117	174	171	161
Ease of storage	107	111	95	75	83	116	105
Market maturity	106	126	132	146	127	74	63
Capital cost	43	67	98	143	149	119	120
Fuel cost	54	70	88	109	114	111	130
Impact on human health	167	114	80	64	33	51	26

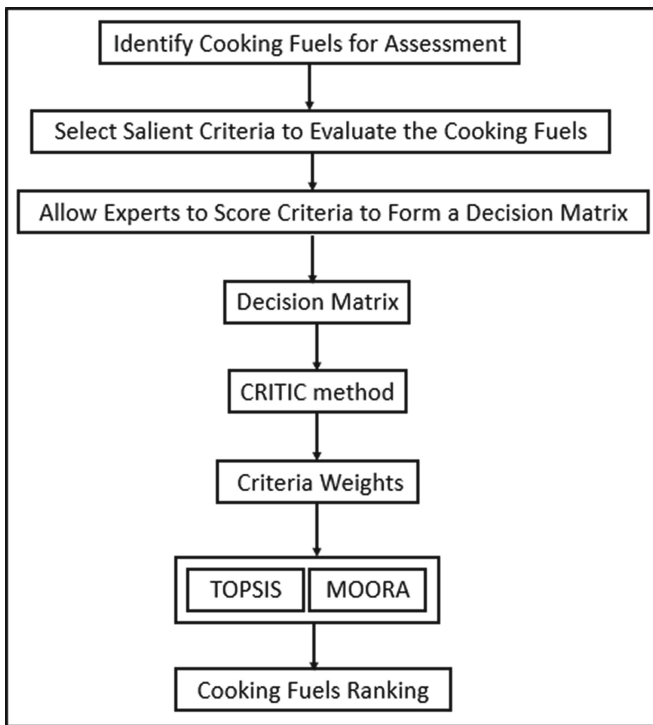
**Table 3.** Key experts’ profile

Measure	Parameter	Frequency	Percentage
Job Position	Faculty member	11	55

(continued)

**Table 3.** (continued)

Measure	Parameter	Frequency	Percentage
	PhD. researcher	2	10
	Consultant	2	10
	Director	3	15
	Manager	2	10
Years of Experience	Below 5 years	2	10
	5–10 years	3	15
	10–15 years	2	10
	15–20 years	5	25
	Above 20 years	8	40
Institution	University	15	75
	Government Agency	5	25



**Fig. 1.** Proposed approach to achieve the study goal

**2.3.1 Criteria Importance Through Intercriteria Correlation (CRITIC) Method**

The CRITIC method is applied to estimate criteria objective weights when decision-makers or experts have a conflicting view on the value of weights for criteria. This helps experts or decision-makers to prevent being biased towards awarding scores to criteria. The CRITIC algorithm incorporates the following 6 steps to estimate criteria objective weights (Diakoulaki et al. 1995):

**Step 1.** Normalise the decision matrix  $\overline{A_{ij}}$

$$\overline{A_{ij}} = \frac{A_{ij} - A_j^{\text{worst}}}{A_j^{\text{best}} - A_j^{\text{worst}}} \tag{2}$$

where,  $A_{ij}$  are the values in the decision matrix,  $A_j^{\text{best}}$  are the best values in the decision matrix that exist in the column and  $A_j^{\text{worst}}$  are the worst values in the decision matrix that exist in the column.

**Step 2.** Compute the standard deviation  $\sigma$  for each criterion as follows:

$$\sigma = \frac{\sqrt{(\sum A_i - \mu)^2}}{N} \tag{3}$$

where,  $N$  denotes population size,  $\mu$  denotes mean population, and  $A_{ij}$  denotes elements in the decision matrix.

**Step 3.** Evaluate the symmetric matrix size  $n \times n$  that contains the element  $r_{jk}$ .

**Step 4.** Compute the measure of conflict as follows:

$$\sum_{k=1}^m 1 - r_{jk} \tag{4}$$

Where  $r_{jk}$  denotes the linear correlation coefficient between the vectors  $x_j$  and  $x_k$ .

**Step 5.** Calculate the quantity of information  $C_j$  for each criterion as follows:

$$C_j = \sigma_j * \sum_{k=1}^m 1 - r_{jk} \tag{5}$$

**Step 6.** Calculate the objective weight  $W_j$  for each criterion using Eq. 6:

$$w_j = C_j / \sum_{i=1}^m C_j \tag{6}$$

**2.3.2 Technique of Order Preference Similarity to the Ideal Solution (TOPSIS)**

According to Yadav et al. (2019), Hwang and Yoon created TOPSIS. TOPSIS is used to rank and select alternatives. TOPSIS selects alternatives closest to the geometrically positive ideal solution and the furthest from the negative ideal solution. (Shafiee et al. 2019; Shyjith et al. 2008). Moreover, the best alternative equals one, while the worst alternative is almost zero (Maliki et al. 2012). TOPSIS ranks alternatives generally through the comparison of Euclidean distances (Pohekar and Ramachandran 2004). The steps utilised in TOPSIS is summarised as follows:

Step 1: Normalising the decision matrix ( $r_{ij}$ ) using Eq. (7):

$$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{v=1}^m x_{ij}^2}} \quad (i = 1, \dots, m; j = 1, \dots, n) \tag{7}$$

Step 2: Estimate the weighted decision matrix ( $A_{ij}$ ) as follows:

$$A_{ij} := r_{ij} \times w_j \tag{8}$$

Where  $W_j$  denotes the objective weights of the criteria.

Step 3: Find the ideal ( $A^+$ ) and negative ideal ( $A^-$ ) solutions as follows:

The ideal solution uses the best value among criteria, and the negative ideal solution uses the worst value among criteria. Ideal and negative solutions are measured as follows:

$$A^+ = (V_1^+, V_2^+, \dots, V_n^+) \tag{9a}$$

$$A^- = (V_1^-, V_2^-, \dots, V_n^-) \tag{9b}$$

Equations (10a) and (10b) determine the ideal value and negative ideal values

$$A^+ = \begin{cases} \max V_{ij}, & \text{the benefits attribute} \\ \min V_{ij} & \text{the negative attribute} \end{cases} \tag{10a}$$

$$A^- = \begin{cases} \min V_{ij}, & \text{the benefits attribute} \\ \max V_{ij} & \text{the negative attribute} \end{cases} \tag{10b}$$

Step 4: Compute the separation values from ideal solutions ( $P_i^+$ ), and negative ideal solutions ( $P_i^-$ ) using Eqs. (11) and (12) as follows:

$$P_i^+ = \sqrt{\sum_{j=1}^n (V_{ij} - V_j^+)^2}, \quad i = 1 \dots; m \tag{11}$$

$$P_i^- = \sqrt{\sum_{j=1}^n (V_{ij} - V_j^-)^2}, \quad i = 1 \dots; m \tag{12}$$

Step 5: Measure the relative degree of closeness to the ideal solution using Eq. (13):

$$RC_i = \frac{P_i^-}{P_i^+ + P_i^-}, \quad (0 \leq RC_i \leq 1; i = 1, 2, \dots, m) \tag{13}$$



**2.3.3 Multi-objective Optimisation on the Basis of Ratio Analysis (MOORA)**

Brauers and Zavadskas (2006) developed MOORA. MOORA is a ranking algorithm that uses both beneficial and non-beneficial criteria. This method primarily employs quantitative attributes only. MOORA is commonly utilised since it is fast and requires few calculations. The MOORA algorithm follows the steps below to rank alternatives (Brauers and Zavadskas 2006; Dey et al. 2012):

Step 1: Develop an initial decision matrix for normalisation

$$x = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} \tag{14}$$

where x are values in the decision matrix.

Step 2: Normalise the decision matrix based on the selection problem, the alternatives, and attribute values in the decision matrix

$$x_{ij}^* = x_{ij} / \left[ \sum_{i=1}^m x_{ij}^2 \right]^{1/2} \quad (j = 1, 2, \dots, n) \tag{15}$$

where,  $x_{ij}^*$  is the normalised value in the decision matrix, and  $x_{ij}$  is the initial value in the decision matrix.

Step 3: Estimation of Assessment Values ( $y_i$ )

$$y_i = \sum_{j=1}^g w_j x_{ij}^* - \sum_{j=g+1}^n w_j x_{ij}^* \quad (i = 1, 2, \dots, n) \tag{16}$$

where, g is the number of beneficial attributes, (n – g) is the number of non-beneficial attributes, and  $W_j$  is the criteria weights.

For the case of beneficial attributes, the normalised performances are added and subtracted for the case of non-beneficial attributes. With beneficial criteria, higher values are the best. Likewise, lower values are the best for non-beneficial criteria.

**3 Results and Discussion**

Table 4 presents estimated weights for all criteria based on the CRITIC method. The weights are pertinent for TOPSIS and MOORA in ranking the cooking fuels. The total weight for the fourteen (14) selected criteria equals one (1). The criteria weight greatly influences and impacts the selection of cooking fuels. The results show that capital costs have the highest weight and have the most significant influence on cooking fuels. Next are fuel cost, market maturity, efficiency, and ease of storage. The lowest criteria weights are attributed to job creation and the impact on human health. The remaining criteria are considered to have intermediate weights. However, the variation between the criteria weights is significant but minimal. For instance, the weight difference between capital costs and fuel costs is only 2.1%. Similarly, the difference between resource

**Table 4.** Estimated criteria weights

Criteria	Quantity of information $C_j$	Objective weights $W_j$
Resource availability	4.6252	0.0739
Efficiency	5.6853	0.0908
Resource reliability	3.8636	0.0617
Safety	3.1162	0.0498
Production process maturity	3.8654	0.0618
Job creation	3.0225	0.0483
Social-cultural acceptance	3.3121	0.0529
Compatible with national energy policy	3.5268	0.0564
Ease of storage	5.6033	0.0895
Market maturity	5.9120	0.0945
Capital cost	6.9508	0.1111
Fuel cost	6.7993	0.1087
Impact on human health	3.0680	0.0490
Emissions	3.2286	0.0516

reliability and ease of storage is only 37%. Also, the difference between the capital cost and emissions is about 73%.

Table 5 shows the negative and positive ideal values for cooking fuels calculated using Eqs. (10a) and (10b). Equations (11) and (12) are used to obtain the separation values from ideal solutions ( $P_i^+$ ) and negative ideal solution ( $P_i^-$ ) for the cooking fuels shown in Table 6. Table 7 shows the relative closeness ( $RC_i$ ) and ranking of the cooking fuels. The  $RC$  scores were obtained using Eq. (13). The cooking fuels with a relative closeness ( $RC_i$ ) score of 1 are the best. The result obtained shows that none of the cooking fuel  $RC_i$  scores is close to 1. However, biogas ranks in the first position, followed by pellet/briquette (second position), kerosene (third position), LPG (fourth position), solar (fifth position), charcoal (sixth position), and firewood (seventh position). This implies that biogas and pellet/briquette are promising and outshine other cooking fuels in consolidating to achieve sustainable development. It can be observed that the cooking fuels  $RC_i$  scores are nearly close, which shows an intense competition within the fuels' performances. For instance, the difference in  $RC$  score between biogas and pellet/briquette is about 4.6%. Also, between biogas and LPG is about 8%. The difference between biogas and firewood is about 20%.

**Table 5.** Positive and negative distances from ideal solution

A <sup>+</sup>	0.033	0.049	0.035	0.021	0.029	0.024	0.022	0.030	0.039	0.046	0.016	0.022	0.005	0.005
A <sup>-</sup>	0.014	0.019	0.012	0.010	0.011	0.006	0.014	0.006	0.025	0.020	0.056	0.054	0.035	0.031

Tables 6 and 7 show that both TOPSIS and MOORA’s final ranking for the cooking fuels is nearly comparable. Biogas (first position), pellet/briquette (second position), LPG (fourth position), charcoal (fifth position), and firewood (seventh position) have the same and consistent ranking performance in both methods. However, only solar and kerosene had slight variations in their ranking based on the two methods. However, only solar and kerosene had slight variations in their ranking based on the two methods.

**Table 6.** TOPSIS ranking for cooking fuels

Fuel type	P <sub>i</sub> <sup>+</sup>	P <sub>i</sub> <sup>-</sup>	P <sub>i</sub> <sup>+</sup> + P <sub>i</sub> <sup>-</sup>	RC <sub>i</sub>	Rank
Firewood	0.06696	0.056447	0.123406	0.457407	7
Charcoal	0.05317	0.05185	0.10502	0.493716	6
Kerosene	0.048886	0.052352	0.101238	0.517117	3
LPG	0.053799	0.057242	0.111041	0.515502	4
Biogas	0.050662	0.064181	0.114843	0.558858	1
Pellet/Briquette	0.048974	0.056102	0.105076	0.533922	2
Solar	0.058647	0.060508	0.119155	0.507811	5

Table 7 shows assessment values (y<sub>i</sub>) obtained for the cooking fuels using Eq. (16). Cooking fuels with higher y<sub>i</sub> values are the best. It can be observed that biogas emerges as the best cooking fuel. Next are pellet/briquette (second position), solar cooker (third position), LPG (fourth position), kerosene (fifth position), charcoal (sixth position) and firewood (seventh position). However, it can be seen that the cooking fuels assessment values are very close with minimum variation. This implies that there is an intense race between the performance of the cooking fuel. Also, the clean fuels such as biogas, pellet/briquette, and solar assessment values are closer to each other. Based on the MOORA method, biogas, pellet/briquette, and solar are the most promising cooking fuels based on the 14 selected criteria to achieve sustainable development.

Furthermore, the ranking results from TOPSIS and MOORA are compared to other MCDM methods for justification purposes. These include the Evaluation Based on Distance from Average Solution (EDAS), Complex Proportional Assessment (COPRAS), and Weighted Aggregates Sum Product Assessment (WASPAS). Figure 2 displays the cooking fuel ranking compared to other MCDM methods. It can be observed that the WASPAS ranking for biogas (first position) agrees with both the TOPSIS and MOORA rankings. However, EDAS and COPRAS rank biogas in the second position, slightly deviating from TOPSIS and MOORA. None of the methods’ rankings for pellet/briquettes match those of TOPSIS and MOORA. However, rankings by both

**Table 7.** MOORA ranking of cooking fuels

Fuel type	$y_i$	Rank
Firewood	0.07546	7
Charcoal	0.11328	6
Kerosene	0.12085	5
LPG	0.13969	4
Biogas	0.17544	1
Pellet/Briquette	0.15766	2
Solar	0.15035	3

COPRAS and WASPAS for pellet/briquette matches. Solar rankings from the methods are nearly different for the cooking fuels, except for TOPSIS and WASPAS, whose rankings correlate. LPG rankings from TOPSIS and MOORA are comparable to COPRAS but slightly deviate from the remaining methods. Kerosene ranks in the fifth position in MOORA, COPRAS, and EDAS but ranks in the third position in EDAS and fourth position in WASPAS. All the methods ranked for charcoal matches except for EDAS, where it ranked differently. Firewood ranks in the same position in the MCDM methods. Based on these findings, the final ranking for the cooking fuels could be summarised as biogas > pellet/briquette > solar > LPG < kerosene > charcoal > firewood. This implies, comparably, biogas is the best cooking fuel among the others suitable for achieving sustainable development in Ghana based on the 14 selected decision-making criteria. These findings are nearly comparable to a similar study by Massoud et al. (2020), which categorised biogas and solar for cooking as the most sustainable over firewood and charcoal in Ghanaian households.

It has been seen that biogas performs better than LPG towards sustainable development. Biogas produced from crop and livestock residues is more sustainable and positively impacts the environment and climate. However, LPG, mainly generated from fossil fuels, has an intense negative impact on the environment. Biogas could be utilised as a substitute for LPG, which is mostly produced from fossil fuels. Also, pellet/briquette could replace existing polluting firewood used mainly in rural areas and certain urban places in Ghana. The decision-makers and policymakers could prioritise biogas, pellet/briquette, and solar for cooking in Ghana. Furthermore, the technologies for these cooking fuels are still underdeveloped, especially pellet/briquette and solar for cooking in Ghana. Presently, biogas technologies have gained attention for cooking and electricity generation in Ghana. For instance, Safisana Biogas has added a 100 kW biogas plant for electricity generation to the national grid. Also, several households and institutions have constructed digesters for biogas generation (Energy Commission 2020). This indicates that biogas production has a good chance of commercialisation in Ghana as a replacement for LPG. However, the same cannot be said for pellet/briquette and solar for cooking. Though Ghana is making an effort to deploy the usage of pellet/briquettes, the technology is still underdeveloped, and it is being challenged by lack of awareness, local market, and availability of cookstoves to burn the briquettes. Likewise, solar for

cooking is also being confronted by the unavailability of solar cookers for domestic and commercial purposes.

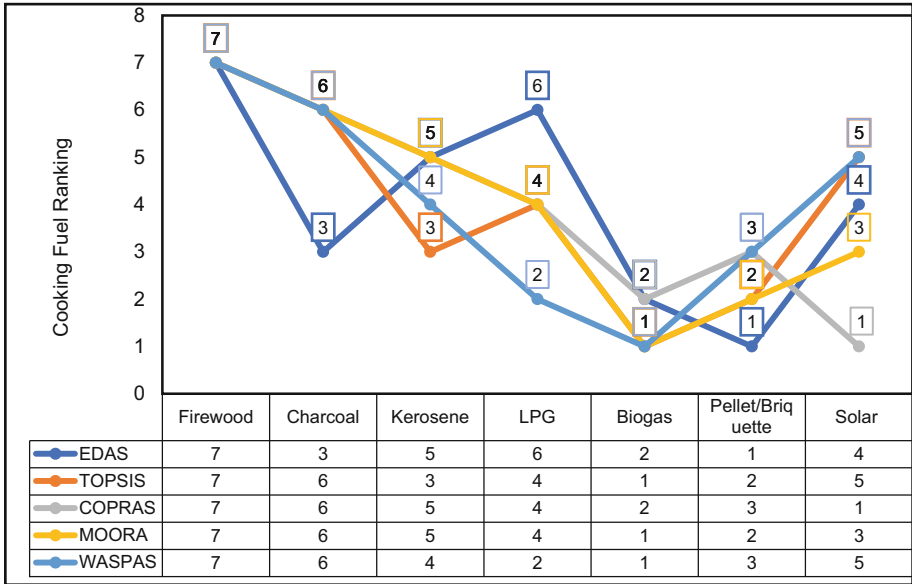


Fig. 2. Comparison of cooking fuel ranking to other MCDM approaches

### 4 Conclusion

This study has assessed fuels including firewood, charcoal, kerosene, LPG, pellet/briquette, biogas, and solar to determine the most suitable for cooking in Ghana. The study employed five different MCDM methods to evaluate the cooking fuels based on 14 selected decision-making criteria. The fuels are arranged as follows in order of performance: biogas > pellet/briquette > solar > LPG < kerosene > charcoal > firewood. This indicates that biogas is the best cooking fuel suitable for achieving sustainable development in Ghana. Also, the results imply that biogas can replace existing LPG for cooking in both rural and urban communities. Likewise, firewood and charcoal could be phased out or replaced with a pellet/briquette for cooking.

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# Effect of Parametric Force on the Chaotic Behaviour of Flexible Rotor System Under the Influence of Mass Unbalanced

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**Abstract. Purpose:** This paper examines the nonlinear behaviour of a flexible rotor-bearing exposed to transverse harmonic excitations owing to mass unbalance.

**Design/Methodology/Approach:** The equations of motion are obtained, and the behaviour of the rotor system around the resonant region is explored. The set-up is made intensely nonlinear by varying the mass unbalance. The incremental variation is done as multiples of the actual value. This model's nonlinear dynamical systems analysis is based on bifurcations detected from the analysis trajectories and the Lyapunov calculations. Strange fractal attractors are observed and periodic orbits evolve into chaos. The emergence of a seemingly chaotic behaviour from perfectly deterministic origins in the system is interestingly observed. The computational method used in this work is facilitated with the *Dynamics 2* software.

**Findings:** Findings show a strong dependence by the system's response on changes in some control parameters, such as mass unbalance, and chaos observed as mass unbalance increases to make the system more nonlinear. The study further establishes that when the parametric excitation term is introduced deliberately, the motion of the system becomes periodic which eliminates vibration.

**Research Limitation/Implications:** The nonlinear behaviour of the flexible rotor-bearing system studied in this work was given an analytical treatment whose solutions were verified numerically. This numerical validation, therefore, gives an assured guide should an experimental investigation be performed on the subject.

**Practical Implication:** A practicable appreciation of the nonlinear behaviour of a flexible rotor-bearing system that has been subjected to transverse harmonic excitations owing to mass unbalance is missing in the literature. Results from this study will enhance the body of knowledge already existent in the field/industry of rotor-bearing systems for effective manufacturing.

**Social Implication:** Stakeholders and industry players can reference results from the study for the efficient design of flexible rotor systems. The methods and



results from this study will be essential reference material on flexible rotor systems for the academic community.

**Originality/Value:** The novelty of this study also lies in the fact that for the first time, a complete analytic and numerical understanding have been given to the nonlinear behaviour of a flexible rotor-bearing system exposed to transverse harmonic excitations caused by mass unbalance.

**Keywords:** Flexible rotor system · Mass unbalanced · Nonlinear · Parametric excitation · Bifurcation

## 1 Introduction

Analysis of nonlinear dynamical systems and their exact solutions are difficult to establish. The qualitative behavior and analytical solutions flexible rotor system can be useful. The dynamic trajectories of the rotor and bifurcation diagrams are included in the analysis methods used in this study. The onset conditions for chaotic motion are determined by the analysis of the maximum Lyapunov exponent. It is difficult to predict and control the behavior of a system under a chaotic regime. It is there critical to identify chaotic motions and preferably, take measures to circumvent the conditions that produce them. Chaos is defined as an irregular, unpredictable behavior that can be observed in deterministic nonlinear dynamic systems. It is the mathematical phenomenon seen in dynamical systems that depend sensitively on their initial conditions. The theory of chaos commenced as branches of mathematics and physics which deals with turbulence structures and fractal geometry of self-similar systems. Henri Poincaré (1854–1912), a French mathematician, was first to report on the unpredictable and chaotic behaviour of simple nonlinear deterministic systems.

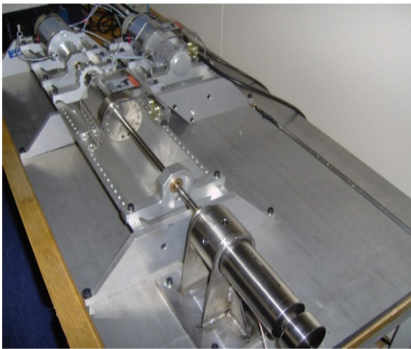
Birkhoff (1844–1944), Andronov (1901–1952), Cartwright (1900–1998), Kolmogorov (1903–1987) and Smale (1930–present), among others, pioneered works in the areas of chaotic dynamics, and can be found in the mathematical literature. Despite these, the consequence of chaos was not fully appreciated until the inception of digital computing and the necessity for numerical simulations to demonstrate chaos in a variety of real-time systems. Abrahams and Shaw (1982) applied creative methods to create three-dimensional representations of bifurcation and phase space structure diagrams. Wolf et al. (1985) devised a method for using experimental data to estimate non-negative Lyapunov exponents. The exponents are used to calculate the mean rate at which nearby trajectories converge or diverge on an overall scale. Positive exponent denotes chaos and divergence while the negative counterparts denote convergence and a periodic orbit, and a zero exponent denotes a marginally stable orbit. A chaotic system or strange attractor, is one with at least a single positive Lyapunov exponent. The numerical size of the exponent gives an information about the time scale on which the system dynamics become unpredictable. The nonlinear flexible rotor bearing system equations were numerically integrated using an approximate method. The motion normally begins on a regular basis and as the mass unbalance increases, the system gradually becomes chaotic. Introducing parametric excitations into the rotor system at the principal resonance frequency makes the chaotic motions eventually become periodic, otherwise

known as automatic shifting and this results in stable periodic motions. When a rotor system is excited at a resonant frequency due to mass unbalance chaotic, nonlinear, and linear feedbacks can be achieved by varying the mass unbalance, and stable periodic motions can be achieved by deliberately introducing parametric excitations into the system at the principal parametric frequency.

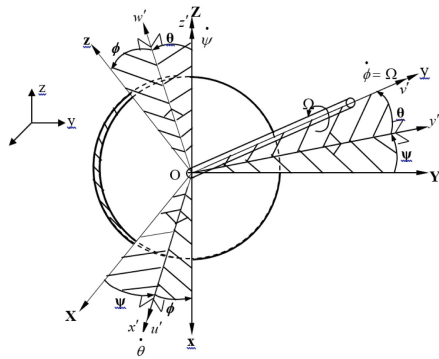
Dynamics of analytically modeled systems can further be appreciated when techniques based on specialized numerical examinations are used. Numerous softwares such as AUTO, Dynamics Solver, XPPAUT and DynPac, have emerged over the years to help in the specific analysis of dynamical systems. These programs can generate bifurcation diagrams, equilibria plots, limit cycles and Lyapunov exponents. Nusse and York (1994) created the numerical analyses software known as Dynamic, which works well for computational and numerical analysis of the dynamic of a system. This software has been used by Nusse et al. (1994); Nusse et al. (1995) and Chin et al. (1994) to determine basins of attraction, bifurcations and Lyapunov exponents for varying physical systems of interest. An updated edition called Dynamics 2, has since been developed by Nusse and York (1998). The Dynamics 2 software is used in this study as a computational basis to be used for qualitative bifurcation valuations. The software is also used in this work to obtain a set of bifurcation in the presence and absence of parametric force terms.

## 2 A Model of the Rotor System

The rotor system model in Fig. 1 represents a Duffing equation with cubic nonlinear terms to denote the behavior of this dynamical system from nonlinear transition to chaos, and is solved using Dynamics 2 – a bifurcation analysis tool. As a result, we can write the Duffing equation of the system as follows. Atepor (2008) provides a thorough understanding of these equations.



(a)



(b)

**Fig.1.** (a) Image of the rotor system, (b) 3-D frames of reference for a disk on a rotating flexible shaft

$$\ddot{q}_1 + \hat{c}\dot{q}_1 - \Omega\hat{a}_5\dot{q}_2 + \omega^2q_1 + \hat{b}q_1^3 = \mu d\Omega^2 \sin \Omega t \quad (1)$$

$$\ddot{q}_2 + \hat{c}\dot{q}_2 + \Omega\hat{a}_5\dot{q}_1 + \omega^2q_2 + \hat{b}q_2^3 = \mu d\Omega^2 \cos \Omega t \quad (2)$$

$$\ddot{q}_1 + \hat{c}\dot{q}_1 - \Omega\hat{a}_5\dot{q}_2 + \omega^2q_1 + \hat{b}q_1^3 - \hat{F}_{act}q_1 = \mu d\Omega^2 \sin \Omega t \quad (3)$$

$$\ddot{q}_2 + \hat{c}\dot{q}_2 + \Omega\hat{a}_5\dot{q}_1 + \omega^2q_2 + \hat{b}q_2^3 - \hat{F}_{act}q_2 = \mu d\Omega^2 \cos \Omega t \quad (4)$$

Where,  $\hat{a}_5 = \frac{a_5}{m}$ ,  $\omega^2 = \frac{k}{m}$ ,  $\hat{b} = \frac{b}{m}$ ,  $\hat{c} = \frac{c}{m}$ ,  $\mu = \frac{m_u}{m}$ ,  $\hat{F}_{act} = \frac{F_o}{m}$ ,  $k$  - linear stiffness coefficient,  $c$  - damping coefficient,  $q_1, q_2$  - displacements,  $\omega$  - natural frequency,  $b$  - nonlinear cubic stiffness coefficient,  $\Omega$  - excitation frequency,  $m_u$  - mass unbalance,  $a_5$  - characteristic equation coefficient,  $F_{act}$  - external applied force,  $F_{act}q_i$  are the axial excitation force terms and differential with respect to time is symbolized with dots on the variable.

After some modifications, the flexible rotor system models shown in Eqs. (1) and (2) are used to analyze the behavior of the system's dynamics with the help of Dynamics 2 software. Equations (1) and (2) are thus written as follows:

$$\ddot{x} + \bar{c}_1\dot{x} - \bar{c}_2\dot{y} \cos(y) + \bar{c}_3x + \bar{c}_4x^3 = \rho \sin(\Omega t) \quad (5)$$

$$\ddot{y} + \bar{c}_1\dot{y} + \bar{c}_2\dot{x} \cos(y) + \bar{c}_3y + \bar{c}_4y^3 = \rho \cos(\Omega t) \quad (6)$$

$$\ddot{x} + \bar{c}_1\dot{x} - \bar{c}_2\dot{y} \cos(y) + \bar{c}_3x + \bar{c}_4x^3 - \bar{c}_5x = \rho \sin(\Omega t) \quad (7)$$

$$\ddot{y} + \bar{c}_1\dot{y} + \bar{c}_2\dot{x} \cos(y) + \bar{c}_3y + \bar{c}_4y^3 - \bar{c}_5y = \rho \cos(\Omega t) \quad (8)$$

Where,  $\bar{c}_1 = \frac{c}{m}$ ;  $\bar{c}_2 = \frac{a_5\Omega}{m}$ ;  $\bar{c}_3 = \frac{k}{m}$ ;  $\bar{c}_4 = \frac{b}{m}$ ;  $\bar{c}_5 = F_{act}$  and  $\rho = \frac{m_u\Omega^2 d}{m}$

### 3 Nondimensionalization

In Eqs. (5) to (8), nondimensionalization of the timescale is instituted by substituting  $\tau = \sqrt{\omega}t$ , where  $\omega$  denotes first mode natural frequency of the flexible rotor. The prime is used to represent differentials with respect to  $\tau$ .

$$x' = u \quad (9)$$

$$u' = \frac{\rho}{\omega} \sin(\phi t) - C_1u + C_2v \cos(y) - C_3x - C_4x^3 \quad (10)$$

$$u' = \frac{\rho}{\omega} \sin(\phi t) - C_1u + C_2v \cos(y) - C_3x - C_4x^3 + C_5x \quad (11)$$

$$y' = v \quad (12)$$

$$v' = \frac{\rho}{\omega} \cos(\phi t) - C_1 v - C_2 u \cos(y) - C_3 y - C_4 y^3 \quad (13)$$

$$v' = \frac{\rho}{\omega} \cos(\phi t) - C_1 v - C_2 u \cos(y) - C_3 y - C_4 y^3 + C_5 y \quad (14)$$

where,  $C_1 = \frac{\bar{C}_1}{\sqrt{\omega}}$ ;  $C_2 = \frac{\bar{C}_2}{\sqrt{\omega}}$ ;  $C_3 = \frac{\bar{C}_3}{\omega}$ ;  $C_4 = \frac{\bar{C}_4}{\omega}$ ;  $\phi = \omega$ ;  $C_1$  - damping coefficient;  $C_2$  - Gyroscopic term;  $C_3$  - linear stiffness coefficient;  $C_4$  - nonlinear cubic stiffness coefficient;  $C_5$  - actuator force;  $\rho$  - excitation amplitude and  $\phi = \omega$ . Values used to initialize the models of the coupled equations including those that have parametric force terms present and absent are presented in Tables 1 and 2.

## 4 Bifurcation Analysis

Topological changes may occur due to changes in systems parameters when dynamical systems are under study. These changes in the system's dynamics are referred to as bifurcation. It is commonly necessary to identify locations of nonperiodic motion within the space of the parameters. Such domains can be represented using bifurcation plots. A bifurcation plot is a beneficial tool to analyse nonlinear behavior and therefore encapsulates vital dynamics of a system (Chang-Jian and Chao-Kuang 2007). Shi et al. (2020) studied the nonlinear dynamics under yawing motion of the marine rotor-bearing system. Their work used bifurcation plots to show that yawing motion affects the dynamic characteristics of the rotor-bearing system significantly, causing the rotor system to be dominated by the quasi-period. Chang-Jian et al. (2018) used bifurcation plots and the Lyapunov exponent to detect the commencement of chaotic motion in their analysis of bifurcation and chaos of a gear pair system that is founded on crack rotor-bearing systems with the effect of rub-impact. The properties and performance of the dual-directional coupled aerodynamic bearing system were investigated in detail by Wang and Lin (2020). They used bifurcation occurrence and the maximum Lyapunov exponent to study the conditions that lead to nonperiodic motions and to prevent irregular vibration. Periodic motions may become unstable when the control parameters are varied. This indicates dynamic stability deterioration and eventually chaos motion follows. Many bifurcations types are explained in literature; however, in this work, a period doubling bifurcation is frequently detected and given a detailed discussion in the next section. The period doubling bifurcation is one resulting from a system whose behavior varies at integer multiples of the original response's periodicity. Further change in the control parameter results in a chaotic motion. The presence of a multi-periodic motion designates dynamic instability. Bifurcation assists to identify system instability. It also affords practical and theoretical viewpoints for the control and optimization of operations of these systems.

### 4.1 Dynamics 2 Program Parameters

The bifurcatory behavior are plotted with the Dynamics 2 software. In order to understand the dynamics within the models, amplitude responses are plotted against the Lyapunov exponent and normalized excitation acceleration in Sect. 2, as shown in Figs. 1 (a, b, c, d).

**Table 1.** Numerical simulations data-dimensional parameters

Stiffness (Linear) [ $s^{-2}$ ]	Damping coefficient [ $s^{-1}$ ]	Actuator force [ $ms^{-2}$ ]	Stiffness (Cubic) [ $m^{-2}s^{-2}$ ]	Excitation amplitude [ $ms^{-2}$ ]
$C_3 = 61901.6$	$C_1 = 21.9$	$C_5 = 1533.7$	$C_4 = 8.15 \times 10^9$	$\rho = 12$

Gyroscopic term  $C_2 = 0.4 s^{-1}$ ;

Reference frequency:  $\omega = 248.8$  rad/s; Parametric frequency:  $\Omega_2 = 497.6$  rad/s

**Table 2.** Numerical simulations data-nondimensional parameters

Stiffness (Linear)	Damping coefficient	Actuator force	Stiffness (Cubic)	Excitation amplitude
$C_3 = 248.8$	$C_1 = 1.4$	$C_7 = 6.16$	$C_4 = 3.28 \times 10^7$	$\frac{\rho}{\omega} = 0.048$

Gyroscopic term  $C_2 = 0.025$ ;  $\phi = 248.8$  rad/s;  $\phi_2 = 497.6$  rad/s

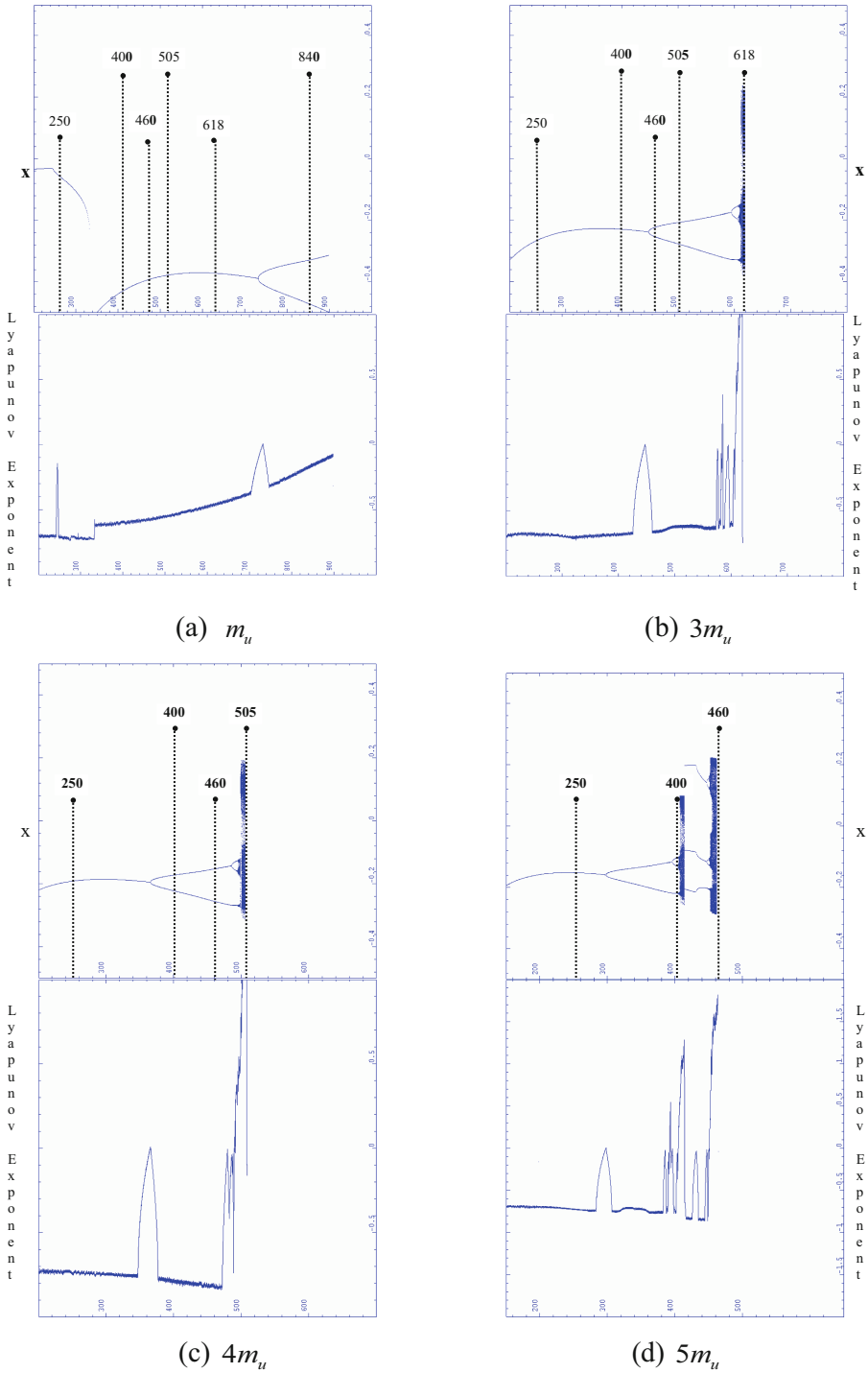
The data employed in this work are experimental rig system parameters, and the nondimensionalized parameters in Table 2 are used to plot graphs. The necessary Dynamics 2 commands are instituted to plot all diagrams in Atepor (2008). This study investigates a weak nonlinear system and to achieve a more intrinsically nonlinear physical system, the nonlinear cubic coefficient and excitation acceleration needs to be increased. This can be achieved by making the shaft more flexible or raising mass unbalance, or both. Varying increment to various multiples of the actual value, causes a strongly nonlinear system which is interesting to investigate. These adjustments alter the excitation value and consequently aid in moving a weak nonlinear system farther away and which amplifies the influence of the nonlinear terms correspondingly. As a result of this effect, the system displays potential bifurcations to chaos.

## 5 Results and Discussions

The rotor system's bifurcation behavior is plotted according to (i) Response amplitude,  $X$ , against nondimensionalised Lyapunov exponent in the horizontal direction and excitation acceleration and (ii) Response amplitude,  $X$ , as ordinate against nondimensionalised excitation acceleration and the Lyapunov exponent as abscissa for Parametric Force Term included models in the horizontal direction.

(a) Response amplitude,  $X$ , against nondimensionalised excitation acceleration and the Lyapunov exponent in the horizontal direction

1. The bifurcation plots for varying mass unbalance in Figs. 2 (a), (b), (c) and (d) show periodic and stable motions at nondimensionalized excitation acceleration of 250, with negative Lyapunov exponents.



**Fig. 2.** Bifurcation diagrams and Lyapunov exponent of amplitude as a function of the normalized excitation acceleration in the horizontal direction.

2. When the nondimensionalized excitation acceleration is set at 400, the diagrams of bifurcation in Figs. 2 (a) and (b) suggest period one motion whereas Figs. 2 (c) and (d) show period two and period four motions respectively.
3. At nondimensionalized excitation acceleration of 460, the bifurcation plot in Fig. 2(a) exhibit period one motion and has a negative Lyapunov exponent whereas Figs. 2 (b) and (c) show period two motions amid a negative Lyapunov exponents and Fig. 2 (d) shows chaotic motion with positive Lyapunov exponent.
4. The bifurcation plots in Figs. 2 (a) and (b) show period one and period two motions respectively amid negative Lyapunov exponents when the nondimensionalized excitation acceleration is 505, whereas chaotic motions with positive Lyapunov exponents are shown in Fig. 2 (c).
5. At nondimensionalized excitation acceleration of 618, the bifurcation diagrams in Fig. 2 (a) displays period one motion and has a negative Lyapunov exponent and that in Fig. 2 (b) shows chaotic motions with positive Lyapunov exponent.
6. At nondimensionalized excitation acceleration of 840, the bifurcation diagram in Fig. 2 (a) depicts period two motions amid a negative Lyapunov exponent.

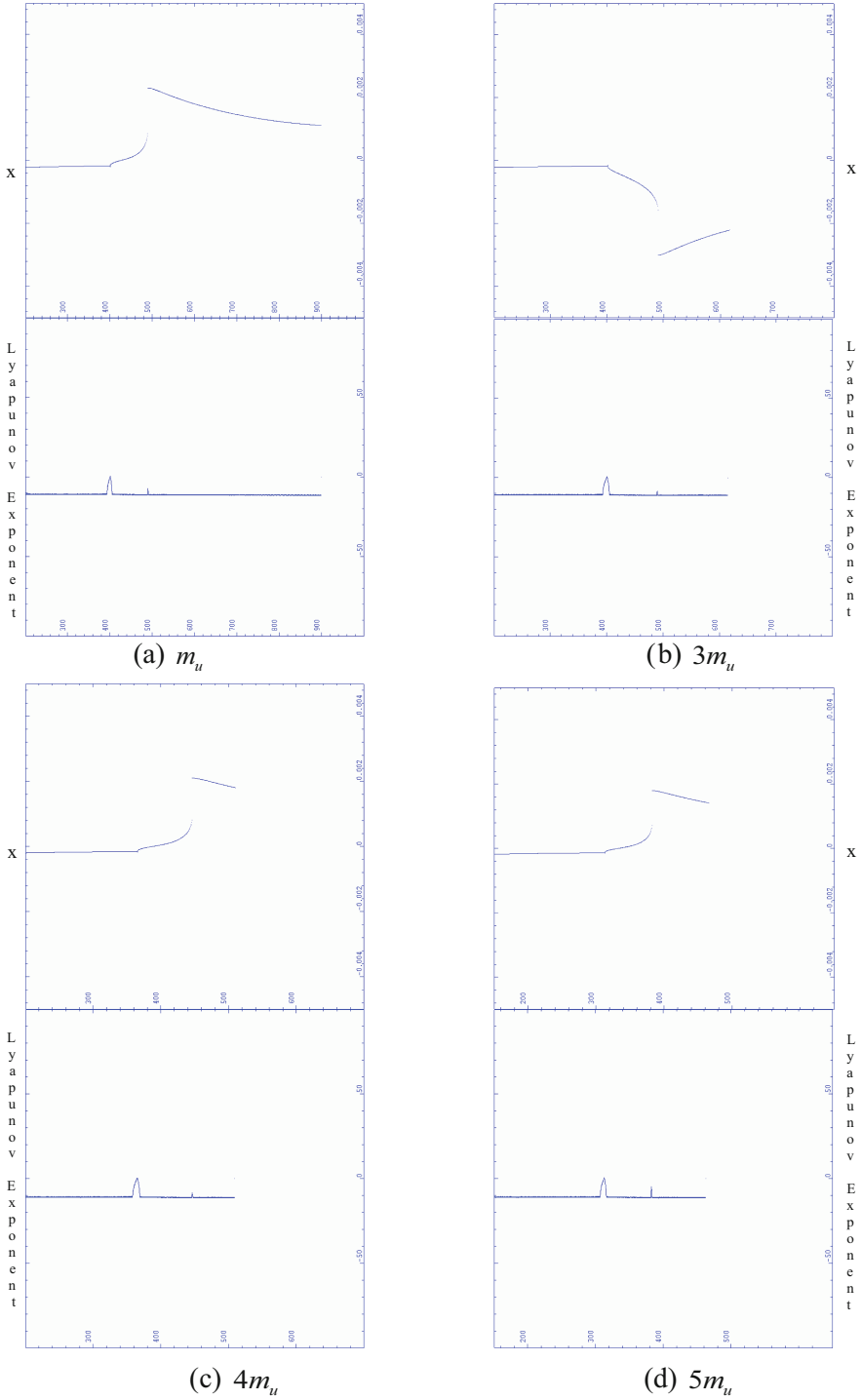
According to the analysis;

- (i) Considering the case with the least mass unbalance otherwise described as the weakest nonlinear response, the periodic response bifurcates to chaos with an increase in mass unbalance as shown in Fig. 2. Figure 2(a)–(d) positive Lyapunov exponents displays clear indications of chaos, whereas stable motion is actioned by negative Lyapunov exponents. It can be inferred from these graphs that small excitation accelerations are necessary for chaotic responses in each of the four cases sequentially. Five types of system motions emerge for a range of excitation accelerations. They are stable single period motion, stable two period motion, stable four period motion, stable quasi-periodic otherwise called multiperiodic motion and chaotic motion.
- (ii) It can also be seen in Fig. 2(a)–(d) that whenever the system bifurcates to higher multiples of periodic motion, the Lyapunov exponent plot jumps up to the zero level, which indicates that the system is moving to higher multiples of the period.

(b) Amplitude of response,  $X$ , as a function of nondimensionalized excitation acceleration and the Lyapunov exponent for the model with Parametric Force Terms in the horizontal direction.

1. At all the nondimensionalized excitation acceleration levels, all the bifurcation diagrams in Fig. 3 illustrates stable periodic motions with negative Lyapunov exponents.

(i) Figure 3 depicts the bifurcation that is controlled by normalized excitation acceleration in the horizontal direction and applying the first mode resonance frequency, in the instance where the parametric force term has a parametric frequency twice that of the first mode resonance frequency. The periodic responses remain periodic with increases in the mass unbalance values. The bifurcation diagrams remain qualitatively unchanged,



**Fig. 3.** Bifurcation diagrams and Lyapunov exponent of amplitude as a function of the normalized excitation acceleration for the case model with Parametric force terms in the horizontal direction.



whereas the negative Lyapunov exponents show stable periodic motion. This implies that the introduction of the parametric force terms into the system, causes all chaotic motions and period doubling present in the system, as shown in Fig. 3 to become stable. It also implies that the bifurcation set automatically shifts the chaotic motion and period doubling, resulting in stable periodic motions and the complete elimination of chaos, noise, and vibration.

## 6 Conclusion

The goals of this work were rooted in the analysis of the dynamic behavior of a flexible rotor system operating in the face of mass unbalance. We sought to distinguish chaotic and stable operating areas, and to analyze the rotor system's behavior in the presence of parametric excitation terms that were deliberately dispensed into the system's dynamics. The system's equations, which were expressed in a Duffing equation with cubic non-linear terms, were solved using Dynamics-2 software, which is a bifurcation analysis tool. Results from the vibration analysis show that the rotor system's trajectory significantly changes as the system's mass unbalance changes. Changes in mass unbalance result in a variety of behaviors such as periods one, two, and unstable nonlinear chaotic motions. Findings also demonstrates that when parametric force terms were introduced, all of the chaotic motions and period doubling present became stable within the system. This means that the bifurcation set's period doubling and chaotic motions are shifted automatically, occasioning stable periodic motions and complete elimination of chaos, noise as well as vibration. These findings provide possible solutions to real vibrational issues seen by the manufacturing industry especially in the designing of new rotating systems including generators and hydraulic turbines. This work also enriches literature for engineering design and control of associate systems.

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# Concrete Rebar Corrosion Inhibitors - A Review of Sustainable Natural Inhibitors

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**Abstract. Purpose:** This paper reviews various natural inhibitors of corrosion of steel rebar and also presents the laboratory and field application situations of this natural inhibitor in the construction of sustainable houses/buildings. This work aims to review sustainable natural substances that are readily available within the Ghanaian community and not harmful to the society that can replace nonrenewable corrosion inhibitors in the market.

**Design/Methodology/Approach:** A simple review of the chemistry and mechanism of the corrosion process is performed. The corrosion inhibition mechanism is also reviewed and the various types of natural corrosion inhibitors are declared. Some recent studies on steel rebar corrosion inhibitors, their working mechanisms or environments, duration of exposure, and inhibition efficiency are also presented.

**Findings:** Findings revealed that natural corrosion inhibitors are primarily obtained from medicinal plants, aromatic spices, and herbs. The phenolic constituents of these plant materials have been found to possess anti-oxidative activities and nutritive value and could be the most sustainable option for enhancing the corrosion durability of steel rebar since they are obtained from renewable sources.

**Research Limitation/Implications:** The study focused on the corrosion activity of rebars used in concretes alone. Reinforcements are placed in concrete materials to strengthen a building. Also, nonrenewable sources of corrosion inhibitors are not recommended in this study since they are expensive and may not be readily accessible within the Ghanaian market.

**Practical Implication:** This review is intended to inform building contractors and any construction engineer of the importance and advantages of the sustainability of natural corrosion inhibitors and the urgent need for its use as a substitute to nonrenewable corrosion inhibitors.

**Social Implication:** This review will enable policy makers within the local construction industry to make informed decisions in reviewing existing policies that will protect the environment as well as advancing new avenues for job creation in the area of innovative natural corrosion inhibitor production.

**Originality/Value:** This review is unique as it serves as an information document of natural corrosion inhibitors and their mechanism to corrosion prevention. It serves as a reference for construction industry players in Ghana to innovate sustainable materials that are locally available and saves the environment.

**Keywords:** Corrosion · Inhibitors · Mechanism · Reinforcement · Rebar

## 1 Introduction

Corrosion is an ancient phenomenon that has impacted human existence both negatively and positively. A typical reason for the premature failure of concrete with reinforcement is as a result of the rebar (Abosrra et al. 2011). Reinforced concrete has taken a prominent position in construction and other related industries. It is perhaps the most prevalently used construction material (Lopez-Calvo et al. 2017). Considering the profuse nature in the usage of reinforced concrete in various fields (Feugeas et al. 2018; Kovler and Belie 2016; Lapiro et al. 2020; Lopez-Calvo et al. 2010), its strength, reliability, safety, possible failure or damage, cost of maintenance and degradation, its corrosion is of grave concern as has been indicated in the works of (Abosrra et al. 2011; Borade and Kondraivendhan 2018; Brooks and Kabir 2011; Pauletta et al. 2020). It has been affirmed that corrosion is the primary cause of the failure of reinforced concrete structures, ultimately resulting in the reduction of the flexural capacity (loss of rebar cross-section), reduction of the bond, and limiting of ductility (Luo et al. 2021).

Within the last decade, various methods have been employed to control corrosion of the concrete rebar (Okeniyi et al. 2015; Yeomans 2016). Among the various corrosion controlling methods, corrosion inhibitors are the most convenient ones (Elsener and Angst 2016). It has been employed as the practical technique to control corrosion by inhibition (Elsayed and ElShazly 2016; Elshami et al. 2020; Usman et al. 2018). Corrosion inhibitors are used mainly as commixtures in concrete (Mangi et al. 2020). However, maintenance for new construction can be achieved through admixing the concrete with steel reinforcements or spraying the concrete surface with the admixtures (James et al. 2019). To further alleviate this degradation process (Li et al. 2021), admixtures for inhibiting corrosion or supplementary cementitious material (SCM) or combination of both are mostly employed the construction industry (Lopez-Calvo et al. 2017).

Numerous research have suggested that properly cured concrete produced with ordinary Portland cement combined with SCMs such as plants extracts (Okeniyi et al. 2017) enhance concrete's mechanical and durability properties (Nair and Celik Ozyildirim 2019). These properties are, however, affected by the corrosion of the rebar. Corrosion of steel rebar usually occur when carbonation reduces the alkalinity of the concrete which therefore eliminates the passivation action of the concrete and the chloride content in the concrete in contact with rebar becomes higher than its critical threshold. The use of rebar in environment where carbonation and chloride attack are eminent, corrosion inhibitors should be employed. For this reason, this study conducts a thorough analysis of the corrosion inhibition process in concrete rebar in the last decade.

### 1.1 Corrosion of Steel Rebar

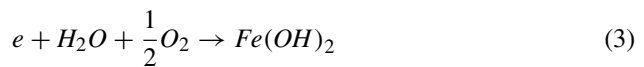
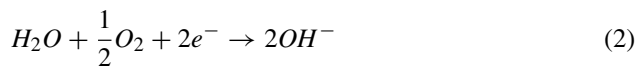
Steel rebar serves as intrinsically resisting the tensile loads by composite action, generally reinforcing the strength of concrete. The total performance of concrete under compressive and tensile loads are improved by the steel rebar (Abosrra et al. 2011). Corrosion

of the rebar is a cancerous phenomenon that ultimately leads to the premature failure of concrete infrastructure, ranging from bridges to sanitary systems. The high alkalinity of concrete causes the creation of a natural passive oxide film on the surface of the rebars that prevent the further dissolution of iron (Feng et al. 2021; James et al. 2019). A minimum pH of 13 is required for the passivation of steel rebar. However, if impurities like chloride are present in the concrete, the passive film breaks down (Borade and Kondraivendhan 2015, 2018; Hansson 2016). Furthermore, a reaction of the concrete cover on the rebar with atmospheric CO<sub>2</sub> results in a reduction in the pH of concrete and causes a breakdown of the passive film and hence accelerated corrosion. It is well known that carbonation, chloride penetration and sulphate attacks affects the resilience of concrete structures in saline environment (Mandal et al. 2020). The use of corrosion inhibitors provides the opportunity to make concretes more durable and hence more sustainable.

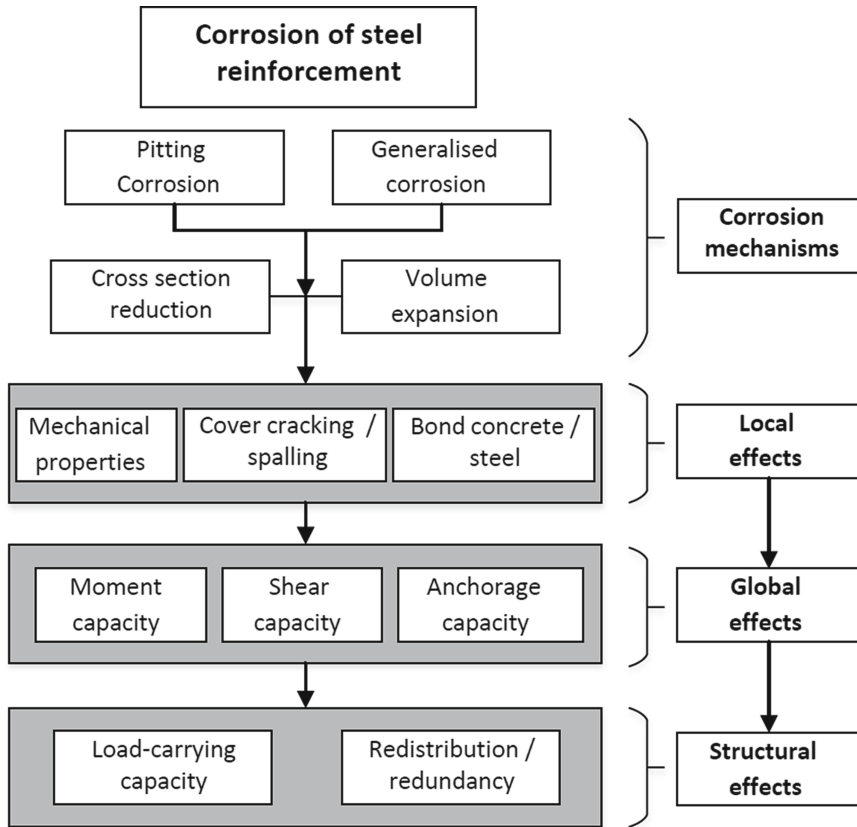
Corrosion effect on the mechanical properties of the steel rebar has been studied by many researchers and can classify corrosion into two significant categories, general and local corrosion (Carasek et al. 2011; Yousif et al. 2014; Ziehl and ElBatanouny 2016). The effects of corrosion on the stiffness, stress redistribution and load-carrying capacity of the concrete rebar are shown in Fig. 1.

## 1.2 Steel Corrosion Mechanism in Concrete

The electrochemical process that occurs in the presence of water and oxygen is known as Corrosion. The main oxidation and reduction reactions are described in Eqs. (1) and (2). The overall reaction is represented by Eq. (3) where Fe.(OH)<sub>2</sub> is just one of the many possible products of corrosion, which depends on the environment (chloride, carbonation, sulphate et cetera.) (Maldonado-Bandala et al. 2011)



A protective iron oxide layer (passive layer) is formed when steel is embedded in unadulterated concrete because of the high alkalinity of the pore solution (Nilsson 2019).

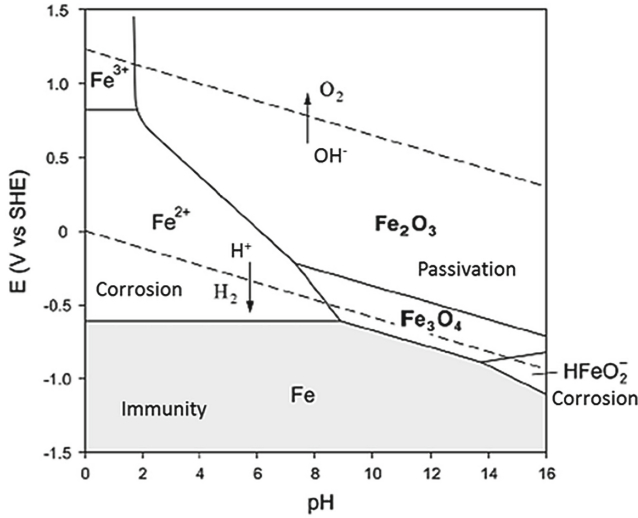


**Fig. 1.** Corrosion effects on stiffness, load-carrying capacity, and force redistribution of a concrete element (Tahershamsi 2016).

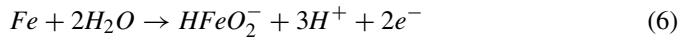
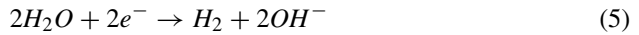
The thermodynamic of resistance, passivity and corrosion of iron and iron oxides in solution are illustrated in equilibrium potential-pH diagrams, known as Pourbaix diagrams (Fig. 2) (Pourbaix 1963).

According to Eqs. (4) or (5), respectively, and Fig. 1, the equilibrium potential under which oxygen or hydrogen reduction occurs is represented by the dash lines. with the respective hydrolysis ions, H<sup>+</sup> and OH<sup>-</sup>, water is in equilibrium between the dashed lines. Equation (4) represent oxygen or low pH deficient environments (e.g. inside the pit). However, at low potentials and in neutral to alkaline media, hydrogen evolution can also occur, as indicated by Eq. (5). Iron is immune to very low potentials, which corresponds to a state where it is not reactive; neither does it dissolve into solution nor react with water to form passive oxides. Low potential corrosion may occur at low potentials and high pH values when the oxygen content is tremendously low, according to Eq. (6). However, this has no consequence practically.





**Fig. 2.** Simplified Pourbaix diagram for iron in water at 25°C (ion concentration  $10^{-6}$  mol/l) (Elsener and Angst 2016).



It has been reported by Feng et al. (2021); Kenny and Katz (2010); Mandal et al. (2020) and Mundra et al. (2017) that, in the passive region under anodic control, the current rapidly decreases as the passive film grows on. Iron dissolution may occur but at a prolonged rate and, in turn, makes the corrosion rate negligible.

## 2 Corrosion Inhibitors

A corrosion inhibitor is a substance or combination of substances that decrease the corrosion rate of metals in that medium when added in relatively small quantities to a corrosive medium. Inhibitors may be dyes, plant extracts and heterocyclic organic compounds, et cetera (Prasanna et al. 2017). Corrosion inhibitors are organic and inorganic compounds, which can be added in a small proportional ratio to concrete and mixing with water, can lag the inception or avoid corrosion of the steel rebar. Corrosion inhibitors have been investigated for reinforced concrete since 1960, largely about chloride-induced corrosion (Elsener and Angst 2016). The initiation of corrosion is regarded as a result of the use of inhibitors in concrete (Borade and Kondraivendhan 2018). Through lengthening the initiation time for corrosion or reducing the rate of corrosion, corrosion inhibitors can increase service life.

Electron-rich organic compounds such as S, N and O are effective inhibitors of corrosion in hostilely corrosive media (Okeniyi et al. 2019). The other class of organic

inhibitors are fatty amides (Hebbar et al. 2015; Oguntade et al. 2019), pyridines, imidazoles and 1,3-azoles (Lindsay et al. 2020). In their study to evaluate the electrochemical behaviour of copper-steel alloy exposed to cooling water, as the concentration of the inhibitor increased, the inhibition efficiency also improves (Yaro et al. 2014). Corrosion inhibitor retards the corrosion process by forming a film on the surface of the reinforcing bar through the process of adsorption. The film adsorbed serves as a protective layer that isolate interaction at the metal/concrete interface (Praveen et al. 2021). The effect of a corrosion inhibitor hinges on the capability of surface adsorption of the rebar to replace water molecule at the metal/concrete interface (Prathibha et al. 2013; Bellal et al. 2021). The types of corrosion inhibitors are reported in Fig. 3.

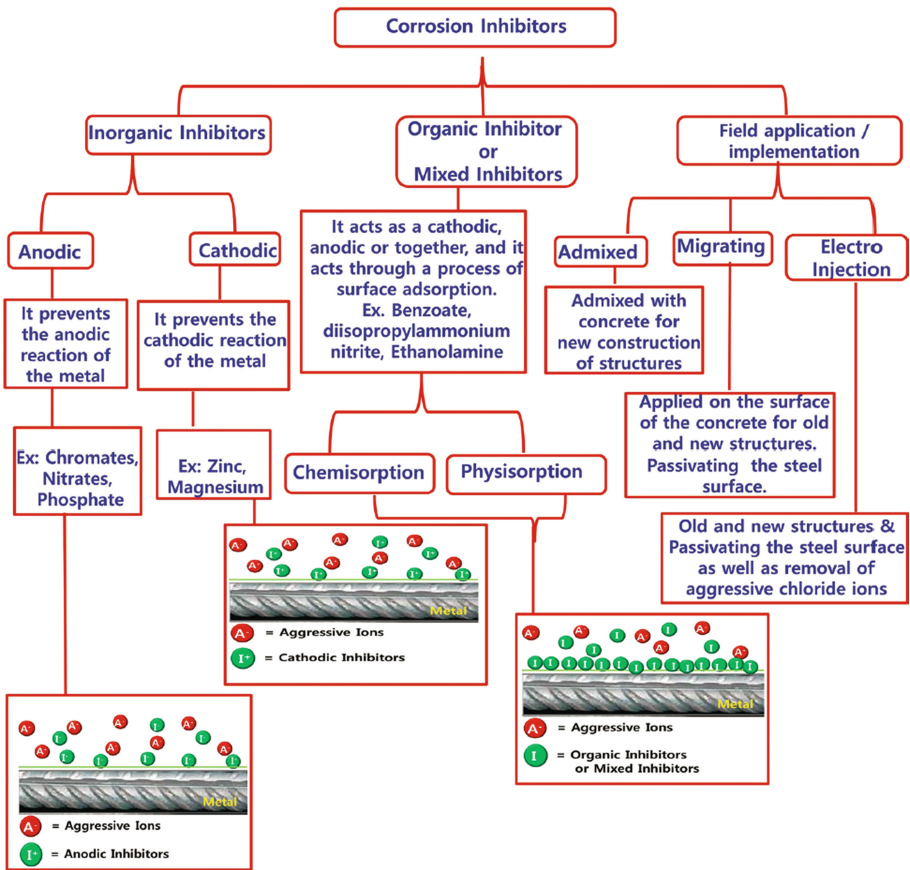


Fig. 3. Corrosion inhibitors adapted from Lee et al. (2018).



### 3 Classification of Inhibitors

Classification of corrosion inhibitor on concrete rebar been studied by numerous researchers (Asmara et al. 2018; Awaliah et al. 2020; Hart 2016; Lindsay et al. 2020; Topçu and Uzunömeroğlu 2020). Topçu and Uzunömeroğlu (2020) classified corrosion inhibitors as commercial and green base inhibitors. Lee et al. (2018) in their review of corrosion inhibitors in concretes, classified corrosion inhibitors on the following basis of their;

- a. Electrochemical mechanism (Cathodic, Anodic or together).
- b. Chemicals Employed (Organic and Inorganic).
- c. Mode of application; sprayed on cured concrete or mix with concrete
- d. Migrating inhibitors.

However, Prasanna et al. (2017) had classified inhibitors of corrosion on the basis of reaction mechanism as follows;

- a. Adsorption corrosion inhibitor
- b. Passivation corrosion inhibitor
- c. Pickling corrosion inhibitor
- d. Vapour phase corrosion inhibitor
- e. Slashing corrosion inhibitor

### 4 Natural Corrosion Inhibitors and Environments

Natural corrosion inhibitors are primarily obtained from medicinal plants, aromatic spices, and herbs (Asmara et al. 2018; Izionworu et al. 2020; Okeniyi et al. 2019; Sharifnasab and Alamooti 2017). Phenolic constituents of plant materials have secured great interest to many investigators because of their anti-oxidative activities and nutritive value (Al-mashhadani et al. 2020). Natural or organic inhibitors provide a more sustainable option for enhancing the corrosion durability of steel rebar since they are obtained from renewable sources. Some recent studies on the corrosion inhibition characteristics of plant extracts are summarized in Table 1.

**Table 1.** List of some plant extracts corrosion inhibitors in recent works

Ref.	Inhibitor	Environment	Concentration	Duration of exposure	Metal	Result/Efficiency
Nwoye and Mbuka-Nwosu (2020)	<i>bilberry cactus</i> extract	HCl	1.5M HCl	5 day	Mild steel	90%

(continued)

**Table 1.** (continued)

Ref.	Inhibitor	Environment	Concentration	Duration of exposure	Metal	Result/Efficiency
Adzor et al. (2020)	<i>telfaira occidentals</i>	H <sub>2</sub> SO <sub>4</sub>	0.5M H <sub>2</sub> SO <sub>4</sub>	4 h	Mild steel	86%
Arguelles et al. (2020)	( <i>calamansi</i> ) <i>citrofortunella microcarpa rind</i> Extract	HCl	1M HCl	4 h	Mild steel	90.6
Ghazi et al. (2014)	<i>indica</i> extract	HCl	1M HCl	4h	Mild steel	91%
Dong et al. (2011)	rice bran extracts	HCl	1M HCl	4 h	Carbon steel	90
Abdulrahman et al. (2011)	<i>bambusa arundinacea</i>	HCl	1M HCl	72 h	Mild steel	72
Loto et al. (2016)	<i>allium cepa</i> Extracts	HCl	1M HCl	5 days	Mild steel	80
Oguzie et al. (2014)	<i>terminalia chebula</i>	HCl	1M HCl	5 days	Mild steel	89–65%
Oguntade et al. (2019)	sesame and castor Oil	Brine		23 days	Mild steel	–
Okeniyi et al. (2019)	<i>rhizophora mangle L.</i> bark extract	NaCl	3.5% NaCl	40–75 days	Steel rebar	98
Kumar et al. (2013)	<i>alpina galinga</i> extract	H <sub>2</sub> SO <sub>4</sub>	0.5 M H <sub>2</sub> SO <sub>4</sub>	2 h	Mild steel	71.7
Arday (2018)	<i>cassia siamea</i> extract	HCL	2M HCl	12	Mild Steel	95%

## 5 Corrosion Inhibition Mechanism

Al-mashhadani et al. (2020) in their study on corrosion inhibition, classified corrosion inhibition mechanism as

1. **Adsorption process;** the corrosion inhibition performance of organic compounds are mostly attributed to their activities on the metal surface by the process of adsorption. However, adsorption process in corrosion inhibition depends on various factors which include the inhibitor's chemical structure, the metal's surface charge and electrolyte solution type. (Sanni, Popoola and Fayomi 2021).
2. **Existence of charge on metal surface;** inhibitor adsorbs on the metal surface by electrostatic forces between the charges on the metal surface and dipoles or ions groups of the inhibitor in this mechanism (Al-mashhadani et al. 2020; Hart 2016)
3. **Chemical reaction;** the effect of this inhibition mechanism is a function of the chemical structure and functional group of the inhibitor. An electron is transferred from the inhibitor to the metal surface, which results in bonding. This method is preferred for transition metals, particularly when the metals have empty electron orbital with low energy (Erşan, Van Tittelboom and Boon., 2018; Han, Wang and Zhang, 2021).

4. **Interaction between water molecules and the inhibitor;** in this mechanism, inhibitors go through a replacement reaction with the water on the surface of the metal resulting in the elimination of water molecules from the metal surface (Awaliah et al. 2020; Elshami et al. 2020),
5. **Electrochemical reaction of inhibitors;** Some inhibitors go through an electrochemical reduction reaction with the metal surface to form a new compound that exhibits the inhibition effect. The inhibitor is added to the metal surface called the primary inhibitor, and the product from the electrochemical reaction is called a secondary inhibitor (Erşan et al. 2018; H. Al-mashhadani et al. 2020; Melchers 2020).
6. **Diffusion wall;** in this mechanism, the corrosion inhibitor formed a barrier on the surface of the metal and prevented any ions or molecules to be transferred from and to the metal surface, and that leads to the decreasing of the corrosion rate (Shi et al. 2020; Szweda, 2019). Protection of steel rebar using boride or intermetallide coatings depends on material having crystalline structures and robust diffusion bonding to the substrates (Galio and Dariva 2016; Stanciu et al. 2019).

In the last decade, significant amounts of research have been done to understand the corrosion inhibition mechanism and various studies to prefer many innovative ways to curb corrosion. For instance, the corrosion in the presence of sulphates have been understood, and different corrosion inhibitors have been suggested. Tekin and Gökçe (2021) used a mixture of up to 30% of pistachio shell ash and 54% and 300% of ordinary Portland cement to show that mechanical properties have improved. The microstructural properties of cement can remarkably be improved. It was also revealed by Elsayed and ElShazly (2016) that sodium dichromate, molybdate and nitrite having concentration of 1, 250 and 50 ppm, respectively are effective corrosion inhibitor. The inhibition efficiency of 98.6% in sodium chloride and ammonium sulfate solutions of 0.01 M and 0.02 M, respectively had been achieved.

Organic compounds act as corrosion inhibition of metals and normally are proceeded by ions and molecules adsorption at the metals surface (Fiori-Bimbi et al. 2015; Lycett and Hughes 2018; Miralrio and Vázquez 2020). Therefore, it is established that the adsorption phenomenon is crucial to the understanding of corrosion inhibition mechanism (Berodier 2015; Ghareba and Omanovic 2016). The hypothetical thought for a connection between the ability of a metal surface to adsorb and the molecular structure of an organic compounds and consequently inhibiting the corrosion process (Goel et al. 2010) is noted by these researches (Enning and Garrelfs 2014; Okeniyi et al. 2017; Okeniyi et al. 2019). It was recently found that heteroatom with unsaturated bonds in an organic compound caused inhibiting effect and reduced the metal dissolution (Miralrio and Vázquez 2020; Okeniyi and Popoola 2017). Protecting efficiency was also improved by increasing the length of the alkyl chain (Miralrio and Vázquez 2020).

## 6 Conclusion

Corrosion is part of our coexistence. Corrosion scientist and engineer should channel their objectives to reduce the rate of corrosion sufficiently enough that structures with

reinforcement to serve their life span. To this end deep understanding of the nature of corrosion need to be done. The study into natural or green corrosion inhibitors should be intensified to reduce the cost of reducing corrosion reinforcing structures.

**Conflict of Interest.** The authors declare that they have no conflict of interest.

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# Education for All: A Recipe for Sustainability in Nigeria

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**Abstract. Purpose:** Education has been the principal instrument for the transformation and development of every citizen in society. It is a vehicle for the economic development and sustainability of the nation. Education for All is the right to education regardless of background, ethics, religion, gender and irrespective of disability.

**Approach:** It is on this premise that this paper, adopted a literature review and observation methods focused on challenges of achieving objectives of inclusive education through Education for All. The paper explained critically the concept of inclusive education, Education for All (EFA) and the society, nexus between education and sustainability, and challenges of Education for All (EFA) were also examined.

**Research Limitation/Implication:** The study focused on Education for all like a recipe for sustainability. The study examined inclusive education and the challenges facing quality education in Nigeria.

**Practical Implication:** The implication of the study is that education should be everybody's business, the government and individuals in society should participate in the education business. There could be adequate provision of infrastructural facilities such as libraries, conducive classrooms, furniture etc. for both students in urban and rural areas.

**Social Implication:** This should be a joint responsibility of the government and all education stakeholders. Finally, the fund released by the government does not get to the right destination. Therefore, the government should take it as a point of duty to follow it up most especially for students with special needs for the stated goals to be achieved.

**Originality/Value:** The uniqueness of this study was based on the methods of achieving the objectives of Education for All (EFA). Hence, inclusive education and its sustainability for the populace are paramount for nation-building.

**Keywords:** Education for all · Sustainability · Inclusive education · Challenges · Nigeria

## 1 Introduction

The roles of education in this 21<sup>st</sup> century cannot be jettisoned. It is one of the major key players in the evolution of any nation from one economic stage to another is education.

It is regarded as fundamental human right that all citizens should have access to in order to tender their meaningful lot to the national growth irrespective of ethics, religion, tribes, or people with special needs. Everybody needs education for adequate change, transformation and for the evolution of the society at large which prompted the idea of Education for All (EFA). This refer to all-inclusive as well as just community, it is also necessary to consider diverseness, which is not restricted to people with special needs with the mission of addressing problem of communal equity, imbalance, civil right and democracy. Ajisafe, Bolarinwa and Edeh in Folorunso (2018) defined education as a potent vehicle for national transformation and development. Education serves as an essential tool for sustainability in Nigeria and as human right for the development of an individual and the entire society.

Education should be concerned with the regard for the citizenry; consequently, the knowledge of this perspective will permeate in various aspects of the community and municipalities representing the natural habitat in considering the Sustainable Development Goal (Polat and Kisanji in Osero 2015). He further stated that inability to cross territories with regards to extensive or far reaching to people with special needs advocating for alliance with inclusive learning structure.

Nevertheless, individual in the society should have access to quality and quantitative education no matter the background or location the person reside. Schooling is a just and a bedrock for rational civilized, economic system and evolution of anybody in the community. This implies that schooling made up of individual pursuit equipped to allow human being to grow in fruitful, fully-operative person in the community; that is a procedure for fruitful growth of human disposition brilliantly, palpably, culturally and excitedly (Uchem et al. 2021). This implies that opportunity should be given to all citizens irrespective of the age, sex, race, location or environment that will make the person to function efficiently and effectively and work towards the growth of the society.

It is globally acknowledged as a tool for communal, governmental, empirical and technical growth. On the basis of this, no communal should play with schooling of its citizen which can upshot into dawdler expansion (Awotua-Efebo 2015). In general, it is the collection of all procedure by which youngsters grow their potentials, characters and other forms of demeanor or behaviours which are of greater importance to the communal. He also develops means of sustaining in the midst of every situation in the environment.

Sustainability is ways of securing current want without arbitrating with the upcoming generation in terms of ecology, advancement and inflation of a nation. A sustainable society is a society that looks after the overall wellbeing of human with the aim of preventing its environment from present and future disaster. Grimsley (2020) averred that sustainable economic development is the attempt or act of satisfying a person's want in a way or manner that preserve mineral deposit and ecology for upcoming creation. While Yasmin (2015) postulated that sustainable economic development is characterized by sustained increase in real per capital income and economic welfare, rational use of resources and resources preservation for incoming generation. This implies that every citizen has the right to the economy of the nation. Okam (2017) saw sustainable development as the capacity of the wealth to assist individuals in a nation and considering the industrial, communal and environmental limitations of the wealth.

Conversely, Sustainable Building Goal stated that inclusion of fair standard schooling and lasting teaching ample opportunities for both in rural and urban region. Inclusion of fair learning will assist the low-class habitant with rightful employability skills for self reliance. In addition, removing bigotry and get rid of gender inequality globally. Therefore, one of the objectives of this paper is that qualitative education should be provided for all the citizens. Also, this paper attempts to provide a succinct assessment of Education for All.

## 1.1 Literature Review

Sustainable Leadership in Education theory is one of the major theories used for this research. Proponents such as Andy (2015) opined that education organizations are apprising ecosystem in modeling environmental friendly and schooling. As well as substantial analysis of educational programme by the collaborators in enduring standard of schooling by means of including sustainable leaders. The theory also delves into Depth learning and real achievements in the educational system. Other works and opinions discuss ideas such as;

## 1.2 Inclusive Education

In recent times, inclusive education in Nigeria is not well embraced. This has caused inequalities among the citizens which have affected the people concerned. Inclusive schooling in the contextual meaning of objectives of Education for All is a compound concern, and no coronet advent in the literature. This can be referred to as method of bolster the scope of pedagogical ways of reaching out to all students. Also, this is a means of educating children with special needs and studying difficulties with that of regular ones in the same condition and environment. This bonds all learners in one learning environment irrespective if they are good or weak. Moreover, this helps them improve their social as well as communication skills. Thus, it is a global rule that must model every teaching method and tutoring, begin from the trust that schooling is a civil right and bedrock for additional equitable in the community. Marta et al. (2020) posited that schooling is generally accepted as a vital instrument for growth, ways of attaining relief, sustainability and good administration. Thus, is an instrument for national growth.

Studies have shown that people with special needs enjoy learning with their counterparts but are insecure of their abilities and dread the attitude of other youngsters. Hayat in Osero (2015) affirmed that people with special needs were desirous in attending mainstream school because they are delighted and study better with other youngsters. Also, with the notion that it will boost their academic performance and eliminate stigmatization related disablement. Besides, they believed that they might be harassed or unable to cope with their mates resulting in most of them not registering in mainstream schools. Therefore, in order to overcome these disadvantage and inequality, the following measure was identified by UNESCO (2001): (a) Addressing education from the foundation irrespective of their background; (b) Enlargement of basic school and academic services; (c) Expanding early childhood education after primary education for fairness and standard aims; (d) Provide for quality teaching; (e) Adopting vibrant and various educational policies; and (f) Improving teachers education and training development programmes.

In a nutshell, the primary effects of all these preparative events obviously indicated that promoting inclusive schooling should be paramount in the nation and province which must be attended to if the actual goals are to be achieved.

### 1.3 Education for All (EFA) and the Society: A Perspective

Education for all is a universal course for all and sundry regardless of cultural, religious affiliations and conditions, this is made up of inclusive education with the general purpose of making education available to all children in the society. Nigeria educational systems are countenance with the challenges of provision quality experiences for youths and full-grown. If education is made available to the citizen in terms of quality and quantity, there would be measurable increase in the Nigeria economy and this will reduce the level of poverty among the citizens.

Nigeria is blessed and endowed with lots of natural resources that can fetch all her members with adequate resources. The standard and sufficiency of assets such as tangible equipment, gargets, pedagogical materials which have straight relevance on standard of teaching and learning, as it's brings about efficacy in the implementation of the syllabus (Republic of Kenya, in Osero 2015). He further stated that other elements like scarcity of materials which has led to provision of more materials to cater for people with meet special needs for the achievement of the stated goals.

Furtherance to this, in the following Goals was set up by The Dakar Groundwork for further activity (2000): (a) Enlargement of infancy education care and learning; (b) Provision of free and mandatory basic education for everyone; (c) Advance experiences and expertise for the youth and the full-grown in the society; (d) Expansion of continuous education by 50 percent; (e) Achievement of gender balance by 2005 and (f) Upgrading of the educational standard. Therefore, for the above stated goals to be achieved there is needs to improve in the effectiveness of participatory of educational fortuity for everyone. This implies that the basis of inclusion to govern the communal approaches, procedures to address the basis and sequel of segregation between the universal groundwork of EFA goals. Cultivating another inclusive pedagogical teaching and learning structure requiring a solid responsibility to work towards a fairness and peaceful community. However, in order to tackle these problems, there is an expanded affection in the idea and the norms of inclusion in educational system.

Contextually, it is generally seen as a means of transformation among the students in different acceptable way for all. It assumes that the goals of inclusive education are to eliminate inequality irrespective of their background social ethnics, religious, cultural and gender competency. In essence, it is a way of assuring that Education for All absolutely indicates that it's for all (UNESCO 2001).

### 1.4 Nexus Between Education and Sustainability

The synergy behind Sustainable Development goal is that all citizens should be able to earn his/her living and survive at all means. From the look of things, education holds the key to achieving sustainability goals. This can also be referred to as the developments of meeting the current want without perpetuate with upcoming generation (Baumann 2011, Nwaigburu and Eneogwe 2013; Ezechi 2013; and Ndu 2002). It was declared

that sustainability is not a permanent approach but should be ethically guided towards balancing justice among nations, humanity, caste and human kind (UNESCO) in (Okoli et al. 2018). This implies that education should be given to all and nothing else. The Western education that was introduced by the missionaries and the European colonial masters did not give room for entrepreneurship education. It is observed that there has been an absence of enterprise education in the Nigeria educational system and this has been primary reasons for destitute and unemployment among the youths in the country today. The Global Goals (GGs) are a global demand to eradicate scarcity, to keep safe the universe and be assured that the populace gets off tranquility and well-being (Un-Habitat, 2018, Isha 2013). The goals include: According to Un-Habitat (2018) in their submission the following goals include:

- To eradicate tranquility at all cost;
- To eradicate famine, accomplish food affluence and promote good diet;
- Assure hearty lives and improve person's well-being in respective of their ages;
- Secure inclusion and justifiable standard schooling and advance life-long teaching privilege;
- Accomplish gender fairness and equip the youngsters;
- Assure accessibility and maintainable of liquid and hygiene;
- Assure economical, dependable, viable, and new age power;
- Advance uninterrupted industrial and profitable job;
- Cultivate buoyant infrastructure, inclusion and advance newness;
- Dwindle fairness in and between the nations;
- Produce urban and people residence safety, and sustainability;
- Assure global expenditure and ways of producing;
- Make exigent deed reduce environmental collapse and its effects;
- Preserve and continuous use the water, liquid and aquatic resources for global growth;
- Safeguard, recreate and advance continuous use tellurian cosmos, sustaining and manage soil degeneration and ecological dropping;
- Assure tranquil and inclusion community for economical growth, advance equity for all and create efficient and effective institutional programme and
- Fortify ways of implementing and renew collaboration for sustainability growth. In summary, it is the absorption of the rules, valuation and custom of communal growth into all areas of educational system (Itari and Ugbe 2018).

## 2 Relevance of Education to Sustainable Development (RESD)

Education can be seen as a pathway to sustainability in general with the aim of providing to the needs of the society. Qualitative education is regarded as a vehicle for achieving sustainability. This promotes expertise, competence, mastery, morals and steps to build a continual ending, for ecology, maintenance, preserving and boost industrial growth. A functional educational system is a veritable catalyst for sustainable development because it provides new ways to quality life in economic, environment and social dimension with conscious of future generation. Besides, going by the EFA goals the major aim is to achieve quality education in identifying learners' cognitive development in terms

of qualitative life without damaging the environment. The learners are aware about importance of standard education for all in a enlightened and integrated path way to education for sustainability (UNESCO 2012).

Oguejiofor and Ezeabasili (2014) affirmed that the primary tools for attaining continual growth in education include: (a) developing standard basic education; re-orienting real educational system in addressing continual growth; (c) establishing popular attention and knowledge; and (d) organising training for private and public sectors. This indicates that education should promote employability skills in preparing the youths for globalization. Therefore, schooling play an important role in communal growth in given acceptable knowledge to students including with special needs for successful living.

### **3 Challenges of Education for All (EFA)**

Evidence has shown from the literature that EFA are yet to accomplish their goals as stated in their reports. Out of the six promising goals that was targeted some are still not totally actualized. There is need to understand the importance of education on every citizen and way of achieving those goals. Education has direct impact on individual wellbeing, nutrition and employment. This drives the realization of sustainable development goals because it equips citizens with knowledge and skills to break the cycle of poverty and prepare them for the challenges of the future. It was stated in Darkar Reported that despite the efforts made so far to achieve the goals. There are three major ones that are still pending which include: (a) inequality: this is one of the major impediments to reaching education for all; (b) Lack of quality education and (c) Financial problem a key to unlocking the crisis in education. Ige (2014) averred that problems confronting the success of Education for All can be attributed to limited access to schools, inadequate infrastructural facilities in schools, inadequate fund and teachers, corruption, increase in population, inappropriate planning and implementation, and wastage, all these can hinder the success and effective attainment of EFA goals. These are major impediment to proper achievement of Education for All in Nigeria. It was discovered that despite the efforts made so far to the achievement of these goals the above stated bottleneck has affected it success. Therefore, in order to overcome and to get results, these difficulties must be tackled.

### **4 Conclusion**

Based on the literature review, the realization of Education for All (EFA) goals has not been fully accomplished although it has been a major effort globally toward the achievement. Effective realization of these goals will enhance sustainability development goals in terms of adequate provision of education for people with special needs, availability of resilient infrastructural facilities, reduction of inequality in the world, eradication of poverty and hunger, universal access to basic services, care for the environment combating climate change and protecting oceans and ecosystems. The implication of the study is that education should be everybody's business, government and individual in the society should participate in education business. There should be adequate provision of infrastructural facilities such as libraries, conducive classroom, furniture etc. for both

students in urban and rural areas. This should be joint responsibilities of the government and all education stakeholders. Finally, the fund released by the government does not get to the right destination. Therefore, government should take it as a point of duty to follow it up most especially for students with special needs for the stated goals to be achieved.

## 5 Suggestions

This paper however suggests the following:

1. Education programme and approaches should be redesigned to achieve the stated goals in order to record huge success.
2. There is need for effective collaboration among the stakeholders to ensure progress in learning.
3. Government should invest more on quality education in order to reduce poverty and unemployment among the youths.
4. Government should try as much as possible to work towards total eradication of inequality among the learners for qualitative and quantitative education.
5. Government should ensure that youths are empowered with employability skills.

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# Accessing Sustainable Quality Education in Rural Areas During Covid-19 in Anambra State, Nigeria

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**Abstract. Purpose:** This paper investigated access to sustainable quality online education by students in rural areas of Idemili North of Anambra State during the Covid-19 pandemic. In achieving the aim other objectives are to discover if all students in rural areas joined the online classes, to find out how many students possess smartphones, to assess the level of internet connectivity and to determine if poverty or low income undermined the accessibility of quality online classes during Covid-19 pandemic in Idemili North.

**Design/Methodology:** Stratified sampling technique was used based on some common characteristics in the population, random sampling technique was used to select proportionately 5 towns from the 10 northern towns in Idemili. In total 50 respondents were sampled for the study using the interview method. The data obtained were analysed and presented in tables and charts using SPSS package for the analysis.

**Finding:** Findings revealed that majority of students living in this area were unable to access a quality online classes during the pandemic period. Basically, for lack of internet services.

**Research Limitation/Implication:** The study examined accessing sustainable Quality Online Classes in Idemili north during Covid-19 pandemic and concentrated only on 5 towns out of 10 towns that made up Idemili North.

**Practical Implication:** This study will be a kind of eye opener to the government and internet service operators to be aware of the factors that could hinder Quality education should the nation be hit by any kind of pandemic in the future. This study will also help policy makers to know the areas to channel resources necessary for quality education.

**Social Implication:** This study has succeeded in exposing the reality or the actual impact of online classes during Covid-19 in the area under study.

**Keywords:** Accessibility · Covid-19 · Online-learning · Quality education · Rural dwellers

## 1 Introduction

Countries all over the world were thrown into an aura of pandemics orchestrated by covid-19. The ravaging nature of the virus necessitated the closure of countries economies of

which the education sector was not left out. Schools all over the world including Nigerian schools were brought to a total close. Developed countries were quick to respond to the call that schools should not be brought to a total closure by resuming or resorting to online teaching and learning. Nigeria private institutions were quick to join too but the public schools were far from getting started up to the time the school lockdown was relaxed. Some public schools joined in online learning. The primary, secondary and tertiary institutions started online teaching and learning. But alas, the problem of technology in terms of internet accessibility set in, this is because not all students and pupils were able to join in the class either because they were too poor to buy smart phones or that they are in remote or rural areas and so lacks internet connectivity. To be able to access the internet three things must be available (i) wifi (ii) data (iii) smartphone. The rural dwellers were not opportune to have access to either of these three prerequisites.

The urban dwellers had the opportunity which their rural counterparts were not having and because of this the issue of accessing quality education by students and pupils of rural dwellers was nothing but a failure in Anambra State as well as in Nigeria as a whole. For education to be adjudged accessible, it must be able to satisfy the needs of the common masses in terms of affordability in the sense that it should not be costly to achieve. Data and smart phones or personal computers are not so affordable for students and pupils in the rural areas given the economic situation and the need neglect constantly faced by rural dwellers from the government. In the area of availability, there is no gainsaying that internet companies prefer to provide services where the population is higher and so urban centers are flooded with internet services to the detriment of the rural areas. Because of the vital nature of education, it is pertinent that rural areas be put into consideration when necessary infrastructures are being provided in the cities, so that rural urban migration will be put to stop and students and pupils who live in the rural areas will have equal opportunities with their counterparts in the urban centers. This study therefore is set to examine the accessibility of quality education by students in rural areas during covid-19 pandemic in Idemili North of Anambra state, Nigeria. The issue of quality education is an important area of concern for educational goal achievement in Nigeria. The quality of education determines the quality of the nations human resources to say that education is the pool from where all other sectors of the economy draw their vital resources from (human) is not an over statement. Therefore, it is pertinent that quality assurance in education should beget quality education at all levels of education.

Quality education is what that gives individuals the enablement to develop all of their skills, attributes to achieve their potentials even their hidden potentials are brought to limelight with quality education, with this the individuals impacts his society positively. Therefore, government should ensure that quality education is given to every child from early childhood to tertiary level. According to Tawl and Cougoureux (2013); educating includes individual and collective directed change with the task of giving opportunities to people with no one left out to develop their full potentials and be creative in their various ways and be responsible to themselves and the society.

A quality education should be able to provide its learners with capability to be productively sound economically and otherwise. Quality education should be able to bring about equity, reliance, sustainability, and balance approach (VVOB 2019). Quality approach is that which allows every child to access educational infrastructures from

wherever and whenever he wants. Because the more a learner is involved in the learning process the more valued he feels.

According to OECD (2012), The best performing education systems should be the one that brings together both equity and equality, they further assets that such system should be able to give to every child equal chance to functional and excellent education. Unfortunately, most children in Nigeria do not have quality education or access to sustainable quality education, due to the prevalent economic situation, hence there is gap in what is taught and what is learned.

Becta (2007) highlighted that there it is required that institutions concentrate mainly on the application of effective and explicit drilling and pedagogy habit, the researcher named the habits to include: personalization of experience, the employing of computers in other to intensify the ability to learn with efficacy, the evoking and merging of learners participation, and the broadening of home access and assistance. In the light of this, learning institutions got inspired towards undertaking online classes. The era of Covid-19 pandemic necessitates that schools partake in online classes across the globe. Also Condie et al. (2007) also asserted that specific benefits have been observed in education sector such as better stimulation and commitment, access resilience, gaining of experiences in information and communication technology and adopting new approaches to acquiring knowledge as a result of technological integration in education.

In essence, education in the 21<sup>st</sup> century cannot be done without technological integration. Schools in Nigeria will be better off, if the aspect of technology is taken more seriously as this will benefit all and sundry. The moment the bridge in the gap in technology is made, majority of students will be greatly advantaged including those in the rural areas.

Accessing quality education is the right of every individual more reason greater access should be given to all students irrespective of place or location or family background. The government should encourage effective learning by enabling the teachers and learners with the needed facilities such as unlimited access to network, provision of data and personal computers. All these will help students to personalize learning thereby making learning effective.

## 2 Theories Underpinning the Study

There are different theories that underpinned this study, such as social-constructivism, social learning theory, constructivism and experiential learning. But out of all these, the researcher based the study on experiential learning because the theory aims at understudy the way in which experiences be it first or second hand can be a motivation to a learner and increase his leaving ability.

Experienced-based knowledge connotes the seeking for experiences out of one's own volition and as asserted by Office of Learning and Teaching (2005), learning becomes significant when threats to learning in an environment is reduced to the barest minimum, things that impede learning in an environment must be reduced and only those things that facilitates learning must be increased and allow to multiply.

In other words, accessibility of online classes can only be possible for students living in rural areas only when the environment is enabling. There should be increase in internet

connectivity and distribution of personal computers to these students so that they can learn on their own as proposed by experiential learning theorists.

### **3 Statement of the Problem**

The issue of educational accessibility in the world over can never be over emphasized, especially in Nigeria and Anambra State in particular for there is no gainsaying that every individual deserves a count when it comes to quality education. This is so because education is the right of every child. In the world of pandemic, it is easier to discover a nation most hit not only in health system but also in educational system. The case of Nigeria was a pathetic one and that of Idemili north in Anambra state in terms of accessing quality education during the pandemic was even more pathetic as observed by this researcher. The pupils and students both in secondary and higher institutions complained bitterly on their inability to access classes online. It is against this backdrop that, the researcher investigated the Accessibility of Quality Online classes by students in rural areas of Idemili North, Anambra State.

This study investigated the level of online education accessibility by students in Rural Areas during covid-19 pandemic in Idemili North Local Government Area of Anambra State, Nigeria. Other specific purposes include: to find out if all students in rural areas joined the online classes during the period under study; to discover if all students in Idemili north have smartphones; to find out if internet services are made available to students in the rural areas; to unveil if poverty or low income undermine the accessibility of quality online classes during covid-19 pandemic; and to find out if lack of smartphones, personal computers and internet access made quality online classes inaccessible.

### **4 Research Methodology**

The research design for this study is a descriptive survey. The population consists of only the tertiary institution's students living in the rural areas of Idemili North. Stratified sampling technique, random and proportional sampling techniques were used to select the sample size of 50 students for the study, data analysis was done using SPSS package.

### **5 Educational Accessibility**

Education is made accessible when courses are designed and teaching styles developed to cater for the demands of learners of diverse backgrounds, abilities, learning styles. According to Ogbudinkpa (2015) educational accessibility should bring about equal participation in education and equal participation in education nurtures the rate at which students complete their education especially those ones from low-income background. Making education more accessible to every Nigerian child should be paramount. Government intervention in areas of scholarships, student's loans, grants, provision of educational infrastructures, and technological infrastructures such as laptops, personal computers, internet connection/services in every part of the nation.

## 6 Problem of Quality Educational Accessibility in Idemili North During Covid-19 Pandemic

Accessibility according to Henry et al. (2014) is seen as the capacity for acquiring and gaining in a kind of a structure or institution, which should not be accompanied as workability, meaning the level that a given commodity like gadget, utility or habitat are put to use by particular end users for accomplishment of stated purpose with efficacy, expertise as well as gratification in an identified condition of usage.

Accessibility is a global pattern that creates brands which can be used by persons with extensive, attainable scope of potentiality, operational in a given broad feasible scale of circumstances. Educational accessibility is being able to use, access and benefit from education made available to all and every child regardless of the location of the school and the area he or she lives should be able to access it.

During the covid-19 lockdown, in which physical classes were stopped for online classes to begin. Students, from Idemili north local government area could not gain access to online classes like their counterparts in urban centers due to the wide technological divide, lack of internet services in the rural areas and largely the problem of not possessing smartphones and personal computers, poverty, internet service unaffordability and unavailability.

Before the advent of covid-19 pandemic which resulted in locking down of schools and other economic sectors, the problem of Technological divide was not so glaring. Provisions in terms of mass purchase of personal computers for student in rural schools, contracting of internet service providers to flood the rural centers with internet services and at an affordable rate (which are the two gadgets needed for students to access online classes) were not made. In order words, before covid-19 pandemic students in the rural areas were neglected and so they became heavily disadvantaged in the current situation.

Problem of quality education accessibility in Idemili local government area of Anambra state got worsened with the advent of covid-19 pandemic as this researcher was able to gather from the interview conducted of which some of the students leaving in the rural areas were interviewed. The researcher gathered that lack of smartphones, internet services, personal computers and poverty were the main problems that prevented students in Idemili north of Anambra State from accessing quality online education during covid-19. Poverty was rated high given that many parents of the students are leaving below poverty line and so could not provide their wards with the necessary gadgets to join or access online classes. Poverty according to Aratani (2009) economically is the aggregate of persons whose livelihood standard is beneath the fictional globally defined lowest level of earnings known as subsistence level that transect universal frontier.

Haruna (2002) sees poverty to be something greater than shortage of earnings, it includes uncertainty, imbalance, health condition as well as ignorance. Rural dwellers shared the opinion that the moment the issue of poverty is sorted out the tendency that the parents will take care of the problems faced by their wards in accessing online classes during the lock down will be very high.

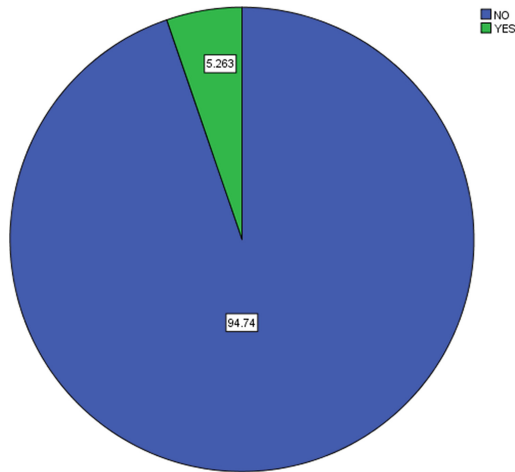
## 7 Result

Table 1 shows that majority 54(94.7%) were unable to join the online classes. 32(56.1%) were unable to join because they had no internet services, 13(22.8%) had no smart phone, 2(3.5%) had no training on online classes, 4(7.0%) had no electricity, and 6(10.5%) had no personal computer. About 50(57.7%) of the students from Idemili LGA had no internet services in their area, while 7(12.3%) had internet services. 35(61.4%) of the respondents said their phones could connect to internet, while 22(38.6%) could not connect. 20(35.1%) of the students had smartphones, 1(1.8%) had a personal computer, and 36(63.2%) had neither a phone nor a computer. Only 2(3.5%) were able to buy data, while 55(96.5%) were unable to buy data for internet service. All the students 57(100%)

**Table 1.** Responses from students of Idemili LGA of Anambra State on internet availability and online classes

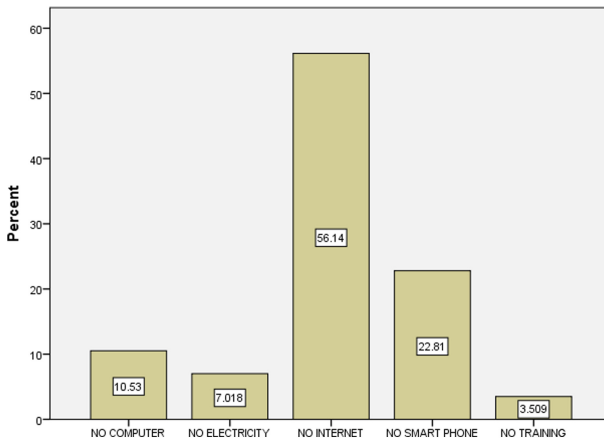
Item	Responses	Frequency	Percentage
Were you able to join online classes from your home during the lock down? If Yes, how? If No, why?	Yes	3	5.3
	No	54	94.7
	No Internet	32	56.1
	No Smart phone	13	22.8
	No Training	2	3.5
	No Electricity	4	7.0
	No Computer	6	10.5
Do you have internet services in your area? Does your phone connect to internet?	Yes	7	12.3
	No	50	87.7
	Yes	22	38.6
	No	35	61.4
Do you have a personal computer or a smart phone? Do you have a personal computer or a smartphone?	None	36	63.2
	Computer	1	1.8
	Smart phone	20	35.1
	None	36	63.2
	Computer	1	1.8
	Smart phone	20	35.1
Do you have a personal computer or a smartphone? Were you able to buy data for internet services? Were you disturbed that other students in the city are ahead of you by attending online classes? Would you have joined if the internet service is accessible to you? Would it have made any difference if the government had provided you with internet connection? Did you feel left out in the whole process? Online or physical classes, which one would you have preferred given the present pandemic?	None	36	63.2
	Yes	2	3.5
	No	55	96.5
	Yes	57	100
	No	–	–
	Yes	57	100
	No	–	–
	Yes	51	89.5
	No	6	10.5
	Yes	56	98.2
	No	1	1.8
	Online	54	94.7
	Physical	3	5.3

said they were disturbed for not attending the online classes. All the students 57(100%) affirmed that they would have joined the online classes if the internet was accessible. About 51(89.5%) agreed that there would have been a difference if the government had provided them with internet connection, while 6(10.5%) said that there would be no difference. Majority 56(98.2%) felt left out in the online class process. About 54(94.7%) preferred online classes, while 3(5.3%) preferred physical classes.



**Fig. 1.** Ability to join online classes during the lockdown

Figure 1 shows that 54(94.7%) were unable to join the online classes, while 3(5.3%) were able to join (Fig. 2).



**Fig. 2.** Reasons for not joining the online classes

The bar chart above shows that 32(56.1%) were unable to join because they had no internet services, 13(22.8%) had no smart phone, 2(3.5%) had no training on online classes, 4(7.0%) had no electricity, and 6(10.5%) had no personal computer (Fig. 3).

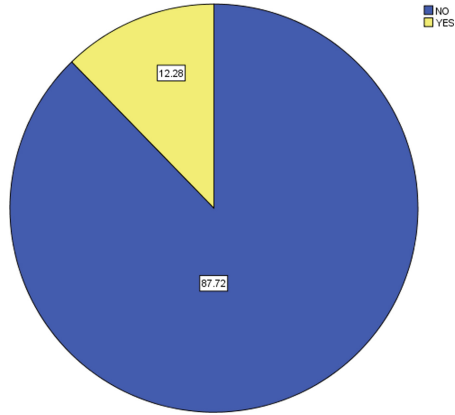


Fig. 3. Availability of internet services

The pie chart reveals that 50(87.7%) of the students lacked internet services in their area, while 7(12.3%) had internet services (Fig. 4).

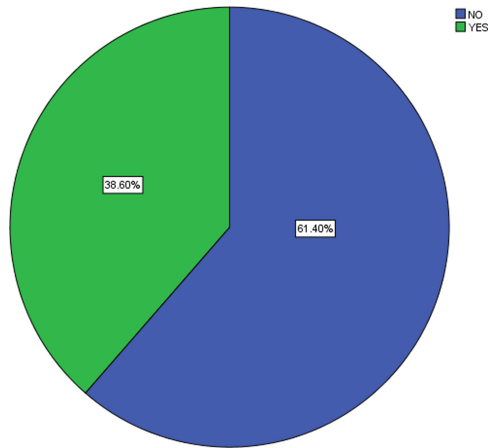
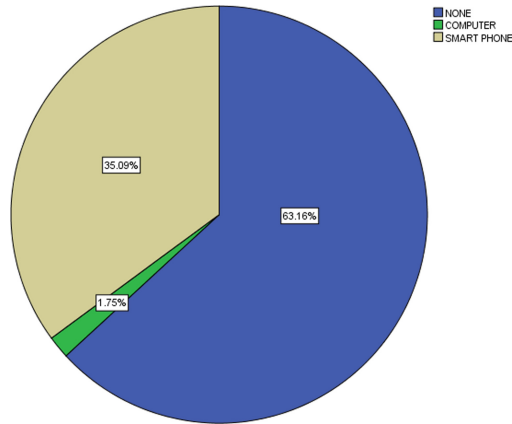


Fig. 4. Connectivity to the internet

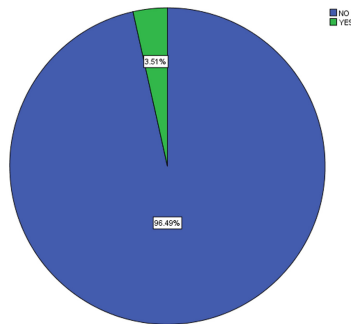


The pie chart shows that only 22(38.6%) had their phone connected to the internet, while 35(61.4%) did not (Fig. 5).



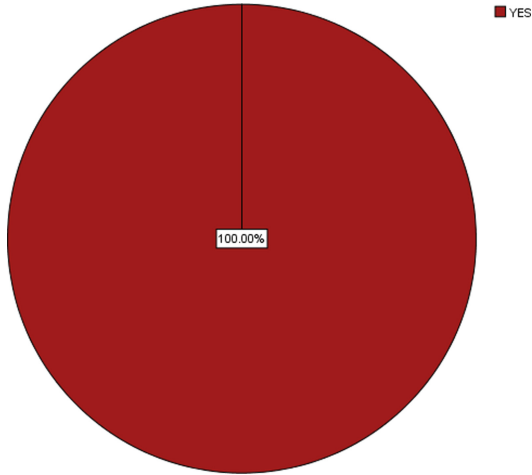
**Fig. 5.** Availability of a personal computer or a smart phone

The chart shows that majority 36(63.2%) of the students had none of these devices. 20(35.1%) had a smart phone, and only 1(1.8%) had a personal computer (Fig. 6).



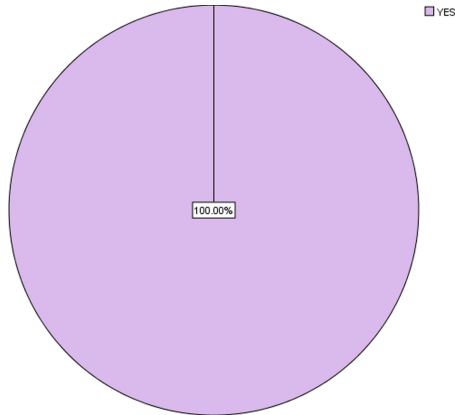
**Fig. 6.** Ability to buy data for internet service

The chart shows that almost all the students 55(96.5%) were unable to buy data for internet services. Only 2(3.5%) were able to afford data(Fig. 7).



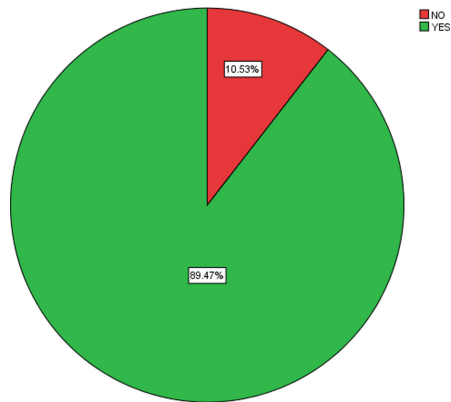
**Fig. 7.** Disturbed for not joining the online classes

Results from the pie chart reveals that all the students 57(100%) were disturbed for not joining the online classes (Fig. 8).



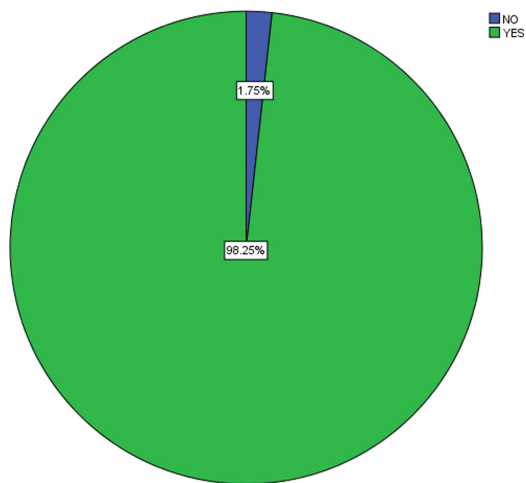
**Fig. 8.** Joining the online classes for internet service accessibility

Results from the pie chart shows that all the students 57(100%) would have joined the online classes if internet services were accessible (Fig. 9).



**Fig. 9.** Provision of internet connection by government

From the pie chart above, majority of the students 51(89.5%) affirmed that there would have been a difference if the government had provided an internet connection (Fig. 10).



**Fig. 10.** Students who felt left out in the whole process

The chart shows that majority 56(98.2%) of the students felt left out in the whole process (Fig. 11).

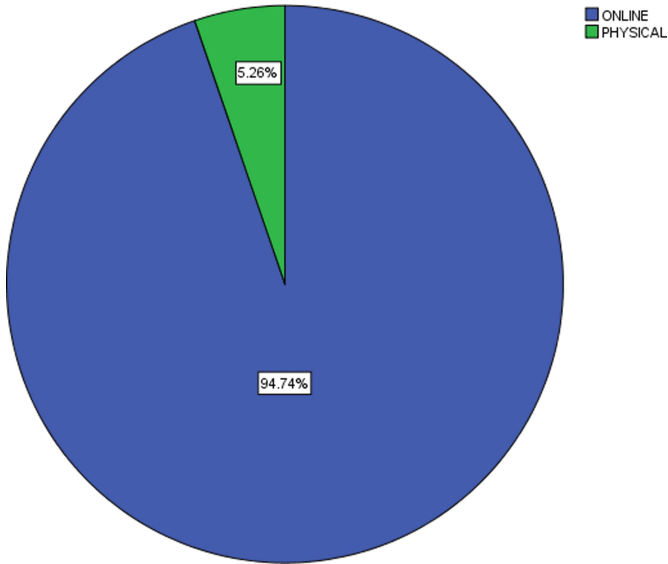


Fig. 11. Preferred class given the present pandemic

The pie chart shows that 54(94.7%) of the students preferred the online classes, while only 3(5.3%) preferred the physical classes.

**Research Question One:** Do all the students in the rural areas joined in the online classes during covid-19 pandemic in Idemili North of Anambra state?

The results from Table 1 reveals that majority of the students in the rural areas did not join the online classes. 54(94.7%) of the students were unable to join. The number of students 3(5.3%) who joined the online classes were insignificant.

**Research Question Two:** Do all the students in Idemili North of Anambra state have personal computers and smart phones?

Table 1 shows that majority 36(63.2%) had none of these devices. 20(35.1%) of the students had smart phones. Only 1(1.8%) had a personal computer.

**Research Question Three:** Are internet services available to the students in Idemili North of Anambra state?

From output in Table 1, it is clearly shown that internet services are not available in Idemili North of Anambra state as affirmed by the students. 50(87.8%) of the students claimed that there was no internet services in their area. Only insignificant number of students 7(12.3%) had internet services in their area.

**Research Question Four:** Is poverty or low family income a major reason for inaccessibility of quality online classes during covid-19 in Idemili North?

From the results in Table 1, lack of internet services and smartphone were the major reasons for inaccessibility of quality online classes during covid-19 in Idemili North of Anambra state. About 32(56.1%) had no internet services, while 13(22.8%) had no smartphones to enable them join the online classes.

**Research Question Five:** Do lack of smartphone and personal computer and internet access made quality online education inaccessible to students in rural areas of Idemili North?

Results from the table shows that lack of smartphone, personal computer, and internet access brought low quality online education. About 36(63.2%) of the students had none of these devices. 20(35.1%) had a smartphone, and only 1(1.8%) had a personal computer. Also, among those who had smartphone had no internet access.

The findings in Table 1, the majority of students sampled could not access online classes largely due to lack of the internet services and other learning facilities such as laptops and smartphones. This finding is line with the studies of Henry et al. (2014) who opined in their studies that accessibility has to do with benefiting from a system or entity. Also according to OECD reports (OECD 2021) it is better to reduce school failures and inequalities by investing in overcoming school failures because it pays off. This study agrees with this report in terms of investing in overcoming school failures, that is, anything in the environment that constitutes school failure should be eliminated. The students in the area under study had as a major barrier to quality online education internet connectivity and unavailability of Laptops or Smartphones.

## 8 Conclusion and Recommendations

The impact of Covid-19 on the accessibility of Sustainable Quality Online Education was grievous as observed in this study. Students in rural areas could not partake in the online lessons which were broad casted through televisions and online distance learning platforms. Such as video conferencing and others, largely due to network inaccessibility, and lack of other facilities such as Smartphones and Laptops. This implies that these students had lost a vital aspect of their learning during Covid-19 pandemic that devastated the education system which will definitely translate into greater learning deficiency and so effort should be made by policy makers to reduce the effect of learning loss by seeking to implement learning recovery programmes through the provision of laptops and free internet services to help this students to catch up to the expected learning targets.

The importance of Quality Education cannot be over-emphasized. It is crucial to the overall development of an individual and the society at large. For quality education to be accessible to all and sundry, the issue of Technological problems must be handled by adequate provision of internet services and laptops to students who reside in the rural areas.

The issue of poverty among the greater number of masses should not be neglected as economic security will be able to nip poverty from the bud and set larger number of students on the same pedestriars with their counterparts in the urban centers. Therefore, to avoid future occurrence or the repetition of what happened during covid-19, governments and Anambra state government in particular must as a matter of urgency address the problems pointed out in the study.

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# The Effect of a 3-Way Viscoelastic Bearing on Super-harmonic Resonance of the Flexible Rotor System

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**Abstract. Purpose:** In this paper, the super-harmonic resonances of a hard driven flexible rotor system performing under the influence of mass unbalance are investigated using a 3-way linear viscoelastic end-stops bearing.

**Design/Methodology/Approach:** The model of the rotor-3-way end-stops bearing system is derived as a modified Jeffcott rotor system. These models are solved using multiple scales of the perturbation method. The numerical method of NDSolve integrator within Mathematica™ is also utilized to analyze the equations of motion, and the effects of the damping ratios and stiffness of the 3-way end-stops bearing on the super-harmonic resonance behaviour, the bifurcatory behaviour, phase plane plots, time plots and Poincaré maps are discussed.

**Findings:** The results show that by strategically selecting the design parameters of the 3-way viscoelastic end-stops bearing, the super-harmonic vibration amplitudes can be effectively suppressed and the observed jump phenomenon can be eliminated.

**Research Limitation/Implications:** The study focused on the analytical and numerical approaches. The experimental approach to obtaining the super-harmonic resonance response characteristics caused by high mass unbalance of a flexible rotor that is supported by viscoelastic elements were not included in this study.

**Practical Implication:** The super-harmonic resonance response characteristics caused by the high mass unbalance of a flexible rotor that is supported by viscoelastic elements is missing in the literature. This investigation will add to the body of knowledge to inform academia and industry of the effect of the novel 3-way viscoelastic end-stops bearing on the super-harmonic resonance case of the flexible rotor system under severe mass unbalance excitation.

**Social Implication:** The knowledge advanced by this research will inform stakeholders in the mechanical engineering fraternity particularly, the manufacturers of flexible rotors in enhancing their designs for efficiency, sustainability and value for money.

**Originality/Value:** Prior studies of the effectiveness of the end-stops bearing was limited to the primary resonance case only. This study gives a unique look

at the super-harmonic resonance response characteristics caused by high mass unbalances of the flexible rotor that is supported by viscoelastic elements.

**Keywords:** Design parameters · End-stop bearings · Mass unbalance · Rotor · Super-harmonic

## 1 Introduction

Vibration reduction in rotor dynamics has been a thorny problem in engineering. Lighter, faster, and more flexible rotating machines are more prone to mechanical vibrations that can cause fatigue, which leads to disastrous failure, decline performance and contribute to untimely collapse. For several years, many phenomena concerning industrial rotating machines exhibiting mechanical vibrations have been studied and much attention has been given to one of them, namely the negative influence on the rotor system by mass unbalance excitation (Atepor 2008). According to the author, interesting physical manifestations occur in rotor systems that are under the action of mass unbalance. These occurrences include subharmonic, jumps, super-harmonic and chaos when the system is driven very hard under large mass unbalance values. Shad et al. (2011) used the multiple scales method to solve a problem of a nonlinear dynamic behaviour of a flexible rotor system and obtained the system's nonlinear frequency response caused by mass unbalance.

Analyzing the dynamic behaviour of rotor systems producing the above-mentioned phenomena is essential to suppress or control the structural vibration magnitudes. The introduction of action is the universal principle of active control, which affects a change in behaviour of the dynamic system in a desirable manner. According to Muszynska (2005) and Bachschmid et al. (2008), rotor vibration control is very relevant for stable and safe operation of machinery. In trying to reduce rotor system's vibration passing through its critical speed, Zhang et al. (2013) introduced the dynamic balancing method. Two significant methods of adjusting parameters and employing external forces are mostly used to control excessive vibration.

In applying external forces to control vibration in flexible rotor systems, Atepor (2008) used an antagonistic SMA/Composite smart bearing. The author used the smart bearing to introduce force externally into the system to adjust the stiffness of the shaft thereby reducing the amplitude of the vibration caused by mass unbalance excitation experimentally. In another experiment Atepor (2009) to successfully reduce the amplitude of vibration, used a piezoelectric exciter fixed at the end of the shaft of a flexible rotor system to introduce force into the shaft to adjust the stiffness. Again, Hemmatian and Ohadi (2013) proposed the use of magnetorheological squeeze film damper in the form of externally introduced force to suppress vibration in rotor systems. Janik and Irretier (1998) also made use of forces generated by electromagnetic exciters to control vibration in the rotor-shaft system.

In adjusting parameters as a means of mitigating the effects of excessive vibration in the rotor system, Queiroz (2012) made use of self-adjusted bearing parameters to lengthen the stability limits for the rotor system. Although the vibration control measures mentioned above have good performance of vibration reduction, there is the problem



of high cost and compactness. Thus the need for less expensive and easily accessible materials that can give equally good results and compact models.

Viscoelastic materials have long been used as an effective means of mitigating vibration and noise in mechanical machines and devices. They exhibit memory effects just like shape memory alloys and piezoelectric materials, and their stiffness and damping properties depend on frequency and temperature (Rade et al. 2019). Viscoelastic materials have been successfully applied in a variety of engineering systems as supports (Muszynska 2005; Bachschmid et al. 2008). Zu and Ji (1998) and Shabanel and Zu (2003) applied Timoshenko beam theory to examine the nonlinear dynamics of a rotor system that was attached to viscoelastic supports at the ends of the shaft. Ribeiro et al. (2015) and Ribeiro et al. (2017) proposed the use of viscoelastic support for flexible rotor systems to enhance the performance of the vibration isolation. Al-Solihat and Behdinan (2019) studied the influence bearing stiffness and damping, disk location and unbalance force magnitude have on primary frequency response and force transmissibility of a flexible rotor system mounted on viscoelastic elements. Almost all the studies mentioned above are based on passive vibration isolation where the disk-shaft arrangements are mounted on the viscoelastic bearings. For an active vibration control using viscoelastic materials, Atepor (2020) proposed a method of using a 3-way viscoelastic end-stops bearing to adjust a flexible rotor system’s stiffness axially and laterally by manipulating the damping and stiffness parameters of the bearing to suppress the amplitude of vibration caused by mass unbalance. The results show that vibration due to mass unbalance in the flexible rotor system can be reduced by using the novel 3-way viscoelastic end-stops bearing. However, the study of the effectiveness of the end-stops bearing was limited to the primary resonance case only. A search shows that the super-harmonic resonance response characteristics caused by the high mass unbalance of the flexible rotor that is supported by viscoelastic elements is missing in the literature. This has led to the idea of investigating the effect of the novel 3-way viscoelastic end-stops bearing on the super-harmonic resonance case of the flexible rotor system under severe mass unbalance excitation in the present paper.

## 2 Equations of Motion

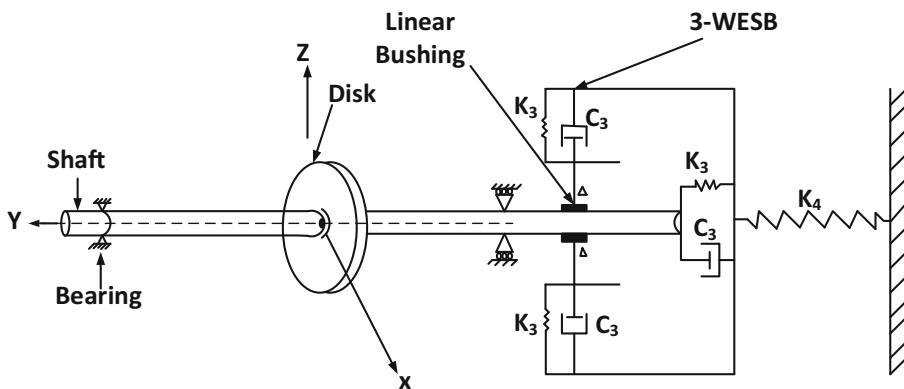


Fig. 1. A flexible rotor system with a 3-way elastomeric end-stops bearing

Two nonlinear equations of motion including the 3-WESB terms of the system shown in Fig. 1 are derived using Lagrangian analysis as follows,

$$\ddot{x} + \hat{c}\dot{x} - \Omega\hat{a}_5\dot{y} + \omega^2x + \hat{b}x^3 - \omega_3^2x^2 - \hat{c}_3x\dot{x} - \omega_4^2y - 2\omega_3^2x - 2\hat{c}_3\dot{x} = \mu\Omega^2 \sin(\Omega t) \tag{1a}$$

$$\ddot{y} + \hat{c}\dot{y} - \Omega\hat{a}_5\dot{x} + \omega^2y + \hat{b}y^3 - \omega_3^2y^2 - \hat{c}_3y\dot{y} - \omega_4^2x - 2\omega_3^2y - 2\hat{c}_3\dot{y} = \mu\Omega^2 \cos(\Omega t) \tag{1b}$$

where  $\hat{a}_5 = a_5/m$ ,  $\hat{b} = b/m$ ,  $\hat{c} = c/m$ ,  $\hat{c}_3 = c_3/m$ ,  $\mu = m_u d/m$ ,  $\omega^2 = k/m$ ,  $\omega_3^2 = \omega^2 = k_3/m_3$ ,  $\omega_4^2 = k_4/m_3$ ,  $k$  is the linear stiffness coefficient,  $c$  is the damping coefficient,  $x, y$  are displacements,  $\omega$  is the natural frequency,  $b$  is the nonlinear cubic stiffness coefficient,  $\Omega$  is the excitation frequency,  $m$  is the mass of the disk,  $m_u$  is the mass unbalance located at a distance,  $d$ , from the geometric centre of the shaft,  $a_5$  is the characteristic equation coefficient associated with inertia,  $k_3$  is the stiffness coefficient of the 3-WESB,  $m_3$  is the mass of the 3-WESB,  $c_3$  is the damping coefficient of the 3-WESB and  $k_4$  represent the linear stiffness coefficient of the supporting spring.

### 2.1 Treatment of Systems Equations

We nondimensionalize the time scale  $t$  to  $\tau$  such that  $\tau = \omega t$  where  $\omega = \sqrt{k/m}$ , and represents the natural frequency and also the equations are ordered by the introduction of the small parameter  $\varepsilon$ .  $\omega$  is normalized to one, therefore  $\tau \cong 1$ . Equation (1a) and (1b) is therefore written as follows;

$$\begin{aligned} \bar{x}'' + \varepsilon \frac{\bar{c}}{\omega} \bar{x}' - \varepsilon \frac{\Omega}{\omega} \bar{a}_5 y' + \bar{x} + \varepsilon^2 \frac{\hat{b}}{\omega^2} \bar{x}^3 - \varepsilon \rho_3^2 \bar{x}^2 - \varepsilon \frac{\bar{c}_3}{\omega} \bar{x} \bar{x}' - \varepsilon \rho_4^2 \bar{y} \\ - 2\varepsilon \rho_3^2 \bar{x} - 2\varepsilon \frac{\bar{c}_3}{\omega} \bar{x}' = \Gamma \sin\left(\frac{\Omega}{\omega} \tau\right) \end{aligned} \tag{2a}$$

$$\begin{aligned} \bar{y}'' + \varepsilon \frac{\bar{c}}{\omega} \bar{y}' - \varepsilon \frac{\Omega}{\omega} \bar{a}_5 x' + \bar{y} + \varepsilon^2 \frac{\hat{b}}{\omega^2} \bar{y}^3 - \varepsilon \rho_3^2 \bar{y}^2 - \varepsilon \frac{\bar{c}_3}{\omega} \bar{y} \bar{y}' - \varepsilon \rho_4^2 \bar{x} \\ - 2\varepsilon \rho_3^2 \bar{y} - 2\varepsilon \frac{\bar{c}_3}{\omega} \bar{y}' = \Gamma \cos\left(\frac{\Omega}{\omega} \tau\right) \end{aligned} \tag{2b}$$

We consider the parameters of the 3-WESB. A mass ratio of  $\varepsilon_\varepsilon = 0.01$  is selected since the 3-WESB’s mass ratio is restricted for the practical consideration. It is a well-known fact that the mass unbalance induced vibration frequency is almost equal to the natural frequency of the rotor, and as such, the natural frequency of the 3-WESB is taken to be equal to that of the natural frequency of the rotor system.

where,  $\zeta = \hat{c}/2\omega$ ,  $\zeta_3 = \hat{c}_3/2m_3\omega$ ,  $\varepsilon_\varepsilon = m_3/m = 0.01$ ,  $\rho_3 = \omega_3/\omega$ ,  $\rho_4 = \omega_4/\omega$  and  $\Gamma = \bar{\mu}(\Omega/\omega)^2$ .

### 3 Approximate Solution

The approximate solutions to the treated Eqs. (2a) and (2b) for the model of the system with 3-WESB are obtained by the application of the method of multiple scales.

### 3.1 For the Primary Resonance Case

The primary resonance case is considered for the system’s Eqs. (2a) and (2b) for up to the second order perturbation level. The terms  $\Gamma \sin(\Omega\tau/\omega)$  and  $\Gamma \cos(\Omega\tau/\omega)$  are expressed in exponential forms going forward, becoming  $i(\Gamma/2)\exp[i(\Omega/\omega)T_0] - i(\Gamma/2)\exp[-i(\Omega/\omega)T_0]$  and  $(\Gamma/2)\exp[i(\Omega/\omega)T_0] + (\Gamma/2)\exp[-i(\Omega/\omega)T_0]$  respectively. Here the assumption that  $\Omega \approx \omega$  is made and the term  $(\Gamma/2)\exp[i(\Omega/\omega)T_0]$  will then be near resonant, and for the nondimensionalized case the detuning parameter is introduced by means of  $\Omega/\omega = 1 + \varepsilon\bar{\sigma}$  and we arrive at Eq. (3) which describes the relation between the detuning parameter  $\bar{\sigma}$ , excitation amplitude  $\Gamma$ , and the system’s responses for the primary resonance case.

$$\bar{\sigma} = 2 + \rho_3^2 - \frac{\Omega\hat{a}_5}{2\omega} \pm \frac{4}{\Gamma} \sqrt{(\eta_1 + \eta_4)^2 + (\eta_2 + \eta_3)^2} \tag{3}$$

where,

$$\begin{aligned} \eta_1 = & -\xi p + \frac{\Omega\hat{a}_5}{2\omega} r + \frac{\rho_4^2}{2} s + \rho_3^2 q + 2\xi_3 \varepsilon_\varepsilon p + \frac{\xi^2}{2} q - \frac{\Omega\hat{a}_5 \xi}{2\omega} s - 2\xi \xi_3 \varepsilon_\varepsilon q - \frac{\Omega^2 \hat{a}_5^2}{8\omega^2} q \\ & - \frac{\Omega\hat{a}_5 \rho_4^2}{4\omega} p + \frac{\Omega\hat{a}_5 \xi_3 \varepsilon_\varepsilon}{\omega} s + \frac{\rho_4^2}{8} q + \frac{\rho_3^2 \rho_4^2}{2} s + \frac{\rho_3^4}{2} q + 2\xi_3^2 \varepsilon_\varepsilon^2 q - \frac{3\hat{b}}{\omega^2} p^2 q - \frac{\hat{b}}{\omega^2} q^3 \end{aligned} \tag{4a}$$

$$\begin{aligned} \eta_2 = & -\xi q + \frac{\Omega\hat{a}_5}{2\omega} s + \frac{\rho_4^2}{2} r + \rho_3^2 p + 2\xi_3 \varepsilon_\varepsilon q + \frac{\xi^2}{2} p - \frac{\Omega\hat{a}_5 \xi}{2\omega} r - 2\xi \xi_3 \varepsilon_\varepsilon p - \frac{\Omega^2 \hat{a}_5^2}{8\omega^2} p \\ & - \frac{\Omega\hat{a}_5 \rho_4^2}{4\omega} q + \frac{\Omega\hat{a}_5 \xi_3 \varepsilon_\varepsilon}{\omega} r + \frac{\rho_4^2}{8} p + \frac{\rho_3^2 \rho_4^2}{2} r + \frac{\rho_3^4}{2} p + 2\xi_3^2 \varepsilon_\varepsilon^2 p - \frac{2\hat{b}}{\omega^2} p^3 - \frac{2\rho_3^4}{3} p^3 \end{aligned} \tag{4b}$$

$$\begin{aligned} \eta_3 = & -\xi r - \frac{\Omega\hat{a}_5}{2\omega} p + \frac{\rho_4^2}{2} q + \rho_3^2 s + 2\xi_3 \varepsilon_\varepsilon r + \frac{\xi^2}{2} s + \frac{\Omega\hat{a}_5 \xi}{2\omega} q - 2\xi \xi_3 \varepsilon_\varepsilon s - \frac{\Omega^2 \hat{a}_5^2}{8\omega^2} s \\ & - \frac{\Omega\hat{a}_5 \rho_4^2}{4\omega} r - \frac{\Omega\hat{a}_5 \xi_3 \varepsilon_\varepsilon}{\omega} q + \frac{\rho_4^2}{8} s + \frac{\rho_3^2 \rho_4^2}{2} q + \frac{\rho_3^4}{2} s + 2\xi_3^2 \varepsilon_\varepsilon^2 s - \frac{3\hat{b}}{\omega^2} r^2 s - \frac{\hat{b}}{\omega^2} s^3 \end{aligned} \tag{4c}$$

$$\begin{aligned} \eta_4 = & -\xi s - \frac{\Omega\hat{a}_5}{2\omega} q + \frac{\rho_4^2}{2} p + \rho_3^2 r + 2\xi_3 \varepsilon_\varepsilon s + \frac{\xi^2}{2} r + \frac{\Omega\hat{a}_5 \xi}{2\omega} p - 2\xi \xi_3 \varepsilon_\varepsilon r - \frac{\Omega^2 \hat{a}_5^2}{8\omega^2} r \\ & + \frac{\Omega\hat{a}_5 \rho_4^2}{4\omega} s - \frac{\Omega\hat{a}_5 \xi_3 \varepsilon_\varepsilon}{\omega} p + \frac{\rho_4^2}{8} r + \frac{\rho_3^2 \rho_4^2}{2} p + \frac{\rho_3^4}{2} r + 2\xi_3^2 \varepsilon_\varepsilon^2 r - \frac{2\hat{b}}{\omega^2} r^3 - \frac{2\rho_3^4}{3} r^3 \end{aligned} \tag{4d}$$

### 3.2 For the Super-Harmonic Resonance Case

The super-harmonic resonance case is also considered for the system’s Eqs. (2a) and (2b) for up to the second order perturbation level. Here the assumption that  $3\Omega \approx \omega$  is made and the term  $(\Gamma/2)\exp[i(3\Omega/\omega)T_0]$  will then be near resonant, and for the

nondimensionalized case the detuning parameter is introduced by means of  $3 \Omega/\omega = 1 + \varepsilon \bar{\sigma}$  and we arrive at the Eq. (5), which describes the relation between the detuning parameter  $\bar{\sigma}$ , excitation amplitude  $\Gamma$ , and the system's responses for the super-harmonic resonance case.

$$\bar{\sigma} = \frac{2}{3} + \frac{\rho_3^2}{3} - \frac{\Omega \hat{a}_5}{6\omega} \pm \frac{8}{9\Gamma} \sqrt{(\eta_5 + \eta_8)^2 + (\eta_6 + \eta_7)^2} \quad (5)$$

where,

$$\begin{aligned} \eta_5 = & -\xi p + \frac{\Omega \hat{a}_5}{2\omega} r + \frac{\rho_4^2}{2} s + \rho_3^2 q + 2\xi_3 \varepsilon_\varepsilon p + \frac{\xi^2}{2} q - \frac{\Omega \hat{a}_5 \xi}{2\omega} s - 2\xi \xi_3 \varepsilon_\varepsilon q - \frac{\Omega^2 \hat{a}_5^2}{8\omega^2} q \\ & - \frac{4\rho_3^4}{3} p^2 q - \frac{8\rho_3^2 \xi_3 \varepsilon_\varepsilon}{3} p^3 + \frac{16\rho_3^2 \xi_3 \varepsilon_\varepsilon}{3} p q^2 + \frac{16\xi_3^2 \varepsilon_\varepsilon^2}{3} p^2 q - \frac{16\xi_3^2 \varepsilon_\varepsilon^2}{3} q^3 \\ & - \frac{\Omega \hat{a}_5 \rho_4^2}{4\omega} p + \frac{\Omega \hat{a}_5 \xi_3 \varepsilon_\varepsilon}{\omega} s + \frac{\rho_4^2}{8} q + \frac{\rho_3^2 \rho_4^2}{2} s + \frac{\rho_4^4}{2} q + 2\xi_3^2 \varepsilon_\varepsilon^2 q - \frac{3\hat{b}}{\omega^2} p^2 q - \frac{\hat{b}}{\omega^2} q^3 \end{aligned} \quad (6a)$$

$$\begin{aligned} \eta_6 = & -\xi q + \frac{\Omega \hat{a}_5}{2\omega} s + \frac{\rho_4^2}{2} r + \rho_3^2 p + 2\xi_3 \varepsilon_\varepsilon q + \frac{\xi^2}{2} p - \frac{\Omega \hat{a}_5 \xi}{2\omega} r - 2\xi \xi_3 \varepsilon_\varepsilon p - \frac{\Omega^2 \hat{a}_5^2}{8\omega^2} p \\ & - \frac{\Omega \hat{a}_5 \rho_4^2}{4\omega} q + \frac{\Omega \hat{a}_5 \xi_3 \varepsilon_\varepsilon}{\omega} r + \frac{\rho_4^2}{8} p + \frac{\rho_3^2 \rho_4^2}{2} r + \frac{\rho_4^4}{2} p + 2\xi_3^2 \varepsilon_\varepsilon^2 p - \frac{2\hat{b}}{\omega^2} p^3 - \frac{2\rho_3^4}{3} p^3 \\ & + \frac{2\rho_3^4}{3} p q^2 - \frac{20\rho_3^2 \xi_3 \varepsilon_\varepsilon}{3} p^2 q + \frac{4\rho_3^2 \xi_3 \varepsilon_\varepsilon}{3} q^3 - \frac{32\xi_3^2 \varepsilon_\varepsilon^2}{3} p^2 q \end{aligned} \quad (6b)$$

$$\begin{aligned} \eta_7 = & -\xi r - \frac{\Omega \hat{a}_5}{2\omega} p + \frac{\rho_4^2}{2} q + \rho_3^2 s + 2\xi_3 \varepsilon_\varepsilon r + \frac{\xi^2}{2} s + \frac{\Omega \hat{a}_5 \xi}{2\omega} q - 2\xi \xi_3 \varepsilon_\varepsilon s - \frac{\Omega^2 \hat{a}_5^2}{8\omega^2} s \\ & + \frac{\Omega \hat{a}_5 \rho_4^2}{4\omega} r - \frac{\Omega \hat{a}_5 \xi_3 \varepsilon_\varepsilon}{\omega} q + \frac{\rho_4^2}{8} s + \frac{\rho_3^2 \rho_4^2}{2} q + \frac{\rho_4^4}{2} s + 2\xi_3^2 \varepsilon_\varepsilon^2 s - \frac{3\hat{b}}{\omega^2} r^2 s - \frac{\hat{b}}{\omega^2} s^3 \\ & - \frac{4\rho_3^4}{3} r^2 s - \frac{8\rho_3^2 \xi_3 \varepsilon_\varepsilon}{3} r^3 + \frac{16\rho_3^2 \xi_3 \varepsilon_\varepsilon}{3} r s^2 + \frac{16\xi_3^2 \varepsilon_\varepsilon^2}{3} r^2 s - \frac{16\xi_3^2 \varepsilon_\varepsilon^2}{3} s^3 \end{aligned} \quad (6c)$$

$$\begin{aligned} \eta_8 = & -\xi s - \frac{\Omega \hat{a}_5}{2\omega} q + \frac{\rho_4^2}{2} p + \rho_3^2 r + 2\xi_3 \varepsilon_\varepsilon s + \frac{\xi^2}{2} r + \frac{\Omega \hat{a}_5 \xi}{2\omega} p - 2\xi \xi_3 \varepsilon_\varepsilon r - \frac{\Omega^2 \hat{a}_5^2}{8\omega^2} r \\ & + \frac{\Omega \hat{a}_5 \rho_4^2}{4\omega} s - \frac{\Omega \hat{a}_5 \xi_3 \varepsilon_\varepsilon}{\omega} p + \frac{\rho_4^2}{8} r + \frac{\rho_3^2 \rho_4^2}{2} p + \frac{\rho_4^4}{2} r + 2\xi_3^2 \varepsilon_\varepsilon^2 r - \frac{2\hat{b}}{\omega^2} r^3 - \frac{2\rho_3^4}{3} r^3 \\ & - \frac{2\rho_3^4}{3} r s^2 - \frac{20\rho_3^2 \xi_3 \varepsilon_\varepsilon}{3} r^2 s + \frac{4\rho_3^2 \xi_3 \varepsilon_\varepsilon}{3} s^3 - \frac{32\xi_3^2 \varepsilon_\varepsilon^2}{3} r s^2 \end{aligned} \quad (6d)$$

where,  $p$ ,  $q$ ,  $r$  and  $s$  are complex transformed amplitudes of the rotor system that are found by solving Eqs. 4a, 4b, 4c and 4a simultaneously for the primary resonance case and Eqs. 6a, 6b, 6c and 6d simultaneously for the super-harmonic resonance case using NDSolve within Mathematica™.

## 4 Results and Discussions

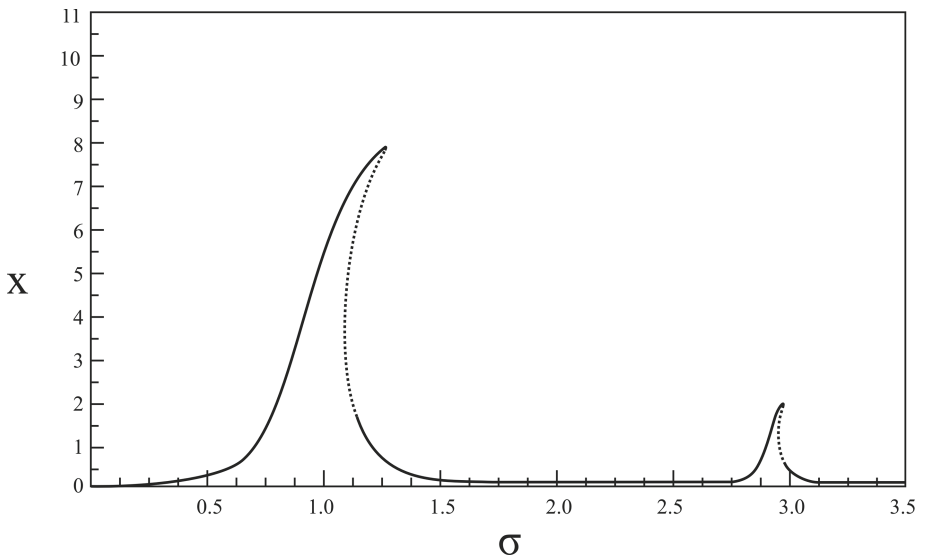
In this section, the system's dynamic behaviours without the 3-WESB and the effect of the parameters of the 3-WESB on the super-harmonic resonance response are discussed. The basic parameters of the rotor-3-WESB system are listed in Table 1.

**Table 1.** Nondimensionalised Parameters of the Rotor-3-WESB-system

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$\Gamma = 0.05$ ; $\omega = 248.8$ ; $\hat{b} = 3.28 \times 10^7$ ; $c_2 = 0.025$ ; $\Omega = 248.8$ ; $\xi = 0.03$ ; $\varepsilon_\varepsilon = 0.01$ ; $\rho_4 = 4.6$
$\rho_3 = 0, 0.05, 0.5, 1$ ; $\xi_3 = 0.01, 0.04, 0.07, 0.09$ ; $p = 0.02$ ; $q = 0.0004$ ; $r = -0.0017$ ; $s = -0.0011$

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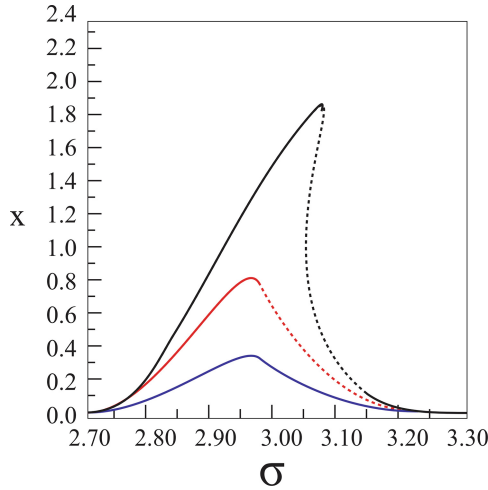


**Fig. 2.** Superimposed plots of primary and super-harmonic resonance responses of the system without the 3-WESB

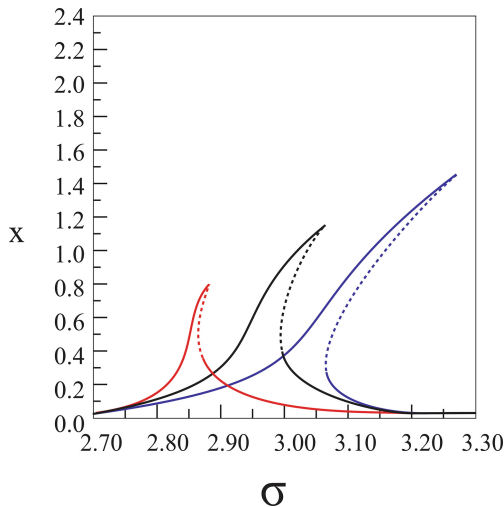
Figure 2 shows the superimposed response curves of the primary and super-harmonic resonances obtained using Mathematica™ program developed by Wolfram Research (Wolfram 1996). A close look shows the familiar stable and unstable solutions as well as the jump phenomena. The unstable regions are approximately around  $\sigma = 1.25$  for the primary resonance response case and  $\sigma = 3$  for the super-harmonic resonance response case. Since the unstable region is centered approximately around  $\sigma = 3$ , it reflects that the analysis is indeed representing the super-harmonic resonance of the system.

The value of the 3-WESB's stiffness,  $\rho_3$ , is kept constant and its damping ratio,  $\xi_3$ , is varied and their effects on the frequency response are examined as shown in Fig. 3. Increasing the values of  $\xi_3$  results in the decreasing of the peak amplitudes with complete elimination of the jump phenomenon and this also demonstrates that selecting the correct

set of parameters for the 3-WESB can result in a reduction of the super-harmonic induced amplitude by 81.4%, which is consistent with results obtained in Atepor (2020).



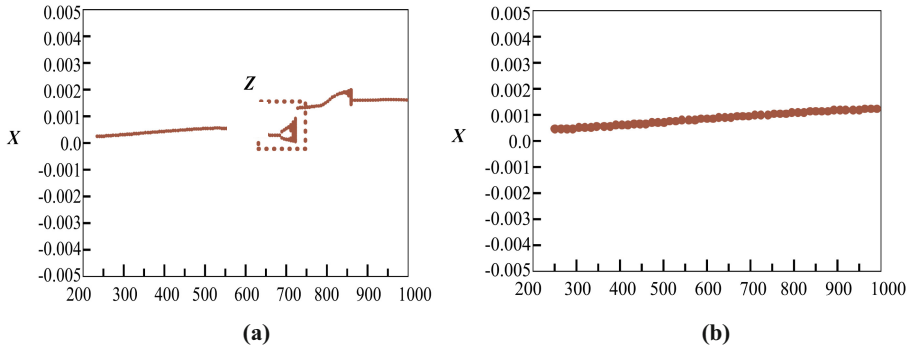
**Fig. 3.** The effect of the 3-WESB’s damping ratio,  $\xi_3$ , on the super-harmonic resonance curves when  $\rho_3 = \text{constant}$ .



**Fig. 4.** The effect of the 3-WESB’s stiffness,  $\rho_3$ , on the super-harmonic resonance curves when  $\xi_3 = \text{constant}$ .

The effect of the 3-WESB stiffness on the super-harmonic frequency response is illustrated in Fig. 4. The system frequency response is studied for  $\rho_3 = 0, 0.5$  and  $1$ , while the 3-WESB’s damping ratio is kept constant at  $\xi_3 = 0.04$ . The results show that the bigger the stiffness value the higher the peak amplitudes and the more pronounced the

nonlinear hardness effects. This shows that the positive stiffness of the 3-WESB brings a harder nonlinearity to the system undergoing super-harmonic resonance. As a result, an overly stiff end-stop in comparison to the stiffness of the rotor system can be detrimental to the amplitude suppression being sought, as it causes the amplitude level to rise. It can, however, shift the frequencies backward and forward. This is an interesting result in that, the 3-WESB is able to help the system to avoid the super-harmonic resonance situation.



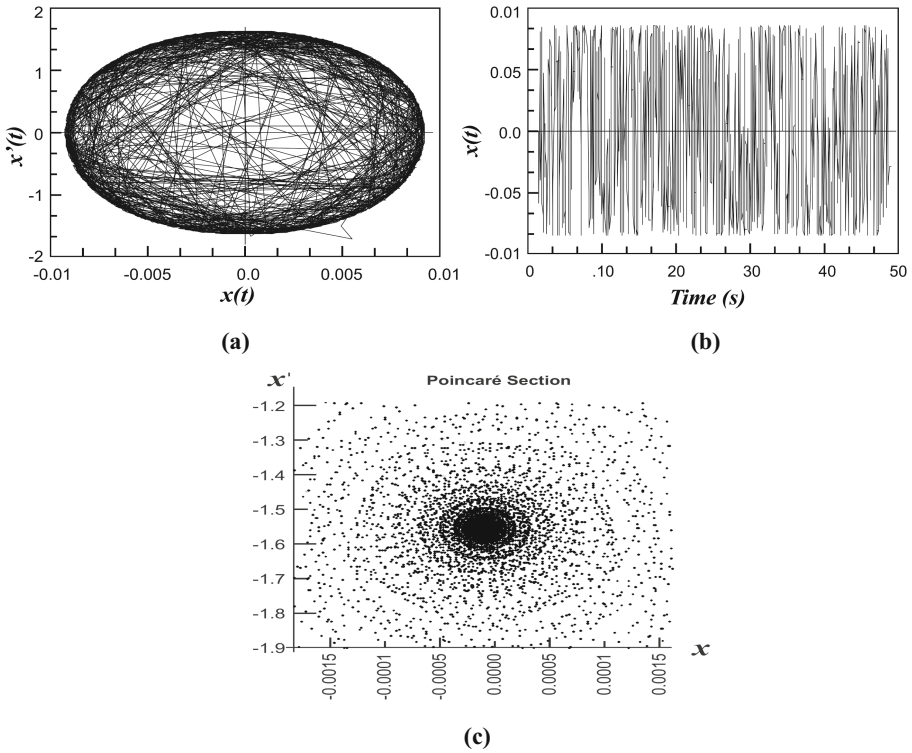
**Fig. 5.** Bifurcation diagrams showing amplitudes  $X$  as functions of normalized excitation acceleration (a) without the 3-WESB and (b) with the 3-WESB

Figure 5 depicts the bifurcation plots of amplitude controlled by the normalized excitation acceleration. The super-harmonic resonance frequency is fixed to the excitation frequency. Four types of system motions appear over the series of excitation accelerations as shown in Fig. 5(a). The system motions are stabilized period-one, -two, -four and chaotic motions. In Fig. 5(b), all of the chaotic and period doubling motions seen in Fig. 5(a) are eliminated when the 3-WESB force term parameters are introduced into the system. This means that the 3-WESB converted all period doubling and chaotic motions into periodic motions automatically.

The analysis of the diagrams in Figs. 5(a) and 5(b) are expanded to include phase plane plots, time plots and Poincaré maps (i.e. Figs. 6 and 7). The NDSolve integrator within Mathematica™ is used to perform the numerical calculations at supposed steady-state conditions to generate the phase plane and time plots. The Poincaré maps on the other hand were generated from transient time and majority show convergence to a period-one motion with only a point. The rest exhibit strange attractors, irregular structures, or a large number of irregular points. The following is a breakdown of observations with and without the 3-WESB.

In Fig. 6(a), overlaid, complicated and repeated orbit crossovers are depicted in the phase plane plots. The oscillations do not repeat and the time plots are non-periodic as shown in Fig. 6(b).

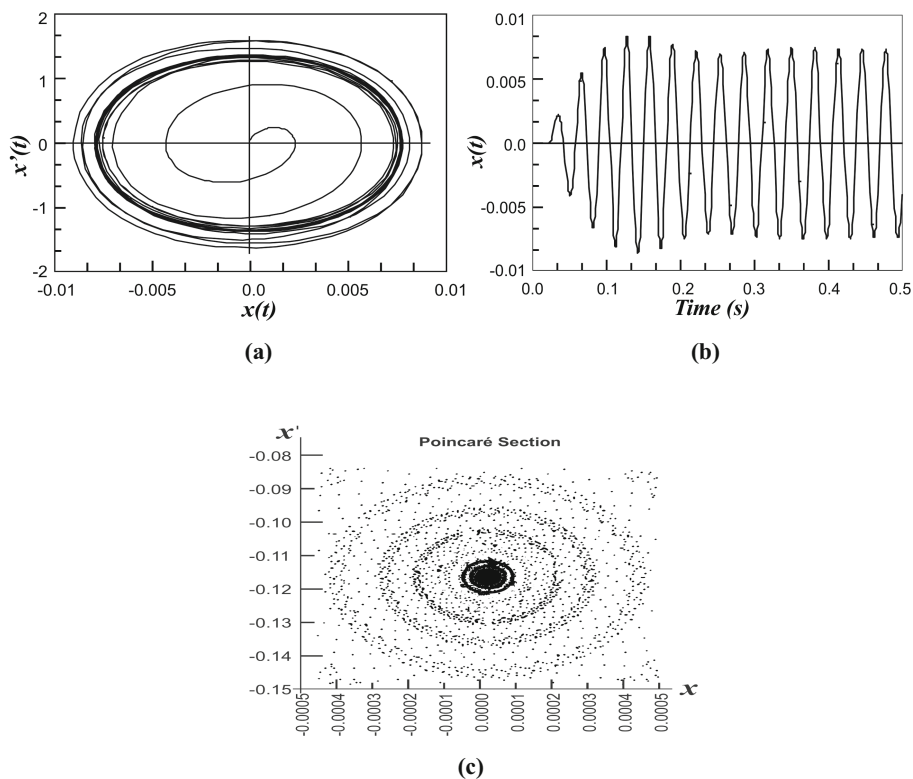
Their corresponding Poincaré maps in Fig. 6(c) exhibit a large number of irregular points, indicating unstable motions.



**Fig. 6.** Phase plane plot (a), Time plot (b) and Poincaré map (c) for the system without the 3-WESB

In Fig. 7(a), the phase plane represents periodic orbits with solutions that begin at the centre and move outwards elliptically. The oscillations do repeat and the time plots are periodic as observed in Fig. 7(b) and from transient times, corresponding Poincaré map is plotted as the points show convergence to a period-one motion and a concentrated area in the centre. It is a clear indication stable motions in the flexible rotor system based on these results.





**Fig. 7.** Phase plane plot (a), Time plot (b) and Poincaré map (c) for the system with the 3-WESB

## 5 Conclusion

The effect of the novel 3-WESB on the super-harmonic resonance behaviour of the mass unbalanced induced vibration of the flexible rotor system was investigated in this paper. The rotor-3-WESB's mathematical model was established. The perturbation method of multiple scales and the NDSolve integrator within Mathematica™ were utilized to obtain the nonlinear super-harmonic resonance responses and the bifurcation plots, phase plane plots, time plots and Poincaré maps. The effects of the stiffness and damping ratios of the 3-WESB on the super-harmonic resonance responses are discussed. Numerical analyses were undertaken and the effect of the 3-WESB on the bifurcation diagrams, phase plane plots, time plots and Poincaré maps was established. Some conclusions are as follows:

1. The super-harmonic resonant response of the amplitude can be suppressed and the jump phenomenon effectively eliminated using the novel-3WESB with some parameter manipulations.
2. It has been demonstrated that the stiffness and damping ratios of the 3-WESB have an interactive influence on the super-harmonic resonance amplitude of the flexible rotor system.

3. Evidence of unstable motions and period doubling surfaced in the bifurcatory behaviour of the amplitude response as dependent on the normalized excitation acceleration and with the introduction of the 3-WESB all period doubling and unstable motions became stable.
4. Further analysis of the bifurcation plots in the form of phase plane plots, time plots and Poincaré maps confirmed the presence of unstable motions and with the introduction of the 3-WESB the phase plane, time plot and Poincaré map displayed periodic motions indication stable motions.

The main contribution of this work is the examination of the super-harmonic response of the nonlinear flexible rotor system using a novel 3-Way End-Stop Bearing and to show that there is a linearization and control mechanism for super-harmonic response amplitude characteristics using different combinations of the parameters of the 3-Way End-Stop Bearing.

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# Conditional Cash Transfer Programs; Compliance to Health Conditions in Tanzania

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**Abstract. Purpose:** This study employed logistic regression in three selected regions in Tanzania namely Dodoma, Singida and Kagera to test the predisposing, enabling and need factors in CCT design and implementation to see how they influence conditions compliance.

**Methodology:** The study used secondary data from TASAF PSSN from 2014 to 2019 where compliance with health conditions was a dependent variable.

**Findings:** At 95% CI, the odds ratio ranged from 0.978 for location (District) to 1.74 for PMT whilst some were significant and others were not. Changing the original location to the other decreases the likelihood to comply as well as the poorer and those with chronic illness – similar to the money given in the higher months of the year. Differently, aged members and male members have shown to have higher likelihood to comply than their counterpart beneficiaries.

**Practical implication:** The study concludes that punishments for noncompliance have to re-consider the nature of the factors, whether they are in favour of or against facilitating compliance.

Although some beneficiaries agree that penalties invites compliance, this paper suggests penalties to be imposed carefully otherwise the absolute use of the penalties becomes counterproductive in changing behaviour, attainment of the programmes objectives and finally poverty reduction.

**Originality/Value:** Policy makers, designers and implementers of CCT will be informed of the key areas that affects compliance positively or negatively and be able to make design and implementation decisions based on the factors that influences CCT conditions compliance.

**Keyword:** Conditions · Compliance · Cash transfer · TASAF PSSN

## 1 Introduction

Conditional Cash Transfer (CCT) programs has been popular and implemented for more than a decade now throughout the world (Owusu-Addo et al. 2018; Bastagli et al. 2016;

Gaarder et al. 2010; Fiszbein and Schady 2009; Lagarde et al. 2009). The main purpose of the CCT worldwide is to ensure the reduction of poverty (Brooks 2015) – poverty from one generation to another – by forcing some behaviour through conditions (Ibarrarán and Cueva 2017; Lagarde et al. 2009). When they fail to comply to the conditions – intentionally or unintentionally – it increases the likelihood of remaining in poverty as the consequences involves penalties (Budlender 2014) which reduces their expected purchasing power and limit consumer choices. Moreover, the worst is when they are removed from the program (Ibarrarán and Cueva 2017; Bastagli, et al. 2016; Budlender 2014).

Compliance in CCT programs can be of two types; one refers to being in appropriate group of either control or treatment and the other is adherence to conditions set for CCT program (Gertler et al. 2016). The latter is the one being used in this study and is tied to adherence to the conditions set as the absolute requirement for receiving the full amount or remain in the program (Gertler et al. 2016; Bastagli et al. 2016; Budlender 2014; Schüring 2010). Health utilization quantifies the use of health services by members derived from illness or preventive care (Kumar et al. 2018; Babitsch et al. 2014) and is a main health condition through which health conditions compliances is determined (Gaarder et al. 2010; Barber and Gertler 2008). Gudmundsdottir and Vilhjalmsón (2010) grouped health service utilization into key three factors i.e. predisposing, enabling and need factors.

Studies which reports compliance in CCT conditions put much emphasis whether there is compliance or non-compliances as well as penalties imposed upon non-compliance or benefits in case of compliance (Bastagli et al. 2016; Budlender 2014; Ibarrarán and Cueva 2017; Fiszbein and Schady 2009). However, how to ensure compliance is achieved has been a question with little attention to both implementers and policy makers dealing with Conditional Cash Transfer (CCT) programs (Pellerano and Barca 2014). This paper intends to examine the likelihood of complying with the health conditions which echoes health utilization by analyzing the key health utilization factors in the design and implementation of the CCT; thus increasing the efficacy of the programme (Consultancy Group 2017).

## 2 Theories Underpinning the Study

### 2.1 Theories

From the approaches in decision theory (Steele 2020) and game theory (Gordillo 2019), people will make choices guided by fixed constraints and bounded to be rational. The intensification of penalties for noncompliance having intention to ensure compliance unfortunately results into neither positive results neither negative (Tsebelis 1991) – inconclusive and indecisive results. Thus, compliances achievement is specific in nature, penalties are not a sure means to achieve compliance. The assumptions is that beneficiaries will tend to maximize the value of the benefits given by the program and the gain from the program but within the limits.

Behind the choices made by individuals, Étienne (2010) informs motivations behind choices and decisions to be within and external to individuals through the works by Braithwaite, Scholz and Frey. Social factors and individual factors in a certain community

has been used as a determinant to influence compliance where's a reward or punishment can be given as a result of compliance or non-compliance accordingly. Conditions in health (Manley et al. 2012; Fiszbein and Schady 2009) that require compliance are mostly tied in utilization of health services. According to Étienne (2010) in combination by the work by Gudmundsdottir and Vilhjalmsón (2010), factors to be tested were grouped into pre disposing, enabling and need factors. In view of factors behind design and implementation of CCT, pre disposing factors included age, sex and locality (district) whilst enabling factors captured were total amount paid (Tsh) and the time (month) in which the payment was effected. Additionally, need factor included chronic illness and PMT score which is an index for poverty rate of an individual and the household in general.

## 2.2 Tanzania Conditional Cash Transfer Program

Tanzania started its Cash Transfer program in 2002 namely Tanzania Social Action Fund (TASAF) aiming at improving social service delivery (The Transfer Project 2021; Word-Bank 2014). TASAF under President's office (PO) has been implemented in phases – phase I ended in 2005 whilst phase II ended in 2012. The third phase started as a scaled up social safety net program namely PSSN (Productive Social Safety Net) – a Conditional Cash Transfer (CCT) program – which incorporated a complimentary intervention namely Public Works Program (PWP) (The Transfer Project 2021; Tanzania Social Action Fund (TASAF), 2013). TASAF –PSSN is the only social safety net scaled out throughout the country in both Tanzania mainland and Zanzibar (Tanzania's Productive Social Safety Net (PSSN) 2016); the main aim is generally to reduce poverty like other CCT programs worldwide (Bastagli, et al. 2016; Fiszbein and Schady 2009).

TASAF – PSSN provides a basic fixed transfer, unconditional to all qualified households – eligible and enrolled to a program while the variable and conditional transfer is given depending on the nature and composition of the household (Tanzania Social Action Fund (TASAF) 2013). The use of unconditional cash transfer was to improve the general living standard and the conditions were meant for education and health improvements (WordBank 2014) – among the vital areas in human capital development (Roelen et al. 2017). Success of CCT's depends on many factors among many includes the design of the program where conditions plays a major role (Jones and Shahrokh, 2013; Fiszbein and Schady 2009). The health conditions in TASAF PSSN requires that pregnant women attends both pre and post natal clinics – and delivery must be at a health facility. Mothers are given training on how best their children can be raised nutritionally (Tanzania Social Action Fund (TASAF) 2016; Tanzania Social Action Fund (TASAF) 2013). All these conditions requires adherence to be termed as compliance (Budlender, 2014); a condition in which subsequent payments are given once compliance is confirmed (Tanzania's Productive Social Safety Net (PSSN) 2016; Tanzania Social Action Fund (TASAF) 2013).

## 3 Methodology

This study selected three regions from Tanzania where different factors that associated with design and implementation of the programme – grouped into predisposing, enabling

and need factors – has been tested to see how they influence compliance – compliance to health conditions as a dependent variable.

### 3.1 Data

The data was obtained from TASAF-PSSN program from 2014 to 2019 for the selected regions. The selected regions in Tanzania were Dodoma, Singida and Kagera because poverty is highly pronounced (URT 2019; UNDP 2018; Kilima 2016), more health problems especially those related with nutrition – a result of poverty – are common (MoHCDGEC 2019; TFNC 2014; WHO 2012) and have the great number of TASAF PSSN beneficiaries (Tanzania’s Productive Social Safety Net (PSSN) 2016). The total number of beneficiaries listed in the three regions is 2,104,154 where male dominated by having 53% unlike 42% of female.

### 3.2 Logistic Regression for Compliance Status with Other Variables

Ordered logistic regression was used to test for how the factors will increase or decrease the likelihood of compliance for beneficiaries as shown in Eq. 1

$$\ln\left(\frac{p}{1-p}\right) = \beta_0 + \beta_d X_d + \beta_s X_s + \beta_c X_c + \beta_a X_a + \beta_{tp} X_{tp} + \beta_{pmts} X_{pmts} + \beta_{pm} X_{pm} \tag{1}$$

Equation 1 where

- X<sub>d</sub>* - stands for the variable location denoted by *d* (district)
- X<sub>s</sub>* - stands for the variable sex denoted by *s*
- X<sub>c</sub>* - stands for the variable chronic illness denoted by letter *c*
- X<sub>a</sub>* - stands for the variable age denoted by *a*
- X<sub>tp</sub>* - stands for the variable total payment denoted by letters *tp*
- X<sub>pmts</sub>* - stands for the variable proxy means test score denoted by letters *pmts*
- X<sub>pm</sub>* - stands for the variable time denoted by letters *pm* (total payment).

## 4 Findings

The variables in the logistic regression (Table 1) includes location as districts, sex of beneficiaries, chronic illness and others as independent variables to compliance for the conditions set by the CCT.

**Table 1.** Logistic regression for compliance

Variable	Parameter estimate (Odd ratio)	Standard error	Z value	P-value
District	0.9765262	0.000718	-32.32	<0.0001
Sex	1.013129	0.008747	1.51	0.1310
Chronic illness	1.015936	0.009335	1.72	0.0850
Age	1.003787	0.000377	10.05	<0.0001
Total amount paid	1.000000	0.000000324	1.41	0.1590
PMT score	1.746671	0.014083	69.17	<0.0001
Payment month	0.9968918	0.002451	-1.27	0.2050

Source: Research data from TASAF PSSN 2021

## 5 Discussion

### 5.1 Compliance Status with Member’s Age and Sex

The results provides the age estimates results (PE = 1.003787,  $p < 0.0001$ ) indicating significant influence to compliance status. The odds indicates that there is 1.004 times larger in compliance as the age increases. One year older member is expected to comply 1.004 times as larger as compared to the younger. That means compliance is increasing with age similar to the observation by Levkovich (2020). Sex, a demographic predisposing factor shows statistically non-significant results at 95% CI. (PE = 1.013129,  $p = 0.1310$ ). Males are likely to comply 1.01 times larger than females; nevertheless not significant. Therefore, sex – being male or female – do not significantly influence compliance even though males are likely to comply more than females, similar with other study (Bohn et al. 2014). Nevertheless, other studies in similar or different fields (Tom and Granié 2011; Grosch and Rau 2016) reports women to comply more than men; for instance in road rules and road signs.

### 5.2 Compliance Status with Chronic Illness

Chronic illness results to compliance with conditions (PE = 1.015936,  $p = 0.0850$ ) indicates statistically not significant results at 95% CI, considering other variables. Having chronic illness and not being chronically ill doesn’t make any statistical differences in compliance. Members without illness are expected to be 1.02 times larger in compliance than those with different chronic illness. The compliance likelihood might be due to the fact that a person who isn’t ill might easily attend to nutritional sessions, clinics for pregnant women and children below five (yrs.) compared to those not facing the long term illness like HIV aids. A similar result was reported by Budlender (2014), where noncompliance wasn’t the fault of beneficiary but a reflection of vulnerability.

### 5.3 Compliance Status with Regard to Location

The relationship between beneficiaries location measured at district level with compliance status shows a significant results at 95% confidence interval (PE 0.9765,  $p <$



0.0001). Movement from one locality has a negative effect, 0.97 times low compared to remaining in the same locality given other variables. This might be caused by introduction of a member and the household to a new environment with new health service supply and access modes thus requires new modality not used before to ensure compliance. According to Ibararán and Cueva (2017), health services aren't the same in all locations which can reduce compliance in case the new environment is having the poor services as compared to the original. In a similar way, Budlender (2014) reported non-compliance to be a result of failure and incompetence of the supply side – the reasons beyond reach of household and members.

#### **5.4 Compliance Status with Amount Paid and Time of Payment**

The results ( $PE = 1.000$ ,  $p = 0.1590$ ) for the total amount paid and compliance status informs that an increase in the total amount to the household doesn't affect the likelihood to comply. In other words, the projected compliance will remain the same when the total amount paid to household is considered given other factors. Moreover, the effect is again not significant at 95% CI. The general picture from the results informs that additional amount of money paid to households and household members cannot be used as a way to increase the likelihood to comply. The results for compliance status derived from payment time (in months) reveals the values of  $PE = 0.9968918$ ,  $p = 0.2050$  for odds ratio and the p value at 95% CI given other variables. This indicates 0.997 times lower in compliance for money paid in subsequent months after the first round which is paid in January/February. Other months are regarded as difficult times (ISPA 2016) which might be a reason for low likelihood to comply. Moreover, the author informs the early time in the year to be the same time when public works is implemented; public works aiming at smoothening difficulties faced by beneficiaries. Nevertheless, the effect of time into which the money is given isn't statistically significant.

#### **5.5 Compliance Status with Proxy Means Test (PMT) Score**

Proxy Means Test (PMT) score is statistically significant in affecting compliance with values of  $PE = 1.746671$  and  $p < 0.0001$  for odds ratio and p-value respectively at 95% CI given other variables. The odds ratio informs a likelihood of 1.75 times larger in compliance when for a person with one more PMT score. As PMT reflects poverty status, the implications is that the poorer will comply less with the CCT conditions than the better off. It might be attributable to the fact that beneficiaries with higher PMT score might easily manage the cost associated with compliance compared to the poorer – having low PMT score. The cost covers the transport cost and time in attending health clinics and trainings. Additionally, the poorer are the one likely to be penalized and even removed from beneficiaries' list than those with higher PMT scores. Other studies (Heinrich and Knowles 2018; Budlender 2014) have reported similar results with the experience that those highly vulnerable are commonly penalized – a non-compliance effect – or removed from the program.

## 6 Conclusion and Recommendations

The results regarding pre disposing factors like sex, location and age have shown to be significantly influencing compliance with exceptional of sex. However, movement from one locality to the other have to be discouraged as it reduces the likelihood of compliance. The results informs that compliance to CCT conditions can be ensured much when men are held accountable to compliance than women. On the other hand, aged individuals are likely to comply more than the younger beneficiaries thus, higher tolerance can be made through more training before imposing penalties considering the need to help the poor with younger age. Moreover, compliance accountability has to be vested to the aged when implementing CCT programs since the likelihood to comply with the set conditions is high.

Enabling factors have been non-significant in influencing compliance – total amount and time of payment in months. The need factors revealed less compliance for both beneficiaries with chronic illness and those with low PMT value. Thus, the presence of the need factors, the less the likelihood to comply and vice versa. This calls for considerations in health and poverty status when making decisions CCT health conditions' compliance. When a good number of members are poorer of faces chronic illness, it is highly expected to encounter non-compliances than when a good number are in a better situation.

Punishment in form of penalties and removal from the program following noncompliance of health conditions have to re-consider the nature of the factors in the design and implementation whether they are in favour of or against facilitating compliance to the set conditions. A member might be in a situation where the likelihood to comply is low and thus require considerations before enforcement of the stipulated measures. Although some beneficiaries agree that penalties for non-compliances invites compliance (Consultancy Group 2017; Budlender 2014), this paper suggests penalties to be imposed carefully looking at the factors that might be a reason for non-compliances. In some cases as discussed, a need factor, pre disposing factor or enabling factor could be the reason behind reach of a beneficiary and hence absolute use of the penalties – imposed in a stringent – becomes counterproductive in changing behaviour, attainment of the programmes objectives and finally poverty reduction using CCT. Poverty reduction as a major intended goal of CCT become a day dream to the most vulnerable individuals. However, to those in a better of position, penalties will be a wakeup call to comply.

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# Risk Management Techniques by Small and Medium Size Contracting Firms

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**Abstract. Purpose:** This study examines the factors that influence the choice of risk management techniques by small and medium sized contractors to enhance appropriate risk management selection within the limited resource of this category of firms.

**Design/Methodology/Approach:** The study used primary data, which were obtained using a structured questionnaire administered to 17 engineers, 12 quantity surveyors, 10 architects, 8 builders and 2 project managers in Lagos State, Nigeria. The data collected were analyzed using mean item score (MIS), correlation analysis and t-test.

**Findings:** Findings show the five (5) most significant criteria influencing the choice of risk management techniques as a type of procurement method/system, availability of skilled personnel, safety during construction, the extent of knowledge of construction manager about risk and duration of the project.

**Research Limitation/Implications:** The study assessed the factors influencing the choice of risk management techniques by small and medium sized contracting firms.

**Practical Implication:** The knowledge advanced in this study will inform project managers or owners of small and medium sized contracting firms of the factors that significantly influence the choice of risk management techniques in their firms.

**Social Implication:** The knowledge advanced by this study will guide the project managers or those undertaking risk management roles in small and medium sized contracting firms in the selection of appropriate risk management techniques.

**Originality/Value:** The novelty of this study also lies in the cross tabulation of the relationship between risk management technique and company worth, company structure/ownership. It informs that these do not determine the choice of risk management technique.

**Keywords:** Construction · Management · Risk · Small and medium firms · Technique

## 1 Introduction

Small and medium sized construction firms contribute significantly to 'low and medium scale' construction and employment generation in developing countries. This category

of firms represents about 96% of all the businesses that contribute not less than 75% of the national employment in Nigeria (Ilori 2017). Small businesses generally are defined by total assets of between N5million-N50million; workforce of between 10 to 49 full-time staff; a turnover  $\leq$  N10million in a year. A medium scale enterprise is defined by a total asset  $>$  N50 million but  $<$  N500million; a staff strength of between 50 to 199 full-time workers; and annual turnover  $>$  N20 million (Small and Medium Enterprises Development Agency of Nigeria (SMEDAN 2009).

The performance of small and medium sized contractors in project delivery is being influenced by many management factors which are mostly finance and risks, among others. Most of the small and medium sized contracting firms have therefore found it difficult to sustain their expansion and growth with the results that they are distressed and fold up within few years of operation (Afolabi et al. 2019). Risk management to contracting organizations has been well documented in construction management literature. However, small and medium sized category of construction firms appears not to have adequately benefited from the previous assessment of risks as studies that have isolated these firms for specific evaluation of risk management are limited. Risk management constitutes the harmonization of activities that an organization takes to direct and control risk variables which aids pre-planning and tactical thinking to assist in making a conversant decision. Effective risk management method helps to understand the type of risks faced and how to manage those risks in different phases of a project. The construction industry's risk factors have been reported the highest when compared to those of other industries (Zafar et al. 2016) due to factors such as delay, bad environment, financial incapability and active organization structure (Akintoye and Macleod 1997; Smith 2003). Most importantly, the construction industry has a poor reputation in risk management when related to other industries. Risk management is thus very vital in attain project objectives and ensuring the sustainable growth of small and medium sized contracting firms.

Previous researches appear to be robust on risk management on the aspect of project objectives to cost and time (Shen 1997). There are also sizeable investigations on risk management relating to various project levels or stages; feasibility stage (Uher and Toekley 1999), design stage (Chapman 2001) and construction phase (Abdou 1996; Adaralegbe et al. 2020). Unlike in the developed countries, risk management practices are not well carried out in developing countries (Oduami et al. 2002). The situation may be much severe in the case of small and medium construction firms as most construction organizations rely mostly on risk mitigation through the inclusion of contingencies sum (Taiwo 2018).

Small and medium contractors face larger problems of risk management with no clear boundaries on how findings of existing risk management studies may be applied to construction firms generally and this category of firms specifically. Besides, small and medium size contractors may be limited in risk management due to the adequacy of skilled personnel (Njuguna 2008), poor record-keeping (Jaafar and Abdul-Aziz 2005) and financial capability (Smith et al. 2006). The assessment of Lichtenstein (1996) which focused on factors of risk management selection invariably provided a better insight but the study may not be directly generalizable to small and medium size contractors. To fill the vacuum of risk management among small and medium size contractors in the

literature regarding factors responsible for the choice of management strategies, this study investigates factors necessary for consideration during the process of choosing risk management strategies in building projects. The study possesses the potential to indicate the relative significance of the variables that could guide the project manager or those undertaking this role in small and medium sized firms in the selection of appropriate risk management techniques.

## 2 Literature Review

The need to improve the operation efficiency and sustainable growth of small and medium sized contracting firms has been well recognized and equally attracted research attention. Firstly, small and medium scale enterprises (SMEs) are widely considered as the tool of economic growth and impartial development in developing economies (Agwu and Emeti 2014). Moreover, they form the largest proportion of businesses in most countries that contribute towards employment generation (Ilori 2017). Despite these contributions, the SMEs sector in Nigeria still performs far from expectation. Specifically, small and medium sized contracting firms appear not to have received adequate research attention towards improving their delivery capability (Afolabi et al. 2019).

Risk has been recognized as a significant factor that impacts contracting firms' performance. However, much of previous attempts on risk management appear to have favoured larger firms. The peculiarities of the small and medium sized firms may make a difference in the application of risk management techniques and the choice. Risk definition and management techniques are well documented generally in literature (Adedokun et al. 2013). However, specific assessment of the risks and their management by small and medium sized firms appear to have received limited focus. Risk occurrences in projects executed by small and medium sized contractors have been reported most recently (Opawole and Kajimo-Shakantu 2021). Earlier studies have also indicated a strong risk impact or effect on construction contracts (Abassi et al. 2005; Mills 2001), especially if the risk factors are not well managed (Adaralegbe et al. 2020). Hence, risk management has to be put in place to help toward attaining projects objectives. Oztas and Okmen (2004) asserted that the necessity to manage risk in the construction project is increasing as a result of the intricacy, size, competition, client customer requirement, political-economic challenges and major conditions involved in projects.

Several authors have also indicated management techniques that are suitable in construction (Odeyinka 1999; Oztas and Okmen 2014; Adedokun et al. 2013). However, the selection of appropriate strategies used in risk management depends on many factors. A comprehensive list of these is indicated by Smith et al. (2006) as; the type of construction project, magnitude of the project, information available, cost analysis and experience of the analyst. Others are; knowledge appropriateness of a risk management strategy, duration of the project, type of procurement method or system, availability of trained personnel, flexibility of project type, ease of usage of a technique, ease of manipulation of data, phase of the project lifecycle, corporate maturity towards risk, extent of knowledge of construction manager about risk, cost implementing risk technique, the purpose of risk analysis, business location, contract sum of a project, nature of the client, clients requirement, ease of interpretation of recent of data processing, the financial status of



the contractor, size and complexity of the project, contractors organization policy, availability of risk experts as staff in the company, workforce availability and skill, safety during construction, communication and data transfer, quality of work, insurance policy and availability of technology (software) to implement a strategy.

Notwithstanding the progressive increase in the number of small and medium size construction firms, the category of construction firms appears not to have adequately benefited from the previous assessment of risks assessment as the studies that have isolated these firms for specific evaluation of risk management are limited.

### 3 Methodology

This study used primary data collected through a quantitative approach. The structured questionnaire was targeted at 100 firms which is about a 40% proportional sample of 245 registered small and medium contractors in Lagos state, Nigeria (Lagos State Public Procurement Agency 2016). This gave the sample size for this study as 98 small and medium sized contractors. The first section of the questionnaire was designed to collect the personal profile of the respondents (personal profile, year of experience, academic qualifications, professional qualification, etc.). This was to ascertain the quality of the data for the analysis. The questionnaire was divided into two sections. The second section elicited information on the purpose of the research which was criteria influencing the choice of risk management techniques. The questionnaire was structured in a closed-type format where typical factors were identified and listed for respondents to evaluate. The scale involving rating on an interval scale of 5 and 1 for quantification of qualitative variable, where 1 represents the least rating and 5 the highest rating was used. The closed-type format of the questionnaire enabled a better understanding of the instrument by the respondents so that completion of the questionnaire was possible on an average of 30 min. At the end of the exercise, a total of 60 copies (62% response rate) out of 82 copies administered were. The extent to which items included in the scale of the instrument used were correlated was evaluated using Cronbach's  $\alpha$ . The results revealed a values range of  $0.928 \leq \alpha \leq 0.952$  which indicates a high-reliable instrument.

## 4 Findings

### 4.1 Respondents' Profiles

The profiles of the respondents were analyzed in Table 1. About 21.6% of the firms were owned as a sole proprietorship, while 29.4% were partnership firms and 47.1% were a limited liability. About 50% of the firms had been established over the past 20 years with 12 employees on average, and 37.3% had been incorporated for more than 21 years. About 68.6% of the firms worth more than N50,000,000; 9.8% worth between N1, 000,001 - N50,000,000, and 5.9% worth up to N1,000,000. Analysis of the types of respondents shows that engineers represented 33.3% while project managers and quantity surveyors represented 3.9% and 23.5% respectively. Moreover, the representations of builders and architects were 15.7% 19.6% of the sample, respectively. Other respondents were represented at 3.9%. The results of the analysis of the highest academic



qualifications of the respondents show that 31.4% of the sample held Higher National Diploma (HND) certificate. Those that held Masters Degrees (MBA and M.Sc.) were 3.9% and 27.5%, respectively. About 35.3% held First Degree (B.Sc.) holders while 2% held Doctorate (Ph.D.) Degree. The respondents were either associate or corporate members of various professional bodies or possessed some other professional qualifications. The average year of experience of the respondents is estimated at 12 years.

**Table 1.** Profile of the respondents

Profile of respondents	Criteria	Frequency	Percentage
Type of respondent	Engineer	17	33.3
	Project manager	2	3.9
	Quantity Surveyor	12	23.5
	Architect	10	19.6
	Builder	8	15.7
	Others	2	3.9
Academic qualifications	HND	16	31.4
	MBA	2	3.9
	First degree	18	35.3
	MSc	14	27.5
	PhD	1	2.0
Type of organization	Missing	1	2.0
	Sole proprietorship	11	21.6
	Partnership	15	29.4
	Limited liability company	24	47.1
Company worth	Missing	13	25.5
	1000001 and above	21	41.2
	500001–1000000	6	11.8
	50001–500000	7	13.7
	5001–50000	3	5.9

## 5 Discussion

The results of the analysis in Tables 2 and 3 that most of the firms favoured the use of contingency sum agreed with earlier finding of Taiwo (2018) across the ownership structure of the firms. However, a cross tabulation of the risk management technique and company structure/ownership ( $\chi^2(10) = 15.769$ ) at  $p > 0.05$  indicates that there is no statistical evidence of the relationship between company structure and risk management techniques they adopt.

**Table 2.** Correlation of risk management technique against company structure/ownership

Risk management technique	Company structure/ownership			Total
	Sole proprietorship	Partnership	Limited liability company	
Contingency sum	2	7	15	24
Swift analysis	3	0	2	5
Delphi method	4	2	2	8
Monte Carlo	0	0	1	1
What-if analysis	0	1	2	3
Failure method and effect analysis	1	0	0	1
<b>Total</b>	10	10	22	42

Similarly, the analysis in Table 3 of a cross tabulation of the relationship between risk management technique and company worth shows that there is no statistical evidence of the relationship between company worth and risk management techniques used by the firms at  $p > 0.05$  ( $\chi^2, 10$ ) = 12.689).

**Table 3.** Correlation of risk management technique against company worth

Risk management techniques	Company worth in Naira		
	0–1,000,000	1,000,001–50,000,000	50,000,001 and above
Contingency sum	2	2	14
Swift analysis	1	1	2
Delphi method	0	0	7
Monte Carlo	0	0	1
What-if analysis	0	0	3
Failure method and effect analysis	0	1	0
<b>Total</b>	3	4	27

**5.1 Factors Influencing the Choice of Risk Management Technique**

The results of the analysis of small and medium sized contractors on the criteria influencing choice of risk management techniques described in Table 4 revealed that five (5) most significant criteria were; type of procurement method or system ( $\bar{x} = 3.97$ ), availability of trained personnel ( $\bar{x} = 3.96$ ), safety during construction ( $\bar{x} = 3.84$ ), the skill of project manager about risk ( $\bar{x} = 3.79$ ), and duration of the project ( $\bar{x} = 3.76$ ). These

**Table 4.** Criteria influencing the choice of risk management techniques

Factors	Overall		Small		Medium		T-Test	
	$\bar{x}$	R	$\bar{x}$	R	$\bar{x}$	R	t-value	Sig.
Type of procurement method or system	3.97	1	4.20	1	3.73	18	1.476	.146
Availability of trained personnel	3.96	2	3.80	2	4.12	1	-.666	.520
Safety during construction	3.84	3	3.60	6	4.07	3	-1.397	.169
Skill of construction manager about risk	3.79	4	3.70	3	3.88	7	-.507	.614
Duration of the project	3.76	5	3.40	13	4.12	1	-1.901	.063
Flexibility of project type	3.73	6	3.70	3	3.76	16	-.177	.860
Financial status of the contractor	3.73	6	3.40	13	4.05	4	-1.892	.064
Communication and data transfer	3.71	8	3.40	13	4.02	5	-1.405	.189
Knowledge of appropriate technique	3.71	8	3.70	3	3.71	19	-.025	.980
Cost implementing risk technique	3.68	10	3.50	7	3.85	10	-1.088	.282
Workforce availability and skill	3.67	11	3.50	7	3.83	11	-.887	.380
Clients requirement	3.65	12	3.50	7	3.80	12	-1.054	.297
Business location	3.61	13	3.50	7	3.71	19	-.576	.567
Size and complexity of the project	3.60	14	3.30	19	3.90	6	-1.290	.224
Contract sum of a project	3.59	15	3.40	13	3.78	14	-.870	.389
Contractors organization policy	3.59	15	3.30	19	3.88	7	-1.309	.218
Availability of risk experts in the company	3.59	15	3.40	13	3.78	14	-1.053	.297
Purpose of risk analysis	3.58	18	3.50	7	3.66	22	-.414	.681

*(continued)*

**Table 4.** (continued)

Factors	Overall		Small		Medium		T-Test	
	$\bar{x}$	R	$\bar{x}$	R	$\bar{x}$	R	t-value	Sig.
Ease of usage of a technique	3.55	19	3.50	7	3.59	25	-.249	.805
Skill of interpretation of data processed	3.53	20	3.30	17	3.76	16	-1.259	.214
Insurance policy	3.50	21	3.20	23	3.80	12	-1.769	.083
Nature of the client	3.48	22	3.40	13	3.56	26	-.433	.667
Phase of project lifecycle	3.47	23	3.30	17	3.63	24	-1.028	.309
Quality of work	3.44	24	3.20	23	3.68	21	-1.632	.109
Corporate maturity towards risk	3.38	25	3.10	25	3.66	22	-1.795	.079
Availability of necessary technology	3.34	26	2.80	26	3.88	7	-3.302	.002*
Ease of manipulation of data	2.84	27	2.70	27	2.98	27	-.765	.448

\* *p*-value is significant at 0.05;  $\bar{x}$  = mean; R = rank

have the overall mean ranking ranged as  $3.97 \leq \bar{x} < 3.76$ , and were ranked 1<sup>st</sup> to 5<sup>th</sup>. These were also ranked high by both the respondents from small and medium contractors and suggest their relative significance in determining the type of risk management techniques they use.

From the results of the analysis in Table 4, other criteria influencing the choice of risk management techniques were flexibility of project type, the financial status of the contractor, financial status of the contractor, cost implementing risk technique, workforce availability and skill, business location, size and complexity of the project and contract sum of the project, which were ranked 6<sup>th</sup>, 8<sup>th</sup>, 10<sup>th</sup>, 11<sup>th</sup>, 12<sup>th</sup>, 13<sup>th</sup>, 14<sup>th</sup> and 15<sup>th</sup> respectively based on the overall ranking. Respondents from small sized contractors ranked them 3<sup>rd</sup>, 13<sup>th</sup>, 3<sup>rd</sup>, 7<sup>th</sup>, 19<sup>th</sup> and 3<sup>rd</sup> respectively, while those from medium sized contractors ranked them 16<sup>th</sup>, 4<sup>th</sup>, 5<sup>th</sup>, 19<sup>th</sup>, 10<sup>th</sup>, 11<sup>th</sup>, 12<sup>th</sup> and 6<sup>th</sup> respectively. The lowest-ranked criteria influencing the choice of risk management techniques based on the overall and rankings by both small and medium sized contractors were; quality of work, corporate maturity towards risk and ease of manipulation of data. The results indicate that, except for one criterion (availability of technology/software to implement a strategy,  $\bar{x} = 3.34$ ) influencing the choice of risk management techniques ( $P < 0.05$ ), there was no significant difference in perception of small and medium contractors within a 98% confidence interval.

It is worth noting that, availability of technology (software) to implement a strategy ranked 26<sup>th</sup> in the overall mean score, ranked 26<sup>th</sup> by small sized contractors and ranked 7<sup>th</sup> by medium sized contractors. It can be strongly argued that small and medium sized

contractors were generally unanimous on their perceptions of these criteria influencing the choice of risk management techniques on building project delivery. Since only one (1) out of the twenty-seven (27) criteria's showed significant difference., it can be inferred that small and medium contractors have the same perception of the criteria's on the delivery of building projects.

## 6 Conclusion

The study revealed the five (5) top significant criteria influencing the choice of risk management techniques by small and medium sized contracting firms as; the type of procurement method or system, availability of trained personnel, safety during construction, the extent of knowledge of construction manager about risk and duration of the project. The results of the analysis favoured the use of contingency sum which agreed with earlier studies across the ownership structure of the firms. However, a cross tabulation between the risk management technique and company structure/ownership indicates that there is no statistical evidence of the relationship between company structure and risk management techniques they adopt. Similarly, there is no statistical evidence of a relationship between company worth and risk management techniques used by the firms at  $p > 0.05$ . The study showed that, except for the availability of technology/software to implement a management technique, there was no significant difference in perceptions of respondents from small and medium contractors within. Small and medium contractors undertaken construction of building works need to be mindful of the identified top risk factors in making the selection of appropriate management techniques. The relative significance of the variables evaluated will guide the project manager or those undertaking risk management roles in small and medium sized firms in the selection of appropriate techniques. The scope of the study could be extended to the assessment of preference for quantitative and qualitative risk management techniques by this category of firms.

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# Translating the Global Goals to Local Implementation: SDG 11 in Focus

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**Abstract. Purpose:** This paper examines the local implementation of some aspects of SDG 11 including transportation, housing, flooding, air, water and noise pollution, waste management and sanitation. It identifies the stakeholders, their responsibilities and extent of collaboration in addressing SDG 11.

**Design/Methodology/Approach:** A qualitative approach was employed for the study. In-depth interviews were conducted on 12 participants consisting Assembly Members and Municipal Officials. Random and purposive sampling techniques were used and Qualitative Content Analysis was used in the data analysis.

**Findings:** The study identifies government and private stakeholders and their responsibilities in addressing SDG 11. Private stakeholders dominate in providing transportation, housing and waste management services while government stakeholders dominate in addressing flooding, pollution and greening of public spaces. Traditional authorities, community members, opinion leaders and Assembly members also play important roles. Collaboration among government stakeholders seem to be stronger and supported by formal structures while little collaboration is found between government and private stakeholders.

**Research Limitation/Implications:** This study focused on a rural community and the implications of the findings cannot be extended to urban communities.

**Practical Implication:** The knowledge from this study will provide guidance to Municipal and District Assemblies in proper implementation of SDG 11 to support efforts from Central Government.

**Social Implication:** The knowledge from this study will provide directions for policies that will improve conditions of human settlements in rural areas.

**Originality/ Value:** This study contributes to the literature on the implementation of SDG 11 in rural settlements.

**Keywords:** Stakeholder · Collaboration · Local implementation · SDG 11

## 1 Introduction

The eleventh goal of the SDGs, also known as SDG11 seeks to make cities and human settlements inclusive, safe, resilient and sustainable. The targets of SDG 11 include

addressing concerns of housing, urbanisation, transportation, and enhancing inclusive and sustainable urbanisation capacity for participatory and integrated human settlement. The SDG 11 has a strong interconnectivity with other goals such as SDG 1, SDG 3, SDG 6, SDG 7, SDG 12, SDG 13, SDG 14 and SDG 15 (Vaidya and Chatterji 2020; Croese et al. 2021). Consequently, addressing issues of housing, transportation, flooding, waste management and sanitation, air, water and noise pollution, amongst others contributes to efforts towards addressing these other related SDGs.

Studies reveal the instrumental role played by community leaders in development projects, spanning from donation of resources, lobbying for development projects, to ensuring sustainability of projects (Ozor and Nwankwo 2008; Senchi and Yelwa 2014; Ajala and Adebajo 2019). Community leaders carry much social influence and can influence the behaviour of their community members towards development agenda (Ajala and Adebajo 2019). They also have high connectivity with the community members and can easily sensitize community members on development concerns and at the same time serve as liaisons between governmental agencies and non-governmental agencies (Ozor and Nwankwo 2008). The global goals are implemented in local communities where opinion leaders such as Assembly members provide community leadership. Thus community leaders' knowledge of the various stakeholders and their responsibilities is relevant in facilitating the implementation of the SDGs.

Due to the level of interconnectedness of the SDG11 with other goals, a multi-stakeholder approach and a higher level of stakeholder collaboration is required to implement SDG 11. Several authors propose a collaborative approach and inclusivity of all relevant stakeholders in the implementation of the goals (Reed et al. 2016; Waage et al. 2015; van Vuuren et al. 2015). Following the framework of responsibility and blame, in the case of diverse stakeholders, there is a high tendency of institutions blaming and shifting responsibilities to other stakeholders when the outcomes are negative (Bickerstaff and Walker 2002; Haldar et al. 2021). An understanding of the extent of collaboration among stakeholders in implementing SDG 11 is central to addressing this problem.

This paper covers the remits of transportation; housing; flooding; air, water and noise pollution; waste management and sanitation; and tree planting and greening of public spaces. This paper contributes to the literature on the implementation of the SDGs by providing insights on the various stakeholders in the space of SDG 11 and their responsibilities. It also adds to the stakeholder theory by identifying the types of stakeholders in addressing development-related issues. So far, studies on SDG 11 have focussed so much on cities and urban settlements (Croese et al. 2021; Koch and Krellenberg 2018). Consequently there is limited information on implementation of SDG 11 in rural communities. There is also limited empirical studies on stakeholders and their collaboration in addressing development-related concerns in human settlements. Studies on stakeholders and their collaboration have focussed on educational institutions (Valk 2014; Valk and Kratoviš 2021) and institutions of care for older persons (Poškutė et al. 2021). The remaining sections of the paper provide information on the review of related literature, underpinning theory, methodology, findings and discussions, and conclusions and policy implications.



## 2 Literature Review

### 2.1 SDG 11, Stakeholders and Collaboration

The first target of the SDG 11 is to provide access to adequate, safe and affordable housing and basic services and upgraded slums. Basic services for human settlements include waste management and sanitation services. Flooding and pollution of all kinds are safety concerns. The seventh target also seeks to provide universal access to safe, inclusive and accessible green and public spaces, in particular for women and children, older persons and persons with disabilities is also a target of SDG 11. The SDG 11 also seeks to provide access to safe, affordable, accessible and sustainable transport systems for all. These targets form the basis of the focus of this paper.

The implementation of the global development goals is expected to be carried out at the regional and local communities where the local authorities work to effect implementation (Graute 2016; Koch and Krellenberg 2018). Thus there is the need to translate the global goals at the local level for implementation. In the case of Ghana, the local government system is decentralized and the Districts or Municipal Assembly (MA) is very powerful in the governance system.. The role of the MA as mandated by the Local Governance Act 2016, Act 936 of Ghana, is to address the overall development of the Municipality. The primary function is to control all public services in the jurisdiction.

Stakeholders refer to groups or individuals who contribute either voluntarily or involuntarily to an institution by creating value that is important for the success of the institution and who potentially benefit or bear risk as a result of the value creation (Post et al. 2002). Stakeholders have been previously classified as either primary or secondary based on the impact of their absence on the success of an organisation. (Mitchell et al. 1997). In another study, stakeholders are classified as definitive, dominant and interdependent based on power, legitimacy and social acceptability. Definitive stakeholders have power, legitimacy and social acceptability whilst dominant stakeholders have power and legitimacy. Interdependent stakeholders have informal power and legitimacy (Valk 2014; Valk and Kratoviš 2021).

Collaboration practices of stakeholders of professional higher education institutions in the field of internal security was examined in a study involving some European Institutions. Collaboration with stakeholders is mostly based on factors such as common interest and personal relationships, formal arrangements and the basis of subordination and dependency (Valk and Kratoviš 2021). The study disaggregated informal collaboration from formal collaboration and developed a descriptive framework for classifying stakeholders of institutions of professional higher education in the field of internal security and also for explaining stakeholder relationships.

### 2.2 Underpinning Theory – Stakeholder Theory

The stakeholder theory is a business-like theory that emanated from the Shareholder theory. It was introduced by a major publication from R. E. Freeman in 1984 titled *Strategic Management: A Stakeholder Approach*. The approach initially built on existing protocol of Mitroff and Mason (1982) and Emshoff (1978). It is believed that the theory was heavily influenced by the Planning Department of Lockheed. The theory places emphasis on

the responsibilities of industries rather than the profitability of industries (Ndaguba and Hanyane 2019). Although the primary aim of organisations is to make profits, stakeholder theorists maintain that in order to maintain profits, social responsibility is critical for sustained relationship between the community and the organisation (Freeman 1984). The components of the stakeholder theory are the shareholder, customers, employees, lenders, suppliers and society. The stakeholder approach is community-driven and participatory. There are three levels of participation in the stakeholder theory, namely primary, secondary and tertiary and it is the preoccupation of the theory that components of the organisation are given equal importance in tackling community challenges no matter the level of participation. Recently, the utilisation of stakeholder theory in business management is highlighting community development and is gravitating towards public institutions and administration. While the stakeholder theory offers explanation on the stakeholders and their social responsibilities in addressing SDG 11, it is limited in explaining the types of stakeholders and they work together to play the function of being responsible to the community and not only focusing on profitability. Mainardes et al. (2011) demonstrates that one limitation of the stakeholder theory is the presentation of the components of the theory without an explanation of the interconnections between the components. This study contributes to the stakeholder theory by classifying stakeholders as major or minor and highlighting the interconnections among stakeholders through collaboration.

### 3 Methodology

The present study lends itself to the qualitative approach. The interpretivist paradigm and the narrative research design were adopted. Narratives of Assembly Members, as well as the Regional and Municipal Officials were obtained through in-depth interviews, each taking an average of 50 min. The Yilo Krobo Municipality was purposively selected for the study due to fact that no study of this topic been done in the municipality. Moreover, the municipality is a fast transforming area due to the provision of social amenities such as a university attracting persons from all parts of the country. This has a consequence in transformation of the Municipality and an intended burden on existing infrastructure. The Municipality has 63 Assembly Members made up of 60 males and 3 females. Six male Assembly Members were randomly sampled while one female Assembly Member was randomly sampled out of the 3 female Assembly Members. Five Local governance officials were purposively sampled, namely the Municipal Director, the Development Planner, the Physical Planner, the Director of Community Development and the Community Development Officer. Data was collected by means of face to face in-depth interviews. The average duration of interview for the Assembly Members was 30 min and the average duration for the Municipal and Regional Officials was 60 min.

Qualitative content analysis (QCA), specifically, the Conventional QCA (Hsieh and Shannon 2005), was employed in the data analysis. The study started with an observation and the codes are defined during data analysis. Although the theoretical framework helped in explaining the phenomena under study, the codes were not necessarily derived from the theories. The analysis was more data-driven than concept-driven.

## 4 Findings and Discussion

### 4.1 Stakeholders and Their Responsibilities in Addressing Human Settlement Concerns

#### 4.1.1 Transportation

The major stakeholders are private transport owners, transport associations and unions, and the Ministry of Roads and Transport. The MA and some of its departments such as the Physical Planning Unit, Development Planning Unit, and Physical Works Departments are also major stakeholders. Other stakeholders, referred to as minor stakeholders include opinion leaders, unit committee members and private landowners. Taking insights from the classification of stakeholders by Valk (2014) and Valk and Kratoviš (2021), we classify stakeholders based on legitimacy, power and social acceptability. Major stakeholders have legitimacy and power and their responsibilities are acceptable to all participants. Minor stakeholders have legitimacy and power but have lesser acceptability by participants.

Private transport owners provide means of transportation such as *taxis*, *trotros*, motor bikes, vans, buses, tricycles and trucks. Almost all commercial means of transportation used in the study area are provided by private stakeholders. Transport associations are instrumental in ensuring the availability of private commercial transport. One of such associations, the Ghana Private Road Transport Union (GPRTU), plays a major role in creating transport stations at various locations and negotiating fares to ensure fair prices are charged.

The Ministry of Roads and Transport, together with the leaders of the Transport Unions, notably the GPRTU, it is responsible for negotiating commercial private transport fares whenever fuel prices increase. The responsibility of the Physical Planning Unit in the aspect of transportation is to facilitate the establishment of new transport stations and the movement of commercial transport to new communities. The Works Department has the responsibility of constructing new roads and maintaining existing roads to ensure all communities are connected by road networks. The responsibilities of the Physical Works Department facilitates that of the private stakeholders. Atuoye et al. (2015), conducted a study in rural Ghana and explored that bad road conditions contribute to the choice of transportation means of users. Pregnant women end up using alternative riskier means such as bicycles, motorbikes and tricycles instead of motor vehicles.

#### 4.1.2 Housing

The major stakeholder in ensuring community members have affordable, safe and secured housing is private property owners. Minor stakeholders include the MA, the Physical Planning Unit and the National Disaster Management Organisation (NADMO) and the Rent Control Agency. Private home owners rent out accommodation to tenants. Participants of the study expect the MA to provide amenities such as water, light and drainage systems since they collect building permits. The Physical Planning Unit has the responsibility of inspection and approval or (denial) of sites for putting up structures while NADMO is responsible for education and sensitization of community members

on inappropriate sites for buildings. Communities close to the Municipal capital have recently experienced high cost of accommodation rentals which participants attribute to the commencement of a university in the vicinity. This has pushed the MA to take up an unusual responsibility of appealing to property owners to charge fair prices for accommodation rentals. The study concludes that housing in the Municipality is mainly provided by private home owners while the MA and its units such as the Physical Planning and NADMO play a supporting role which ensures that community members have safe and affordable housing.

The housing market is monopolized by private individual home owners and this has a tendency to increase prices with the slightest change in any contributing factor. Unlike, fuel prices, there is no structure of negotiation to agree on fair prices that favours both the consumer and the provider. In addition, no other stakeholders are competing with private home owners. Real Estate Developers and Government housing projects are not visible in the Municipality and there is an opportunity to include such entities in providing affordable and safe housing.

#### **4.1.3 Flooding**

Flooding is an indicator of insecurity of human settlements. The major stakeholders responsible for addressing concerns of flooding are NADMO, Physical Planning Unit, Physical Works Department, Social Welfare and Community Development Unit and Environmental Health Unit. Minor stakeholders such as Community-Based Organisations (CBOs) and some religious groups and private individuals also respond to help people during flooding. The responsibility of NADMO is to de-silt drainage paths to enable free flow of water and also ensure that people do not build in waterways. In the event of flooding, NADMO is responsible for providing relief services to community members. In preventing flooding, the Physical Works Department is responsible for appropriate construction of roads and drains to facilitate free flow of water and also prevent community members from building in waterways. The Physical Planning Unit plays a similar role of preventing community members from building at unsafe places earmarked for drainage and waterways. They are also expected to sensitise community members on areas to avoid when purchasing land for building and also to follow the right procedures in acquiring building permits. The effectiveness of authorities in inhibiting building construction on waterways and unsafe place was questioned strongly by participants. The Social Welfare and Community Development, and Environmental Health Units are responsible for sensitisation on proper waste disposal practices to avoid flooding. It is interesting to note that most of the stakeholders play the preventive role which participants acknowledge as very important and a compromise on this poses so much cost to the municipality.

#### **4.1.4 Waste Management and Sanitation**

The major stakeholders responsible for managing waste and addressing sanitation issues are the MA, private service providers and Environmental Health Unit. Minor stakeholders are the Unit committee members, Assembly Members, queen mothers, chiefs and community members. The MA manages solid waste at no cost. Other responsibilities of

the MA are to negotiate with existing private waste service providers to provide good services and also lobby with new private stakeholders to come on board. The MA is also supposed to make financial resources available for waste management. Private Service providers manage both solid and liquid waste. The key private service provider is Zoomlion Company Limited, which manages solid waste at a fee. Dustbins are provided from which solid waste is collected regularly and dumped at designated sites. This company is classified as a *legalized* private service provider and works with the government in a private-public partnership. There is also a waste recycling company near the municipal capital.

One major observation in waste management is that outreach of Zoomlion and the MA is insufficient to reach out to all communities. Consequently, other private service providers that are *not legal* service providers also fill in the gaps in solid waste management. These usually cart the solid waste in tricycles known as *Aboboyaa*. Some small communities, do not receive solid waste collection services from the MA or private providers and prepare their own dumping sites for waste disposal and treat their waste or burn it. In such cases, the opinion leaders such as chiefs, queen-mothers and Assembly Members play a role in deciding where to use as dumping sites. Management of liquid waste is dominated by private stakeholders.

The Environmental Health Unit and the Unit Committee members in each community are responsible for education on sanitation and waste disposal practices. The Unit Committee has an additional duty of reporting offenders to the MA. The following quotes provide evidence on the responsibilities of the Unit Committee. Assembly Members mobilise community members to clean up the communities occasionally while queen mothers and chiefs also sensitize community members on sanitation.

#### **4.1.5 Air, Water and Noise Pollution**

The study site is predominantly rural and it was observed from the Assembly members that air and water pollution is less of a problem than noise pollution. The major stakeholders responsible for addressing all forms of pollution are the Environmental Protection Agency (EPA), the MA, Environmental Health Unit and the Social Welfare and the Community Development Unit. Minor stakeholders include traditional authorities, community members and Assembly Members. The EPA is represented at the regional level and not represented at the municipal level. Consequently, complains made to the MA are forwarded to the regional capital for action. The EPA is responsible for educating and sensitising community members on all forms of pollution and enforcing laws on pollution. Emphasis was laid on the education and sensitisation on air and noise pollution by participants. The Social Welfare and Community Development Unit is responsible for sensitisation of community members on all forms of pollution. The Environmental Health Unit also plays a similar role and is also responsible for education as well. An interesting finding on the responsibilities of minor stakeholders emerged from the data. Some communities through the community members and traditional authorities have by-laws and enforcement procedures for prevention of noise. The voice of one male official provide credence as follows:

*What I noticed is that many of the communities have by-laws that restrict noise-making beyond a certain time. Upper Manya, Lower Manya, they came out of Yilo. They each have these by-laws and it is spreading from community to community.....usually when they set these by-laws they set up Community watchdogs. They appoint people from the various communities who are like custodians to enforce that particular regulations. So those who go contrary to it, maybe the chiefs or Tade Mantse and the Traditional rulers are there to enforce it. They will bring you to the chief and fine you.*

– Regional Official 2

Another interesting observation made by the authors was that of an Assembly Member taking personal responsibility of enforcing laws on noise making and social gathering following the Covid-19 protocols. The police is also responsible for enforcing laws on noise-making during funerals. It appears from the participants that although noise is the major form of pollution in the municipality, there is little awareness on it as an offence and this requires sensitisation.

#### **4.1.6 Public Parks and Places of Leisure, Tree Planting and Greening of Public Places**

The major stakeholders responsible for addressing this aspect of SDG 11 include the MA, Forestry Commission<sup>1</sup>, Department of Agriculture and NADMO. Schools, opinion leaders, and community members are minor stakeholders. The MA is responsible for providing public parks and places of leisure and also providing seedlings for planting while the Forestry Commission is responsible for planting trees and greening public places. During tree planting exercises, the Forestry Commission and the Department of Agriculture are responsible for providing seedlings and supervising planting of trees in the Municipality. Opinion leaders such as chiefs and Assembly members are supposed to educate and sensitise community members on tree planting and mobilise them for tree planting. NADMO, community members and schools are also responsible for planting trees.

#### **4.2 The Extent of Collaboration Among Stakeholders – Ways of Collaborating**

Table 1 presents the codes derived from the data that reflect the ways by which stakeholders collaborate in addressing the concerns of SDG 11 namely transportation, housing, flooding, waste management and sanitation, and air, water and noise pollution.

The categories developed from the data indicate that stakeholders collaborate through various ways such as embarking on community engagements, personal arrangement, planning activities together and sitting on issues together. Collaboration also occurs through the execution of huge programs and common tasks. Following the framework developed by Valk and Kratovitš (2021), the ways of collaborating can be further classified as either formal or informal. Formal collaboration include community engagements, meetings, planning, sitting on issues and executing huge programs. According

<sup>1</sup> The Forestry Commission is only visible at the Regional level and does not have an office at the Municipal Assembly level. However, when there are special assignments such as massive tree planting exercises, the office provides support at the Municipal Assembly level.

**Table 1.** Collaboration among stakeholders

Main categories	Subcategories	Elaborations/Exemplars
Ways of collaborating	Community engagements	<i>We look at where there are similarities...., we can fix a day....we move and do that single activity or engagement and it is done</i>
	Personal arrangements	<i>...so speak to the CHIPPS compound person that Thursday the women will be coming for weighing so you want to come and have some animation and role playing with them and it is working</i>
	Meetings	<i>Apart from having community engagements together, we have meetings together..... In the issue of building, the one who want to build must send the site plan to the Assembly and all the authorities there, the Physical Works, Planning and NADMO meet and discuss your issue</i>
	Planning together	<i>....almost all of them plan their activities so in your plan you need to factor the other departments in your plan so that they will also factor it in their itenary and plan for it</i>
	'Sitting on issues'	<i>.... the Physical planning will also go through it (site plan and indenture) then they will sit on it and see whether where you want to put up the building is convenient for the building to be put up... So they will sit on it, they take your drawing and they look at it, the location...ooo let's consider this drawing...no, this drawing let's leave it. So they collaborate before they give the go-ahead</i>
	Huge programs	<i>....So we have a program on child protection. It is a huge program. Other departments like Community development goes for community engagement and tease out issues.....If it is child abuse, you refer to Social Welfare, if it becomes criminal, you refer to DOVSU</i>
	Common task	<i>Almost all the departments are playing interwoven roles, what community development is doing is the same as what NCCE is doing..... so we have to collaborate with everybody</i>

to the framework of Valk and Kratovitš (2021), formal collaboration is aimed at broadly meeting some kinds of goals or guidelines. It seeks to follow procedures and structures. Collaboration through personal arrangements is classified as informal collaboration. The execution of common tasks is formal collaboration.

**4.3 The Extent of Collaboration Among Stakeholders – Structures**

The participants provided evidence of some formal arrangements or structures in place through which stakeholders collaborate (Table 2). These structures facilitate formal collaboration. These are the *Inter-sectoral Standards Operating Procedures (ISSOPs)*, *The Community-Led Total Sanitation Program (CLTSP)* *The technical sub-committee*, *The Municipal Planning Coordinating Unit (MPCU)*, and *the Composite Program of Action*. The researchers observed that most of the departments and units of the MA are all located on the same compound. This proximity facilitates collaboration.

**Table 2.** Collaboration structures

Main categories	Subcategories	Elaborations/Exemplars
Structures	Inter-sectoral Standards Operating Procedures	<i>In collaborating, government has brought up a program, Inter-sectoral Standards Operating Procedures (ISSOP. ....we look at where there are similarities so if I have to do my community engagement against flooding, we can fix a day.....we move and do that single activity and it is done</i>
	Community-Led Total Sanitation Program	<i>One program that the Assembly is running now is the Community-led total sanitation which is spearhead by Environmental health and in collaboration with Community Development</i>
	Technical Sub-committee	<i>There is a technical sub-committee, which is a committee that approves building permits. The members of this committee include Development Planning, ..... NADMO....we are about 10</i>

(continued)



**Table 2.** (continued)

Main categories	Subcategories	Elaborations/Exemplars
	Municipal Planning Coordinating Unit	<i>We also have MPCU which is the Municipal Planning Coordinating unit...It is made up of 23 Departments and units.....we have Education, Agric..... What we do is to prepare the medium term development plan</i>
	Composite Program of action	<i>So we have what we call the Composite program of action. We do a composite budget... then we all bring our budgets together</i>

The *Inter-sectoral Standards Operating Procedures (ISSOP)* is a Government initiative which spells out agreed standards and procedures for all stakeholders responsible for child protection and family welfare programs. The CLTSP is also an initiative of the MA, which naturally brings together stakeholders responsible for addressing concerns of sanitation, environmental health and community development. The technical sub-committee is a set-up made up of a group of representatives of various units and departments in the public service that work together to appraise building permits. This committee is made up of 9 units, namely the Development Planning, Physical Planning, Physical Works, Feeder Roads, EPA, NADMO, Environmental Health, and the Ghana National Fire Service. The established guidelines and goals of the committee enables the members work together. Another set-up that makes collaboration possible is the MPCU, which consists of 23 representatives of various departments including business persons. The common activity is the preparation of the Medium Term Development Plan. Another outlet for collaboration is the Composite Program of Action which requires that each unit or department prepares the budget and later all the units sit together and synchronise their budgets to prepare a composite budget that pools all resources together and also avoids duplication. These arrangements are mainly classified as formal collaboration which facilitate working together.

## 5 Conclusion and Policy Implications

The study identified various major and minor stakeholders responsible for addressing the aspects of SDG 11 under study. Private stakeholders are very instrumental in providing transportation and housing services as well as managing waste and sanitation in the municipality. However, the support of the MA is also necessary to facilitate and support the private stakeholders. Notably, the Physical Works Unit's role has implications for facilitating road transportation, which is the main transport system in the municipality. It also has implications for access to transport by communities far from the Municipal capital having challenges with bad roads. Lack of maintenance of bad roads also have implication for food stuff transportation and food security as bad roads

increase the transportation time of agricultural produce and result in post-harvest losses. In addition, the cost of transportation is increased when road networks are bad, resulting in high consumer food prices. The presence of private home owners as the sole providers of housing has implications for monopoly and exploitation. This requires the MA's engagement with real estate developers and government to provide housing. The demand gap in waste management has consequences for pollution of water bodies. This also has implications for poor sanitation and hygiene in the municipality. An increase in financial support for waste management activities by the MA is recommended. Also, the MA needs to engage other private stakeholders to come on board.

Concerns of air, water and noise pollution; public spaces and places of leisure, tree planting and public spaces greening are dominantly the responsibility of the government stakeholders. The lack of awareness of noise pollution is a problem in the community and the participants recommend aggressive sensitisation of community members on noise pollution. The lack of public parks in the municipality require policy attention.

Collaboration is seen among government stakeholders and this is facilitated by several structures in place such as the technical sub-committee, the ISSOPs and other initiatives. Little collaboration is seen between private stakeholders and Government Authorities and such collaborations are *ad hoc* such as when there is fuel price increments and there is the need to agree on transport fares. This has consequences for deepening negative externalities and free-rider problems. This will enhance the effectiveness of private stakeholders. Structures that will facilitate collaboration among private and local authority stakeholders will propel activities to address concerns of transportation, housing and waste management.

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# Analysis of Electrochemical Machining-Textured Surfaces Under Point Contacts in Rolling Tribo-Test

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**Abstract. Purpose:** The need for the right textured surface and selecting the right material in tribology is critical to friction reduction and energy savings in machine elements under full film lubrication rolling point contacts. This study provides a guide to proper material selection and the right surface texturing technique to enable machine elements to carry heavy loads at different speeds under the fully-flooded EHL regime.

**Design/Methodology/Approach:** A lapped GCr15 ball bearing, cast iron (HT 500) plates, GCr15 tempered plates and GCr15 plates without tempering were used. The electrochemical machining (ECM) technique was used to manufacture Micro-texture surfaces on the plates. The ECM micro-textured surfaces and lapped plain surfaces of the same material were subjected to friction and wear behaviour between a ball and a plate test in a fully-flooded EHL point contact rolling condition. The tribological test was conducted under different rolling speeds and pressure. The topographical characteristics of the lapped plain surfaces and the Electrochemical Machining (ECM) textures surfaces were analysed by both optical and scanning electron microscopy.

**Findings:** The outcome of the study showed that the geometry characteristics (micro-textured and lapped untextured) and the densities of the micro-texture impact was critical to the film formation in the tribological behaviour test against the lapped GCr 15 steel bearing balls. Significantly, low friction and wear were observed for the micro-textured surfaces as compared to the lapped untextured surfaces.

**Research Limitation/Implications:** The research was on rolling point contact in fully-flooded EHL tribo-test using lapped untextured and micro-textured surfaces in contact with ball bearing. The study did not consider line contact and sliding force. The rolling point contact is the predominant phenomenon in gears, cams, tractions and balls in energy transmission.

**Practical Implication:** The outcome of this research increase the knowledge base of this area, it informs technologies and tribologies to select and design machine elements with energy-saving criteria in mind. In addition, this work has opened other opportunities for research to harness the full potentials of the micro-texturing.

**Social Implication:** This paper also guides to industrial and manufacturing sectors using machine elements as moving systems to generate and transmit energy in adopting energy-saving systems and policies that is based on the outcome of such studies.

**Originality/Value:** The innovation of this research is centered on the tribological performance of GCr15 undergoing Micro-texturing by Electrochemical Machining which demonstrates better film thickness formation within EHL regime over HT 500 counterpart material. This outcome is a good starting point for further research and development.

**Keywords:** ECM micro-texturing · Friction · Wear · Microhardness · Lubricated contact · Point contact

## 1 Introduction

Energy saving and work efficiency are a driving forces to improve upon machine elements (gear set, cams and followers, ball and roller bearing, etc.) under rolling and sliding concentrated contacts. This not excluding the several mechanical devices often operating under a substantial load of Hertz pressure ( $PH > 0.5$  GPa) and at low sliding/rolling speeds ( $<0.2$  m/s). Contrary to sustaining and building effective and efficient lubrication, these parameters do not allow that in machine elements. In some cases, harsh environmental conditions such as elevated operating temperature, dusty conditions, contaminated lubricant and starved lubrication made the operation not effective and efficient. Friction and wear effect becomes inevitable, leading to loss of energy and poor work efficiency. Thus, it is very important for developing the possible efficiency and energy saving lubricated point concentrating contact with much reliable performance to extend the life span of the machine elements.

## 2 Literature Review

One of the unavoidable technique of our dispensation is surface texturing established by (Sasaki 2010), Koji (2011), Gropper et al. (2016), Holmberg and Erdemir (2017) and Uddin et al. (2017) which has the potential of controlling the friction and wear, the prime concern of the industry. Surface texturing is known to be an effective technique to reduce and control friction and wear between point contact rolling surfaces separated by a thin film lubricating oil. Surface texturing has been accepted and adapted to improve upon the tribological properties of machine elements for many years according to Etsion (2005), Erdemir (2005), Bijani et al. (2016) and (Dingui et al. 2020). Most of these finding is narrowed down to the micro irregularities on the surfaces, and this could be trace down in 1966, Hamilton, Walowit and Allen [10] investigated micro irregularities on

the surfaces of rotary-shaft seals prove that, hydrodynamic pressure were produced and hence, created a load carrying capacity. The conclusion of Anno et al. (1968) and (Anno et al. 1969) on the introduction of micro-asperities was that, it is an effective method for lubricating parallel rotating thrust bearings and mechanical face seals. Surface texturing application on the commercial front, was first investigated on the cylinder liners of combustion engines by Willis (1986) and the result was very successful. The life span of the cylinder liners were prolonged by introducing the micro-grooves onto the liner surface by the honing procedure. These were able to retain oil and also entrap the wear debris between the contact.

An extensive literature review that dealt with the design and structure of the surface texture under tribological characteristics was done by Wang et al. (2010). Wang, et al. (2010) further presented the state of surface texture and its topographies at the concerted contacts and concluded that, for positive results, the surface texturing and its features must be designed based on the lubrication regimes. Vilhena et al. (2009) and Pettersson and Jacobson (2003), investigated shallow micro features with sizes below the contact patch measurements, they reported that it is useful when the concerted contacts are within boundary/mixed lubricated regimes. This was as a result of the retaining of lubricant/oil between the contacts with micro dimples features, which eventually offer enhanced lubrication even in tough working conditions Krupka and Hartl (2009). Additionally, Pettersson et al. (2003); Shum et al. (2013) investigation concluded that these tiny dimples/micro features can hold/retain the wear fragments created in the course movement between the bodies in contacts, result to reduce the likelihood of producing the three-body abrasive wear. Many other related works of literature on the lubrication of concerted contacts with bodies of surface textures were reported by Dumont et al. (2002), Wang et al. (2008), Krupka et al. (2008), Krupka et al. (2009) and Xu et al. (2019), disclosed that the low depth of micro dimples produces improvement in lubricating film thickness formation. Likewise, it was admitted by Krupka et al. (2010), Sengu and Kim (2013), Podgornik et al. (2012), Kovalchenko et al. (2011), Sudeep et al. (2015), Wang et al. (2013), Greco et al. (2010) and Wang et al. (2018) that, friction reduces immensely when surface texturing is introduce at the concentrated contacts. But these successes could not be possible without giving great attention to the dimples dimensions and the texture of the patterns; hence all the reports point out the important design issues micro dimples and patterns for obtaining the favourable condition between contacts in various lubrication regimes.

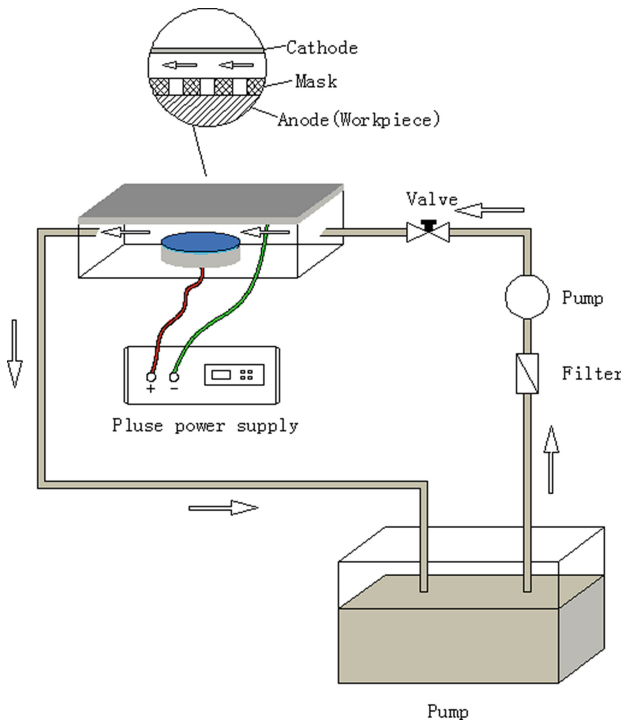
On this note, literature regarding to the tribological performances of fully lubricated textured concerted contacts, it is put forward that, clear understanding and a systematic approach is needful for the design of the textures. Significant understanding is very necessary of the materials of the mating parts, the characteristics of micro/nano topographies of the texture surface, the methods adapted for the surface texture creation, the operating parameters and conditions etc. for acquiring the beneficial effects, particularly in the contact fatigue according to Greco et al. (2010) and Vrbka et al. (2010). Interestingly, the reports of all these authors in their tribological studies for the textured surface concerted point contacts and under the unidirectional motions have been investigated using the lubricating oil, instead of grease, although oil is not usually used in the ball bearing lubrication.

There have been many micro dimple texturing techniques employed over the years for tribological applications. Among them all, Electrochemical machining (ECM) is a process of removing materials selectively instead of depositing it by the electrochemical reaction at the work piece (anode) in an electrolyte fluid combining with the right machining parameters by Munda and Bhattacharyya (2008). ECM is preferred over the others of late and in this research because ECM has many significant advantages in many applications such as: no residual stresses, no cracks and absolute absence of tool wear a major concern in mechanical machining by Kozak et al. (2004). Additionally, this technique is not affected by the hardness or strength of the work material and has no thermal effects on the layer according to Bhattacharyya et al. (2001). Therefore in this research work, ECM technique was developed to manufacture micro-dimples shape. The objective is to compare and highlight the tribological behaviours of the oil lubricated textured point contacts under different loadings, speeds and texturing surfaces. The research is designed for exploring surface texturing operating regimes of low speed and high loads to enhance the oil lubricated elements in engines for improving the tribological behaviors.

### 3 Experimental Procedure

#### 3.1 Test Specimens Design and Method

The GCr 15 bearing steel balls and disks (GCr 15 and Cast iron respectively) were prepared, which are known to be suitable materials for producing automotive engine



**Fig. 1.** The ECM technique for micro-texturing



parts such as liners, piston rings, or bearings. Table 1 shows an elemental analysis of the modelled materials used in this study. Basically, two types of commercially purchased materials (GCr15 and HT500) were used but treated under different conditions including tempering, ECM micro-texturing and untextured surfaces (disc). These were machined as a sphere with a diameters of 22.1 mm (Cast iron disc), 24.8 mm (GCr 15 untempered), and 24.8 mm (GCr 15 tempered), and all these samples have flat surface area (Fig. 3). The other mating part at point contact was the GCr 15 bearing steel ball which is held in the upper holder attached to the head of the tribo-meter. The diameter, surface roughness and hardness of the GCr 15 bearing steel ball was 4mm,  $0.04\mu\text{m}$  and 60 HRC respectively. The disk specimens were also made from cast iron and GCr 15, each with a thickness of 3 mm. The samples consist of untextured surface and textures surfaces, the textured surfaces consisting of micro-dimples of various sizes and depths, which were fabricated on the disks by ECM technique. The ECM technique adapted is shown in Fig. 1, this was fabricated to create the micro-dimples shapes on the work piece surfaces.

**Table 1.** List of samples and their features

Material	Feature (Textured/Untextured)	Width ( $\mu\text{m}$ )	Depth ( $\mu\text{m}$ )	Pitch ( $\mu\text{m}$ )	Density (%)	Aspect ratio (depth/width)
HT-500 (A)	Untextured	–	–	–	–	–
HT-500 (B)	Textured	154	8	251	29.6	0.052
GCr15 N (C)	Untextured	–	–	–	–	–
GCr15-T (D)	Untextured	–	–	–	–	–
GCr15 N (E)	Textured	147	8	235	30.7	0.054
GCr15-T (F)	Textured	147	6	250	27.2	0.041

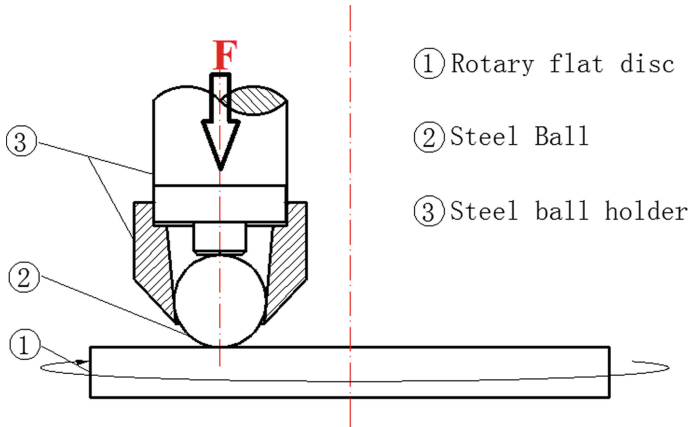
This is a non-contact process, wherein a power supply source provide a direct current controlled by a constant voltage with 150 A maximum output current and 30 V maximum output voltage within time duration of a minimum of 10 s and the maximum of 17 s, this was for all the materials. Before and after the ECM, the micro dimples appearance was examined by the two-dimensional (2D) profilometer and the scanning electron microscope, SEM was also employed to further investigate the micro dimples generated which are shown in Fig. 3. The 3D profilometer was used to examine and measure dimensions of the micro-dimples asperities, precisely, the dimple diameter and depth in the cross-sectional profile. In order to investigate the effect of different dimple size, densities, speed, and material type on the tribological performance of rolling surfaces, the surfaces of the disc specimens were grouped into two state (textured and untextured). The materials were made up of HT-500 (cast iron), GCr 15 non-tempered and GCr 15

(T) tempered. The geometrical texture features and parameters used in this research are outlined in Table 1. In Fig. 3, comparing the features of the asperities, the diameters of the micro dimples textured surfaces generated at (c) looks very close to the designed from the masked shown in (a) as the targeted dimensions. However, a great deviations of the dimensions of the depths and the diameters of the micro dimples generated from the designed dimensions of the micro dimples were observed under the scanning electron microscopy (SEM) images and optical micrograph (OM) of the textured surfaces shown in Fig. 3 (b) and (c) respectively. The surface area to densities ratio (total dimple area/total surface area) ranges from 27.2% to 30.7% as could be seen in the Table 1.

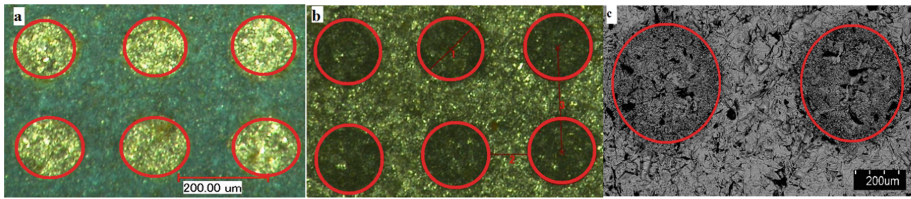
### 3.2 Test Equipment and Procedure

To investigate the effect of micro-dimples on Tribological behaviour, the specimens were tested out using the ball-on-disk tribo meter friction tester (MS-T3000, China). All the samples were carefully cleaned in a pool of acetone for 10 min in ultrasound followed by rinsing with isopropyl alcohol before each test. The friction experiments were done using textured and untextured discs, under fully lubricated conditions in unidirectional rotation. All the experiments were conducted at the room temperature  $\pm 20$  °C, the experiments were conducted at 32N (PH = 1.1GPa), 47N (PH = 1.3 GPa), and 59N (PH = 1.4 GPa) normal loads applied at the point contacts through the dead weights for average rolling velocities (0.063, 0.094, 0.16 and 0.20 m/s). The commercially available engine lubricating oil, SAE #30, with  $\eta@40$  °C = 148 mm<sup>2</sup>/s,  $\eta@100$  °C = 14.5 mm<sup>2</sup>/s, density 0.91g/cc was employed in the experiments. This oil was selected for its technical importance, and it use in many automotive engine applications. The upper head of the tester had the ball holder mounted on. The loading was at the upper head and on the ball against the untextured/textured surface of a flat disc specimen. Pre-run for 10 s is done before the test to ensure the point contact and counter formal contact of the ball and the disc. The radius of the contact of tracking was set to 3 mm for the test. The ball was stationery against the rotationally flat untextured/textured surface. Each test was run for 15 min of testing. Furthermore, the magnitude of the normal force was regulated by adding the dead weights on the upper head which direction was perpendicular to the rotational flat surface.

Every experiment was conducted with the combination of new disc surface in contact with a new ball surface. The average frictional force and the coefficient of friction were both recorded from the tribotester which was equipped with an in built software displaying the two values on the computer monitor attached to the friction tester. A typical schematic diagram of the tribo-meter and the test setup is shown in Fig. 2.



**Fig. 2.** The ball on the disc schematic diagram



**Fig. 3.** (a) Mask surface of the sample using OM, (b) Optical Micrograph of the sample after unmasking and (c) SEM image visualizing the features of textures.

## 4 Elastohydrodynamic Lubrication (EHL) Regime

Micro-dimple, as part of the physical parameters, has demonstrated a great influence in the friction and wear characteristics of the tribological contacts. Up until now, very little has been the publication of film thickness measurements in EHL in micro-dimple contacts even though of its immense importance to the tribological world. This might be due to lack of the available techniques with much convenient for micro-dimple contacts, more so, the complicity nature of the design method of the micro-dimple of the mating parts involved. Although there have been a number of related theoretical studies of EHL and equations for film thickness in EHL contacts have been developed, yet not that much has been done experimentally. The work of Hamrock and Dowson (1976), that generated numerical solutions for point (elliptical) equations for film thickness the best known and mostly used equation for EHL by Wheeler et al. (2016). But where the  $k$ , the ellipticity parameter, is reduced to unity for the circular contact of interest in this investigation for a ball on flat contact, the equation becomes as follows;

$$H_c = 2.69U^{0.67}G^{0.53}W^{-0.067}\left(1 - 0.61e^{-0.73k}\right) \quad (1)$$

$$H_m = 3.63U^{0.68}G^{0.49}W^{0.073}\left(1 - e^{-0.68k}\right) \quad (2)$$

Where

$H = (h/R_x)$ ,  $W = (w/E'R_x^2)$ ,  $k = 1$  at pure rolling contact. Here  $H_c$  and  $H_m$  are the dimensionless central and minimum film thicknesses respectively by Greenwood (2020). The  $U$  is the entrainment speed,  $W$  the applied load,  $\eta$  the lubricant dynamic viscosity,  $R_x$  the reduced radius of curvature in the entrainment direction,  $G$  the material properties parameter and  $E'$  the effective elastic modulus. The  $R_x$ ,  $G$ ,  $U$  and  $E'$  are defined as below:

$$R_x = \left[ \frac{1}{R_1} + \frac{1}{R_2} \right]^{-1}, G = E'\alpha, U = \eta u/E'R_x \text{ and } E' = \left[ \frac{1-\nu_1^2}{E_1} + \frac{1-\nu_2^2}{E_2} \right]^{-1}, \text{ where } R_1,$$

$R_2$ ,  $E_1$ ,  $E_2$ ,  $\nu_1$ , and  $\nu_2$  signify the radii in the entrainment path, the Young's moduli, and the Poisson's ratios of the elements in contact as shown in Fig. 2. The pressure viscosity coefficient,  $\alpha$ , and the dynamic viscosity of the oil used is  $22.04 \text{ GPa}^{-1}$  and  $0.205 \text{ Pa.s}$  (Table 2).

**Table 2.** Experimental materials data sheet

Material	Feature (Flat/Ball)	Poisson ratio $\nu$	Modulus of Elasticity $E$ (GPa)
HT 500	Flat	0.21	100
GCr 15 N	Flat	0.29	140
GCr 15_T	Flat	0.25	121
GCr 15_B	Ball (3 mm)	0.28	140

## 5 Findings and Discussion of Experimental Results

### 5.1 Friction Coefficients Under Lubricated Rolling Point Contact

The average coefficient of friction test as conducted was recorded base on varied loads and speed. The influence of load and speed on the surfaces tested results are investigated and shown in this section. The variation of the frictional coefficient at the point contact model with varied rotational speed for the samples was tested under fully-flooded lubricated pure rolling contact using engine oil as lubrication agent.

The graph with (P) is the lapped surface (no micro-texturing) and that of (T) is the ECM – Micro-textured surface at their respective loads. The graph (HT 500) is the cast iron bearing material, the graph (GCR 15 T) is the GCr 15 (T) bearing material which was tempered before Micro-texturing and the (GCR 15 N) is the normal GCr 15 (N) bearing material without tempering before Micro-texturing.

However, they are tested at different loads and speeds. The average coefficient of friction obtained during the tribo-test are carefully discussed as follows.

The graph HT 500 values of the coefficient of friction ( $>0.12 > 0.16 < 0.17$ ) for both lapped and micro-textured surfaces shows that, the tribo-test contact was found within the boundary lubrication condition. Even though, the test was conducted under EHL regime, the results reveal the dominate of the boundary system. Subsequently, the progress of the coefficient of friction observed was seen on the textured surfaces as

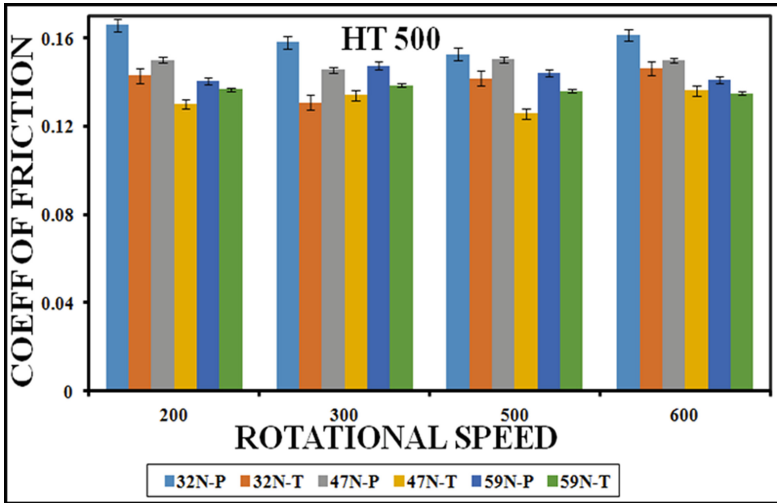


Fig. 4. Variation of frictional coefficient with rotational speed (HT 500)

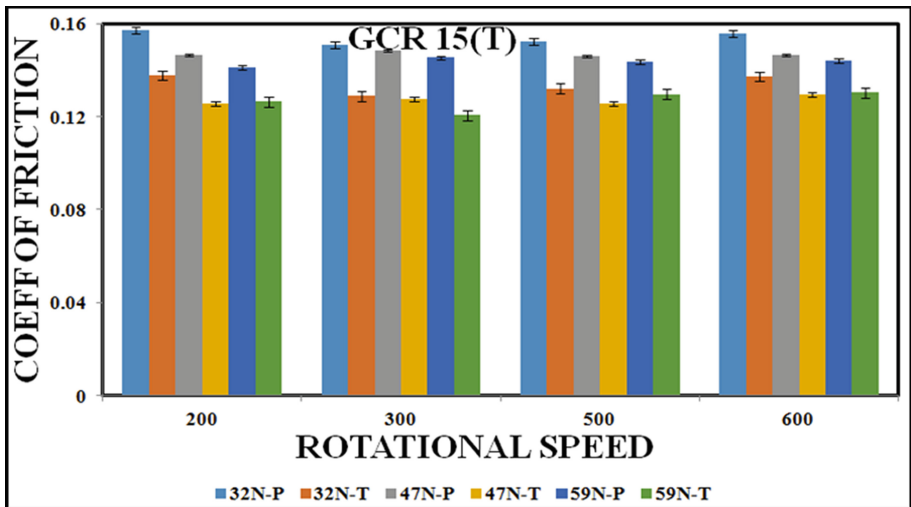


Fig. 5. Variation of frictional coefficient with rotational speed (GCR 15 T)

compared to the lapped surfaces as shown in the Fig. 4. The surfaces with the texturing exhibit a lower coefficient than those without the textured surfaces. Even though it was inconsistent, yet clear and appreciable reduction was observed on the textured surfaces over the lapped surfaces. This was attributed to the nature of the surface at the point of contact.

Due to pure rolling nature of the experiment, the magnitude of the load was a great factor that was supposed to impact the values of the coefficient of friction. But the load influence was not that high due to the selected loads used in this work. Nevertheless, the

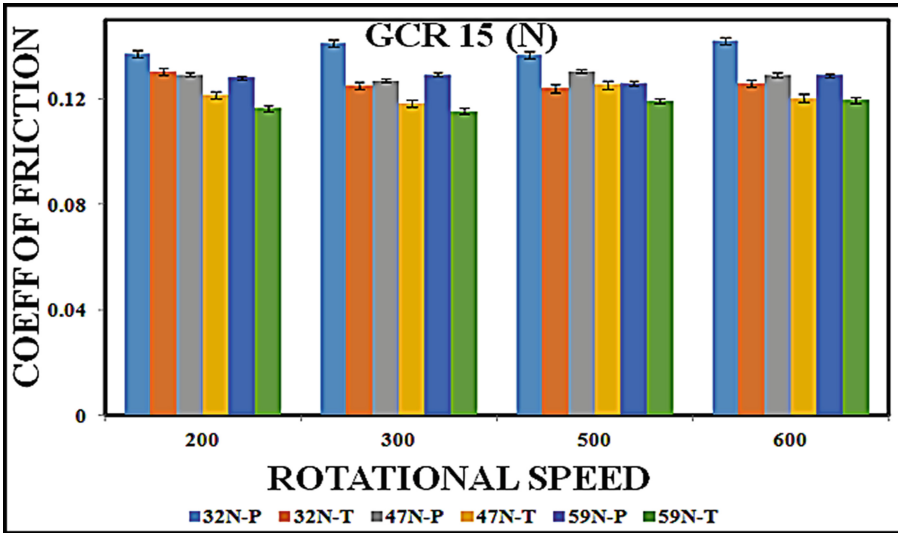


Fig. 6. Variation of frictional coefficient with rotational speed (GCR 15 N)

lowest coefficient of friction on the textured surface was recorded at the medium pressure (1.3GPa) at a corresponding speed of 0.16 m/s. The highest value for the textured surface was also achieved at the pressure (1.1 GPa) with it corresponding speed of 0.2 m/s. However, the speed variation exhibits an inconsistent behavior of the frictional coefficient of both the textured and lapped surface of the sample HT 500. There was virtually an equal trend of declination or rising when the speed is varied for all the samples tested.

On the Fig. 5, the coefficient of friction values (>0.12 < 0.16) for both the lapped and the micro-textured surfaces. It is very clear here that, due to the irregular nature of the surface on the surfaces of the plain as against the ball might have been the cause. There is reduction of the area of contact on the textured surfaces as compared to the lapped surfaces, as a result of that, the values for the coefficient of friction was less for the textured surfaces. This material was tempered before the micro-texturing and the tribo-test. But the tempering condition did not have any significant impact on the reduction of the coefficient of friction. However, the GCR 15 T values maintain better reduced coefficient of friction than the HT 500 material. The sample recorded the lowest coefficient of friction at 1.4 GPa at the speed of 0.094 m/s as compared to its highest value at the pressure of 1.3 GPa and 0.094 m/s. The impact of the pressure (1.1 GPa, 1.3 GPa and 1.4 GPa) is clear here. The speed (0.063 m/s, 0.094 m/s, 0.16 m/s and 0.2 m/s) used shows less change either in reduction or in increase of the coefficient of friction.

The Fig. 6, give the Coefficient of Friction values (<0.12 < 0.15) which presupposes that, the overall performance of this sample at the same operating condition just as the previous two samples is much better. Considerable reduction of the frictional coefficient of this material was achieved both on the lapped and the micro-textured surfaces. However, significant reduction was obvious on the textured surfaces. The textured surface had it lowest value of the coefficient of friction at the pressure of 1.4 GPa and the velocity of 0.094 m/s, while the highest value was also recorded at 1.1 GPa pressure

with 0.0063 m/s. This could be attributed to the nature of the asperities generated on the surfaces in contact with the lapped steel ball. The load and speed were both relatively important to the values obtained, nevertheless, the speed variation was not that large to impact significantly on the values. Unlike the load, the variation was significant yet the influence on the values was not so much high.

Considering the textured surfaces of the two GCr 15 types of samples, both had their lowest coefficient of friction at the highest operating pressure of 1.4 GPa with the corresponding velocity of 0.094 m/s, meaning the optimum designed parameters for the textured surfaces is 1.4 GPa and 0.094 m/s. The GCr 15 N sample with textured surface coefficient of friction was almost 5% better than the GCr 15 T with textured condition.

In comparative analysis of the friction coefficient, the optimum pressure and speed for the texturing surfaces that gave reasonable less coefficient of friction were (1.4 GPa and 0.094 m/s) respectively. These combination was evidence on the GCr 15-T and GCr 15-N samples. However, the highly recommended sample among the two textured surfaces with the lowest friction coefficient is the GCr - N, without tempering before the micro-texturing of the surfaces was done. The value recorded was 0.1154 with the corresponding pressure of 1.4 GPa. This could be attributed to high number of peaks generated at the highest load of the design. In addition, the oil retainability was better than the other surfaces. The poor performance of the HT 500 could be attributed to the brittleness of the sample, it easily break and flakes under high loads. This developed grooves and high plowing on the surfaces after the tribo-test.

Generally, there was oil splashing under the EHL condition at the point of contact. This leaves the regime into starving of the lubricant at the point of contact for all the tested samples. As a result of that, the values obtained for the coefficient of friction is classified under boundary lubrication regime.

## 6 Wear Track Analysis

Below gives the brief description of the different spacing of the different surface texturing under different operating conditions such as speed and load used in the experiments conducted. These were done with the 3-D profile analyzer and the optical micrograph on the surfaces after the tribotest to consider the coloration of density on the wear of the surfaces. The pressure GPa range was 1.1–1.4, the corresponding speed m/s was between 0.063–0.2. The textured surfaces were categorized under two spacing between the periphery of the dimples, 0.2  $\mu\text{m}$  and 0.4  $\mu\text{m}$  which eventually gave us different densities. The profiles below outline the effect of the spacing which influences the densities of the surfaces textured for all three samples (HT 500, GCr 15 T and GCr 15 N) at Fig. 7, Fig. 8 and Fig. 9 respectively. In each sample case is the 0.2  $\mu\text{m}$  and 0.4  $\mu\text{m}$  spacing, the first from the left is the 0.2  $\mu\text{m}$  and the right side is the 0.4  $\mu\text{m}$ .



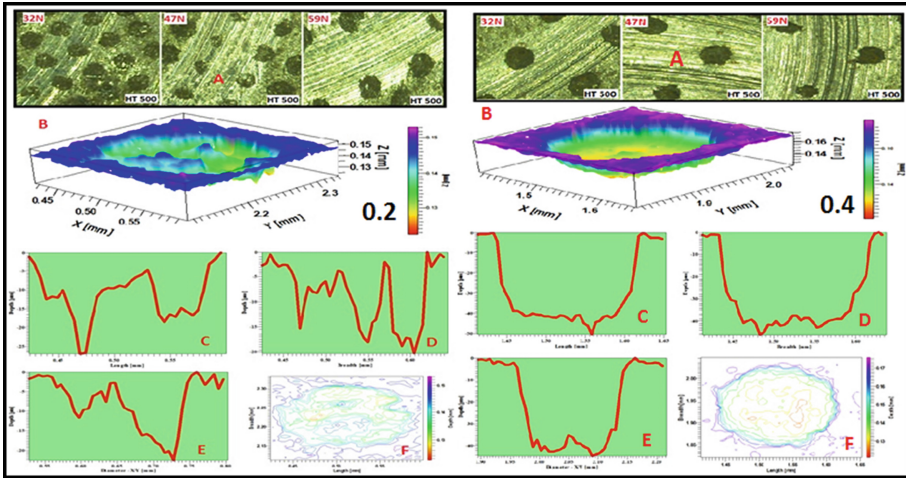


Fig. 7. Cast Iron damaged surface at high density surface (0.2 μm) and low density (0.4 μm)

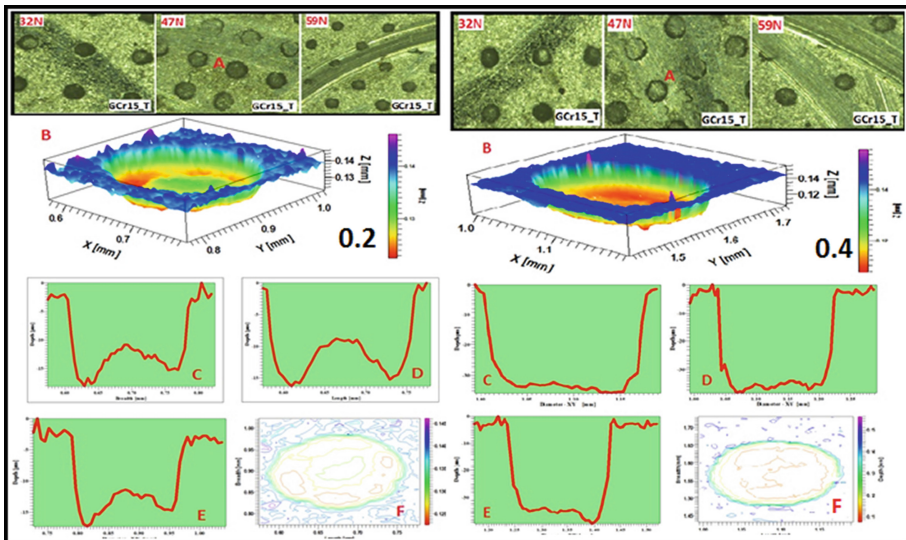
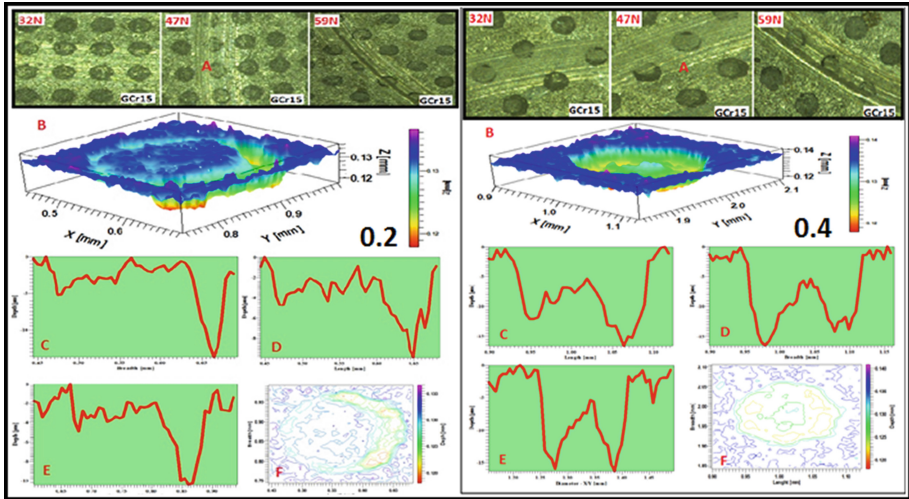


Fig. 8. GCr15\_T damaged surface at high density surface (0.2 μm) and low density (0.4 μm)





**Fig. 9.** GCr15\_N damaged surface at high density surface (0.2  $\mu\text{m}$ ) and low density (0.4  $\mu\text{m}$ )

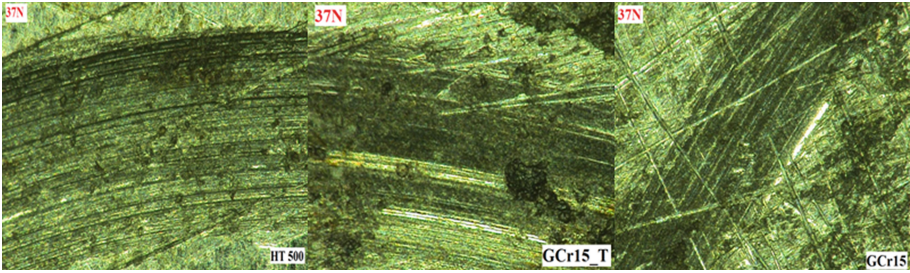
### 6.1 Spacing Effect

The spacing effect was evaluated on the basis of the density. The influence of density over the wear regime was purely on the the density, even though of the influence of the load and speed. Looking at Fig. 7, it shows the profiles that gives information on the 0.2  $\mu\text{m}$  spacing wear surfaces at different loads, the depth and nature of the dimples after the tribo-test, the same time gives the profile of the 0.4  $\mu\text{m}$  spacing. The cross sectional views of the dimples as shown in C, D and E exhibits the irregularities of the dimple diameter and depth which clearly confirmed in the 3-D profile at B on the photo. The depth of the dimple influences the nature of the wear track generated as seen from the profiles of the surfaces. The dimples act as oil retention to lubricate between the ball and the surface. The 0.2  $\mu\text{m}$  spacing are the high density textured surfaces whereas the 0.4 m spacing are the low density textured surfaces. However, the higher density suffered less surface damage than the lower density surfaces comparatively of all the wear graphs shown in A. This could be attributed to the fact, the high density surfacce are able to trap more debris and high oil retention existing on the the contact surface. Subsequently, low wear track were generated. On the other hand, the low density had lower oil retention leading the surfaces exposed to the hard periphery of the ball to scratch and generate visible wear tracks and grooves, three body abrasions at the interfaces.

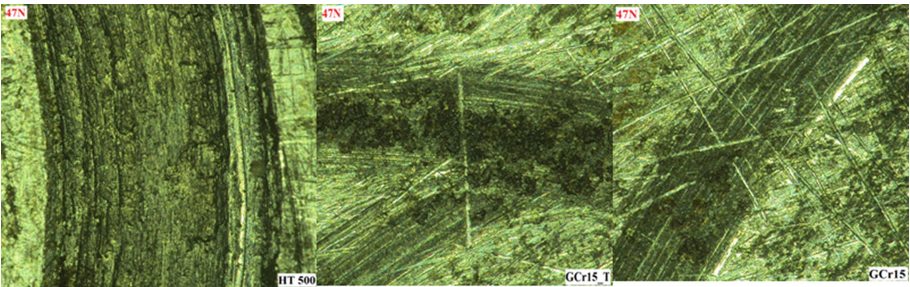
The HT 500, the surfaces at three different loads suffered severe damage but less at lower loads in general. The mild surface damage ocured at the the GCr 15-T samples. Perhaps, the tempering process had virtually no impact on the ability to reduce the coefficient of friction and subsequently, reducing wear and surface damage. However, the GCr 15 without tempering had fairly reduced coefficient, less wear and considerable low surface damage to the surface. These are all very evidential on the wear tracks analysis and the 3D potographic analysis.

### 6.2 Lapped Surface

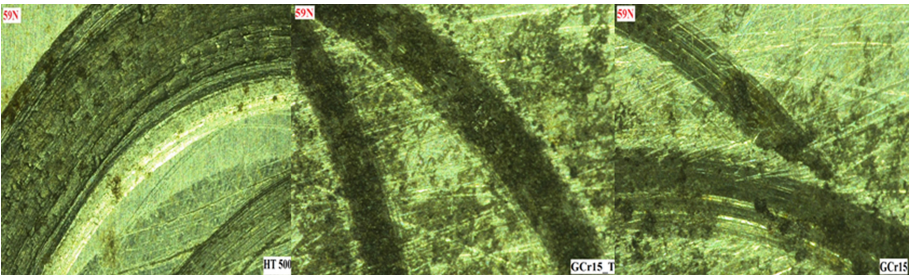
The lapped surfaces with the lapped steel ball generated the following wear surfaces exhibiting the intensity of the effect of the load and speed on the type of material, treatment and surface nature. The Figures used the combinations of loads (PH = 1.1, 1.3 and 1.4 GPa) and the velocities (U = 0.063, 0.094, 0.16 and 0.2 m/s) to evaluate the tribological life with the oil as the lubricant such as the wear mechanism and the regime of the lubrication (Figs. 10, 11 and 12).



**Fig. 10.** Damaged surfaces for all tested samples at 37N



**Fig. 11.** Damaged surfaces for all tested samples at 47N



**Fig. 12.** Damaged surfaces for all tested samples at 59N

The observations of the lapped surfaces at different loads under the microscopic reveal a noticeable wear tracks at all the loading regardless of the speed. Nevertheless,

much noticeable wear marks were found at higher loads (PH - 1.4 GPa) on all the three samples tested. But extreme visible wear tracks were known on the HT 500 samples. The dominant wear tracks that were observed appears as the abrasive because of the micro-cutting which are as the results of the poor surface finishing on the ball and the lapped surfaces. The views of the microscopic wear tracks with flake-like nature are clearly seen with HT 500 samples at higher loads even though of the presence of lubricant. The surfaces of the severe wear tracks and flake-like were presumed to be as the result of lubricant starvation due to the centrifugal action that disperses the lubricant from the interface of the ball and disc. The wear track diameters in this case were very large in comparison with textured surface. However, on the entire lapped disc, the GCr 15 had the smallest wear track. The wear track depth of the HT 500 was also found to be the deepest as compared to the other materials. It also recorded the largest wear track. Moreover, this large size of wear track shows the poor lubrication condition between the contact zone of the disc and the ball.

## 7 EHL Regime Analysis

To evaluate the film thickness variation as against the selected entrainment speed for all the three tested materials, the numerical solution of Hamrock & Dowson was used. The reported values obtained for both central and the minimum film thickness for all the three samples of the surfaces were shown in Fig. 13. The interpretation of the results confirms the practical behavior of a relative motion between two surfaces with a lubricant interface. This may form a hydrodynamic fluid film between them which obtain a full film regime when the thickness of the fluid film is large enough to establish complete separation between the two mating elements in spite of their surface roughness by Greenwood (2020) and Gachot et al. (2017). Under three different pressure 1.1 GPa, 1.3 GPa and 1.4 GPa (L1, L2 and L3 respectively), the film thickness for the both the central ( $H_c$ ) and the minimum ( $H_m$ ) confirmed the impact of pressure on the film thickness regardless of the entrainment speed. The individual materials subjected to the analysis behaved differently, the effect of the pressure on each surface is confirmed by the film thickness formation. The graphs explicitly confirm the classical EHL theory. High film thickness were recorded generally on the  $H_c$  and low film thickness were recorded at the  $H_m$  at the same entrainment speed but at varied pressure.

The surface texturing on the surfaces enhanced the load carrying capacity at both the central and minimum film thicknesses. The GCr 15 N with textured surface demonstrated a better load carrying capacity and less wear than both the GCr 15\_T (GCr 15 tempered) and H500 (Cast iron) which confirms the friction coefficient experiment results in Figs. 4, 5 and 6. The above outcomes are consistent with the fact that at the high pressure on the point contact in rotation motion, there may be appreciable decrease of the film thickness. Eventually, this may cause film thickness rupture which results in metal-to-metal contact and consequently leading to increase in the traction coefficient.

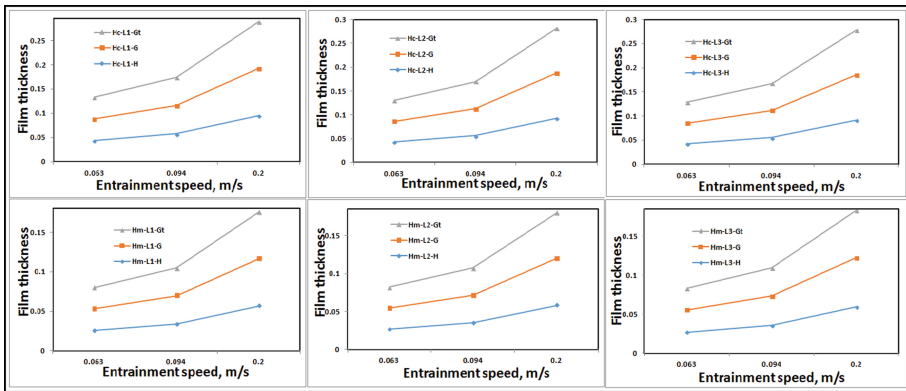


Fig. 13. Film thickness varied with entrainment speed

## 8 Conclusion

This experimental studies reports the preliminary findings on the GCr 15 tempered before micro-texturing and non-textured, GCr 15 non tempered before micro-texturing and non-textured and HT 500 cast iron micro textured and non-textured materials. The following conclusions were drawn:

1. The research indicates that, the friction increased on both the lapped and textured HT 500 material to about 13% higher than GCr15 N lapped and textured, and 6% higher than GCr15 T lapped and textured.
2. The HT 500 wear surfaces of the textured at the three pressure loading indicate severe damage as compared to GCr15 T and GCr15 N. The 3D analyzer shows the degree of the damage on all the samples.
3. The effect of the spacing resulted into high (0.2  $\mu\text{m}$ ) and low (0.4  $\mu\text{m}$ ) density textured surfaces impact on the wear track. The samples of high density surfaces were able to accumulate much oil as compare to low density surface area, therefore, the high density surface was less damage than the low density.
4. Under the microscopic observation, the dominant wear track appears to be abrasive because of the micro-cutting which is as a result of poor surface finish of the lapped surface and the ball. HT 500 demonstrated flake-like nature of wear under high pressure because of lubricant starvation which is caused by the centrifugal action that disperse the oil from the interface of the ball and disc. However, the GCr 15 wear performance were observed to be milder than the HT 500.
5. The GCr 15 N with textured surface demonstrated a better load carrying capacity and less wear than both the GCr 15 \_T (GCr 15 tempered) and H500 (Cast iron) which confirms the friction coefficient experiment results.

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# Challenges on Collective Information-Seeking Behaviour in Tanzanian Vocational Training Institutions (TVETS)

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**ABSTRACT. Purpose:** The study aimed to identify barriers of CISB of student groups in the VETs in Tanzania (VETA). It involved students groups in Electrical installation, Tailoring, Cookery, Mechanics, Masonry, Electronics, carpentry, Tailoring, Observation and interview was prominent tools for collecting data.

**Design/Methodology/Approach:** The study was purely qualitative, the naturalistic observation method was used to collect data from groups during task accomplishments, without manipulating work environments. Face to face interviews and FGD's was used in collecting site-specific data during the accomplishment of group activities. Subject teachers and group leaders were consulted to clarify issues noted by the researcher during observation. The thematic analysis was employed to analyse data collected, which "patterns across data sets" used to describe all phenomena associated specifically with specific research questions.

**Findings:** Finding revealed some challenges such as; lack of computer laboratories or connected computers, lack of tools and systems to support collaborative information seeking, lack of libraries or support from librarians, limited awareness and search skills, lack of time to seek information, distance problems and the negative perception towards group work towards task accomplishments.

**Research Limitation:** The study involved masonry, carpentry and mechanics however, during the process of data collection, it was found that some of the selected courses were not offered, which resulting the researcher add other prominent courses such as tailoring, cookery, electronics and electrical installation.

**Practical Implication:** This study will therefore inform the vocational training or librarians on significant strategies that will lead them on effective plans for better services delivery in the collaborative environment.

**Social Implication:** The knowledge advanced by this study will help policy-makers to amend policies to make it mandatory for all VETs schools that need registration to have a library or a computer laboratory as well as qualified librarians. That will ensure a supportive environment for groups to information seeking.

**Originality:** This is an inclusive study that assesses the challenges of CISB of student groups in the TVETs. The study provides empirical evidence that influencing challenges in a collaborative environment. The study will have wider implications for TVETs management and librarians who are engaged in the vocational training.

**Keywords:** Behaviour · Collaborative · Innovation seeking · Problem solving

# 1 Introduction

Collaboration is the practice of creating sharing a group with the same or different knowledge collaborates to create common understanding helping them in solving difficulties” (Schrage 1999). According to Golovchinsky and Pickens (2011), collaboration is among the key components for the group’s information-seeking behaviour. In this regard, group pairs bring minds together and critically evaluate their information needs for better decisions for the existing problems. Foster (2010) underscores the value of teamwork as an essential tool useful for undertaking any difficult task. According to Nkebukwa (2018), the nature of human beings is to team up in accomplishing tasks that may not be easily carried individually. Significantly, to seek information collaboratively promotes an organisation performance (Talja and Hansen 2005). Therefore, organisations usually make collective decisions in developing strategies, managing projects and design products. The collaborative-seeking behaviour is still a new concept in information studies (Foster 2010; Jansen 2009; Hansen and Jarvelin 2005 and Talja 2002). This study therefore, aimed at establishing facts on barriers affects group’s information-seeking behaviour during accomplishment collaborative tasks. The Vocational Education and Training Authority (VETA) was established to prepare Tanzanians with specialised specific vocational occupations in line with Industrialization and Business growth for National Economic Development in Tanzania. In other words, TVETs aim to withstand the industrial innovations in line with the higher and quality productions (Ajithkumar 2016; Wolf-Dietrich 2004; UNESCO 2012). In sub Saharan Africa VETs institutions led by unprecedented demographic youth bulge due to the global economic situation which was limiting absorption of the labour market growth (Atchoarena and Delluc 2002; Durango 2002; Mshoro 2010). The same situation was also noted in Tanzania in 1990’s when public organisations retrenched and left Tanzanians unemployed (Rugumyamheto 2000). In that period the private sectors took the lion’s share to employ and create jobs, as the government was no longer main employer (Ishumi 1998; Babette and Ewald 2000; Kigadye 2004; Mutarabukwa 2007; URT 2010; Kafyulilo et al. 2012; Fidel et al. 2014 and Solomon 2016; Nkebukwa and Luambano 2018). In this regard, the Competence Based Education Training (CBET) and Competence Based Assessment (CBA) systems took hold for students’ technical occupations and skills. Challenges in VETA were even noted when libraries in these institutions inadequately supported student groups’ information needs, contrary to CBA and CBET (Kigadye 2004; Kafyulilo et al. 2012; Fidel 2014).

## 1.1 Barriers Hinders the Group Information Seeking Processes

Barriers of collaborative information-seeking have to be studied because they hamper collaborative information-seeking behaviour. Various authors conducted studies to identify barriers of CIS in various organisation (Shah 2008; Hertzum 2008; Karunakaran et al. 2010). These studies revealed the set of four categories; namely, individual barriers, lack of time, technology and conflicting task responsibilities (Hertzum 2008).

Lee (2013) surveyed graduate students’ CIS in group-based settings at the University of North Texas, the study revealed poor communication and organisation among group members hampered the process of seeking information during groups’ task accomplishment.



Shahvar and Tang (2013) in a study of CIS of undergraduate students in library and Schools of Information Studies (LIS) in America, the study revealed students “felt strange” about keyboard, mouse and sharing the screen. Most of the students expressed their frustrations during finding of the search terms while looking for filters to decide on the best results fitting for the task.

Denning and Yaholkovsky (2008) studied limitations of CIS of students groups in schools Libraries at North Carolina University, students groups specifically investigated when they were solving complex tasks, group members claimed that collaborative tasks consumes much time as it is not suitable for activities needs quick decisions. However, findings also revealed that the different formats in which information is provided is a challenge, as it requires special devices to be used, but these devices are not available.

Shah (2008) investigated a group of eight specialists who were performing the same task but working in separate hospitals, the study revealed that the process seeking information collaboratively stopped when the schedule of task conflicting group members or when one team member was missing. Further, Shah’s study showed the lack of accountability among group members which lead team members to have weak collaborative information-seeking roles.

In the study by Karunakaran et al. (2010) revealed lack of trust among organisation team members. According to the author some members fail to effectively collaborate due to worry or shyness. It was noted when group members were unwilling to contribute during stages of seeking information, as some members preferred working alone, and unfavourably affecting timely accomplishment group activities.

O’Brien (2006), revealed inequality of power and poor relationships among team members is the factor negatively affects groups to seek information collaboratively. In this regard, some team members lost their working morale especially when group leaders exercised more power to influence them on certain decisions. According to Shah (2008) and Draycott and Rae (2010) such a situation limits groups’ failure to seek and share information collaboratively.

## 2 Methodology

The aim of the study was to identify barriers for the collective information- seeking behaviour of student groups in the Vocational Training institutions in Tanzania (VETA). This study employed qualitative researcher design. Observation and interview are prominent tools for collecting data in Collaborative Information-seeking studies (Reedy and Jansen 2008; Kim 2013). In this study therefore, the naturalistic observation method was used to collect data from groups in which the researcher observed groups during task accomplishments. It is recommended for the researcher to observe student tasks in their natural settings without manipulating work environments (Sonnenwald and Pierce 2000; Poltrock et al. 2003; Bruce et al. 2003; Hansen and Jarvelin 2005 and Reedy and Jansen 2008). According to Shah (2008) observing collaborative tasks resulted only in increased site-specific data, instead of rich information of the process of accomplishing activities. Moreover, face to face interviews used to collect data from the subject teachers and group leaders. In this study interviews aimed at providing more clarification of every issue that was noted in observation. Further, FGDs involved second year students’ studied similar courses, it involved 12 students in each trades. Thematic analysis employed

to analyse data collected, which “patterns across data sets” used to describe all phenomena associated specifically with specific research questions. The study involved five (5) regions, three from Tanzania mainland; namely Dar es Salaam, Morogoro, Dodoma and two regions namely; Zanzibar (Urban West Region and Southern Pemba). According to URT-GODP (2014) there are a total of 894 Vocational Training Centres all over the country. Dar es Salaam being the headquarters of the Vocational training Institutions in Tanzania was a criteria for inclusion, and Dodoma and Morogoro regions were included purposely from its proximity or remoteness from headquarters. Zanzibar being with different VETs training systems from that of the Tanzania Mainland was the criteria to be involved in the study. However, the number of courses taught in the VETs institutions, only one prominent course taken from each of the selected institutions. The distribution of VETs in relation to selected courses as shown in Table 1.

**2.1 Finding on Challenges Facing Student Groups in VET Institutions**

Information on barriers obtained through Focus Group Discussions (FGD) and interview after the researcher observing students task, which was confirmed through interviews with subject teachers and students group leaders as well as FDG specifically with selected student groups. VETs principals and librarians in selected institutions also interviewed to provide more insights. The finding is based on barriers encountered specifically when student groups accomplish their tasks or undertaking collaborative information-seeking processes. During gathering data, the mixed method approach was taken into consideration. The specific trades and barriers encountered are presented in Table 1.

**Table 1. .**

Case studies involved	Barriers student groups encountered during accomplishment tasks	Institutions surveyed
Case study 6 & 7	Lack of computer laboratories or connected computers,	Institutions 5 & 6
All trades surveyed	Lack of tools and systems to support collaborative information seeking,	All surveyed institutions
Case study, 5, & 7	Lack of libraries or support from librarians	Institutions 3, 4 & 6
All trades surveyed	Limited awareness and search skills,	All, surveyed institutions

*(continued)*

**Table 1.** (continued)

Case studies involved	Barriers student groups encountered during accomplishment tasks	Institutions surveyed
All trades except Case study 2, 7, 8 & 9	Lack of time to seek information,	Institutions 1, 3, 4, 5 & 6
Case study 1, 2, 8 & 9	Distance problems	Institutions 1, 2, 7 & 8
Case study 4, 5, 6 & 7	Negative perception towards group work,	Institutions 3, 4, 5, 6
All trades surveyed except Case study 7	Language barrier	All except institution 6

Source: Field data, 2016/2018.

### 3 Discussion of the Findings

#### 3.1 Inadequacy of Connected Computers and Laboratories

Based on the study findings, some VETs institutions did not have computer laboratories; namely, specifically, Lugalo MVTC, Amali Zanzibar, Dodoma VTC and Chango'mbe VTC. Lack or absence of computer laboratories denies students' opportunities on the usage of technologies in promoting their occupations. This also limited access to electronic resources, which could be available if computers would be connected to the internet. Access to the Internet provides an opportunity for students and other users' in academic institutions to have access to myriad information resources useful in learning, teaching and research. Therefore, access to the Internet would be a panacea to overcome the problem of inadequate relevant library resources, particularly VETs institutions. Moreover, internet access facilitates communication among students both locally and internationally, therefore, the institutions must ensure availability of internet services in libraries. However, it has been noted that in most surveyed institutions internet cafes played a very crucial role for students' access.

In most cases lack of institutions' support on internet services necessitates scholars to rely on personal mobile devices. The advancement of technology allows small devices to do nearly everything that had formerly been done by the larger personal computers (pcs). The researcher also noted that, to meet groups' information needs, few team members used smartphones to seek information. Due to the lack of searching skills or awareness on scholarly databases they relied mainly on 'Google search engine' and so they were unable to retrieve relevant information. In the same vein the researcher noted the cost-related problems that had to be paid for bundle connectivity to the Internet service provider. Furthermore, during observation in VETA institutions, the researcher realised only few of them had computer laboratories as well as the libraries, for example, institution 8, 5 & 6 had computer labs and institution 4, 5 & 6 had library as well as institution 5 & 6 had both library and computer labs, while institution 1, 2 and 7 had neither library no computer labs. However there were few computers connected to the internet at institution 5 & 6 but no one was providing the information literacy

training to create awareness among students and teachers. Based on observation and Focus Group Discussion with student teams, the researcher noted that the available computers were not enough to the needs of students. To give clarification on the lack of computer laboratories and internet connectivity, teachers at institution 6 and institution 5 specified “budgetary constraints” as the major factor for institutional failure investing on internet infrastructure and computers. Basing on the obstacles to development of internet in Africa, various scholars mentioned the following; high costs of hardware (Mutula 2001); low bandwidth (Chivhanga 2000) and high telephone costs (Ngini et al. 2002); lack for the appropriate frameworks (The National ICT Policy 2016), this was associated with the lack for the utilisation of ICT infrastructures and the insufficiently power supply especially in rural areas, inadequacy skilled personnel as well as illiteracy levels amongst citizens was among of the hindrance of ICT development in Tanzania. Further teachers during the interview told the researcher that the nature and the scope of VETA curricula do not put more emphasis on the usage of e-resources. This led to the majority in VETA student’s community fear to use modern technologies due to the technophobia. The interpretation is that students in such institutions lied most in print resources to meet the information needs.

### **3.2 Inadequate Systems and Tool Supports the Collaborative Information-Seeking**

Findings have shown non-use of collaborative tools. According to Krishnappa (2005), such tools support multiple users’ abilities to collaborate synchronously and communicate during the information seeking process, unlike the mostly used single-user search engines. However, during observation the researcher noted that very few computers were connected to the internet. The VETs principals during interviews with the researcher associated this challenge with unavailability of hardware and software, but the importance for this study revealed unawareness on the concept of collaborative tools. Based on the nature of activities in VETs schools, the use of collaborative tools could promote the effective collaborative information-seeking and sharing or used to lay the foundation for the accomplishment of group tasks. Information sharing among team members happens by providing awareness of other searchers’ through search process (Krishnappa 2005).in this regard the information may reach directly through chat interfaces. Moreover, this study highlighted useful tools supportive to the collaborative environments such as FoR-SIC, Gopher and MOO, Ariadne and Collaborative Browsing and Commercial Tools. The researcher during the FGD even revealed that students were unaware of collaborative tools. Further, the researcher concluded that the awareness, absence of computer laboratories and lack of libraries in VETs institutions means that the use of collaborative tools to seek information is impossible.

### **3.3 Absence of Libraries or Support From Librarians**

According to Kaufman (2005) the library provides an extensive educational resources supports learning, teaching and research. The presence of libraries makes it possible for work teams to have access on the information sources, also it could provide opportunities for the provision of the information literacy programmes to assist users. Since, it has

been noted inadequacies of print sources in the library, access to e- resources would supplement possibly if the library is connected to the internet. In most cases, for example at institution 3, 4 & 6 student failed to locate books from the library collections, during the observation no librarian found assisting student teams to address their information needs. Based on the findings, other VETs institutions did not have libraries, the clarifications for the lack of libraries given was budgetary constraints or low priorities in establishing libraries (Udoka 2010). Moreover, in the institutions with libraries the researcher during observation noted inadequate reference books which were not current. Another thing noted by the researcher was the problem of inadequacy of professional librarians (institution 3 & 5) even though books were not properly shelved. Based on such challenges, students in VETs institutions lose the morale of using their institutional libraries due the negative perceptions towards the library services. Similar, scholars revealed number of limitation to the library development in developing countries, such as inadequate skilled human sources (Nyerembe 2004); inadequate infrastructure (Okoroafor 2010); deficiency of information literacy among librarians (Nawe 2013), material resources (Okebukola 2012), institutional politics and financial constraints (Mcharazo and Olden 2000). Furthermore, during observation and interview with librarian at institution 3, the researcher noted inconveniences of the library schedule. For example, the library service provided from 9.00am to 3.00pm, times coincided class hours. This meant that students could not get enough time to visit the library after classes. This was in line with Kigadye (2004) who noted the prevalence of challenges in VET's library associated with the lack of motivation for librarians. To address challenges hindering library development in Tanzania, Nawe (2003) proposed having good policies and plans for library development in Tanzania. Also, Kigongo-Bukenya (2009) proposed the provision of information literacy programs as the way of decreasing knowledge gap regarding the usage of e- resources.

### **3.4 Limited Awareness and Search Skills**

Awareness of information sources is a prerequisite in meeting group information needs in teams. In the same vein, search skills are important for a person to meet information needs. As emphasised by Asemi and Riyahiniya (2007) that a person may use something that is aware of them. Through being aware of the information tools and sources, as well as search skills in working teams members become easily able to accomplish a given tasks, the opposite to that they will not be able to accomplish the and timely. In this study, the researcher revealed lack of awareness on available information sources and tools relevant for assisting them in meeting their specific information needs. As also revealed by Ajayi and Akinniyi (2004) that limited searching skills and lack of awareness on sources and tools usually affect accessibility information in the health sector.

### **3.5 Lack of Time to Seek Information**

Students are usually assigned tasks within a time frame, sometimes it is not possible for a student group to visit the library due the limitation of time needed to complete the assignment. For example at the institution 4 (Case study 5) student teams were reading and interpreting the construction drawing, the group had to complete the task within 6 h. In this case, specifically teachers in the surveyed areas did not provide extra time needed

for groups to seek information. Based on the nature of the tasks, most of them were done in outside cities. In this regard students were facing long distances from their working cities to libraries. Being distant from the library where student group teams could access books and other information sources it necessitated them rely on colleagues, teachers and people outside the group who were around. Another example where distance was a problem includes institution 6 (Case study 7) students doing collaborative tasks of constructing a building's roof or servicing an engine out the institution. Thus the failure to timely access information often resulted in delays or in-completion of the tasks. Such a situation was noted even at institution 2 (Case study 2) where a team assigned to prepare bridal wedding dress could not complete timely due the lack of information. The implication of the finding is that, no consideration of time for seeking information as part of task accomplishment. Zhang's (2014) stressed that successful task accomplishment depends on the extent in which individuals are embodied in the information seeking process.

### 3.6 Negative Perception Towards Group Work

To accomplish the task group members needed to have a positive perception towards group tasks. That attitude encourages individuals to work more collaboratively. However, basing the findings of this study, some team member's thought that working in teams would result in other group members being less cooperative. Such persons would like working alone, but according to Yue and He (2010) group work facilitates labour divisions members. To eliminate such challenges Csernica et al. (2002) proposed group size limits. According to him an effective team should have at least three to four members. As supported by Johnsons and Holubec (2008) that a formal group of four or five members allows members to collaborate more effectively. In addition to that Simon (2011) concludes that, the reasonable number working teams promotes higher performance and raised psychological satisfactions as well as increases trust in groups. One of the reasons for student collaboration is to share expertise.

### 3.7 Language Barrier

Although Swahili is the national language, with English being a foreign language, it is the one used in VETA for teaching. Even learning materials used in VETs libraries are also in English. Based on the findings, the use of English language has been a challenge for a long time in teaching and learning. This was intensified by the poor language background in lower levels. In this study, this has been noted specifically when students have been searching information through Google or books, could not comprehend well within the results retrieved. According to Ayodele (1985) the low proficiency of English language affects academic success specifically at the post-secondary levels since 1980's. Moreover, Iliyas (2011) associated poor performance in schools with language problems. This was noted during the interview with teachers at institutions 2 in Case study 2 where student groups were facing such challenges. This was unlike institution 6 in Case study 7 where English was not a problem because it was established to train trainer of trainers (TOT) of higher levels. In view of the findings, it is enough for the researcher to make

a conclusion that students in VET's institution still have poor proficiency in English language.

## 4 Conclusion

The conclusion to be made by the researcher through the findings of this study is that during this survey some VETs institutions did not have libraries, despite the importance of the library providing students the opportunity to have access information and opportunity for the information search taught by librarians. Moreover, VETs with libraries found with inadequate and outdated print sources which were poorly organised. Most of VETs with libraries lacked a qualified library staff to manage libraries. Absence of library or poor internet connectivity meant that student groups were timely to meet information needs. Instead group teams relied on informal sources, such students themselves and subject teachers. In this regard, there is a need to ensure that libraries are established in all VETs schools. Furthermore, researchers realised that VETs centres in the country lack some important tool that would promote collaborative information-seeking behaviour in meeting information needed in accomplishment of the group tasks. These institutions therefore, should establish o libraries hand in hand with the library automation plans. Some recommendation were made that policy makers to amend policies to make it mandatory for all VETs schools both in public or private that need registration to have a library or a computer laboratory as well as qualified librarians, as other education regulator does, the need for the VET institutions acquire adequately information sources as well as establish wireless local area networks for fee access, the need VETs in Tanzania establishing well equipped libraries with relevant information sources and qualified staff, the need of teacher allocating time adequately for student group seek information while accomplishing their tasks.

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# Investigation of Fuel Properties and Engine Analysis of Desert Dates Biodiesel of Ghanaian Origin

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**Abstract. Purpose:** This study investigates the physical and chemical properties of biodiesel produced from desert dates and evaluates the biodiesel's performance in an engine.

**Design:** Biodiesel production from desert date oil was performed in the laboratory, using the following steps: mixing catalyst and alcohol, reaction, separation of glycerin and biodiesel, removing alcohol, glycerin neutralisation, and biodiesel washing. The desert date biodiesel (DDB) physical and chemical properties were evaluated and compared to petroleum diesel (D2). Afterward, an engine test was conducted by applying different loads to a four-stroke diesel engine to measure mechanical efficiency, brake specific fuel consumption, thermal efficiency, and exhaust temperature. Also, the impact of DDB and D2 samples on emissions at different loads was investigated.

**Findings:** The findings indicate that the DDB properties obtained conformed to biodiesel standards. The DDB brake specific fuel consumption was relatively higher than D2. Also, its combustions performance outshines D2. However, D2 emissions performance was better than DDB.

**Research Limitation/Implication:** The study was limited to only a four-stroke diesel engine during the diesel engine test

**Practical Implication:** Biodiesel production from non-edible crops like desert dates of Ghanaian origin could be utilised as a substitute for petroleum diesel.

**Social Implication:** The study's findings have a positive environmental implication and could help improve air quality and combat climate change in Ghana.

**Originality/Value:** The study's novelty stems from the production of biodiesel from desert date (*Balanites aegyptiaca*) seed of Ghanaian origin, which has not yet attracted much attention.

**Keywords:** Alternative fuel · Desert date biodiesel · Engine tests · Emissions · Ghanaian

## 1 Introduction

Globally, energy is a vital resource. The energy crisis that began in the mid-1970s has become a serious global issue. Fuels are vital because they can be used to generate large amounts of energy. There are many everyday activities dependent on fuel, including the transportation of commodities and people for household uses and agricultural productions, among other things. Primary energy resources from fossil fuels, including petrol, diesel, coal, and natural gases, are becoming expensive, unreliable, and unsustainable due to fossil fuel depleting and associated with negative environmental impacts. Due to this, the search for alternative fuel has intensified. Recently, numerous studies have been undertaken to investigate low-cost raw oil sources, including vegetable oil, used vegetable oil, unrefined vegetable oils, animal waste fat, and fish waste (Rajak and Verma 2018; Pollardo et al. 2018; Rivero et al. 2016; Elkady et al. 2015).

Studies on the use of vegetable oils, degummed soybeans mixed with petroleum diesel, semi-refined rapeseed oil, refined palm oil, and many others as fuel substitutes in diesel engines exist in the literature (Peters et al. 1982; Adams et al. 1983; McDonnell et al. 2000; Togashi and Kamide 1999; Suporn 1987; and Prateepchaikul and Apichato 2003). The authors have shown that these vegetable oils can be converted easily into biodiesel, similar to diesel fuel. However, the drawbacks of vegetable oils in internal combustion engines are high viscosity, carbon deposit accumulation in the engine, and inefficient fuel combustion, which decreases engine life. (Honary and Pramanik 2001; Pramanik 2003).

Numerous researchers have found fish oil as another large and inexpensive source of biodiesel. Highly unsaturated fatty acids from fish oil have improved low-temperature fluidity and lowered the cold filter clogging threshold. Additionally, fish oil exhibits comparable ignition capabilities and great combustion characteristics to diesel oil and requires low preparation before being used as fuel. Similarly, studies have shown that biodiesel derived from fish waste emits less carbon monoxide (CO), carbon dioxide (CO<sub>2</sub>), and Cxty than commercial fuel. (Anguebes-Franceschi et al. 2019; Enascuta et al. 2018; Shaminathan and Sarangan 2012; Preto et al. 2008). Even so, the following are some drawbacks associated with fish oil biodiesel: High polyunsaturated fatty acids (PUFAs) might result in the development of insoluble substances, thereby increasing their obstruction actions (Ushakov et al. 2013). Biodiesel has poor oxidative stability due to its high polyunsaturated fatty acid (PUFA) composition, making it possible to enhance the fuel using anti-oxidants (Martins et al. 2015). The acid values of some of the fishes were found to be (1.4 mg KOH/g) in comparison to the American (ASTM D-6751) standards (0.5mg KOH/g), emphasising the necessity for subsequent processing to ensure compliance with regulations.

Based on the above deductions, it is very prudent to investigate other sources of oil-bearing crops to produce biofuel that is cheaper, environmentally friendly, sustainable, economically viable, and meets the accepted standards. Presently, in Ghana, oil-producing plants such as the desert date (*Balanites aegyptiaca*) are underutilised but can produce modern forms of environmentally friendly and economically viable energy. There are few studies and testing on biodiesel production in Africa, including Ghana. However, Ghana has commercial fossil fuel reserves but still imports fuels due to the

inability to process these fuels. Importing liquid fuel is costly and takes up a lot of foreign exchange. Despite Ghana's potential to produce biodiesel, limited study has been undertaken on the issue. However, the Ghana Renewable Energy Masterplan targets producing about 20,000 tonnes of biofuels by 2030 (Energy Commission 2019). This encourages and promotes the development of liquid biofuels for blending and export from locally available crops.

Plant oil and its origin determine the type of biodiesel to be produced. For example, numerous researchers have revealed that desert date seed oil is an economically viable oil source because it has a high oil content. Also, the oil properties contain a proportion of medium-chain fatty acids with a high degree of unsaturation, rendering it a preferred resource for producing biodiesel that is superior to many other feedstocks (Salia 2016; Chavan et al. 2014; Giwa et al. 2016; Dass et al. 2018 and Kamil et al. 2019). Desert dates are shrubs that belong to the family of (Balanntaceae). It grows in arid and semi-arid environments as well as sub-humid savanna (Elfeel 2010; Hall and Walker 1991) and is primarily found in northern Ghana at elevations of up to 1000 m above sea level. It is a semi-evergreen plant that grows to a height of 12 m. The trees can produce a range of about 10,000 fruits annually. (Chapagain and Wiesman 2005).

From the author's best of knowledge, no study has highlighted an in-depth investigation and comparison (based on fuel characterisation and full engine tests) of producing biodiesel from desert date oils of Ghanaian origin. This study represents desert date seeds from Ghana as novel raw parent stock for biodiesel production. The study investigates the short-term combustion properties of biodiesel from desert date oils and its performance and behaviour in an engine.

## 2 Materials and Method

### 2.1 Physiochemical Properties of Kernel Oil of Desert Date

As reported by Salia (2016), the seed oil of *Balanites aegyptiaca* peroxide (of Ghanaian origin) for value (PV), free fatty acid (% FFA), and moisture content was 6.0 meq/kg, 0.18 mg KOH/g, and (0.27%) respectively. According to Abu-Al Futuh (1983), the kernel oil yield of desert dates was 45% containing four major fatty acids: Linoleic, oleic, stearic, and palmitic; the level of unsaturated fats (65%) is higher than that of saturated (34.4%). The oil remains stable when heated and has a high smoking point, and therefore its free fatty acid content is low (Orwa et al. 2009).

### 2.2 Local Extraction of Oil from the Nuts of the Desert Date

Dried nuts are cracked to obtain seed kernels. The kernels are then dried in the sun for two to four days. The kernels are then fried in a pot on fire for twenty minutes to change the colour from light yellow to brown. They are then allowed to cool for about one hour before milling into a paste using a grinding mill. Oil was extracted from the kernel paste by pouring hot water gradually onto the paste in a basin while kneading with the hand until such a time that little or no more oil was flowing from the pate into the container kneaded (Balami et al. 2009). The oil was heated to reduce the moisture content and other impurities to settle to the pot's bottom. After which, it was allowed to cool before decantation and filtration to remove other impurities further.

### 2.3 Desert Date Biodiesel (DDB) Production Using Transesterification Process

Desert date oil undergoes a transesterification process to produce biodiesel. The extracted oil is transformed into fatty acid methyl or ethyl esters during transesterification, which constitutes desert date biodiesel (DDB). The biodiesel (methyl ester) is produced by reacting the oil's triglycerides with an active intermediate generated by the reaction of an alcohol with a catalyst (KOH-based base catalyst). As outlined in Nagi et al. (2008), the following steps were followed to produce the DDB at the University of Cape Coast (UCC) Chemistry Laboratories.

**Step 1:** Mixing catalyst and alcohol: A potassium hydroxide (KOH) mixture as the alkaline catalyst with methanol (CH<sub>3</sub>OH) to produce biodiesel.

**Step 2:** Reaction: The desert date is introduced after charging the methanol/potassium hydroxide solution into a closed reaction chamber. The reaction mixture is heated to the boiling point of alcohol (up to 60 °C) and refluxed for a specified period with agitation. The reaction mixture converts 98% to 99% of the substrate in a reasonably short period (around 1 h). When the reaction mixture is halted, it separates into an upper layer of methyl esters (DDB) and a lower layer of glycerol diluted with unreacted methanol (since the two phases have different densities).

**Step 3:** Separation of glycerin and Biodiesel: When the process is complete, two significant products are obtained: glycerin and DDB (methyl ester). However, glycerin and DDB products include a significant proportion of excess alcohol. Purification of the upper layer is done in two ways: removing alcohol and removing saponified products.

**Step 4:** Removal of alcohol: The upper layer's fatty ester is neutralised and vacuum distilled to eliminate methanol.

**Step 5:** Glycerin Neutralisation: Phosphoric acid is used to neutralise the upper layer of soaps, yielding potassium phosphate. Thereafter, the glycerin is stored.

**Step 6:** DDB Washing: The Desert Date biodiesel produced is then rinsed with hot water (because water is immiscible with biodiesel) and centrifuged.

Testing of the fuel properties of the DDB samples was carried out per the standards represented in Table 1.

**Table 1.** Standard methods for testing fuel properties

Property	Units	Test method
Sulphur	ppm	ASTM D 5453
Flash point	°C	ASTM D 93
Water content	% volume	ASTM D 2709
Kinematic viscosity	mm <sup>2</sup> /s	ASTM D 445
Cetane number	—	ASTM D 613

(continued)

**Table 1.** (continued)

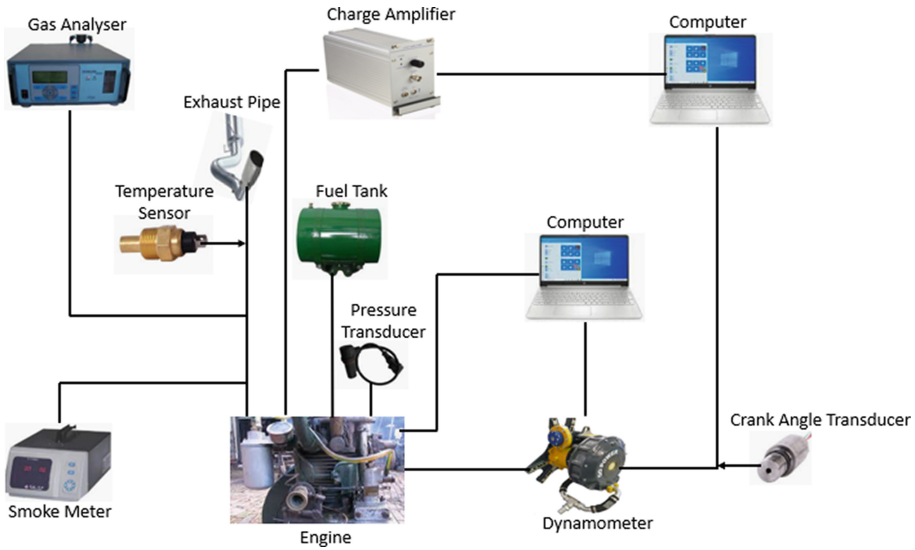
Property	Units	Test method
Cloud point	°C	ASTM D 2500
Carbon residue	% weight	ASTM D 4530
Acid number	Mg KOHg <sup>-1</sup>	ASTM D 664
Phosphorous content	% mass	ASTM D 4951
Oxidation stability	Hr@110 °C	EN 15751

## 2.4 Engine Tests Equipment and Methods

The experimental testing was conducted with a four-stroke diesel engine. The diesel engine's specifications are listed in Table 2. Figure 1 illustrates the engine testing components' linkages. The component was set up, and the technique was adopted from Maina (2014). The engine was connected to a dynamometer to create brake load, whereas a computer regulated the engine's throttling and dynamometer configuration. Inside one of the piston cylinders, a pressure transducer was mounted. The charge amplifier amplified the cylinder pressure signals from the pressure transducer and coupled them to the computer to obtain data. Externally, the crank angle transducer activated the data acquisition system approximately 1,024 times each revolution. Fuel was introduced via a flow metering device installed in a fuel tank. Throughout the fuel switching, the fuel tank was drained of the engine fuel, new fuel was added till the fuel filter became filled, and the engine was restarted and left running for some time to clean the fuel lines and stabilise. The gas analyser was utilised to measure carbon dioxide, carbon monoxide, total hydrocarbons, and nitrogen oxide emissions from the engine exhaust pipe. A smoke metre was linked to the engine exhaust pipe to measure smoke emissions.

**Table 2.** Specification of test engine

Manufacturer	Victor Diesel Engine Company Ltd
Engine	Number 42
Type	Single cylinder, 4 stroke, vertical compression, Air cooled, fixed throttle
Cylinder bore	80 mm
Torque arm	10 mm
Stroke	100 mm
Swept volume	0.5 L
Fuel	Diesel
Maximum speed	1500 rpm
Brake power	2.982 kW at 1500 rpm



**Fig. 1.** Engine test layout

### 3 Results and Discussions

#### 3.1 Biodiesel (DDB) Properties

Table 3 summarises the properties of DDB. The properties of Date seed oil Biodiesel (DSO Biodiesel) from Kamil et al. 2019 and petroleum diesel are summarised for comparative analysis. The results show that DDB is a viable fuel for diesel engines in this study. The DDB properties were within the limits of biodiesel standards (ASTM D6751 and EN 14214).

**Table 3.** Comparison of DDB and DSO biodiesel and petroleum diesel

Property	Units	DDB	DSO biodiesel	Petroleum diesel
Sulfur	ppm	0.25	0.93	45
Flash point	°C	168	164	52
Water content	% vol	0.021	0.019	0.05
Kinematic viscosity	mm <sup>2</sup> /s	4.23	4.38	4.1
Cetane number	–	64.2	62	42
Cloud point	°C	9.3	9.4	18
Carbon residue	% wt	0.019	0.023	0.35

*(continued)*

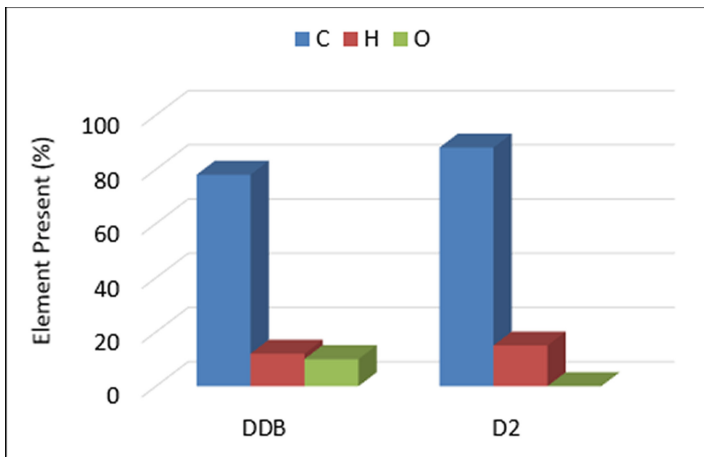


**Table 3.** (continued)

Property	Units	DDB	DSO biodiesel	Petroleum diesel
Acid number	Mg KOH/g	0.27	0.29	–
Phosphorous content	% mass	0.00015	0.0002	–
Oxidation stability	Hr@110 °C	8.2	7.4	–

### 3.2 Elements Present in Fuels Carbon, Hydrogen, Oxygen (C, H, O)

Figure 2 shows the percentage of the main elements of carbon, hydrogen, and oxygen (C, H, O) present in fuel samples. It can be seen that diesel fuel (D2) has the highest carbon content. The amount of H is about the same for the two fuels. The DDB has the highest O content, and a significant quantity of it in fuel leads to improved combustion. Also, a higher cetane number and sufficient presence of oxygen could result in an emission reduction because complete combustion takes place, resulting in fewer carbon monoxide and hydrocarbon emissions.

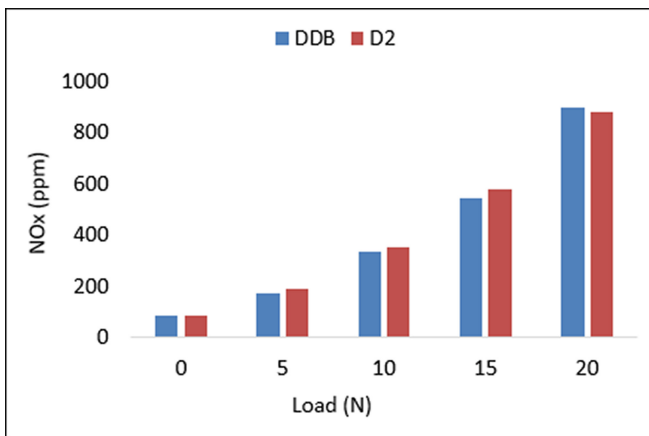
**Fig. 2.** Contents of elements in the fuel sample

### 3.3 Emissions

Figure 3 shows the fuel samples' impact on NO<sub>x</sub> emissions investigated at various loads. The in-cylinder temperature rises with increasing load, resulting in higher absolute NO<sub>x</sub> (ppm) formation. An increase in-cylinder pressure could increase NO<sub>x</sub> emissions due to higher peak combustion temperatures. The findings correspond with existing findings in literature (Purushothaman and Nagarajan 2009a; Purushothaman and Nagarajan 2009b). D2 had slightly higher NO<sub>x</sub> emissions than DDB at lower engine loads, but DDB had the

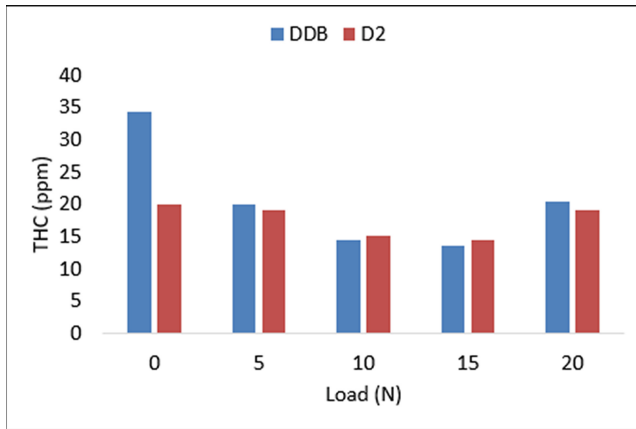
highest overall NO<sub>x</sub> emissions at load 20N. This could be due to the slower combustion of viscous biodiesel due to the longer residence time in the high-temperature zone. Moreover, the increase in NO<sub>x</sub> emissions could be linked to the oxygen content of the fuel samples, as more oxygen may be required for NO<sub>x</sub> formation (Ramadhas et al. 2005b; Maina 2014).

Figure 4 shows the fuel samples impact THC emission at different loads. THC emissions are highest when the engine is idle, especially for biodiesel, and lowest when running at 10 N and 15 N loads. High THC emission is found at low and high loads (Shi et al. 2006). THC emission differences between D2 samples may be due to greater fuel delivery per load, which causes slower combustion durations and negates the advantage of fuel carried oxygen in boosting DDB combustion (Aliyu et al. 2011; Banapurmath et al. 2008; Maina 2014).

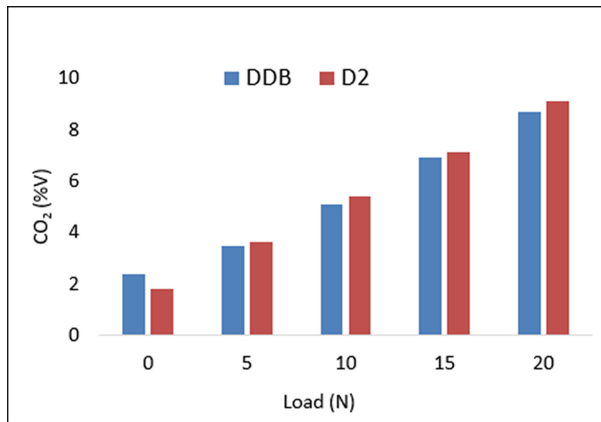


**Fig. 3.** Fuel samples' impact on NO<sub>x</sub> emissions at different loads

Plant/vegetable oil fuel decreases total CO<sub>2</sub> emissions in diesel engines since plants absorb CO<sub>2</sub> during photosynthesis (Demirbas 2008; Balat and Balat 2008). Figure 5 shows that CO<sub>2</sub> emissions rise with load at the same engine speed. DDB has the lowest CO<sub>2</sub> emissions under higher loads. The implication is that oxygen in biodiesel promotes burning; hence, it produces greater CO<sub>2</sub> at low loads. This finding has been reaffirmed by (Mbarawa 2008), highlighting that diesel emits less CO<sub>2</sub>. Nevertheless, poor fuel atomisation and shorter combustion time at greater loads outweigh the benefits of more oxygen in DDB, and incomplete combustion happens due to insufficient oxygen.



**Fig. 4.** Fuel samples' impact on THC emissions at

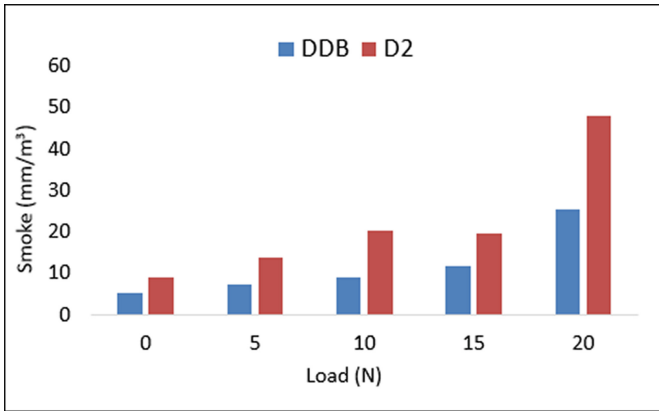


**Fig. 5.** Fuel samples' impact carbon dioxide emissions

### 3.4 Engine Performance

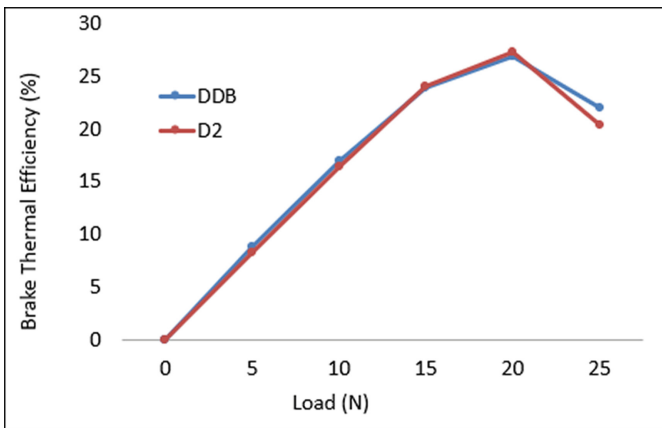
The salient parameters that determine the engine performance are thermal efficiency, specific fuel consumption, exhaust gas temperature, and mechanical efficiency. Figure 6 shows that diesel (D2) produced more smoke at all loads. Moreover, DDB and D2 fuels produced the maximum smoke at 20 N load. The lower smoke emissions in the DDB might be due to oxygen in the biodiesel samples (Chen et al. 2008, Purushothaman and Nagarajan 2009b).

Figure 7 displays the fuel samples' impact on brake thermal efficiency at various loads. The results indicate brake thermal efficiency increases with increasing load for biodiesel (DDB) and diesel (D2). When the load is increased, there may be a reduction in heat loss and increased power. DDB's brake thermal efficiency is near to that of D2 across the full operational range. The study indicated a maximum brake thermal efficiency of



**Fig. 6.** Fuel samples’ impact on smoke emissions

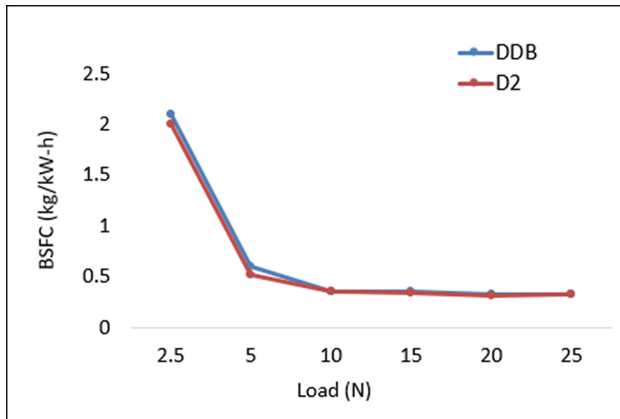
DDB to be 26.8% against 27.2% of D2 at loads of about 20 N. These results indicate that the brake thermal efficiency of DDB is nearly equal to D2.



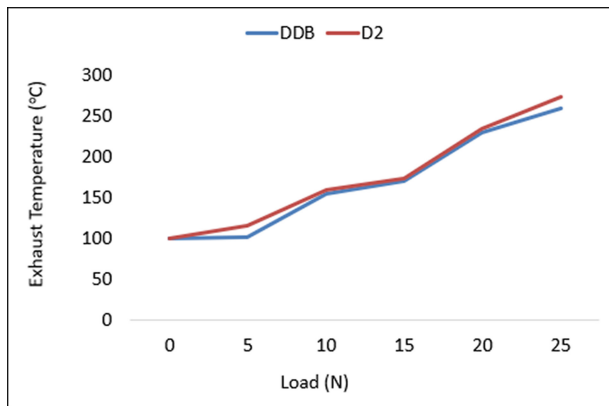
**Fig. 7.** Fuel samples’ impact on brake thermal efficiency

Figure 8 shows the fuel’s impact on brake-specific fuel consumption (BSFC) at different loads. The results revealed that the BSFC of the DDB closely matches that of D2. The minimum BSFC of DDB is about 0.321 kg/kW-h compared to 0.313 kg/kW-h for D2. Also, the BSFC desert date biodiesel (DDB) is about 0.008 kg/kW-h higher than that of petroleum diesel (D2).

The DDB and D2 impact on exhaust gas temperature at different loads is depicted in Fig. 9. The exhaust temperature of DDB has lower values compared with diesel. The exhaust temperature of the two fuels surges with the surge in operating load. The DDB has a better performance than D2, which can be due to a reduction in exhaust loss (Chavan et al. 2014).

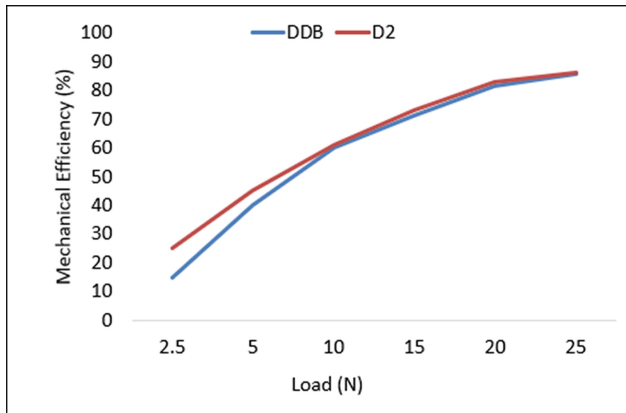


**Fig. 8.** Fuel samples' impact on specific fuel consumption



**Fig. 9.** Fuel samples' impact on exhaust gas temperature

Figure 10 displays the impact of DDB and D2 on mechanical efficiency at different loads. The results indicate a slightly lower mechanical efficiency for DDB than D2. However, they are very close. DDB has a maximum mechanical efficiency of 85.6%, while D2 has a maximum mechanical efficiency of 86.03%. In comparing the two fuels, the lower mechanical efficiency of the DDB could originate from diesel's suitable lubricating property, which decreases frictional losses (Chavan et al. 2014).



**Fig. 10.** Fuel samples' impact on mechanical efficiency

### 3.5 Summary of Key Findings

- Desert Date biodiesel (DDB) properties obtained conformed to biodiesel standards (EN 14214 and ASTM 6751).
- Petroleum diesel emitted more CO<sub>2</sub> and smoke than biodiesel. The loading had a greater impact on the THC emissions, where DDB emissions outshine D2 at lower loads. However, D2 THC is lower compared to DDB at higher loads.
- The NO<sub>x</sub> emissions were nearly the same for D2 and DDB except at the maximum load, where DDB showed slightly higher emissions.
- The DDB's maximum braking thermal efficiency is nearly comparable to D2.
- The DDB minimum BSFC is 0.008 kg/kW-h higher than D2.

## 4 Conclusion

The experimental test performed on a diesel engine to investigate the utilisation of desert date biodiesel produced suggests that the DDB from desert dates of Ghanaian origin can conveniently be employed as fuel in diesel engines, had lower emissions, better fuel characteristics, and engine performance compared to petroleum diesel (D2).

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# Effects of Sport Betting Practices on Income and Livelihood Among Youths in the Dodoma City, Tanzania

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**Abstract. Purpose:** This study assessed the effect of sports betting practice on income and livelihood among youth in Dodoma city, Tanzania. To achieve the objective, the study examined the major demographic characteristics of youth involved in sport betting in Dodoma city and assessed the factors influencing the income size of youth in Dodoma city.

**Design/Methodology/Approach:** The study employed a cross-sectional design in gathering primary data in which the researchers collected information at once in the study area. The study involves 100 respondents which were selected using a two-stage stratified sampling procedure. The Multiple regression models were employed in analyzing the effect of sport betting practices on youth income.

**Findings:** Findings from the study indicate that the education level of youth, amount of savings, the level of risks propensity and the profit earned from betting were found to be key factors positively influencing the income size of youth. While risks propensity and age were found to be negatively influencing the income size of youth.

**Research Limitation/Implications:** The study was focused only on sport betting practices in Dodoma city and not on the gambling industry as a whole. This limits its generalization in the gambling practices both in urban and semi-urban settings. This implies that, the influence of

**Practical Implication:** The knowledge generated from this study will inform gamblers/bettors and gambler mentors or owners of sport betting companies in Tanzania of the factors that influence the income and livelihood of youths in the gambling industry.

**Social Implication:** The knowledge obtained from this study will help policy-makers both in the gambling industry and government to review the existing gambling and sport betting policy which intended to increase employment and revenue for both government and youths in the country and thus poverty reduction. Also government should organize an orientation programs to educated youth on the negative impacts of sport betting and gambling on their income and livelihoods.

**Originality/Value:** This study carries its originality from uncovering important social and economic factors that catalyzes the participation of youths in the sport betting and gambling in Tanzania which has impacted them negatively.

**Keyword:** Income and livelihood · Sportsbetting · Tanzania · Youth

## 1 Introduction

For many thousands of years, humans have been engaging in sports betting and lotteries. The origins of betting globally cannot be known for certain as it has been with mankind since pre-historic times. In the current world, betting and risk-taking have been part of human culture since ancient times (Stephen 2017; Mwadime 2017). Furthermore, most of the problems faced by youths in the gambling games have been associated with sports betting, for example, in Australia, it was estimated that there is an increase of 70% in the number of young males who are affected with betting problems (Delfabbro 2012; ACMA 2013). According to (Gainsbury et al. 2017), it was reported that about 10 million people in Africa lives with a gambling addiction problem especially youths. This indicates that the majority of people in the continent spend their income on gambling and betting games. This situation if not well monitored by policy makers and governments could bring negative effects to the life of youth and the community. In the recent life, the development of betting practices have grown enough to cover the large part of the world including African countries of which betting and sport betting has being part of daily activities of youth in different forms (Mykhalchenko 2016). However, despite the increase in youth unemployment in African and other continents, yet most of youth especially those in urban and semi-urban areas are still participating in sports betting using cash and mobile money payments. This implies that, the African continental has now becoming a place where betting is an experienced activity and cash income distortion for most of young generations (Gainsbury et al. 2017; Ofosu and Kotey 2020). Based on this fact, it is visible to the community that most of the youth in the world are busy with betting in the different betting companies. For stance, in Nigeria and South Africa, sport betting and lotteries such as sport team, slot machine, casino games and on line gambling are the common activities among youths (Sule and Adam 2018; Stephen 2017). All these justify why there has been an increasing involvement of youths in gambling in many countries in Africa.

Similar to other African countries, in Tanzania betting practices existed even before the establishment of formal betting stations like in other African countries including Kenya and Nigeria. The findings by TGB (2017) show that, in Tanzania, there are more than 2,684 betting stations countrywide, in which about 1,344 stations found in Dares Salaam alone. This situation has attracted more attention from both government and individuals in the country. Moreover, sport betting are deemed to grown faster due to the increase of gaming shops across the country and online financial services. The rapid increase in in-game practices has made betting to be the major source of national revenue, whereby in Tanzania it generates for about TShs 1.4 billion in a month TGB (2017). This resulted from the introduction of 18% tax on gambling games in Tanzania. Furthermore, Ahaibwe et al. (2016) reported that about 52% of youth in Tanzania gambles once a week or more while only 5% they not at all gamble. The common sport betting in Tanzania is that of Simba Sport Club and Young African Sport Club (Yanga) teams, the two big football team and English Premier League in which youths spend their money for betting.

Findings from the study by Derevensky and Gupta (2007) and Omanchi and Okpamen (2018) reported that, betting is the game of money lose and gain in our daily life, thus increases risks of losing money to people involved especially young and teenagers. This is because, youths are vulnerable for the development of betting-related problems such as betting addiction, gambling debts, borrowing for finance gambling, absenteeism and inefficiency in school/work performance. The involvement in sports betting by youth can be linked to the decrease in income and savings among members of society. The decrease in savings for workers and youth due to income spent in gambling has resulted into school drop out for students, laziness, and domestic violence, selling off household assets and increased likelihood of unemployment (Victor 2016; Stephen 2017). Moreover, in Tanzania sports and games instead of bringing many people together as intended, they are leading to an increase in theft, corruption, and violence (Know the odds 2018). This raises more concerns among researchers as to why the intended outcomes for introducing gambling activities like employment creation are not coming out. Therefore, it is under this background this study attempted to evaluate the effects of sport betting practices on income among youths in Dodoma city. Specifically to examine the current status of betters in Dodoma city and to assess the effects of sport betting practices on income among youths in Dodoma city.

## 2 Theories Underpinning the Study

Two theories governed this study-Gambling theory and Information Theory. The game theory was developed by John Larry Kelly (1954), who explained that in gambling, the main objective of the sports bettor is to maximize the probability or chance of winning. Further, Kelly noted that it is the probability of invested capital expectation that is additive in the betting process and not capital. The theory demonstrated that in gambling games there are two possible outcomes win or lose. Therefore, with involvement in gambler practices, youth are exposed to a high risk of losing their money because of information asymmetry. This is because betting companies and mentors are more informed the better (youth). However, information theory further stipulated the way of quantifying information to make the best decision in the situation of imperfect information. The theory demonstrates how to make the best decision using only the information you have available. The sport betting is the process of making rational assessment on all relevant variables of an uncertain game and then compares them to the bookmaker's assessments. Sports betting practices fit itself to information theory because their success depends on what extent the bettor is informed about the chances of a win or lose. Sports betting is believed to operate under perfect market conditions whereby the market mechanism will adjust itself to fit with any new information. Therefore, in such a situation, a single company cannot influence the market practices because all companies are trading on the same information from which the market adjusted itself (Eboh 2015; Hansen 2006).

Contrary to this, in Tanzania betting Companies are more informed than youth and majority of youths are not employed roaming to search employment opportunities for income generations. This relation could lead to an increased in sports betting participation by young men and women in the country. The reason behind being the true fact that, unemployed person will tend to seek a source of income which could fulfill his needs

(Breen and Gainsbury 2013). According to the Tanzania Gaming Board Report (2017), the sports betting industry overtook the legacy casino industry by generating over TShs 30 billion in revenue. For the year ranging between 2014 and 2016 revenue from sports betting grew by 90%, this is due to fact that about 70% of Tanzanians are under the age of 24 (40.6M people) (Know the Odds 2018). In Tanzania, Dar es Salaam city is the leading in betting games whereby one cannot move more than a kilometer away before meeting with sports betting agents or companies. This shows how youth in the country are subjected to sport betting practices. Previous empirical studies reported that, most of the youths in Tanzania use a lot of money in sports betting games the thing which forces them to borrow money from friends to playing betting games (Menya 2016; TGB 2018). Because of the thin chances of winning in sports betting, most youth loses the borrowed money, the things which expose them to social, economic and psychological problems. Despite such concerns on sports betting, there is a dearth of information related to the effects and impacts of sports betting on the income of Youths in Tanzania and Dodoma city.

### 3 Methodology

The researcher used a cross-sectional design in the collection of data since data on sport betting practices in Dodoma city were collected at one point in time. Purposive sampling was used in the selection of the study area. Dodoma city was selected because of the high number of youth and betting companies. In this respect, three wards were selected namely Airport, Saba Saba, and Majengo. To select wards and streets, the study used a proportion stratified sampling technique and was involved study. The stratification of wards in the study area was based on several betting companies in the city to create homogeneity among the selected wards and streets. The selection of respondents which are included in the sample size for each street was proportional based on the population size (2018) using the using Yamane (1967) and Kothari (2009) formula. Therefore, a total of 100 respondents were selected from the three wards and interviewed. Semi-structured questionnaires and an interviews guide were used in collecting the data. The collected data through questionnaires were firstly coded, cleaned, and entered into statistical computer software and analysed using STATA statistical package version 11. Both descriptive and inferential analysis was conducted in analysing the effects of sport betting in which descriptive statistics figures and measures were used to summarize the information from the demographic characteristics. The results were then presented in tables, histograms, graphs, and pie charts from which inferences were drawn. On the other hand, Multiple regression models were used to analyze the effects of betting practices on youth income and livelihood was used. This is because, income as a dependent is the continuous variable. The regression equation was expressed as:

$$Y_i = \beta_0 + \beta_1 Age_i + \beta_2 Sex_i + \beta_3 Tax_i + \beta_4 Profit_i + \beta_5 Risk + \beta_6 savings_i + \beta_7 Edu_i + \varepsilon_i$$

Whereby: Age = Age of respondent.

Sex = Sex of respondent.

Tax = Tax rate paid by youth and betting companies

Profit = Profit earned by youth from betting  
 Risk = Risks propensity taken by youth in involving sport betting  
 Saving = the amount of money saved by youth from the normal income  
 Edu = Education level of the respondent

#### 4 Findings and Discussion

This section presents findings on the status of sports bettors and the effect of sport betting practices on the income of youth in Dodoma city, Tanzania.

Findings, as presented in Table 1, revealed that 84% were male while only 16% were female. This implies that sports betting is the game of males and not for females whereby those who practice sports betting were using smartphones (they betting online), and others used male friends to bet on behalf of them in the betting stations. These results support those of Agbala (2016) who reported that the majority of gamblers in Nigeria and South Africa were males and few women. Also, the finding are in line with those of (Oforu and Kotey 2020) who found that, In Ghana majority of bettors were male as compared to few female.

**Table 1.** Demographic characterizes of respondents

Gender	Frequency	Percent (%)
Male	84	84
Female	16	16
<b>Total</b>	<b>100</b>	<b>100.0</b>

Level of education	Frequency	Percent (%)
Standard Seven	10	10.0
Form Four	60	60.0
Form Six	20	20.0
University	7	7.0
None	3	3.0
<b>Total</b>	<b>100</b>	<b>100.0</b>

On the other hand, findings revealed that most (69.3%) of respondents completed secondary education (form four and above) while 13.3%, 6.7% and 6.7% have completed University, Form six and standard seven respectively. This reflects the fact that, most of people engaged in sport betting practice are those who do not have a guarantee of an official employment in the government rather that private institution, which means they might depends on more energy activities in their new employment. These findings concurs to those of (Masaba et al. 2015) who reported that, about 70–80% of high school students were gamblers in Nigeria and Uganda. Also, they support findings by (Peltzer and Pengpid 2014) that, most of the youths involved in gambling activities were University students. This indicated that the majority of bettors were having a high level of education to enable them to get more information about sports betting.

Results, as presented in Table 2, indicated that the mean age for youth was 33 years in which the highest age (the oldest respondent) was 56 and the lowest age (the youngest respondent) was 18 years. This implies that there is a very big difference between ages, this is because of the nature of the study hence the gamblers are mostly the youngest people in the community. Similar to that of Ayomide (2017) and (Omanchi and Okpamen 2018) who reported that, about 60 million youth demographic are heavily involving in sport betting in Nigeria. Also, the finding are in line to those of (Glozah et al. 2019) who noted that, young generation were involved more in sport betting than older generation due to the fact that, young people are still searching for employments.

**Table 2.** Age of respondents in the study area

N	Range	Minimum	Maximum	Mean	Std. deviation	Variance
100	38	18	56	33.25	8.237	67.840

#### 4.1 Income Level of Respondent

The study found that the average income of the respondent is TAS 698, 000, and the highest income was TShs. 2, 400,000 while the lowest income was TShs. 10,000. These indicate that betters have a reasonable income to enable them to participate in sports betting. The larger figure of standard deviation implies that, income inequalities among youths in Dodoma is high. The findings are in harmony with those of Breen and Gainsbury (2013) that about N 1.8 billion is spent on sport betting daily. This also supports the argument that lower-income does participate more in sport betting than people with higher income (Table 3).

**Table 3.** Income level of respondents

N	Range	Mean	Minimum	Maximum
100	2,400,000	698,000.00	10,000	2,400,000

#### 4.2 Effects of Sports Betting Practices on Income of Youth

In the Multiple regressions technique was employed in estimating the Effects of Sport Betting Practices on Income of Youth in the Dodoma city in Dodoma region. The income of youth was measured by the total income received from formal earning activities in a month in Tshs. The results in Table 4 indicate that the education level of youth, amount of savings and the profit earned from betting were statistically significant at 5 and 10%. While risks propensity and age were found to be negatively influencing the income size of youth and were significant at 5% .

**Table 4.** Regression Results on the effects of sport betting on the income of youths in Dodoma city

Variables	Coefficients	Std. error	t- Value	Sig
Age of farmer (Years)	-1.42*	1.615	-1.77	0.517
Education level of HH head	2.64*	1.754	2.125	0.021
Sex of respondent)	1.123	1.334	0.22	0.009
Savings (Tshs)	1.154	0.960	0.16	0.042
Risk propensity (1 = High, 2 = Low)	-0.446**	0.864	-2.78	0.002
Profit (Tshs)	0.664**	0.021	-2.42	0.006
Constant	1.327***	3.265	2.74	0.000
R-square			0.69	

Results in Table 4 indicate that the education level of youth showed a depressing effect (-0.446) on the income of the youth and was significant at 5% (Table 4). The negative coefficient of risk indicates that as the level of risk propensity increases, the ability youth to participate in the sport betting could decrease by 44%. On the other hand, the education level of bettors also showed a positive relationship to the size of income and was significant at 5%. The positive relationships of education to the income implies that, youths who have higher education level can easily win in the sporting game because of having more market information as compared to those of low level of education. These findings are in line with those of Sule and Adam (2018) and Abarbanel (2012) who found that educated young men and women were roaming in the street searching gambling stations in Nigeria.

Savings own by youth show a positive influence on the size of income which indicates that youth who have more savings were able to pay the entry fee and participated in the betting games (Table 4). Furthermore, the profit earned from betting was found to had a positive influence on the income size of youth with a coefficient of 0.66 and significant at 5% ( $p = .006$ ). This implies that a unit increase in profit and money saved by youth could increase the income size by 66%. This is because saving is the most important motivational factor for youth to participate in betting games (Gainsbury 2013; Kamara 2015). The findings concur with those of Agbala (2016) and Stephen (2017) that, a larger percent of the participants in commercial gambling is the low-level income population who involve in saving schemes. Also, they are similar to those of Ofosu and Kotey (2020) that, people with a low-income level in Ghana participated more in sports betting as compared to those with higher income levels. In addition, findings from this study are in line with those of Delfabbro (2012) who not that, South Africans people are becoming poorer because they concentrate more on betting than other economic activities. The same author further suggests there is a strong relationship between betting activity and income, employment status and casino proximity.

In contrast, risks propensity and age were found to be negatively influencing the income size of youth in Dodoma city. This implies that, as the youth become older he/she reduces the frequency of participating in sport betting games. The findings concur with

those of Ofofu and Kotey (2020) and Glozahet al. (2019) who noted that in Ghana the gambling activities were dominated by the youth aged between 18–24 years old.

## 5 Conclusion

In favour of these findings, we concluded that the income of youth in Tanzania Dodoma city were influenced positively by savings, education, profit and sex of youth for being male. In contrast, risks propensity and age reduced the income from betting by youth. This implies that more involvement of youth in sports betting and gambling could lead to income depression which in later could cause social and psychological problems. Moreover, the knowledge obtained from this study will help policy-makers both the gamblers and government to review the existing gambling and sport betting policies which intended to increase employment and revenue for youths in the country by converting the negative impacts of sport betting into positive as intended by the gambling policy. The government also should organize orientation programs to educated youth on the negative impacts of sports betting and gambling on their income and livelihoods. The Tanzania Gambling Board (TGB) in collaboration with the Ministry of Information, Sports and Culture to improve the business environment of betting activities and other requirements. This study carries its originality for uncovering important social and economic factors that catalyze the participation of youths in sports betting and gambling in Tanzania.

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# Marketing Services and Export Performance of Tanzanian Handicrafts Operators: Moderating Effect of Export Incentives

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**Abstract. Purpose:** The study adopted resource dependency theory and examined how home market export incentives moderates the nexus between marketing services and export performance of Tanzanian micro and small handicrafts enterprises (MSHEs).

**Design/Methodology/Approach:** Descriptive cross-sectional research design was adopted, and data were gathered through key informant interview and survey questionnaire administered to 171 sampled MSHEs. Purposive and proportionate stratified sampling techniques were used. The moderating effect was tested by comparing Ordinary Least Square and Moderated Multiple Regression models.

**Findings:** Findings indicate the existence of high market for handicrafts in African countries and fewer exports are available to USA and EU countries. It was further revealed that there is an expansion of handicrafts in foreign markets due to participation in trade fairs. A significant moderating effect of export incentives on marketing services and export performance of MSHEs was established.

**Research Limitation/Implications:** The study focused on MSHEs exporting handicrafts in Dar es Salaam Tanzania, hence concentrated mainly on the 15 informal handicrafts markets in the city.

**Practical Implication:** The knowledge advanced in this study will inform actors in the handicrafts industry that export incentives moderates the nexus between precise marketing strategies and export performance, thus MSHEs who make an effective combination of export incentives demonstrate superior performance in export markets.

**Social Implication:** The knowledge contributed by this study will help policy-makers to review the existing export incentives, harmonise tax policies and programmes in a way that will help local handicrafts operators improve their export performance.

**Originality/Value:** The uniqueness of this study lays in the handicrafts export framework for local handicrafts exporters. The study demonstrates the dependence on access to resources like export incentives among handicrafts operators. The study substantiates that if these resources are easily accessible in the home market, exporting MSHEs will be more likely to compete easily in foreign markets. This scenario substantiates the need for the Resource Dependence Theory (RDT).

**Keyword:** Export performance · Handicrafts · Incentives · Marketing services · MSHEs

## 1 Introduction

Micro and Small Handicrafts Enterprises (MSHEs) are classified by Ghouse (2012) as an important sector for many developing economies. They contribute substantially to the development of international economies by attracting foreign investments and earnings (Singh and Fatima 2015). Global market for handicrafts is expanding simultaneously with interest in global goods, this lead to new-market potentials for the crafts persons (Ghouse 2012). Handicrafts international market is projected to be \$100 billion and the US is the leading importer at \$67 billion, followed by the EU at \$29 billion annually (USAID 2009; UNCTAD 2008). This therefore necessitates the export of handicrafts as it contributes significantly to socio-economic development.

Despite exporting being considered as inevitable in the progressively more integrated world markets, most MSHEs are not participating export trade (Pinho and Martins 2010). This tendency according to Dusoye et al. (2013) is attributed by barriers from within and outside the firm. These barriers include product quality, firm resources, firm scale, poor management practices, and experience. Others are forces like unfavourable global business environment, trade laws, market forces of demand and supply, trade financing regimes, trade policies, infrastructure facilities, network linkages, cultural differences, and geographic factors (Dusoye et al. 2013).

The contribution made to the developing economies through handicrafts is increasing such that there is an evidence of new entrants in the industry as a means to unemployment (Ipsos 2012). Kenyan handicrafts exports are increasing extensively over the years and they contribute significantly to the country's economy through selling mainly in Europe, Middle East, USA, and Japan. The development of this sector is articulated in country policies and programmes like the 2005 Session Paper No. 2 on MSEs development, the Economic Recovery Strategy (ERS) 2003–2007 for Wealth and Employment Creation and the National Export Strategy (NES) of 2003–2007 (Wambui 2013; Mukami 2012). Rwandan handicrafts industry employs more than 2,546 people and has a broad range of high-quality handicraft products (Malunda 2012). However, the Rwandan handicraft industry is hampered by a number of marketing related problems which includes: input supply, small size of the companies involved in export trade, market penetration techniques, unclear description of potential sub-sectors, lack of coordination among stakeholders, quality control, standardization, and foreign markets entry strategies (MTI 2009).

In Tanzania, the key actors in the handicraft industry are producers (craft workers), marketers (handicraft exporters), and support system (the government) (Makyao 2013). They are specialised in bone jewellery, *tingatinga* paintings, bowls, baskets, decorations, candles, ebony and wood carvings, (Anderson 2011). While annual total goods exports from Tanzania are reportedly increasing from US\$ 5, 258.1 million in 2013 to US\$ 5, 194.1 million in 2014, US\$ 5,316.8 million in 2015, US\$ 5, 661.2 million in 2016 and US\$ 4, 827.8 million in 2017 (BOT 2018), the country's handicraft exports is declining with few operators engaging themselves in export trade over the past five years (HT 2010; IMF 2016).

Tanzanian MSHEs are placed in the manufacturing sub-sector which contributes to just 8% of GDP and exports (SIDO 2014). This gives an evidence of underperforming of the local handicrafts industry in comparison to other economic sectors in the country.

The observed declining export trend in the handicrafts industry is majorly caused by stiff competition largely from foreign traders with advanced technology, marketing strategies, export incentives, chains of distribution, and marketing services (Anderson 2011). Similarly, local handicrafts traders are constrained with marketing information (Walonzi 2014), awareness of fair-trade practices, production capacity, quality and standards issues (Ipsos 2012). From these challenges, local MSHEs offers low-quality products which do not compete into international markets and therefore confine their export performance. A solution to such problems is provision of vibrant marketing services necessary for MSHE's effective performance. However, issues affecting Tanzanian exporting MSHEs have not been fully addressed and in particular the appropriate home market export incentives for this sector, therefore creating a knowledge gap. This study therefore is intending to seal this gap by assessing the moderating influence of export incentives on marketing support and Tanzanian MSHE's export performance nexus.

## 2 Theoretical Underpinnings

The current study takes on the Resource Dependence Theory (RDT). The ideology of this theory is scarcity of resources, which pushes multiple organizations into scrambling for the same scarce resources. From the RDT, survival of a firm is largely depending on its capability to attain and preserve resources from its business environment (Hessels and Terjesen 2010). RDT also takes into account the need for firm to secure appropriate exporting resources (Mwiti et al. 2013). In this case, one fundamental resource needed by these firms is favourable export incentives and marketing services necessary for internationalization. Export incentives are benefits that are claimed and passed onto the export units without any deduction or else, they are offered by the government agencies and give the option to units to claim the benefits themselves. These incentives help exporters to overcome trade barriers and therefore achieve their goals (Gilaninia et al. 2013). The tradition of giving export incentives is virtually the same all over the world, and Tanzania is no exemption. Nevertheless, the extent and types of incentives as key resources vary from country to country depending on its economic condition, resource availability and usefulness of export incentives in comprehending its export potential. The most common export incentives include: export marketing assistance subsidies, duty draw back schemes, exemption on customs duties, preferential tax rates, zero-VAT rating on exports, tax holidays, grants, preferential loans and infrastructure access, reductions and exemptions in corporate tax rate and capital gains tax (Tuomi 2012; IPAR 2011; UNCTAD 2010). To assess the moderating effects of home market export incentives on market support and MSHEs export performance nexus, this study take on four (4) export incentives which are: access to low-cost credit schemes, zero- VAT rating on exports, export market assistance, and duty draw back schemes.

Marketing services are important determinants of a company's business strategy as longer as they support it to acquire a competitive advantage over its competitors and results into a greater performance (Davicik and Sharma 2016). Marketing services emanates from the tradition 4P's of marketing (i.e. Product, Pricing, Promotion and Place) famously known as marketing strategies (Kotler and Armstrong 2012). This study have extrapolated the tradition 4p's and adopted the following as marketing services:

product development, collective marketing, pricing, foreign market information, trade fair and exhibitions which have an underlying association with export performance of MSHEs. It is from these services, handicrafts exporting firms will execute new marketing strategies to cope with the dynamic global market conditions by merging the existing resources in innovative means (Al-Aali et al. 2013).

Export performance of MSHEs signifies the end result of their actions in foreign markets (Papadopoulos and Martín 2010). It refers to the degree on which a firm achieve its objectives as a result of exports activities (Navarro et al. 2010). The definition, categorisation and conceptualisation of factors leading to export performance differ among several scholars (Khamwon 2012). Gilaninia (2013) is of the opinion that a firm's export performance is categorised into three: (i) financial (sales, profit and growth), (ii) non-financial (success satisfaction, achieve goals) and (iii) complex criteria. Durmusoglu et al. (2012) classified it into: (i) financial goals, (ii) communicating tool, Strategic goals, and (iii) Organizational learning goals. Export performance is further conceptualised and categorised into: (i) Strategic measures (number of export markets, and new exported products), (ii) Economic or objective measures (percent of export-sales, market-share, and export profits), and (iii) Subjective measures (how management perceive firm's performance and success in export markets) (Hammami and Zghal 2016; Gilaninia 2013; Khamwon 2012). A multidimensional approach to export performance measurements is adopted in this study, where by multi-items measures are used. This approach is said to be more reliable, provides a clear picture of export performance and has less measurement error when compared to single-item measures (Khamwon 2012; Sousa et al. 2008). In this study the conceptualisation by Hammami and Zghal (2016), Gilaninia (2013), and Khamwon (2012) on which two economic (i.e. growth in export sales and profitability) and two strategic (i.e. number of export markets and customer served) indicators were used to examine export performance of Tanzanian MSHEs.

From the RDT, exporting MSHEs have fewer resources, mainly if compared to medium and large (ML) international enterprises. Exporting MSHEs are largely dependent on the export resources existing in their home market environment. Resources such as export incentives and schemes provided by the home markets governments are among the most limited resources among local MSHEs. Base on this theory, when incentives like tax exemption, access to technology, market information, finance and raw materials are extensively available and accessible, MSHEs may be in a better position to compete in foreign markets. Again, with favourable production costs in the home market, MSHEs may be able to produce internationally competitive products. Thus, MSHEs accessing export incentives and schemes are in a better position to develop such international competitive products. This study adopts export incentives such as low-cost credit schemes, Zero VAT rating on exports, export market assistance and duty draw back schemes. This theoretical context triggered a hypothesized that:

*H<sub>A</sub>: Marketing services has a positive effect on export performance of Tanzanian MSHEs, moderated by Home market export incentives.*

*Home market export incentives moderates the relationship between marketing services and export performance of Tanzanian MSHEs.*

### 3 Methodology

This study used descriptive cross-sectional research design as it gives information which describe organizations, industry, people, settings or phenomena, which is the requirement of this study. Data were collected once to measure pattern of association among variables of the study. The design also has enough provision for protection of bias maximized reliability and it encompasses the use of both qualitative and quantitative data (Wilson 2014). The study too took on positivism paradigm (quantitative research). The paradigm offers the basis for explaining the phenomena under investigation using causal-effect relationships between the variables of the study which are measured using quantitative techniques (Collies and Hussey 2013; Burns and Burns 2012; Scotland 2012). It is from this paradigm that a valuable research is anchored on the use of a theories, test of hypotheses and quantitative data.

The target population for the study were 1018 exporting MSHEs in Dar es Salaam Tanzania. This is the leading commercial and one of the most attractive cities to many local entrepreneurs, immigrants and traders of handicrafts (Walonzi 2014). Dar es Salaam has over 15 handicraft markets which form the strata of interest to this study. The markets are in Kariakoo Market on *Tandanti* Street, *Mwenge*, House of Art (*Nyumba ya Sanaa*) and the Village Museum (*Makumbusho*), amongst others. The study applied purposive sampling technique to identify MSHEs with export experience of at least five (5) years for the study. These are believed to have adequate information useful in assessing business export performance. Proportionate stratified sampling technique was then used to ensure proper representation of each stratum of the population, has higher statistical efficacy and greater precision (Cooper et al. 2012). The population was then stratified into six (6) strata and a proportionate sample size of 171 exporting MSHEs was computed by using the Cochran (1977) formula since the study population is less than 10,000.

Structured questionnaires were hand administered as the main data collection instrument. Interview schedules were also used to compliment questionnaires data, where a total of ten interviews were done with selected operators in the handicrafts industry. A review of published reports helped to collect secondary data. This was intensively done through perusing and reviewing of both empirical and theoretical literature sourced from research reports, policies, trade associations' reports, books, government and non-governmental reports on handicrafts, MSMEs export trends. This technique was adopted since it provides real information and evidence on the study (Saunders et al. 2012).

Qualitative and quantitative data analysis techniques were adopted in this study. Qualitative data were firstly categorized into arguments and themes given by the interviewees and then compared and contrasted. The explanations were at that point harmonised with the contents of the reviewed literature and empirical evidence. Quantitative data were tested by using Ordinary Least Squares (OLS) and Moderated Multiple Regression (MMR). According to Ndung'u (2014) MMR eases the examination of a wide range of relationships and function forms. It also allows the numerous associations between dependent and independent variables to be determined by the levels of other independent variable(s) as it is the case in the current study.

To estimate the interaction effect, an OLS model, MMR model and a continuous independent variables X, Y, Z (moderator) were developed (Aguinis and Gottfredson 2010). Then the OLS and MMR model were compared in order to establish presence

of moderating effect. Equation (1) displays OLS regression for a model forecasting Y scores obtained from the first-order effects of observed scores from variables X and Z:

$$Y = \beta_0 + \beta_1X + \beta_2Z + \varepsilon_o \tag{1}$$

Where:

- $\beta_0$  = Coefficient of the intercept
- $\beta_1$  = Regression coefficient of X observed scores
- $\beta_2$  = Regression coefficient of Z observed scores
- $X_1$  = Marketing services
- Z = Home market export incentives.
- $\varepsilon_o$  = Error term.

Equation (2) shows, the MMR model is obtained from a new set of scores for the two independent variables (i.e. X, Z), and comprising it as a 3<sup>rd</sup> term in the equation, which gives Eq. (2):

$$Y = \beta_0 + \beta_1X + \beta_2Z + \beta_3X * Z + \varepsilon_o \tag{2}$$

Where:  $\beta_3$  = Regression coefficient of the interaction term scores.

Empirical studies that have used OLS model and a MMR model to assess the moderating effect include Alabede and Muff (2015) and Ndung’u (2014). The study used P-value to determine the significance of an individual variable weight to the dependent variable at 5 per cent significance level. The rule of thumb is, if p-value  $\leq 0.05$   $H_A$  is accepted, or else it is rejected (Cooper et al. 2012). The dependent variable ( $Y_i$ ) is export performance of MSHEs. Observed measures (numerical measures) were used in terms of summated scores of profit gained, customer acquired, sales growth and foreign markets served, over the past five years. The definitions, measurements, and operationalization of variables are in Table 1.

**Table 1.** Variable measurements and definitions

Variable	Definition
<i>Dependent variable:</i>	
Y = Export performance	Performance measured in terms of summated scores of sales, number of foreign markets served, and customers
<i>Independent variable:</i>	
X = Marketing services	MSHEs’ access to marketing services
<i>Moderating Variable:</i>	
Z = home market export incentives	MSHEs’ access to zero-VAT rating on exports, low-cost credit, export marketing assistance, and duty draw back schemes

## 4 Findings and Discussion

### 4.1 Marketing Archetypal for Handicrafts

The study examined the model used by the local handicrafts operators to market their products. It was established that local handicrafts operators exports a substantial varieties of products such as batik, jewels, candles, wall plates kikoyo ebony wood, beads “*shanga*”, baskets, carvings, greeting and cards. Others include: musical instruments, Maasai dresses, tingatinga paintings, clothing, doorstoppers, leather goods (coats, belts, sandals, folders shoes, boots, and wallets), spoons, bone jewellery, letter openers, traditional decorations, bowls, and wood carvings. This portray that local operators have a substantial range of handicrafts products which escalates their competitiveness and attractiveness in export markets.

Results in Table 2 shows that 75.4% of the exports are crafted by MSHEs, 9.9% by the crafts workers, 8.8% by co-operatives while 5.8% from the agents. Table 2 revealed that 37.4%% of the handicrafts are traded to nearby African countries mostly Kenya, Rwanda and Uganda, 14.9% to Asia, 16.1% to Europe, 18.1% to USA and 12.4% to Middle East. This proves that Tanzanian handicraft traders sell more through the regional economic integrations such as the East African Community and Southern Africa Development Community. EU and USA are observed to be potential markets for the growth of this industry as they offer profitable export market openings like Everything But Arms (EBA) as well as the AGOA (UNCTAD 2008).

**Table 2.** Handicrafts marketing archetypal

	Category	Frequency (171)	Percent (%)
Producers	Local operators	129	75.4%
	Crafts workers	17	9.9%
	Co-operative groups	15	8.8%
	Agents/dealers	10	5.8%
Export markets	Africa	64	37.4%
	Asia	25	14.9%
	Europe	28	16.1%
	Middle East	21	12.4%
	USA	31	18.1%
	Others	2	1.2%
Export mode	Indirect export	92	53.8%
	Direct export	42	24.6%
	Both ways	37	21.6%

Further, results in Table 2 revealed that 53.8% of the exporters uses indirect export strategies though agents and foreign distributors, 24.6% are exported directly to foreign markets by the handicrafts’ operators, while 21.6% uses both ways (direct and indirect).



This substantiates the dominance of indirect export mode for handicraft products from Tanzania. This domination is endorsed by smallness in terms of capital among operators which limits their ability to adopt direct export strategies which have high costs, risks and profitability. Consequently, the use of such export mode entails that local handicraft traders certainly not get enough of the profits accumulated from their handicrafts exports. It is the agents who benefited to the utmost with the shared profits since they have the opportunity to negotiate with the clients in the foreign markets for better prices as opposed to the prevailing market prices (Mukami 2012).

## 4.2 Marketing Services

The study used five point Likert scale to determine perceptions of handicrafts operators on accessibility and influence of marketing services in way of collective marketing (CMK<sub>1-5</sub>), trade fair (TRF<sub>1-5</sub>) and product development strategies (PDS<sub>1-5</sub>) to their export performance. As in Linyiru (2015), the study established an index for marketing services based on the Likert means using the means ( $\bar{x}$ ). In this index, the extent to which marketing services influence export performance was rated as: zero extent ( $1 < \bar{x} < 1.5$ ), little extent ( $1.5 < \bar{x} < 2.5$ ), moderate extent ( $2.5 < \bar{x} < 3.5$ ), greater extent ( $3.5 < \bar{x} < 4.5$ ) and very great extent ( $\bar{x} > 4.5$ ). Findings in Table 3 show a mean score

**Table 3.** Marketing services

Item	Statement	Likert mean
CMK <sub>1</sub>	We use collective marketing ties	4.0000
CMK <sub>2</sub>	We team up with others in production of handicrafts	4.1345
CMK <sub>3</sub>	Collective marketing ties helped us in foreign markets promotion	4.1404
CMK <sub>4</sub>	Collective marketing helps us in distributing our products in foreign market	4.1170
CMK <sub>5</sub>	Our prices are determined through collective marketing ties	4.1930
TRF <sub>1</sub>	We participate well trade fair and exhibitions	4.4269
TRF <sub>2</sub>	Foreign markets have expanded through trade fair and exhibitions	4.4269
TRF <sub>3</sub>	Trade fair have increased products awareness	4.4795
TRF <sub>4</sub>	More of our products have been sold through trade fair and exhibitions	4.4971
TRF <sub>5</sub>	The number of foreign customers have increased subsequently	4.4561
PDS <sub>1</sub>	We are well equipped with production strategies	3.9766
PDS <sub>2</sub>	We are well equipped with branding strategies	3.9415
PDS <sub>3</sub>	We are well equipped with labelling strategies	3.9415
PDS <sub>4</sub>	We are leaders in packaging handicraft products every so often	3.6959
PDS <sub>5</sub>	We have acquired sufficient training on product quality	3.6784
<b>Average</b>		<b>4.1403533</b>

of 4.1403533. This indicates that to a greater extent majority of operators of handicrafts exporting MSEs established that marketing services influences their export performance.

In the course of the interviews, it was proved that marketing services are very crucial for MSHE's export performance despite the fact that some operators do not access such services easily. Interviewees acknowledged to have been receiving marketing services from Government organizations (i.e. SIDO and VETA). However, some operators do access them from trade associations (e.g. TWCC, TCCIA, TanCraft). The significance of marketing services in enhancing export performance of MSHEs is also revealed by Ezeani et al. (2012) who demonstrated the necessity of marketing skills in enhancing business success. These observations corroborates with Tambwe (2015) who established the relevance of marketing services in business performance, as it supports in identifying business ideas, product designs, positioning, pricing, promotion, customer identification, attracting, retaining, and coping with competitions in the market place.

Furthermore, the study anticipated to identify the trade fairs that handicrafts operators do participate as one of their marketing strategies. During interviews, it was revealed that handicraft usually participate in the *saba saba* fair (Dar es Salaam International Trade fairs), Arusha Charismas fair, East and Central Africa trade fairs, Farmers fair (*nane nane*), and SIDO fair. Further, it was advocated during interviews that such trade fairs are important to export performance as highlighted by one operator that:

*"...through trade fairs we are exposed to a different competitive business environment..., we easily manage to create buyers awareness on our products, the fairs are useful in building and managing business networks among key players in the handicrafts industry..."*. Likewise, the other one said that: *"...I only had very few local customers before participating in these trade fairs, but customer base have started increasing ever since I started participating in the trade fairs. The fairs have helped my business to broaden its scope of operations, identifying customer needs and improving products innovativeness..."*

### 4.3 MSEs Export Performance

Descriptive analysis for MSHEs export performance was measured using summated scores of sales, number of foreign markets served, and customers where all measures used were grounded on literature. Findings in Table 4 indicate a mean score of 3.610825 which indicates that to a greater extent export performance of MSHEs is improving. These findings agrees with Piza *et al.* (2016) who found that performance constructs such as growth in sales, firm profits, markets and number of employees influence firm export performance.

Despite the improved export performance of MSHEs, there are specific issues that need to be intervened for effective firm performance. One interviewee pointed out that:

*"...it is much cost full for us to export our products to foreign markets. We really need for a vibrant government agency that will facilitate us with arrangements for distributors in other countries who will serve us at cheaper price..."*. Again,

**Table 4.** MSHEs export performance

Export performance construct	Mean
Export sales growth	3.8749
Firm profit growth	3.3918
Number of customers served	3.5205
Number of foreign markets served	3.6561
<b>Average</b>	<b>3.610825</b>

another interviewee highlighted that: “...our firm has very weak packaging materials which are constraints our export performance, we therefore need to be facilitated with access to packaging materials and strategies for our exports...” Nevertheless, another interviewee reacted that: “...our firm experiences a different story, we sell over 80% of our handicrafts in East African market, which in turn gives us very minimal profits. I think we need to be exposed to more profitable markets in Europe, Far East, America and Asia...”

#### 4.4 Home Market Export Incentives

Descriptive analysis for home market export incentives were measured using 9 items on a five-point Likert scale where all measures used were grounded on literature. A mean score of 3.643667 for all statements on export incentives was obtained, this indicates that over the past five years the provision of export incentives to MSHEs has improved to a greater extent. However, the extent of provision of low-cost credit, duty draw back schemes and Zero-VAT were not in the favoured side of the exporting MSHEs. Overall, these findings reveal the importance of home market export incentives and that a large number of MSHEs in Tanzania benefits from such incentives offered by the Government organisations, NGOs and private BDSPs. This observation is in line with Ahmed et al. (2006) who observed that export incentives tested were significantly important to exporting entrepreneurs (Table 5).

Respondents were also asked to state the main challenges that they are facing in relation to access to export incentives. It was mentioned by one interviewee that:

“...Most of us are not aware of where to access these vital incentives for export performance of our businesses...”. Hitherto another interviewee clearly identified that: “...the problem is with us and no one is to be blamed, we have been hearing about such incentives here and there but we have not taken any step to get to access them...”. Yet another interviewee pointed out that “...we have been experiencing very high tax charges in the boarder the government should do something on this if at all they want us to do well in this business...”

**Table 5.** Home market export incentives

Item	Statement	Likert mean
EI1	We have been receiving low-cost credit over	3.7076
EI2	We have been regularly receiving Zero-VAT rating on our exports	3.6550
EI3	The government do assist us with export marketing	3.3392
EI4	NGOs do assist us with export marketing	3.8269
EI5	We have been regularly given exemption on customs duties	3.5263
EI6	We are using duty draw back schemes for handicrafts exporters	2.7310
EI7	We sell more through export promotion schemes for handicrafts exporters	3.9719
EI8	We have access to international trade fair and exhibitions	3.9649
EI9	We are regularly participating into regional trade fair and exhibitions	4.0702
<b>Mean</b>		<b>3.643667</b>

**4.5 Moderation of Export Incentives on Marketing Services-Export Performance**

Moderating effect of export incentives (i.e. interaction term) was analysed by using the interpretations of the R<sup>2</sup> change in models 1 and 2 (in Table 6), and the coefficients of the interaction term attained from the MMR model summary and the model coefficients’ tables respectively. Model 1 in Table 6 indicates that R = 0.204, R<sup>2</sup> = 0.042 and [F (2, 164) = 3.576, p = 0.000]. R<sup>2</sup> signify that 4.2% of the variation in export performance is accounted by export incentives scores and MSHE’s access to marketing services. Model 2 gives the outcome of adding the interaction term (Export incentives scores\*MSHEs access to marketing services) into the model. Results in Table 6 also shows a significant moderating effect with R<sup>2</sup> change of 0.037, [F (1, 163) = 6.536, p < 0.10] resulting from the inclusion of the interaction term. To differentiate it, the moderating effect of export incentives gained 3.7% variance in MSHEs export performance, over and above the variance by access to marketing services and export incentives. Thus, the research hypothesis (H<sub>A</sub>) is accepted and therefore the conclusion that home

**Table 6.** MMR model summary

Model	R	R <sup>2</sup>	Adjusted R <sup>2</sup>	Std. error of R2	Change statistics				
					R <sup>2</sup> change	F change	DF1	DF2	Sig.
1	0.204 <sup>a</sup>	0.042	0.030	0.15103	0.042	3.576	2	164	0.030
2	0.281 <sup>b</sup>	0.079	0.062	0.14855	0.037	6.536	1	163	0.011

*a. Predictors: (Constant), Marketing Services, Export Incentives*

*b. Predictors: (Constant), Marketing Services, Export Incentives, Mkts\_x\_ExpoInc*

*c. Dependent Variable: Export Performance of MSHEs*

market export incentives moderate the linkage between marketing services and export performance of MSHEs is drawn.

Model 1 in Table 7, indicates that marketing services was not significant ( $p < 0.10$ ;  $\beta = -0.114$ ). Nevertheless, export incentives was found to be significant ( $p < 0.10$ ;  $\beta = -0.152$ ). From Eq. 3 a 1-unit increase in marketing services, MSHEs' export performance is expected to have a difference of 0.024, holding marketing services constant. The regression coefficient related to marketing services implies that the variation in MSHEs' export performance between MSHEs with high and MSHEs low marketing services is 0.023, provided that export incentive is kept constant. Using the values obtained above, the regression equation is as follows:

$$\text{ExpPerf} = 1.172 - 0.023\text{MS} - 0.024 \text{EI} \tag{3}$$

Model 2 in Table 7 give results of the introduction of the interaction term in the model. Export incentive was significant ( $p = 0.041 < 0.10$ ,  $\beta = 0.714$ ). Marketing services was significant ( $p = 0.033 < 0.10$ ,  $\beta = 0.727$ ), and export incentives \* marketing services too was found to be significant ( $p = 0.041 < 0.10$ ,  $\beta = 0.714$ ). After substituting the coefficients in Eq. (4), the regression equation becomes:

$$\text{ExpPerf} = 0.554 + 0.147 \text{MS} + 0.114 \text{EI} - 0.038 \text{EI} * \text{MS} \tag{4}$$

Findings in Table 7 show that for a 1-point increase in export incentives, MSHEs' export performance is expected to have a difference by 0.114, holding marketing services constant. This shows a difference of 0.038 between the slope of MSHEs' export performance on export incentives between those handicrafts exporting MSHEs with low and high marketing services. Thus, from Eq. (3) a significant moderating effect of export incentives is established.

**Table 7.** MMR model coefficients

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.
		$\beta$	Std. error	Beta		
1	(Constant)	1.172	0.075		15.585	0.000
	EI	-0.024	0.012	-0.152	-1.958	0.052
	MS	-0.023	0.016	-0.114	-1.470	0.144
2	(Constant)	0.554	0.253		2.189	0.030
	EI	0.114	0.055	0.714	2.057	0.041
	MSS	0.147	0.068	0.727	2.153	0.033
	MS_x_EI	-0.038	0.015	-1.317	-2.557	0.011

The moderating effect of home market export incentives on the nexus between market support services and export performance of Tanzanian MSHEs is found to be significant

( $\beta = -0.038$ ,  $t = -2.557$ ,  $p = 0.011$ ).  $H_A$  is accepted and the conclusion drawn is that home market export incentives moderates the relationship between marketing services and export performance of Tanzanian MSHEs (Table 8).

**Table 8.** Summary of hypothesis

Hypothesis	$\beta$	Standard error	T statistic	P-value	Conclusion	Empirical result
$H_A$ : Home market export incentives moderates the relationship between marketing services and export performance of Tanzanian MSHEs	-0.038	0.015	-2.557	0.011	Significant	Accepted

## 5 Conclusion

MSHEs accessing export incentives and exceptional marketing resources in way of product development strategies, collective marketing, promotion (i.e. trade fair and exhibitions) are more likely to perform better in export markets. It was also observed that export incentives in the form of zero-VAT and duty drawback schemes are still a challenge to many exporting MSHEs. It is concluded that the success of exporting MSHEs is attained through adoption of proper marketing decisions and strategies by owner-managers. MSHE's access to collective marketing ties aiming at production, pricing, promotion and distribution of handicrafts will result into better performance in export markets. It is also concluded that, export incentives moderates the association between marketing services and export performance among MSHEs.

**Practical Implication:** The knowledge contributed by study will inform handicrafts operators that export incentives moderates the link between marketing services and export performance. Thus MSHEs who make effective combination of export incentives such as low-cost credit schemes, Zero VAT rating on exports, export market assistance and duty draw back schemes demonstrate superior performance in export markets.

**Social Implication:** The conclusions drawn from this study will help the government though Tanzania Revenue Authority and policy-makers to review the existing export incentives, harmonise tax policies and programmes in a way that will help MSHEs advance their productivity and performance in export markets. Operators of handicrafts exporting MSEs are also advised to organise dialogues for advocating tax clemency through their respective associations.

**Originality:** The distinctiveness of this study is anchored in the handicrafts export framework for local handicrafts exporters. The study evidently established a critical dependence in terms of access to production and marketing resources like export incentives among handicrafts operators. The study proved that exporting MSHEs are more likely to compete easily in foreign markets if these resources are easily accessible in the home market. This situation confirms the relevance of the Resource Dependence Theory (RDT) in the framework of handicrafts industry.

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# Enhancement of the Complex Trigonometric Nonlinear Crank Mechanism for Energy Scavenging

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**Abstract. Purpose:** This paper numerically investigates the complex trigonometric nonlinear crank energy harvester, with emphasis on optimizing the operating points so as to achieve an efficient harvesting of energy for eventual validation experimentally.

**Design/Methodology/Approach:** The primary goal of this paper is to propose an enhancement procedure for selecting the ideal nonlinear crank mechanism parameters for an experimental investigation that will result in an efficient pre-prototype. Furthermore, using Bifurcation diagrams and Poincaré maps, the effect of the power take-off on the dynamics of the system is presented.

**Findings:** Findings from study show that the trigonometric nonlinear crank energy harvester acts more periodically in the case where power is extracted from it. Increasing the torque leads to an increase in mean power output and that the best energy extractions occur at lower excitation frequencies and lower crank lengths of the mechanism.

**Research Limitation/Implications:** The study presents a theoretical and subsequent numerical analysis of the complex trigonometric nonlinear crank energy harvester. The experimental part of the work, which will study the complex trigonometric nonlinear crank mechanism is relegated for forthcoming research.

**Practical Implication:** The knowledge advanced in this study will enable energy harvesting using the complex nonlinear mechanism. This work gives a working understanding of the behaviour and feasibility of implementing such complex nonlinear mechanism for energy harvesting.

**Social Implication:** The knowledge advanced by this study will help policy-makers in the energy industry to review the existing global and national energy policy which is geared towards alternative energy use for sustainability.

**Originality/Value:** Many mechanical oscillators have been useful in the field of energy harvesting and have been extensively studied in the last three decades. However, there are practical or fundamental vibration principles constraints associated with systems that have been examined to date. To overcome these restraints and thus encompass a wider range of applications, this work examines the complex trigonometric nonlinear crank mechanism.

**Keywords:** Complex · Energy harvester · Take-off torque · Trigonometric nonlinear crank · Power output

## 1 Introduction

Vibration is everywhere and vibration energy harvesting research field deals with developing decentralized generators proficient in transforming vibration energy into beneficial electrical energy (Erturk and Inman 2009). Since the 1990s, there has been an emergence in modern academia of vibration energy harvesting research that relied on using directly excited linear oscillators (Antaki et al. 1995; Umeda et al. 1997; Meninger 1999). It was observed in the early research periods that these linear oscillators can be tweaked to target either broadening frequency bandwidth or maximizing power output but both cannot be enhanced simultaneously.

To solve the issue of significant barriers of narrow operational frequency bandwidth and insufficient power density, a vast number of techniques have been proposed, including a plethora of uncoupled or coupled oscillators over numerous frequencies, mechanism of frequency tuning through mechanical or electrical means, and several nonlinear vibratory phenomena for vibration energy harvesting (Tang et al. 2010; Zhu et al. 2010). The above-mentioned techniques were aimed at enhancing power peak, broadening of frequency bandwidth, tuning frequency bandwidth and enhancing responsiveness to broadband noise excitation. Nonetheless, not all nonlinear mechanisms have totally been effective in accomplishing these goals due to practical or fundamental vibration principles constraints.

Daqaq et al. (2009), Stabler (2010), Daqaq and Bode (2011) and Jia et al. (2014) investigated parametrically excited systems for energy harvesting and it was observed that these systems provide broader bandwidth and greater power as compared to their linear counterparts and that the bandwidth and power can upsurge at the same time as with lower damping. However, there are the problems of design and simulation complexity, complexities to assemble and tune to match internal frequency and complex impedance matching are all required.

Another nonlinear system investigated for energy harvesting is the stochastic resonance of which the bistable system is an example. This is a vibrational phenomenon in which an excitation normally considered too little to produce a significant result tend to become impactful when noise is added (Ando and Graziani 2000; Droogendijk et al. 2013; Zhang et al. 2014; Zheng et al. 2014). The studies showed that broadband noise could be utilized amongst the mechanisms to produce power and that the system fits both high- and low-frequency vibration sources. However, there is still the problem of complexity of design and simulation, and that it is not simple to design a system that will inherently match the system-specific Kramers' rate and application within its system parameters, is far from simple. In addition, a clear sinusoidal signal, which must be matched, is still required.

Work in the area of complex trigonometric nonlinear oscillatory mechanism within vibration energy harvesting field is still very scarce and studies are necessary to assess the feasibility and behaviour of employing such complex nonlinear mechanism for energy harvesting. This has led to the introduction of this work with the focus of addressing the above-mentioned problems using the complex trigonometric nonlinear crank mechanism. The complex trigonometric nonlinear crank energy harvester is numerically investigated in this paper, with a precise emphasis on optimizing the operating points so as to obtain an efficient energy harvesting for eventual validation experimentally.

## 2 Model of the Geometrically Nonlinear Crank

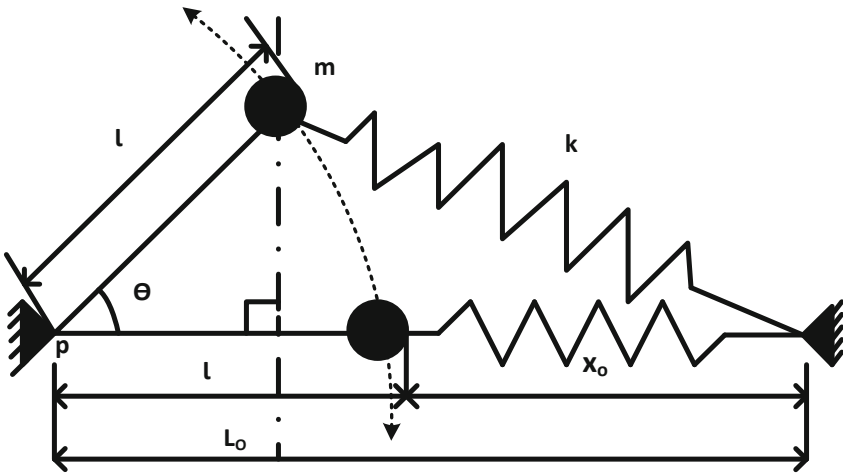


Fig. 1. Graphical depiction of nonlinear crank mechanism (after Akuro and Collins 2019)

Consider a geometrically nonlinear crank with a mass  $m$ , length  $l$  and a linear elastic spring with stiffness  $k$ , as shown in Fig. 1. In the coplanar position, the spring free length is  $x_0$  and the Lagrangian approach is used to obtain the vibratory equation of motion of the mechanism. Following the approach of Akuro et al. (2019), the mass’s linear displacement is taken as  $s = l\theta$ , with a linear velocity  $v = l\dot{\theta}$ . As a result, the potential and kinetic energies are described as follows:

$$T = \frac{1}{2}mv^2 = \frac{1}{2}ml^2\dot{\theta}^2 \tag{1}$$

$$V = \frac{1}{2}kx^2 = \frac{1}{2}k \left[ \left( L_0^2 + l^2 - 2lL_0 \cos \theta \right)^{1/2} - x_0 \right]^2 \tag{2}$$

where  $x_0$  denotes the extension of the spring caused by the crank’s angular displacement and  $L_0 = l + x_0$ . The Lagrangian thus becomes

$$L = T - V = \frac{1}{2}ml^2\dot{\theta}^2 - \frac{1}{2}kx^2 = \frac{1}{2}k \left[ \left( L_0^2 + l^2 - 2lL_0 \cos \theta \right)^{1/2} - x_0 \right]^2 \tag{3}$$

The vibration model is derived from the Lagrange equation stated as:

$$\frac{d}{dt} \left( \frac{\partial L}{\partial \dot{\theta}} \right) - \frac{\partial L}{\partial \theta} = 0 \tag{4}$$

The nonlinear crank vibration model was derived by combining Eqs. (3) and (4) and upon simplifying becomes:

$$\ddot{\theta} + \frac{kL_0 \left[ (L_0^2 + l^2 - 2lL_0 \cos \theta)^{1/2} - x_0 \right]}{ml \left[ (L_0^2 + l^2 - 2lL_0 \cos \theta)^{1/2} \right]} \sin \theta = 0 \tag{5}$$

Let  $\frac{k}{m} = \Omega^2$ ,  $\frac{l}{L_0} = r < 1$  and using the Maclaurin series for  $\sin \theta$  and  $\cos \theta$  and truncating each of the series after  $O(\theta^2)$  and substituting them into Eq. (5) leads to

$$\begin{aligned} \ddot{\theta} + \frac{\Omega^2 \left[ (1 + r^2 - 2r + r\theta^2)^{1/2} + r - 1 \right]}{r \left[ (1 + r^2 - 2r + r\theta^2)^{1/2} \right]} \\ \theta - \frac{\Omega^2 \left[ (1 + r^2 - 2r + r\theta^2)^{1/2} + r - 1 \right]}{6r \left[ (1 + r^2 - 2r + r\theta^2)^{1/2} \right]} \theta^3 = 0 \end{aligned} \tag{6}$$

Equation (6) is an odd complex trigonometric nonlinear Hamiltonian equation describing the geometrically nonlinear crank system that is a function of  $\Omega$  and  $r$ . The constant parameter  $\Omega$  encapsulates the physical properties of the system while  $r$  is a geometric constant with no dimension. Equation (6) is also a prove that the geometrically nonlinear crank exhibits a strong nonlinearity for amplitude vibrations. To make the equation physically descriptive, a classical linear viscous damping term is placed into Eq. (6). Also, to allow for system’s conversion, we add a power take-off term in the angular direction of  $\theta$  to Eq. (6) to make scavenging of energy from the system possible (see Eq. (7)). This term refers to a load torque that turns off and on depending on the sign of the velocity of motion of the mass. A detailed discussion of the power take-off term is done in Subject. 2.1.

**2.1 Power Take-off Term and Its Functionality**

$$\ddot{\theta} + 2\xi\omega\dot{\theta} + \frac{\Omega^2}{r} \left( \frac{B+r-1}{B} \right) \theta - \frac{\Omega^2}{r} \left( \frac{B+r-1}{6B} \right) \theta^3 = Q_\theta \tag{7}$$

Where,  $B = (1 + r^2 - 2r + r\theta^2)^{1/2}$  and  $Q_\theta$  is a term used to represent an external torque and it is assumed to be the resistive load applied by the power take-off. Care must be taken to ensure that the externally applied torque is practical and achievable in practice. It is assumed that  $Q_\theta$  contains both static and time dependent elements such that  $Q_\theta = \Gamma_0 + \Gamma_1(t)$ . Thus,

$$Q_\theta = \frac{\Gamma_0}{ml^2} + \frac{\Gamma_1(t)}{ml^2} \tag{8}$$

The  $ml^2$  is to ensure that the inertial terms in Eqs. (6) and (7) are appropriately torques also. By the approach of Watt and Cartmell (1994) and McRobb (2014),  $\Gamma_1$  is set to be  $\Gamma_1 = -\frac{2\Gamma_0}{\pi} \sin(\Omega_T t + \psi)$  where we introduce a phase angle  $\psi$  and an oscillating load function with frequency  $\Omega_T$ . The amplitude of the square wave dc offset is halved in a way that the dc offset equals  $\Gamma_0/2$ , thereby making the approximating sinusoidal fit exactly together leading to

$$Q_\theta = \frac{1}{ml^2} \left[ \frac{\Gamma_0}{2} + \frac{2\Gamma_0}{\pi} \sin(\Omega_T t + \psi) \right] \tag{9}$$

Noting that  $\psi$  should be equal to 0 or  $\pi/2$  Substituting the loaded torque terms of Eq. (9) into Eq. (7) results in

$$\begin{aligned} \ddot{\theta} + 2\xi\omega\dot{\theta} + \frac{\Omega^2}{r} \left( \frac{B+r-1}{B} \right) \theta - \frac{\Omega^2}{r} \left( \frac{B+r-1}{6B} \right) \theta^3 \\ = \frac{1}{ml^2} \left[ \frac{\Gamma_0}{2} + \frac{2\Gamma_0}{\pi} \sin(\Omega_T t + \psi) \right] \end{aligned} \tag{10}$$

The loading terms on the right-hand side of Eq. (10) are proposed to mimic a half cycle positive power take-off stroke for the mass  $m$  in Fig. 1, progressed by a recovery half cycle stroke as follows:

$$\begin{aligned} f(\dot{\theta}) &= \Gamma_0 \text{ for } \dot{\theta}(t) > 0 \\ f(\dot{\theta}) &= 0 \text{ for } \dot{\theta}(t) \leq 0 \end{aligned} \tag{11}$$

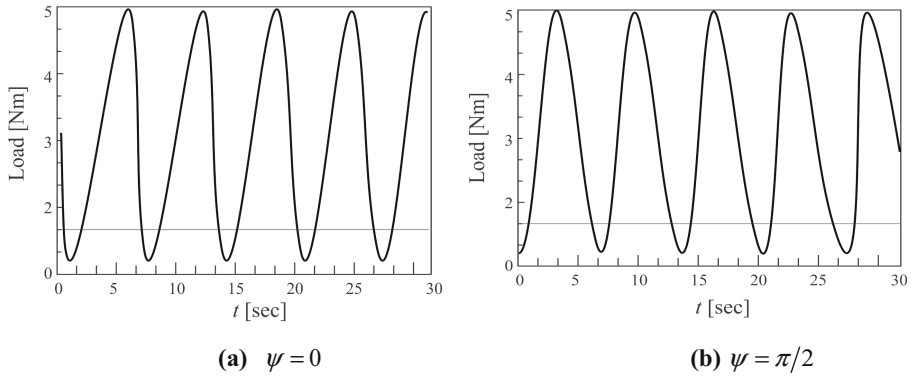
Equation (11) is to enable the power take-off to load the complex trigonometric nonlinear crank system every half cycle, identical to the approach used in the models of Watt and Cartmell (1994) and McRobb (2014). A simulation shown in Fig. 2 endorses the sinusoidal behaviour of the loaded torque terms,  $\left[ \frac{\Gamma_0}{2} + \frac{2\Gamma_0}{\pi} \sin(\Omega_T t + \psi) \right]$ , for arbitrarily chosen  $\Gamma_0 = 5 \text{ Nm}$  and  $\Omega_T = 1 \text{ rad/s}$  with  $\psi$  being 0 and  $\pi/2$  for  $0 \geq t \leq 30 \text{ s}$ .

### 3 Numerical Results

In this section, we examine the numerical results of the complex trigonometric nonlinear system depicted in Eq. (10). The following are parameters used for the numerical calculations, if not indicated otherwise,  $m = 1 \text{ kg}$ ,  $g = 9.81 \text{ m/s}^2$ ,  $k = 1.0 \text{ N/m}$ ,  $x_0 = 1 \text{ m}$ ,  $r = 0.5$ ,  $L_0 = 2 \text{ m}$ ,  $l = 1 \text{ m}$ ,  $\Omega = 1 \text{ rad/s}$ ,  $\Omega_T = 1 \text{ rad/s}$ ,  $\Gamma_0 = 5 \text{ Nm}$ ,  $\psi = \pi/2$  and  $0 \geq t \leq 30 \text{ s}$ .

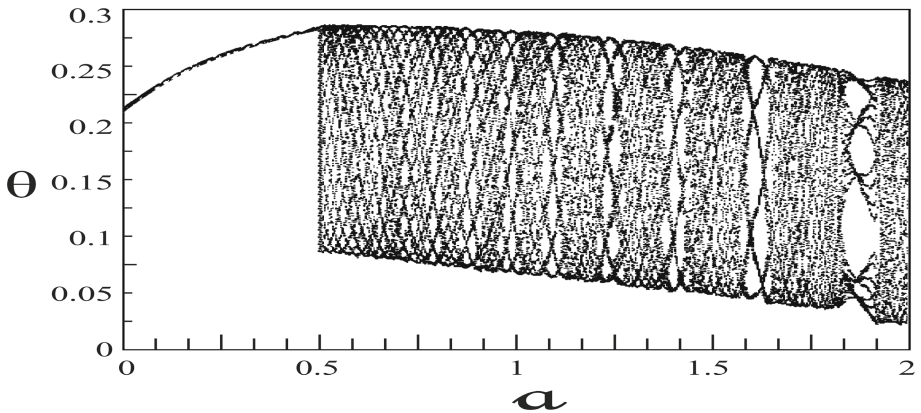
#### 3.1 Bifurcation Diagrams and Poincaré Plots

To enhance the power output, a suitable torque must be chosen in a way that an optimal operating point is realized by the appropriate deflection. As a result, the bifurcation plots for the angular displacement  $\theta$  are considered to provide a good understanding of the system’s dynamics. This is done with and without a power take-off and then with a



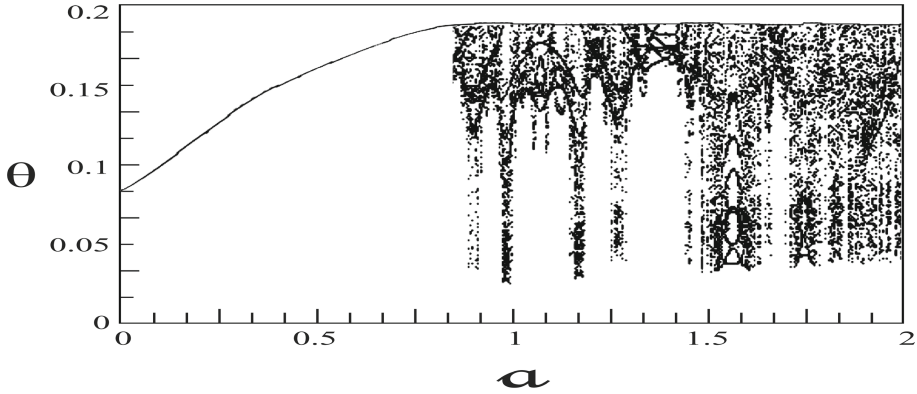
**Fig. 2.** Loading character traits for simulating an approximated (on/off) wave torque with dc offset.

power take-off. In Fig. 3, the bifurcation of the angular displacement  $\theta$  is charted as a function of the excitation amplitude  $a$  without the power take-off. A stable region exists within the bifurcation diagram beginning from  $a = 0$  to  $a = 0.5$  after, which follows what looks like unstable and chaotic behaviours with the highest angular displacement figure of  $\theta = 0.285$  at  $a = 0.5$ . Figure 4 depicts the bifurcation diagram and also shows the excitation amplitude  $a$  with a power take-off torque. In this figure, the stable region extends beyond the  $a = 0.5$  point to  $a = 0.83$  after, which exits different types of quasi and unstable behaviours that are quite different from what is observed in Fig. 3. However, bifurcation do still exist but are generally more controlled with a smaller number of limit cycles. We also expect the angular displacement,  $\theta$  to decrease with a corresponding increase in power take-off, as this directly signify an increase in damping. This this may lead to a considerable decrease in system’s motion as expected.

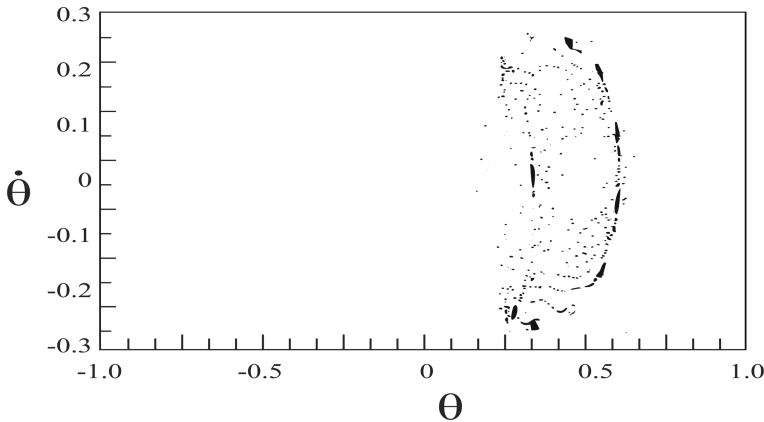


**Fig. 3.** Bifurcation plot for the angular displacement  $\theta$  and the excitation amplitude  $a$  as control parameter for power take-off torque is off at  $\Gamma_0 = 0$ .

When comparing the bifurcation diagrams with and without power take-off, the initial deflected start point changes from  $a = 0.5$  point to  $a = 0.83$  with a corresponding decrease in angular displacement from  $\theta = 0.285$  to  $\theta = 0.18$ . The periodic zone is extended in Fig. 4 and when the power take-off is activated, the dynamics change dramatically.



**Fig. 4.** Bifurcation plot for the angular displacement  $\theta$  and the excitation amplitude  $a$  as control parameter for power take-off torque is on at  $\Gamma_0 = 5 \text{ Nm}$ .

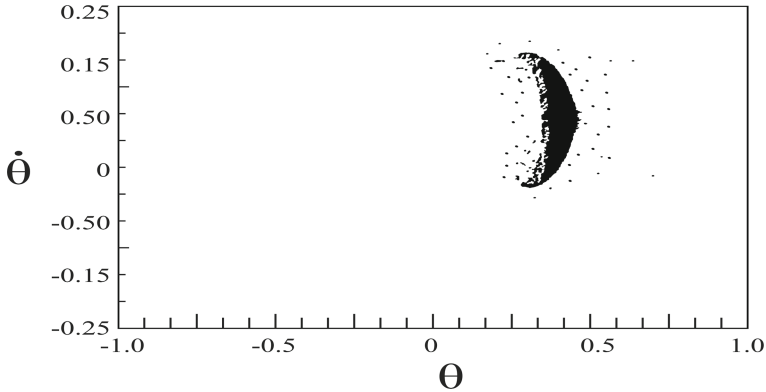


**Fig. 5.** Poincaré map for the acceleration point  $a = 0.6$  of Fig. 3 when the power take-off torque is off at  $\Gamma_0 = 0$  with other parameters defaulted.

Figure 5 depicts the Poincaré map for the acceleration point  $a = 0.6$  of Fig. 3 when the power take-off torque is off while other parameters are defaulted. The map depicts chaotic motion, where more points are added as the simulation advances in a disorderly fashion, detailing the strange structure of the path of the chaotic motion underpinning the behaviour in Fig. 3.



As expected from Fig. 4, the Poincaré map in Fig. 6 changes dramatically after the power take-off is introduced. The map converges to a distinct point at the middle of the darkest region. A period-1 motion is depicted in this case since the map consists of a finite number of points. This confirms that the chaotic dynamics region has become periodic for the same acceleration point  $a = 0.6$  after the power take-off is activated.



**Fig. 6.** Poincaré map for the acceleration point  $a = 0.6$  of Fig. 4 when the power take-off torque is on at  $\Gamma_0 = 5$  Nm with other parameters defaulted.

### 3.2 Power Output

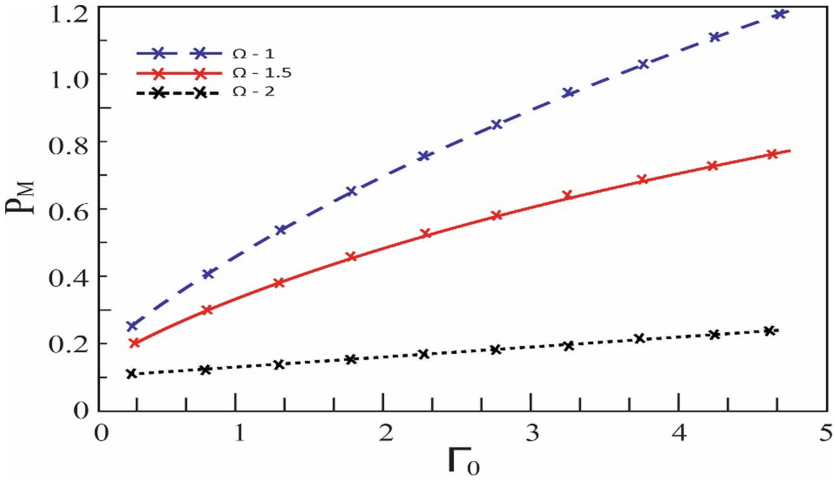
The mean energy output  $P_M$  is a useful quantity for determining an energy harvester’s efficiency and it is investigated for a variation of some parameters of the crank mechanism. The power real power output  $P_0$  measured in Watts is computed using Eq. (10). The part  $5ml^2\Omega^2$  emanates from the right-hand side of Eq. (10) when the oscillating load function phase  $\psi$  is set at zero.

$$P_0 = 5P_M ml^2\Omega^2 \tag{12}$$

As a result, the mean power output is examined in this section for variations in other parameters.

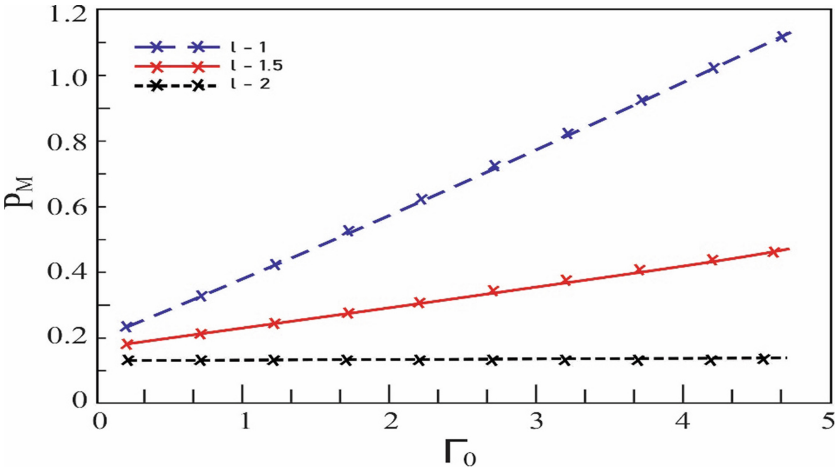
The real power is determined. If this power were to be determined experimentally, a rectifier will be employed either electrically or mechanically. Figure 7 shows the average power output a function of the power take-off torque for various excitation values as the other parameters are left at their default settings. Of the three frequencies compared, the most power is extracted when  $\Omega = 1$  rad/s giving  $P_M = 1.18$ . The lowest output is extracted for  $\Omega = 2$  rad/s and surprisingly, the nature of the graph differs slightly from those for the other two frequencies. It is as well observed that the higher the torque the more the power output. It can be said that this happens in a broad operating area.

In Fig. 8, the mean power output  $P_M$  over the power take-off torque  $\Gamma_0$  for a variety of crank lengths is shown. It can be observed that an increase in the torque diverges the graphs from each other. In general, it can be said from the plots that the lesser the crank



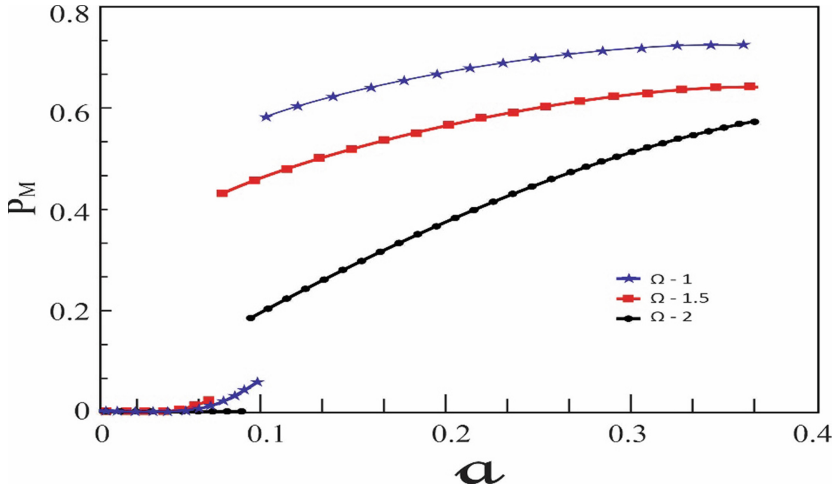
**Fig. 7.** Mean power output  $P_M$  with the power take-off torque  $\Gamma_0$  as control parameter for varying excitation frequencies.

length, the greater the power that can be converted. The most power is achieved for the length of  $l = 1$  m at  $P_M = 1.12$  which is slightly less than that converted for the lowest frequency of  $\Omega = 1$  rad/s in Fig. 7 for the same power take-off torque.



**Fig. 8.** Mean power output  $P_M$  with the power take-off torque  $\Gamma_0$  as control parameter for different crank lengths.

Figure 9 shows the mean power output  $P_M$  plotted as a functions of the excitation amplitude  $a$  for various excitation frequencies. The plot-lines begin at point zero then spread out at a distance from each other but converge as the excitation amplitude increases. The most power can be extracted from the range shown when  $\Omega = 1$  rad/s,



**Fig. 9.** Mean power output  $P_M$  with the excitation amplitude  $a$  as the control parameter for different excitation frequencies.

followed by  $\Omega = 1.5$  rad/s and  $\Omega = 2$  rad/s. In general, the smaller the excitation frequency  $\Omega$ , the more power can be extracted, which is consistent with the observations in Fig. 7.

## 4 Conclusions

The purpose of this paper was to offer a theoretical investigation into a complex trigonometric nonlinear crank energy harvester that has the potential of overcoming the limitations of previous linear and nonlinear vibration harvesters. The second goal was to propose a benchmarking method for selecting the ideal crank mechanism parameters for an experimental program that will result in an optimized pre-prototype.

The dynamic behaviour of the energy harvester proposed in this work was examined using bifurcation diagrams and Poincaré maps. The system was observed to perform more periodically as power is recovered from it. The quantity of power delivered was also investigated through plots of the mean power for different system parameters. These graphs explained the effects the length, excitation frequency and power take-off torque have on the mean power output. It has been observed that, increasing torque leads to an increase in mean power output and that the best energy extractions occur at lower excitation frequencies and lower crank lengths of the mechanism. Furthermore, the results show that the operating ranges are highly dependent on these variables. The experimental side of the complex trigonometric nonlinear crank mechanism will be the focus of future research.

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# Productivity Index of Horizontal Wells from Shut-In Pressure Data in Reservoirs with Partial Pressure Support

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**Abstract. Purpose:** The methods available for calculating productivity index of a horizontal well are performed on premises of steady or pseudo-steady state flow regimes. Many times, the longtime reservoir flow regime is neither in a steady nor pseudo-steady state. The equations developed for predicting the productivity indices under these two states are largely not applicable when the reservoir pressure drops due to limited aquifer or pressure support. A good substitute approach is to use pressure data acquired from the downhole pressure gauge. This work present models that are applicable for the evaluation of reservoir flow behaviors as well as estimate horizontal well producibilities in reservoirs whose flow are neither steady nor pseudo-steady.

**Design/Methodology/Approach:** Historical shut-in pressure data replaced with reservoir boundary pressure are used to calculate the pressure drop arising from a corresponding production rate at any time. A simple ratio of the production rate to the total pressure drop is then used to compute the productivity index. The models were tested with field data and no particular flow regime was assumed.

**Findings:** Findings revealed that the productivity index of a horizontal well is a function of the flow conditions that exist in the reservoir and that the assumption of steady or pseudo-steady state condition for any horizontal well without reason have shown to produce erroneous estimations of productivity indices. Downhole pressure gauges may be sustainable tools as flow behavior of a reservoir inferred from downhole pressure gauges and information obtained from structural maps can produce representative analytical reservoir models to be used for effective well performance monitoring. In addition to accurately identifying the reservoir flow boundary conditions, models presented in this work could predict the direction of the pressure support or water influx.

**Research Limitation/Implications:** Models developed in the study are not limited to reservoirs under steady or pseudo-steady state flow regimes. It however

limits the use of pressure data to those that are obtained using downhole pressure gauges

**Research Limitation/Implications:** Models developed in the study are not limited to reservoirs under steady or pseudo-steady state flow regimes. It however limits the use of pressure data to those that are obtained using downhole pressure gauges

**Practical Implication:** The results from this study will inform academics and industry of a sustainable and simple approach of using shut-in pressure data to accurately estimate productivity indices of horizontal wells including cases where bottom hole flowing pressure data is absent.

**Social Implication:** The knowledge advanced by this study will enlighten academics and industry players on the new methods of identifying reservoir flow regimes and the accurate estimation of productivity indices of horizontal wells including those in reservoirs with partial pressure support.

**Originality/Value:** The approach presented in this work does not involve using any rigorous derivations yet yields reliable results.

**Keywords:** Boundary conditions · Duhamel theorem · Horizontal well · Pressure · Productivity index

## 1 Introduction

The productivity index is a key parameter of any oil and gas well, be it a producing well or an injection well. It is the quantitative measure of a well's potential to produce fluids and functions of reservoir rock and fluid properties including well-completion procedure (Li et al. 2021; Yuan et al. 2021). It is therefore necessary to ensure proper evaluation practices during the planning, drilling, completion and production phases in the life of a well.

Many authors have developed various techniques for evaluating the productivity index of horizontal wells that are in different flow regimes. Babu and Odeh (1988) presented a thorough method for predicting productivity index of horizontal wells. Their work considered a closed system which assumed a pseudo-steady state problem in rectangular coordinates of a plane source by the Green's function's approach. Mutalik et al. (1988) presented a similar solution which incorporated the relationship between the skin factor and the infinite conductivity of the horizontal well as well as a comparison of the length of a well to the extent of the reservoir. Economides et al. (1994) established dimensionless form of the point source pressure solution of unit length in a rectangular box with an impermeable flow boundary. Some interesting steady state solutions are worthy of note. For instance, an early analytical model developed by Borisov (1984) considered a circular reservoir drainage with flow perpendicular to fracture while Giger (1983) considered an elliptical geometry for the same problem. Giger et al. (1984) again presented a theoretical model which gives a criterion for selecting horizontal wells for a particular field application. Joshi's (1988) elliptical flow model acknowledges the eccentricity of the horizontal well from the middle of the drainage area and permeability anisotropy. For a simple derivation of the productivity index Equation based on the drainage area concept refer to Shedid et al. (1996).

However, in the works mentioned above, no consideration was given to the reservoir flow regime, be it steady or pseudo-steady states. It is also worthy of mention that the above-mentioned works did not also consider the producibility of a horizontal well producing from reservoirs under partial pressure support. Also, these methods are often used to evaluate horizontal well performances to various degrees of error especially when the partial pressure support case has not manifested. A search through literature shows that no simple analytical model exists for estimating productivity indices of horizontal wells producing in reservoirs under partial pressure support. This work present models that are applicable for the evaluation of reservoir flow behaviors as well as estimate horizontal well producibilities in reservoirs whose flow are neither steady nor pseudo-steady. The pressure drops due to production at any given time are computed via reservoir boundary pressure data which proxies historic shut-in pressure. The productivity indices were computed for various cases and results compared to the Babu et al. (1988) and Joshi (1988) solutions.

## 2 Mathematical Formulation

Many fluid flow problems in porous media are similar to the heat conduction problems in solids. As such, solutions of temperature distribution of heat conduction are similar to solutions of pressure distribution of porous media in cases where the geometry used to describe the spatial parameters are also similar. This is evident at first glance, when one compares the heat diffusion equation to that of the pressure diffusion equation. This paper employs an analogous temperature distribution solution and Green’s functions for instantaneous plane source solution in a rectangular parallelepiped.

### 2.1 Duhamel’s Theorem Approach

Given the heat equation with constant thermal diffusivity  $\kappa$  as (Amanifard et al. 2007; Badruddin et al. 2020; Carbonell and Whitaker 1984)

$$\left( \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2} - \frac{1}{\kappa} \frac{\partial}{\partial t} \right) T(x, y, z, t) = 0 \tag{1}$$

where  $T(\cdot)$  is the temperature distribution. Carslaw and Jaeger (1959) applied the Duhamel’s theorem to solve Eq. (1) for a rectangular parallelepiped with dimensions  $-a < x < a$ ,  $-b < y < b$  and  $-c < z < c$  with zero initial temperature and surface temperature  $\varphi(t)$ . The solution is given as

$$T(x, y, z, t) = \frac{64}{\pi^3} \sum_{l=0}^{\infty} \sum_{m=0}^{\infty} \sum_{n=0}^{\infty} \frac{\alpha_{l,m,n} (-1)^{l+m+n}}{(2l+1)(2m+1)(2n+1)} \cos \frac{(2l+1)\pi x}{2a} \cos \frac{(2m+1)\pi y}{2b} \\ \times \cos \frac{(2n+1)\pi z}{2c} e^{-\alpha_{l,m,n} t} \int_0^t \varphi(\tau) e^{-\alpha_{l,m,n} \tau} d\tau \tag{2}$$

where  $t$  is time and  $\alpha_{l,m,n}$  is given as

$$\alpha_{l,m,n} = \frac{\kappa\pi^2}{4} \left[ \frac{(2l+1)^2}{a^2} + \frac{(2m+1)^2}{b^2} + \frac{(2n+1)^2}{c^2} \right] \tag{3}$$

For an anisotropic porous media flow, the diffusivity equation is given as (Ahmed 2019, Kazemi and Seth 1969)

$$\left( k_x \frac{\partial^2}{\partial x'^2} + k_y \frac{\partial^2}{\partial y'^2} + k_z \frac{\partial^2}{\partial z'^2} - \frac{\phi\mu c_t}{0.006329} \frac{\partial}{\partial t} \right) p(x', y', z', t) = 0 \tag{4}$$

where  $p(\cdot)$  is the pressure distribution and  $k_x, k_y$  and  $k_z$  are the directional permeabilities in the  $x', y'$  and  $z'$  directions respectively.  $\phi$  is the rock porosity,  $\mu$  is the oil viscosity and  $c_t$  is the total compressibility of the containing fluid and porous media. The factor 0.006329 can be replaced by 11.2709 to convert from field units to S.I. units (Fanchi 2018). Through the transformation  $x = x'k_x^{-1/2}, y = y'k_y^{-1/2}$  and  $z = z'k_z^{-1/2}$ , Eq. (4) can be written as

$$\left( \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2} - \frac{\phi\mu c_t}{0.006329} \frac{\partial}{\partial t} \right) p(x, y, z, t) = 0. \tag{5}$$

Equation (5) is analogous to Eq. (1) and as such the point source solution of the former can be written as

$$p(x, y, z, t) = p_{bd} - \frac{64}{\pi^3} \sum_{l=0}^{\infty} \sum_{m=0}^{\infty} \sum_{n=0}^{\infty} \frac{\alpha_{l,m,n}(-1)^{l+m+n}}{(2l+1)(2m+1)(2n+1)} \cos \frac{(2l+1)\pi x}{2a} \tag{6}$$

$$\times \cos \frac{(2m+1)\pi y}{2b} \cos \frac{(2n+1)\pi z}{2c} e^{-\alpha_{l,m,n}t} \int_0^t \varphi(\tau) e^{-\alpha_{l,m,n}\tau} d\tau$$

where  $p_{bd}$  is the pressure at the boundaries of the reservoir, and

$$\alpha_{l,m,n} = \frac{0.006329\pi^2}{4\phi\mu c_t} \left[ \frac{(2l+1)^2}{a^2} + \frac{(2m+1)^2}{b^2} + \frac{(2n+1)^2}{c^2} \right]. \tag{7}$$

**2.1.1 Case 1**

In this case, we apply Eq. (6) to estimate the productivity index of a horizontal well in a reservoir which experiences no-flow at its North, East and West boundaries. If we consider the dimensions of the reservoir as  $a_H, b_H$  and  $h$ , such that  $a_H = 2a\sqrt{k_x}, b_H = 2b\sqrt{k_y}$  and  $h = 2c\sqrt{k_z}$ , then the pressure due to the source horizontal well with positions  $y_1$  and  $y_2$  inferred from Eq. (6) is given as

$$\Delta p_{wf}(x, y, z, t) = p_s - \frac{0.656b_H}{\pi^4 L} \Lambda_c \tag{8}$$

where  $p_{bd}$  is replaced with the static reservoir pressure,  $p_s$  for practicality,  $L = y_2 - y_1$ , represents the length of the horizontal well and  $\Lambda_c$  is defined as



$$\Lambda_c = \sum_{l=0}^{\infty} \sum_{m=0}^{\infty} \sum_{n=0}^{\infty} \frac{\alpha_{l,m,n}(-1)^{l+m+n}}{(2l+1)(2m+1)^2(2n+1)} \cos \frac{(2l+1)\pi x_w}{2a} \cos \frac{(2n+1)\pi z_w}{2c} e^{-\alpha_{l,m,n}t} \times \left[ \sin \frac{(2m+1)\pi y_2}{2b} - \sin \frac{(2m+1)\pi y_1}{2b} \right] \int_0^t \varphi(\tau) e^{-\alpha_{l,m,n}\tau} d\tau. \tag{9}$$

The total pressure drop in the well is obviously one with inherent pressure drop due to skin damage and can be stated as

$$\Delta p = \Delta p_{wf} + \Delta p_{skin} \tag{10}$$

where the pressure drop due to skin as a function of the skin factor,  $s$  can be estimated as

$$\Delta p_{skin} = \frac{141.2q\mu B}{k_h L} s. \tag{11}$$

$q$  is the oil rate,  $B$  is the formation volume factor and  $k_h = \sqrt{k_x k_y}$ , represents the lateral permeability. The productivity index of a horizontal well in a reservoir which experiences no-flow at its North, East and West boundaries can then be estimated as follows (Jreou 2021, Oaikhena and Oloro 2013);

$$J = \frac{q}{\Delta p_{wf} + \Delta p_{skin}}. \tag{12}$$

**2.1.2 Case 2**

This case considers water movement into the reservoir from the within faults located at the South and West. We also consider a structural positioning bottom of the oil-water contact in order to allow for bottom water movement into the reservoir. In this regard, the no-flow boundaries are set at faces  $x = 0, y = 0$  and  $z = 0$ . The product solution method enables the rewriting of Eq. (6) to define the solution of pressure due to the source for a rectangular parallelepiped with dimensions  $0 < x < a, 0 < y < b$  and  $0 < z < c$  as

$$p(x, y, z, t) = p_{bd} - \frac{128}{\pi^3} \sum_{l=0}^{\infty} \sum_{m=0}^{\infty} \sum_{n=0}^{\infty} \frac{\alpha_{l,m,n}(-1)^{l+m+n}}{(2l+1)(2m+1)(2n+1)} \cos \frac{(2l+1)\pi x}{2a} \times \cos \frac{(2m+1)\pi y}{2b} \cos \frac{(2n+1)\pi z}{2c} e^{-\alpha_{l,m,n}t} \int_0^t \varphi(\tau) e^{-\alpha_{l,m,n}\tau} d\tau. \tag{13}$$

The transformations for the reservoir dimension thus changes to  $a_H = a\sqrt{k_x}, b_H = b\sqrt{k_y}$  and  $h = c\sqrt{k_z}$ . The pressure due to the source horizontal well is given as

$$\Delta p_{wf}(x, y, z, t) = p_s - \frac{1.312b_H}{L} \Lambda_c. \tag{14}$$

Substituting Eqs. (11) and (14) into Eq. (12) produces an expression that estimates the productivity index of a horizontal well in a reservoir with no-flow boundary set in its North, East and top with a bottom water movement.

### 2.2 Green’s Function Approach

This approach estimates the productivity index of a horizontal well using source functions for the instantaneous plane source solutions or Green’s functions (Carslaw et al. 1959, Gringarten and Ramey 1973). Integration of the appropriate point sink functions produces general expressions that can be used to estimate the pressure drop ( $\Delta p_{wf}$ ) at any arbitrary point  $(x, y, z)$  at any time  $t$ . We assume the line sink (horizontal well) is parallelly aligned to the  $y$ -axis and positioned alongside the line  $x = x_w, y_{w1} \leq y \leq y_{w2}$  and  $z = z_w$ . The work also considers three different sets/cases of boundary conditions.

#### 2.2.1 Case 3

A mixed boundary condition is applied in this case. The boundaries of the reservoir to experience no-flow are the East and West flanges, and its top. However, the North and South flanks are mixed boundaries with water movement from the bottom. This case has the solution given as

$$\Delta p_{wf} = p_i - p(x, y, z, t) = \frac{5.615qB}{\phi c_t a b h L} \int_0^t \int_{y_1}^{y_2} G_x G_y G_z dy d\tau \tag{15}$$

where  $G_x, G_y$  and  $G_z$  are the Green’s functions otherwise referred to as the instantaneous point sink functions and defined as

$$G_x = \frac{1}{a} \left[ 1 + 2 \sum_{l=1}^{\infty} e^{-l^2 \pi^2 \eta_x \tau / a^2} \cos \frac{l \pi x_w}{a} \cos \frac{l \pi x}{a} \right] \tag{16}$$

$$G_y = \frac{2}{b} \left[ \sum_{m=1}^{\infty} e^{-(2m+1)^2 \pi^2 \eta_y \tau / 4b^2} \cos \frac{(2m+1)\pi y_w}{b} \cos \frac{(2m+1)\pi y}{b} \right] \tag{17}$$

$$G_z = \frac{2}{h} \left[ \sum_{n=1}^{\infty} e^{-(2n+1)^2 \pi^2 \eta_z \tau / 4h^2} \cos \frac{(2n+1)\pi z_w}{h} \cos \frac{(2n+1)\pi z}{h} \right] \tag{18}$$

These point sink functions are positioned at  $(x, y, z)$  and satisfies the no flow boundary conditions at  $x = 0, y = 0$  and  $z = 0$ .

Substituting Eqs. (16)–(18) into Eq. (15) and performing the integration, we produce an expression to estimate the pressure drop at the horizontal line source well at any location  $(x, y, z)$  within the reservoir at any time  $t$  and given as

$$\Delta p_{wf}(x, y, z, t) = \frac{14.3qB\sqrt{k_y}}{\phi c_t a h L} \left( \Gamma_o(x, y, z, t) + \frac{1}{2} \Gamma_c(x, y, z, t) \right) \tag{19}$$

The functions  $\Gamma_o$  and  $\Gamma_c$  are defined as

$$\Gamma_c(x, y, z, t) = \sum_{l=1}^{\infty} \sum_{m=1}^{\infty} \sum_{n=1}^{\infty} \frac{1 - e^{-\beta_{l,m,n} t}}{\beta_{l,m,n}} \cos^2 \frac{l \pi x_w}{a} \cos \frac{\pi y_w}{b} \cos^2 \frac{(2n+1)\pi z_w}{h} \times \left[ \sin \frac{(2m+1)\pi y_{w2}}{b} - \sin \frac{(2m+1)\pi y_{w1}}{b} \right] \tag{20}$$

$$\Gamma_o(x, y, z, t) = \sum_{m=1}^{\infty} \sum_{n=1}^{\infty} \frac{1 - e^{-\beta_{m,n}t}}{\beta_{m,n}} \cos \frac{\pi y_w}{b} \times \left[ \sin \frac{(2m+1)\pi y_{w2}}{b} - \sin \frac{(2m+1)\pi y_{w1}}{b} \right] \times \cos^2 \frac{(2n+1)\pi z_w}{h} \quad (21)$$

where

$$\beta_{l,m,n} = \frac{0.006329\pi^2}{4\phi\mu c_t} \left[ \frac{4l^2 k_x}{a^2} + \frac{(2m+1)^2 k_y}{b^2} + \frac{(2n+1)^2 k_z}{h^2} \right] \quad (22)$$

$$\beta_{m,n} = \beta_{l,m,n} - \frac{0.006329\pi^2}{4\phi\mu c_t} \frac{4l^2 k_x}{a^2} \quad (23)$$

Substituting Eqs. (11) and (19) into Eq. (12) produces an expression that estimates the productivity index of a horizontal well in a reservoir with no-flow boundaries set at the North, East, West and Top and a bottom water movement.

### 2.2.2 Case 4

The East and North flanks of the reservoir are impermeable to flow in this case. Although the top is restricted as a no-flow boundary, water could move into the reservoir from that face. The Green's functions for the stated boundary condition are given as

$$G_x = \frac{2}{a} \left[ \sum_{l=1}^{\infty} e^{-(2l+1)^2 \pi^2 \eta_x \tau / 4a^2} \cos \frac{(2l+1)\pi x_w}{a} \cos \frac{(2l+1)\pi x}{a} \right] \quad (24)$$

$$G_y = \frac{2}{b} \left[ \sum_{m=1}^{\infty} e^{-(2m+1)^2 \pi^2 \eta_y \tau / 4b^2} \cos \frac{(2m+1)\pi y_w}{b} \cos \frac{(2m+1)\pi y}{b} \right] \quad (25)$$

$$G_z = \frac{2}{h} \left[ \sum_{n=1}^{\infty} e^{-(2n+1)^2 \pi^2 \eta_z \tau / 4h^2} \cos \frac{(2n+1)\pi z_w}{h} \cos \frac{(2n+1)\pi z}{h} \right] \quad (26)$$

Substituting Eqs. (24)–(26) into Eq. (15) and performing the integration produces an expression to estimate the pressure drop at any point  $(x, y, z)$  within the reservoir at any time  $t$ . The pressure drop at the horizontal well is given as

$$\Delta p_{wf}(x, y, z, t) = \frac{14.3qB\sqrt{k_y}}{\phi c_t a h L} \Theta_c(x, y, z, t) \quad (27)$$

The function  $\Theta_c$  is defined as

$$\Theta_c = \sum_{l=1}^{\infty} \sum_{m=1}^{\infty} \sum_{n=1}^{\infty} \frac{1 - e^{-\gamma_{l,m,n}t}}{\gamma_{l,m,n}} \cos^2 \frac{(2l+1)\pi x_w}{a} \cos \frac{\pi y_w}{b} \cos^2 \frac{(2n+1)\pi z_w}{h} \times \left[ \sin \frac{(2m+1)\pi y_{w2}}{b} - \sin \frac{(2m+1)\pi y_{w1}}{b} \right] \quad (28)$$

where

$$\gamma_{l,m,n} = \frac{0.006329\pi^2}{4\phi\mu c_t} \left[ \frac{(2l+1)^2 k_x}{a^2} + \frac{(2m+1)^2 k_y}{b^2} + \frac{(2n+1)^2 k_z}{h^2} \right] \tag{29}$$

Substituting Eqs. (11) and (27) into Eq. (12) produces an expression that can be used to estimate the productivity index of a horizontal well in a reservoir with its boundaries as considered in the case of this section.

**2.2.3 Case 5**

The mixed boundary conditions for this case are such that, the reservoir experiences no-flow from the East, North and West flanks. The reservoir’s top and bottom faces are also bounded to flow and water floods the reservoir only from the South. This case conditions have its Green’s functions given as

$$G_x = \frac{1}{a} \left[ 1 + 2 \sum_{l=1}^{\infty} e^{-l^2\pi^2\eta_x\tau/a^2} \cos \frac{l\pi x_w}{a} \cos \frac{l\pi x}{a} \right] \tag{30}$$

$$G_y = \frac{2}{b} \left[ \sum_{m=1}^{\infty} e^{-(2m+1)^2\pi^2\eta_y\tau/4b^2} \cos \frac{(2m+1)\pi y_w}{b} \cos \frac{(2m+1)\pi y}{b} \right] \tag{31}$$

$$G_z = \frac{1}{h} \left[ 1 + 2 \sum_{n=1}^{\infty} e^{-n^2\pi^2\eta_z\tau/h^2} \cos \frac{n\pi z_w}{h} \cos \frac{n\pi z}{h} \right] \tag{32}$$

Substituting Eqs. (30)–(32) into Eq. (15) and performing the integration produces an expression to estimate the pressure drop at any time and point within the reservoir. The pressure drop is expressed as

$$\Delta p_{wf}(x, y, z, t) = \frac{14.3qB\sqrt{k_y}}{\phi c_t a h L} \left( \frac{1}{4} \Omega_M(y, t) + \frac{1}{2} \Omega_L(x, y, t) + \frac{1}{2} \Omega_o(y, z, t) + \Omega_c(x, y, z, t) \right) \tag{33}$$

The functions  $\Omega_M$ ,  $\Omega_L$ ,  $\Omega_o$  and  $\Omega_c$  are defined as

$$\begin{aligned} \Omega_c(x, y, z, t) = & \sum_{l=1}^{\infty} \sum_{m=1}^{\infty} \sum_{n=1}^{\infty} \frac{1 - e^{-\delta_{l,m,n}t}}{\delta_{l,m,n}(2m+1)} \cos^2 \frac{l\pi x_w}{a} \cos \frac{(2m+1)\pi y_w}{b} \cos^2 \frac{n\pi z_w}{h} \\ & \times \left[ \sin \frac{(2m+1)\pi y_{w2}}{b} - \sin \frac{(2m+1)\pi y_{w1}}{b} \right] \end{aligned} \tag{34}$$

$$\begin{aligned} \Omega_L(x, y, t) = & \sum_{l=1}^{\infty} \sum_{m=1}^{\infty} \frac{1 - e^{-\delta_{m,n}t}}{\delta_{m,n}(2m+1)} \cos^2 \frac{l\pi x_w}{b} \left[ \sin \frac{(2m+1)\pi y_{w2}}{b} - \sin \frac{(2m+1)\pi y_{w1}}{b} \right] \\ & \times \cos \frac{(2m+1)\pi y_w}{b} \end{aligned} \tag{35}$$

$$\Omega_o(y, z, t) = \sum_{m=1}^{\infty} \sum_{n=1}^{\infty} \frac{1 - e^{-\delta_{m,n}t}}{\delta_{m,n}(2m+1)} \left[ \sin \frac{(2m+1)\pi y_{w2}}{b} - \sin \frac{(2m+1)\pi y_{w1}}{b} \right] \times \cos \frac{(2m+1)\pi y_w}{b} \cos^2 \frac{n\pi z_w}{h} \tag{36}$$

$$\Omega_M(y, t) = \sum_{m=1}^{\infty} \frac{1 - e^{-\delta_m t}}{\delta_m(2m+1)} \cos \frac{(2m+1)\pi y_w}{b} \left[ \sin \frac{(2m+1)\pi y_{w2}}{b} - \sin \frac{(2m+1)\pi y_{w1}}{b} \right] \tag{37}$$

where

$$\delta_{l,m,n} = \frac{0.006329\pi^2}{4\phi\mu c_t} \left[ \frac{4l^2 k_x}{a^2} + \frac{(2m+1)^2 k_y}{b^2} + \frac{4n^2 k_z}{h^2} \right] \tag{38}$$

$$\delta_{m,n} = \frac{0.006329\pi^2}{4\phi\mu c_t} \left[ \frac{(2m+1)^2 k_y}{b^2} + \frac{4n^2 k_z}{h^2} \right] \tag{39}$$

$$\delta_{l,m} = \frac{0.006329\pi^2}{4\phi\mu c_t} \left[ \frac{4l^2 k_x}{a^2} + \frac{(2m+1)^2 k_y}{b^2} \right] \tag{40}$$

$$\delta_m = \frac{0.006329\pi^2}{4\phi\mu c_t} \left[ \frac{(2m+1)^2 k_y}{b^2} \right] \tag{41}$$

It can be noticed that averaging the pressure drop in Eq. (33) does not result in a zero pressure drop, rather some terms are left from which an accurate total drop calculation can be made. The average pressure drop over the total volume is given as

$$\Delta\bar{p}(x, y, z, t) = \frac{1}{abh} \int_0^a \int_0^b \int_0^h \Delta p \, dx dy dz = \frac{3.57qB\sqrt{k_y}}{\phi c_t a h L} \Omega_M(y, t) \tag{42}$$

Hence the total pressure drop experienced by the horizontal well is calculated as

$$\Delta p = \Delta p_{wf} - \Delta\bar{p} + \Delta p_{skin} \tag{43}$$

The productivity index is estimated as

$$J = \frac{q}{\Delta p_{wf} + \Delta p_{skin} - \Delta\bar{p}} \tag{44}$$

### 3 Results and Discussion

#### 3.1 Analysis of Mathematical Models

Referring to Eqs. (8) and (14), it can be observed that the computation of the pressure drop at the wellbore do not require an input of oil rate, as seen in Cases 1 and 2. The decline

rate of the reservoir pressure is manifested as the rate impulse variation. Therefore, the challenges that are associated with the rate variation are eliminated.

Cases three, four and five are applicable to nonvarying oil rates as used by the Babu et al. (1988) and Joshi (1988) methods. Realistically, wells under production, do so under varying rates throughout their lifespan. A practical approach of eliminating challenges associated rate variation is by the use of the average rate. The average rate is simply a ratio of the cumulative rate to production time. Alternatively, a restatement of Eq. (15) via superposition (Chaudhry 2004), can also be used to solve challenges associated with rate variation and this new equation is written as

$$\Delta p = \frac{5.615B}{\phi c_t a h L} \sum_{i=1}^N (q_i - q_{i-1}) \int_0^t \int_{y_1}^{y_2} G_x(t - \tau_{j-1}) G_y(t - \tau_{j-1}) G_z(t - \tau_{j-1}) dy d\tau_j \quad (45)$$

Following Babu et al. (1988), Eqs. (19) and (27) can further be explored for applications in calculating pressure drops. Equation (45) also needs to be validated with field data to study the effect of what an assumption of constant rate has on the prediction of productivity indices. Interestingly, downhole pressure gauges readily give data on bottom hole flowing pressures and as such, the external flow boundary conditions of a reservoir can be ascertained via the pressure derivative of Eq. (45). The actual bottom hole flowing pressure of a horizontal well can be fashioned using the downhole pressure gauge by simply taking the derivative of the original Green’s function for the external flowing boundary conditions as follows,

$$\frac{\partial \Delta p}{\partial t} \int_{y_1}^{y_2} q(t) G_x G_y G_z dy; \quad (46)$$

$$t \frac{\partial \Delta p}{\partial t} \int_{y_1}^{y_2} tq(t) G_x G_y G_z dy \quad (47)$$

### 3.2 Field Application

The wellbore pressure and pressure drop due to skin are computed and used to estimate the productivity index in all five cases. Actual field data obtained from Shell Nigeria are used to validate our model and estimate the above-mentioned productivity index of the horizontal well in all five cases.

Figures 1 and 2 represents the reservoir model for Cases 1 and 2 respectively. In Fig. 1, the reservoir boundaries to flow are located in the North, East and West as compared to Fig. 2, where the North, East and Top of the reservoir are restricted to flow. Figure 3 shows field pressure data recorded for 200 days of production from a horizontal well.

The data show severe near wellbore damage. Curve fitting the pressure data with time, we obtain the function  $\varphi(t)$  given as

$$\varphi(t) = 2854 + 0.000024t^2 - 0.142329t \quad (48)$$

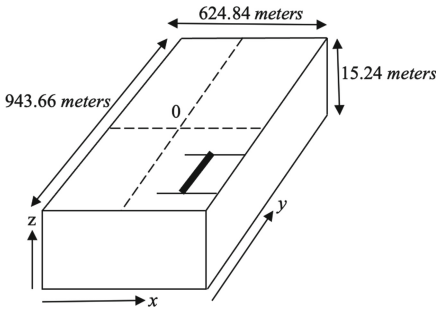


Fig. 1. Model for case 1

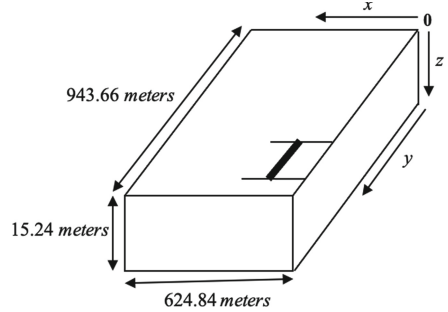


Fig. 2. Model for case 2

The dimensions of the horizontal well are shown in Table 1. Table 3 displays the actual field data used to validate the models and estimate the bottom hole flowing pressures, the pressure drops due to skin and the productivity indices of the horizontal well for the five cases.

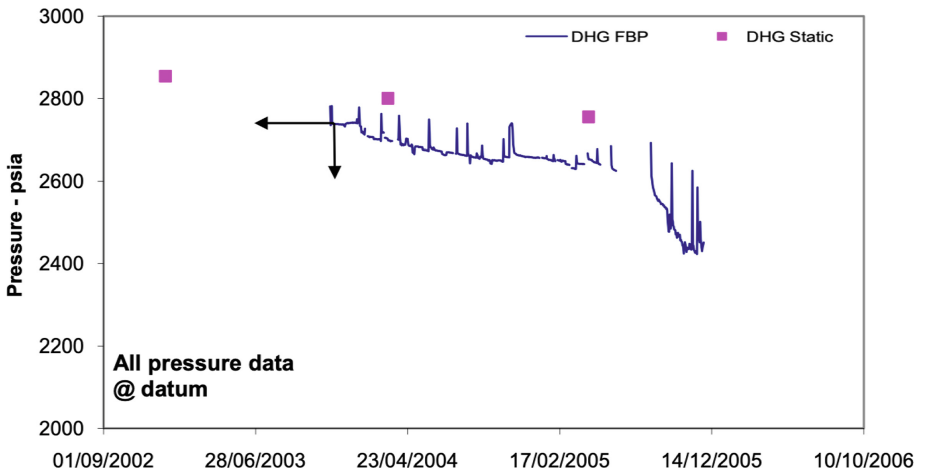


Fig. 3. Downhole pressure gauge data used in estimating  $\varphi(t)$ .

The mechanical skin damage,  $s$ , was varied in order to model the productivity indices. The objective of the variation of  $s$  was simply to include effects of progressive damage. MATLAB was used for the numerical exercise. The results obtained from the estimations are presented in Table 4.

**Table 1.** Well dimensions

Parameters	Value (Field unit)	Value (S.I unit)
<b>Well dimensions for Case 1</b>		
Well coordinate, $x_w$	900 ft	274.32 m
Well coordinate, $z_w$	6 ft	1.83 m
Well coordinates, $[y_1, y_2]$	[1350, 50] ft	[411.48, 15.24] m
<b>Well dimensions for Case 2</b>		
Well coordinate, $x_w$	100 ft	30.48 m
Well coordinate, $z_w$	19 ft	5.79 m
Well coordinates, $[y_1, y_2]$	[1600, 2900] ft	[487.68, 883.92] m

### 3.3 Discussions

The preliminary well test in the horizontal well produced a skin factor of 62 with regards to the actual field data. Thus, models from Case 3 can be considered best for well performance monitoring. Comparing results from the steady state solutions of Joshi (1988) and especially skin factors with the actuals from Table 2, the reservoir fits the description to be modeled as one in the steady state flow regime.

**Table 2.** Summary results from Babu and Odeh (1988) and Joshi (1988) models

Babu et al. (1988)				Joshi (1988)			
s	$\Delta p_{skin} \times 10^2$ (kPa)	$\Delta p_{wf} \times 10$ (kPa)	$J \times 10^{-2}$ ( $m^3/hr/kPa$ )	s	$\Delta p_{skin} \times 10^2$ (kPa)	$\Delta p_{wf} \times 10$ (kPa)	$J \times 10^{-2}$ ( $m^3/hr/kPa$ )
82.5	4.41	7.86	<b>6.03</b>	61	4.81	3.86	<b>6.05</b>
90.1	5.81	9.51	<b>5.60</b>	69	6.32	4.07	<b>5.62</b>
96.2	6.10	9.31	<b>5.30</b>	75	6.60	3.86	<b>5.31</b>

Another similarity can be seen in the results of Cases one, four and five in comparison with the Babu and Odeh (1988) model. Note that the skin factor obtained from preliminary test is lower than the one used for the modeling which elapsed for a year of production. Like the former, the reservoir is almost a closed boundary system and its manifestations can be seen in the results of Case five and the Babu and Odeh (1988) model. Even though cases two and four share similar boundary conditions, the results obtained for the pressure drop at in the horizontal wells are different. This disparity could be explained as one based on the variant mathematical statements of the two models. Models of Cases one and two are mathematically less stable and as such do not converge faster as compared to models produced in Cases three, four and five. Models of Case 3 describes the field’s reservoir accurately in terms of its boundary conditions and best estimates the productivity index of the reservoir. Hence models of Case three are recommended for the field as opposed to the Joshi’s steady state method even though it



produced similar results. The Joshi steady state solutions fail to describe the reservoir flow boundary conditions and thus cannot be the best model to employ for the reservoir at hand. Furthermore, Joshi’s models work well for equivalent horizontal wellbore radius and will accurately predict the productivity indices of horizontal wells should such assumptions be made. Estimations of pressure drops due to skin is done based on the thickness of the formation and the mean horizontal permeability  $\sqrt{k_x k_y}$ . This supposed method will produce a matched skin factor in the neighborhood of 15, a value less than the actual skin factor recorded in the preliminary test. It is therefore conclusive, that Case three singularly describes the reservoir and accurately models actual productivity index of the field’s reservoir.

**Table 3.** Input parameters Summary results of comparison between computed and actual field data

Parameters	Value (Field unit)	Value (S.I unit)
Total compressibility, $c_t$	$2.00 \times 10^{-5} \text{ psi}^{-1}$	$2.9008 \times 10^{-6} \text{ kPa}^{-1}$
Rock porosity, $\phi$	0.3	0.3
Oil viscosity, $\mu$	0.422 cp	0.422 mPa · s
Formation volume factor, $B$	1.38 rb/stb	$1.38 \text{ rm}^3/\text{std.m}^3$
Length of horizontal well, $L$	1300 ft	396.24 m
Formation thickness, $h$	50 ft	15.24 m
Length of reservoir, $a_H$	2050 ft	624.84 m
Reservoir width, $b_H$	3096 ft	943.66 m
Directional permeability, $k_x = k_y$	2500 mD	2500 mD
Directional permeability, $k_z$	60 mD	60 mD
Oil rate, $q$ , at time, $t = [301, 407, 803]$ days	[4746, 5731, 5634] stb/d	[31.44, 37.98, 37.33] m <sup>3</sup> /hr
Initial reservoir pressure, $p_i$	2854 psi	19677.56 kPa
Static reservoir pressure, $p_s$ at $t = [407, 803]$ days	[2800, 2755] psi	[19305.24, 18994.98] kPa
Bottom-hole flowing pressure, $p_{wf}$ at $t = [407, 803]$ days	[2701, 2653] psi	[18622.67, 18291.72] kPa

**Table 4.** Summary results of comparison between computed and actual field data

Time (hr)	Actual		Case 1			Case 2				
	$p_s \times 10^4$ (kPa)	$J \times 10^{-2}$ ( $m^3/hr/kPa$ )	$s$	$\Delta p_{skin} \times 10^2$ (kPa)	$\Delta p_{wf} \times 10$ (kPa)	$J \times 10^{-2}$ ( $m^3/hr/kPa$ )	$s$	$\Delta p_{skin} \times 10^2$ (kPa)	$\Delta p_{wf} \times 10$ (kPa)	$J \times 10^{-2}$ ( $m^3/hr/kPa$ )
7224	1.94	<b>6.05</b>	82	4.39	8.27	<b>6.03</b>	90	4.81	3.86	<b>6.05</b>
9768	1.93	<b>5.61</b>	92	5.94	8.41	<b>5.60</b>	98	6.32	4.07	<b>5.64</b>
19272	1.90	<b>5.30</b>	98	6.09	8.20	<b>5.30</b>	104	6.60	3.86	<b>5.34</b>

$s$	Case 3			Case 4			Case 5				
	$\Delta p_{skin} \times 10^2$ (kPa)	$\Delta p_{wf} \times 10$ (kPa)	$J \times 10^{-2}$ ( $m^3/hr/kPa$ )	$s$	$\Delta p_{skin} \times 10^2$ (kPa)	$\Delta p_{wf} \times 10$ (kPa)	$J \times 10^{-2}$ ( $m^3/hr/kPa$ )	$s$	$\Delta p_{skin} \times 10^2$ (kPa)	$\Delta p_{wf} \times 10$ (kPa)	$J \times 10^{-2}$ ( $m^3/hr/kPa$ )
66	3.53	1.65	<b>6.07</b>	82	4.39	8.07	<b>6.05</b>	76	4.06	11.3	<b>6.06</b>
74	4.78	1.99	<b>5.61</b>	90	5.81	9.79	<b>5.59</b>	84	5.43	13.6	<b>5.60</b>
80	5.07	1.96	<b>5.30</b>	96	6.09	9.58	<b>5.29</b>	90	5.71	13.4	<b>5.29</b>

## 4 Conclusions

This work has modeled and used shut-in pressure data to estimate the productivity index of a horizontal in a reservoir considered to be under partial pressure support. The conclusions from the results are as follows:

- The productivity index of a horizontal well is a function of the flow conditions that exist in the reservoir. Every reservoir has unique flow boundary conditions and must be modeled with such flow conditions. The assumption of steady or pseudo-steady state condition for any horizontal well without reason have shown to produce erroneous estimations of productivity indices.
- Downhole pressure gauges are best when it comes to well performance and reservoir monitoring and are there highly recommended. The flow behavior of a reservoir inferred from downhole pressure gauges and information obtained from structural maps can produce representative analytical reservoir models to be used for effective well performance monitoring.
- In addition to accurately identifying the reservoir flow boundary conditions, models presented in this work could predict the direction of the pressure support or water influx.

**Conflict of Interest.** The authors declare that they have no conflict of interest.

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# Participation of Women Local Political Leaders in Water Services in Tanzania

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**Abstract. Purpose:** This paper develops a basis for women political leaders' participation in improving water services. To achieve this, the paper is guided by objectives; to examine the status of water sources, to examine the strategies used by women political leaders and to examine community members' perceptions on water services in the study councils.

**Methodology:** Descriptive research design was used. A cluster sampling technique was used to obtain 3 wards, 3 villages and 3 *mitaa* (*Mtaa* (in singular) *Mitaa* in (Plural) means a lowest government administrative structure in an urban area in Tanzania which include a number of streets). 390 household heads were drawn from the population and data collected were analyzed and presented in tables.

**Findings:** The findings revealed that, women political leaders influenced decisions affecting the accessibility of water supply. As a result, water sources were improved through different strategies and community members satisfied with the water services provided.

**Research Implications:** The study focused on women political leaders in selected villages/*mitaa* in local government authorities in Tanzania.

**Practical Implication:** The knowledge advanced in this study will inform women political leaders the capacity they have in influencing decisions related to water services in their respective localities.

**Social Implication:** The information generated from the study, will help decision makers and development practitioners to provide more opportunities where women can contest for community development.

**Originality:** The present study lies in gender and development framework on water services. It inform the government and community at large, the capacity women have in influencing decisions for community services.

**Keywords:** Women political leader · Water services · Political participation

## 1 Introduction

Women's involvement in decisions regarding delivery of community services including water services in the society has been recognized by different countries in the world (Were *et al.* 2008; Domingo *et al.* 2015). Globally, there are different measures to improve sustainable development in the community including the involvement of women political

leaders in improving water services (UNDP 2006; Sugden 2015; Holmes *et al.* 2019). However, in Tanzania, there is limited information on the relationship between participation of women leaders in local government structures and the improvement of water services for sustainable development (Brown and Brown 2010). The government of Tanzania has undertaken different initiatives to improve water services provision since independence in 1961, but it has continued to encounter some challenges (Mahoo *et al.* 2015). For example issues of long distance to access the nearby water sources, poor means of transportation from/to the household, tradition water sources and insufficient obtainability of water, and quality of water services is deprived (Masanyiwa 2013). In 1967 the government of Tanzania announced a policy (Arusha Declaration) so as to overcome these challenges. In the implementation of the policy community members worked together, lived and shared the same resources in a unity essence. Additionally, there was a government process of transferring decisions from central government to local government in 1972 (Shivji and Peter 2003). Despite of these efforts, yet community utilities like water were not been in better-quality in Tanzania (Mandara *et al.* 2013). These challenges have been resulting problems to local dwellers including inadequate water services and hazardous drinking water bases which lead to eruption of diseases related to contaminated and eventually lead to health problems to expectants women and children (Mandara *et al.* 2013; Lyoni *et al.* 2017).

The major anxiety of this paper is to look into a gender dimension the participation of women political leaders as a marginalized group in the community through their leadership roles in improving access and quality water services in selected local structures in the country. Specifically the current paper examines the status of water services available, mobilization strategies used by women political leaders and perceptions of citizens on women political leaders in water services in selected local government authorities in Dodoma Region.

## 2 Theoretical Framework

The theories that form the basis of this study include Liberal Feminist and Principal-Agent Theories. In Tanzania there is underrepresentation of women in local politics especially in local government structures. This has resulted the government to introduce quota<sup>1</sup> system to increase the number of women representation in decision-making organs (Meena 2015). Different Theories can describe the participation of women political leaders, but the information collected for this paper hinged on the use of Liberal feminist Theory and Principal- Agent Theory (Tong 2012). This is outstanding to the circumstance that any political appointment/elected heads much better if there is equal representation of voices from men and women in the community sphere for the society's requirements. Principal-Agent Theory was considered applicable due to its assumptions that can investigate and describe the association among women political leaders (agents) and the community members group (principals) in satisfying their management roles. This theory consider women in local politics as 'agents' who were allocated tasks and responsibilities which can be satisfied in their control. Equally, public members were

<sup>1</sup> A lowest government administrative structure in an urban area which include a number of streets in Tanzania.

considered as the 'principals with the purposes of transferring those responsibilities to their legislatures in the decision-making organs. However, the knowledge gap which remained unfilled include: Do women in local politics able in transferring public needs, requests, views and challenges faced by other members in decision-making structures? Or would they air out the needs of their voters and party-political?

### 3 Research Methodology

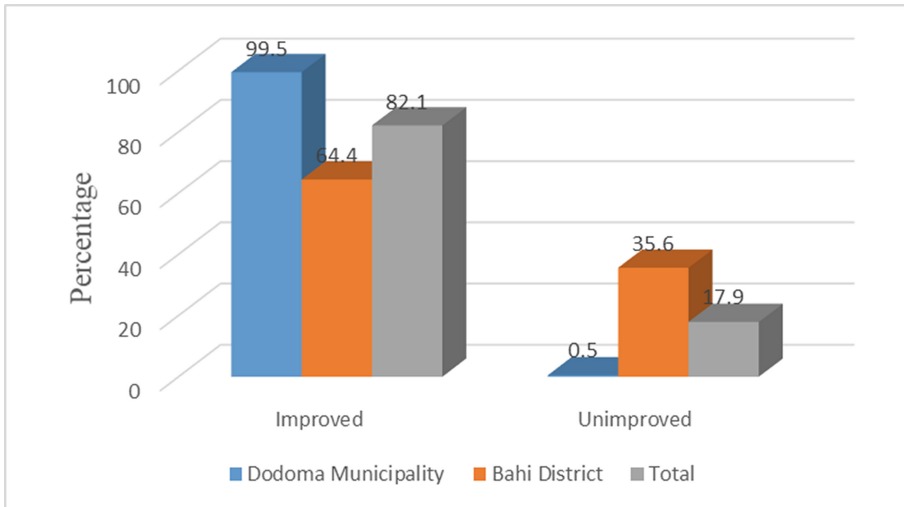
The present study employed a descriptive - cross sectional research design. To obtain the study wards, villages and *Mitaa*, cluster sampling technique was used. In every ward of the study council, 3 villages and 3 *Mitaa* were selected. Systematic sampling technique was used to obtain household heads in the study area (Kothari 2004). A sample of 390 households heads both men and women were selected which included 195 from Dodoma Municipality and 195 from Bahi District. In total, the sample was added by selecting 32 *mitaa*/villages members in the committee, 16 Committee members from the ward, 8 ward councilors (selected 4 from every district council) by using purposive sampling technique. Again from the study Districts council 2 District Commissioners, 2 Executive Directors from the Districts (EDD), 2 council chairpersons, 2 Members of Parliaments and 2 committee chairpersons from water department were selected. Also, six (6) members from the department of water were selected to have a whole sample size to achieve 466 people. Descriptive statistics was used to get frequency counts, tables, percentages and mean. Contrariwise, information collected by using qualitative methods from non-participant observation in-depth interviews, research notes, key informants interviews, Focus group Discussion (FGDs), informal discussions were recorded and were thematically analyzed.

### 4 Findings

The major goal of this paper was to assess the involvement of women in local politics in improving water services in Dodoma Municipality and Bahi District in Tanzania by focusing on the status of water sources available, strategies used by women political leaders and the water user's perception as presented in Figs. 1 and 2 and Tables 1, 2, and 3.

**Research Question One:** What is the status of water sources in the study councils?

Result in Fig. 1 indicate that sources of water in the study area were better (99.5%) in Dodoma Municipality and in Bahi District, more than half (64.4%) of the sources were in the same condition. These discoveries are more than what URT (2013) reported from the national census conducted in 2012 that, more than half (54%) of rural households accessed adequate water supplies and 85% of urban dwellers get water services from the improved sources.



**Fig. 1.** Available water sources (n = 390). Source: Field Data, (2019)

**Table 1.** Condition of water sources (n = 390)

Status of water	Bahi District	Dodoma Municipality	Total	Chi-square values
Local Unprotected well	66(34.0)	1(0.5)	67(17.2)	$\chi^2 = 315.470, df = 6, P = 0.000$
Seasonal water	1(0.5)	0(0.00)	1(0.3)	
Traditional spring	2(1.0)	0(0.0)	2(0.5)	
Improved spring	4(2.1)	0(0.0)	4(2.1)	
Improved well	61(31.4)	0(0.0)	61(15.6)	
Shared community Taps	60(30.9)	25(12.8)	85(21.8)	
In house connections	0(0.0)	138(70.4)	138(35.4)	
Neighborhood Taps	0(0.0)	32(16.3)	32(8.2)	

Field Data (2019) – Percentages (%) are indicated in brackets

The information collected suggests that most of the households surveyed in urban area (Dodoma Municipality) have an access from better sources of water while in rural area (Bahi District) more than half avail water sources which are also protected. The improvement of water services was confirmed from the discussion with one official from Water Department in Dodoma Municipality that women leaders influenced decisions affecting water services more often than men leaders. This means that, women as custodians of children and other members in the household and leaders in the community, managed to influence decisions for water services to be adequately supplied. The



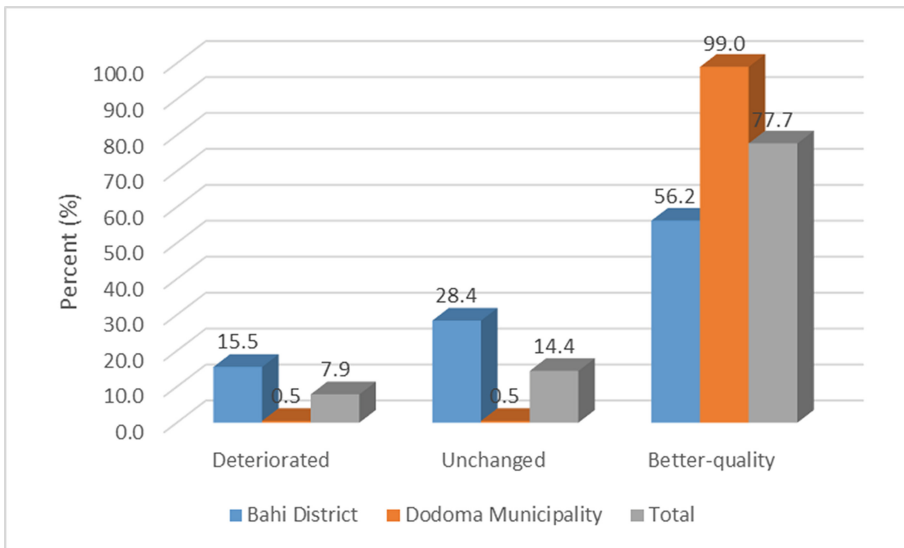
result in Table 1 show that, there was a variation ( $p = 0.000$ ) on water sources situation in the study area. In Bahi District, water sources were local unprotected wells (34.0%), improved wells (31.4%) and shared community taps (30.9%). Compared to Bahi District, in Dodoma Municipality, many water users access community water arrangement and therefore, used in house connections (70.4%) and some accessed from the nearby household' connections (16.3%).

### ***Mobilization' Strategies by Women Leaders for Improved Water Services***

It was revealed in the interview that: *Women local leaders use the forum available to present community opinions, concerns and views in village/Mtaa assembly meetings* (a woman District Executive Director). In a FGD (a man *Mtaa* Committee Member), the findings showed that women political leaders speak loud on issues affecting water services in their respective localities. Likewise, in the discussion with one councilor (a man), reported that women local leaders do seat together for discussing and outlining the issues intend to present in a district full council before time. Furthermore, it was noted that, women used "fair" tone-language to inspire members in the community to involve in voluntary activities whereas men demonstrated relatively "forceful" language. The study also observed that, women political leaders demonstrated as a role model to their followers as they worked together with members in the community. In the interview with district staff in Bahi District explained that, men and women political leaders involved people to participate in water projects in their respective localities. One FGD participant (a woman) showed that, women political leaders used women groups to interact easily with other women in their social groupings (such as women group in the street, women business group, working place group) than men.

### ***Community Members' Perceptions on Access and Quality Water Services***

The result in Table 2 indicated that, members in the surveyed *Mitaa* and villages were satisfied (94.9%) in urban areas (Dodoma Municipality) compared to only 42.8% in rural areas (Bahi District). In respect to the water quality supplied, most of the household heads (97.4%) and more than half (53.1%) had indicated to be satisfied in the study districts (Dodoma Municipality and Bahi District), respectively. In addition, the result indicated variations in the level of satisfaction with water accessibility under the control of women across Dodoma Municipality and Bahi District. It was observed that 97.4% and 49.0% of the surveyed households had indicated to be satisfied in urban area (Dodoma Municipality) and in rural ones (Bahi District). The researcher requested the surveyed household's heads to indicate who contributed to the improved water sources. Different opinion were given including the facilitation of women political leaders in the study *mitaa* and villages (Table 3).



**Fig. 2.** Service users' perception in the improvement of water sources (n = 390)

**Table 2.** Water user' satisfaction level (N = 390)

Variable	Bahi District	Dodoma Municipality	Chi-square values
<i>Access of water</i>			$\chi^2 = 117, df = 2, P = 0.00$
Satisfied	95(49.0)	191(97.4)	
Neither satisfied	60(30.9)	4(2.0)	
Dissatisfied	39(20.1)	1(0.5)	
<i>Quality of water</i>			$\chi^2 = 103.394, df = 2, P = 0.00$
Satisfied	103(53.1)	191(97.4)	
Neither satisfied	48(24.7)	3(1.5)	
Dissatisfied	43(22.2)	2(1.0)	
<i>Source of water</i>			$\chi^2 = 123.7, df = 2, P = 0.00$
Satisfied	83(42.8)	186(94.9)	
Neither satisfied	72(37.1)	6(3.1)	
Dissatisfied	39(20.1)	4(2.0)	

Field Data (2019) - Percentages (%) are indicated in brackets

**Table 3.** Contribution of different groups in water services in the study area (n = 390)

Facilitator	Bahi District	Dodoma Municipality	Total (%)	Values of Chi-square
Commissioner of the District	31(16.0)	132(67.3)	83.3	$\chi^2 = 109.049$ df = 2 P = 0.000
Members of <i>mtaa</i> /Village committee	65(33.5)	90(45.9)	79.4	
Ward Councilors	6(3.1)	13(6.6)	9.7	
Development project/NGOs	25(12.9)	2(1.0)	13.9	
Public creativities	88(45.4)	26(13.3)	58.7	
No contribution	38(19.6)	5(2.6)	22.2	
Others*	29(14.9)	11(5.6)	20.5	

*Field Data (2019) - Percentages (%) are indicated in brackets.*

**Others\*** comprise groups of Youth and Women in the study area.

## 5 Discussion of Findings

The findings showed that women political leaders in the study councils had the capacity to influence decisions for the improvement of water sources (Fig. 1). This is similar to what Feijoo and Fürst (2021) opined that because of gender roles of women in cooking, cleaning and child care activities, women have a great role to ensure adequate supplies of water services. Furthermore, Jalal (2014) exemplified this by arguing that, in developing countries, water services is women's business which is inseparable from the daily households responsibilities and office duties. More emphasis by Insights (2015) reported that in countries like Bangladesh, Mozambique and Tanzania half of the members of water user groups are women who influence decisions than men groups.

The findings further showed a significant variation ( $p = 0.000$ ) on the water services supplied in the study districts. Most of the surveyed households reported to had accessed water through in house water connections and some through their nearby houses and community standing taps in Dodoma Municipality. Whereas in Bahi District majority of the households water sources were local unprotected wells, improved wells and community standing taps. This indicates that, in fulfilling household responsibilities by women in rural areas is a great challenge compared to those in urban areas. This is because sustainability of rural water infrastructures are not reliable (Rautanen and Koppen 2014) due to technical and financial resources constraints (Moriarty *et al.* 2013). By considering the gender roles of women in the society as care takers and managers of the family welfare and local leaders in the community, have the opportunity to influence decisions for water services to be adequately supplied. As such, this responsibility of women consider them as main users and managers of water sources (Geere 2017) and thus are more likely to be involved in water management activities (Hablemitoglu 2010).

The analysis of the research question two observed that women political leaders had different approaches in mobilizing community members to participate into water management activities. Also the analysis revealed that women use public premises such as village/*mitaa* assembly meetings to deliver community needs and demands for decisions. The experience was similar to what Khandker *et al.* (2020) observed in Bihar State in India that, women leaders raised voices in meetings on issues that affect water services. It was also observed that, women used “fair” tone-language to inspire members in community but men reported to use “forceful” language. Since most of the community activities are voluntarily, have no incentives, the style of leadership used by women encouraged members in the community to participate in community water activities willingly. As Snaebjornsson and Edvardsson (2013) commented that, leadership style of men and women are different in terms of behavior and characteristics. It was in this ways women leaders managed to motivate more members in the community to participate in community activities for better management of community water supplies (Pond and Pedley 2011).

In examining the community perceptions in research question three, the researcher requested water users in the surveyed villages and *Mitaa* to analyze the condition of water sources for the past two tenures of women leadership. The findings in Fig. 2, showed that most of the respondents indicated that water sources had improved (77.7%), 14.4% reported no changes and 7.9% indicated that had deteriorated. Chi-square test results showed significant variation ( $p = 0.000$ ) on service users’ perceptions between the two districts. Whereas nearly two thirds (64.0%) of service users in Dodoma Municipality reported water services to have had improved, this suggests that, because of the gender roles of women in the society, compel them to influence decisions for water services to be adequately supplied. This is similar to what, Fauconnier *et al.* (n.d.) found that women are the great beneficiaries of water resources, hence should demonstrate their leadership power to influence decisions for such water services to be provided.

The researcher analyzed who facilitated the improvement of water services in the study councils and different opinions were given. Majority of the surveyed household heads reported that, Commissioners of the Districts (83.3%), *mtaa*/village committee members (79.4%), public creativities (58.7%) and Development projects/NGOs (13.9%) were part of the improvement of water services. Across the two study districts, test of the Chi-Square showed a variation ( $p = 0.00$ ) of the facilitation. In the surveyed *Mitaa*, in Dodoma Municipality, respondents indicated that, commissioners of the district facilitated the improvements (67.3%) then followed by members of the *mtaa* committee (45.9%). Whereas, public creativities (45.4%) council members of the village (33.5%) were mentioned to contribute to the improvement of water services in Bahi District. Since main sources of water in Bahi District are owned by the citizens, public creativities is a great tool to facilitate water management at different stages. Community members in the society are supposed to be part of the decisions regarding water services provided in their localities as a result can participate voluntarily in water activities. Because the major goal of this paper was to examine the participation of women political leaders in water services, the finding suggests that, women leaders have the capacity to facilitate the improvement.

## 6 Conclusion and Recommendations

It is concluded from the research question one that, majority of respondents use improved water sources in Dodoma Municipality and some in Bahi District use unimproved water sources. It is therefore recommended that The Ministry responsible to elect and appoint women should provide more opportunities so that women can contest to hold local leadership. By using quota system the number of women representation will increase and ensure gender equality in local decision- making structures. It is further concluded that mobilization strategies is a tool for community members to participate in community activities voluntarily for improvement of water services in the study areas. For example women strategies enhanced a democratic way for community members to participate into community activities in the study area. It is therefore recommended that women have the capacity of enhancing community engagement through their convincing power, social organizations although few of them are given opportunities as local leaders. The study further conclude that, water service users' satisfied with water supplied in terms of accessibility and quality. It is therefore recommended that the government should formulate policies that will promote equal participation of men and women in development programmes so as to enhance water services provision in terms of gender. This can only be achieved through participation of women and men leaders in decisions affecting the welfare of the community.

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# Impact of Rainfall on the Flood Menace of the Federal Capital Territory of Nigeria

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**Abstract.** Flood is one of the most common disasters in Nigeria and has become a challenge in the Federal Capital Territory, Abuja; cases of flood menace have had a tremendous effect on the socio-economic life of the people within the territory. One of the intentions that preceded the creation of the Federal Capital Territory was that the new city would be designed and constructed in a way that problems would not arise about city planning in the future and little will be heard about flood disasters. In the master plan of the new city, provisions were made for “green development” to boost environmental conservation and add to the aesthetic value of the capital. Rainfall is found to be correlated with flooding. This research is an attempt to scientifically investigate if the amount of rainfall in the FCT is the main course of all these incidences of flooding in the FCT. Rainfall and runoff data of the area of Interest covering 34 years was extracted from Satellite Imagery and was used to study the pattern and Intensity of rainfall in the FCT in general. Graphical analyses were conducted, using Microsoft excel package and SPSS version 20 for all the statistical analysis on rainfall variability map/graphs/tables. Decrease in rainfall amount, rainfall intensity and rainfall distribution over watersheds among others are known to affect runoff in an area. Buildings constructed across the narrow floodplain, inadequate drainage facility, land sealing, a pattern of the drainage network, vegetation, basin shape and drainage area were some of the other factors responsible for the flood menace in FCT. The need to sensitize the people of the FCT on Disaster Risk Reduction was recommended.

**Keywords:** Flood disasters · Flood menace · Nigeria · Rainfall · Sustainability

## 1 Introduction

Flooding is a global phenomenon and it is among the oldest, most recurring, devastating and known natural hazards for ages. Various types are impacting upon human lives and causing severe damage and disruption throughout the world (Ishaya et al. 2009; Abhas et al., 2012; Ojigi et al., 2013; Aderoju et al., 2014.a; Qi, et al., 2014; Tanvir, 2015). In a study, it was discovered that about 196 million people in more than 90 countries are exposed to catastrophic flooding, and that some 170,000 deaths were associated

with floods worldwide between 1980 and 2000 (Karki, 2011). Adriana et al. (2015) in a research opined that, for over thirty years, floods worldwide killed more than 500,000 people and displaced over 650,000,000 people. With a compilation of the worst flooding events across the world, the prediction of more rainfall by experts, most cities of the world are currently battling with the stark reality of flood and the fear is that the worst is just in front of us (Strange Sounds, 2016). Flood was described as an incidence that normally occurs when more rain falls than the soil and vegetation can absorb (Aladelokun and Ajayi, 2014). Such heavy rains periodically cause rivers or streams to overflow their banks spilling onto the surrounding floodplains. In most instances, although flooding carries a negative connotation, it is a natural process. This is so because it is simply the response of a natural system (a river system) to the presence of too much water during an interval of time, and not finding a place to drain away the overflow water thereby causing floods. What this connotes is that flooding can be caused by heavy rains, melting snow and ice, and frequent storms within short time duration. The end result is that, the floods become a cause for serious concern when they exceed the coping capacities of affected communities, damaging lives and property (Khurshid et al., 2008; Ishaya et al., 2009; Karki, 2011; Abhas et al., 2012). In recent times, economic losses due to natural hazards such as, flood disasters have increased in folds and have also resulted in major loss of human lives and livelihoods, the destruction of economic and social infrastructure, as well as environmental damages (Aderoju et al., 2014b; John-Nwagwu et al., 2014).

Flooding is also one of the most common disasters in Nigeria. Majority of Nigeria's states are increasingly suffering from this menace every rainy season. Several factors are linked to this, parts of which are increased precipitation linked to climate change, human activities to mention a few (Echendu, 2020). The Federal Capital territory Abuja is a developing urban city in Nigeria; and cases of flood have had tremendous effect on the socio economic life of the people within the territory. During the flood instances, havocs were wreaked across the city as many houses and roads would be submerged in the water body, commercial activities would be grounded to a halt in some parts of the territory. One of the intentions that preceded the creation of the Federal Capital Territory was that the new city would be fashioned out in a way that problems would not arise about city planning in the future and little will be heard about flood disasters. In the master plan, provisions were made for "green development" in order to boost environmental conservation and add to the aesthetic value of the Federal Capital (Stanley, 2016).

In recent times, the spate of flood occurrences has increased and this is quite worrisome. According to reports, there have been incidences of floods all over the territory in different magnitude and with different level of destruction since its inception (Sambo, 2014). Over the years, there were cases in both residential and open areas of floods. Roads and streets would be flooded; gridlocks are seen in different places all over the FCT. Examples are places like Garki, Area 1, Wuse, Jabi, and other commercial areas in the city. Major roads were more often than not taken over by flood, properties and human lives were also lost. Floods also caused some communities to be cut off as a result of persistent downpours, which also damaged roads and bridges. There were also many reported cases of human casualties, who were either drowned or declared missing as a result of flooding in recent years in areas like Kubwa, Kwali and lokogoma estate in Abuja (Ezeobi et al., 2018; SaharaReporters, 2019).





**Fig. 1.** Lokogoma Estate Abuja after a flood in September 2019. Source: Authors Field work, 2019.



**Fig. 2.** Floods on Nyanya road in Abuja. Source: Authors Field work, 2019.

Figure 1 is a flooded scene in Lokogoma Estate (2019). Houses were submerged, streets were taken over by flood and a lot of havoc was wrecked. Figure 2 shows a section of Mararaba Nyanyan road that was flooded after one early morning downpour. This research is an attempt to scientifically investigate if the amount of rainfall in the FCT is the main course of all these incidence of flooding in the study area.

## 1.1 The Study Area

The Federal Capital Territory of Nigeria constitutes the location in which this study is conducted. The territory lies between latitude  $8^{\circ}25^1$  and  $9^{\circ}25^1$  north of the equator and longitude  $6^{\circ}45^1$  and  $7^{\circ}45^1$  east of Greenwich. The territory covers an area of 8,000 square km. It is bordered to the north by Kaduna state, to the east by Nasarawa State, to the south west by Kogi State and to the west by Niger State (Yahaya et al., 2014). The FCT climate is the hot, humid tropical type. It is such that its major elements have regimes that are transitional from those of the southern and northern parts of the country. Thus, relative humidity is not as high as in the southern part and temperatures are not as high as in the far north, either (Balogun, 2001). Adakayi (2000a) revealed that the Federal Capital Territory (FCT), records the highest temperatures during the dry season which are generally cloudless. The maximum temperatures occur in March with amounts varying from  $37^{\circ}\text{C}$  in the south-west to about  $30^{\circ}\text{C}$  in the north-east. This is the period of high diurnal ranges of temperatures when drops of as much as  $17^{\circ}\text{C}$  may be recorded. By July to August, diurnal range rarely exceeds  $7^{\circ}\text{C}$ . In the FCT, like most parts of Nigeria, two distinct seasons can be defined. These are the hot and cold season. Temperatures are generally higher in the months of March-October which encompasses the rainy season, having an average temperature of  $30^{\circ}\text{C}$ . In the months of November to February, the temperatures are generally lower ranging between  $15^{\circ}\text{C}$ – $30^{\circ}\text{C}$ . The type of precipitation prevalent in the FCT consists almost entirely of rainfall (Adakayi (2000a)). It is the most variable element of tropical climate. Other rainfall characteristics, such as its seasonal and diurnal distribution, intensity, duration and frequency of rain-days also show important differences in both place and time within the FCT. According to Adakayi (2000a), rainfall in the FCT starts at about 20th of March on the southern boundary of territory to about 10th of April at the northern limits. Rainfall cessation dates range from 20th October in the north to about 18th November in the south, giving a duration of between 190–240 days. There is extreme concentration of rainfall in two to three months of July, August and September in the FCT. These three months accounts for about 60% of rainfall in the region, and more pronounced was the northern areas of the territory (Adakayi, 2000b). Kwali area council has distinct wet (March - October) and dry (November - February) seasons with average annual rainfall of 102.5 mm and mean temperature range of between  $20.70^{\circ}\text{C}$ – $30.80^{\circ}\text{C}$  (Bello et al., 2010).

## 2 Methodology

The data utilized for this research work were collected from primary and secondary sources and, analyzed to produce the final output maps.

Rainfall data of the areas of Interest covering a period of 34 years was extracted from Satellite Imagery. This data was used to study the pattern and Intensity of rainfall in the FCT as a whole. The essence of the analysis done on this data was also to determine if rainfall intensity was a contributory factor to the cases of flooding in these areas. Graphical analyses were conducted, Microsoft excel package and SPSS was used for all the statistical analysis carried out and rainfall variability map/graphs/tables were derived using the data. Alongside the rainfall is the runoff analysis done. The essence was to study the trend in runoff; it was also to find out if there was a significant trend in runoff

**Table 1.** Data source and their characteristics

Data Type	Date	Scale/ Resolution	Duration	Acquisition Source	Data Type
Administrative Map of Abuja	Nov. 1991	1:200,000	—	OSGOF, Abuja	Secondary
Rainfall data	May 2016	5 km	1981–2015	CHIRPS Data	Secondary
Runoff data	May 2016	5 km	1981–2015	ERA-Interim Data	Secondary
Drainage Capacities	Field work 2017/ 2018/2019			Project Site	Primary
Hand-Held GPS	Field work 2017/ 2018	For ground truthing and data verification			Primary

Source: Researcher's Analysis, 2018.

event over time in the area as well as determine the influence of rainfall amount (mm) on runoff (mm).

### **Rainfall of the FCT**

In this session, the trend in rainfall was studied and analyzed. Patterns and trends in rainfall as well as rainfall anomaly over FCT in the past 34 years were examined. Attempt was made to find out if the trend in rainfall pattern of the FCT for 34 years is significant as well as know the average amount of rainfall recorded over time. Furthermore, the possible effect rainfall amount has on runoff amount experienced over time was also examined.

### **Yearly Summary of Rainfall in the FCT from 1981–2015**

The result gives information on minimum, maximum, total amount, average and standard deviation of rainfall over 34 years in the FCT. It also gave information on skewness and kurtosis of rainfall amount for the period under investigation. The result indicated that 1991 had the highest annual rainfall with value of 1,532.7 mm followed by 1994 and 1989 with annual rainfall values of 1,473.4 mm and 1,429.0 mm respectively. The lowest annual amounts were recorded in 2013 with the amount of 791.3 mm, then 1983 with the sum of 991.9 mm and 1993 with the rainfall amount of 1,038.5 mm. A cursory look at the rainfall values showed that, lower rainfall amounts were recorded across the FCT between 1982 to 1987, 2000 to 2005 and 2014 to 2015. The result further showed that the minimum amount of rainfall in the FCT in the period under review occurred in 1984 with an amount of 1.9 mm followed by 1985, 1989, and 2000 with rainfall amounts of 2.0 mm respectively. The highest amounts of rainfall occurred in the 1990s implying that this time period experienced the highest amount of rainfall. The skewness result implied that the distribution of rainfall in the FCT during this period were uneven with 1991, 1994 and 2015 having the most uneven rainfall amounts in the area. Rainfall trend was most uneven in the 90s which is an indication that the period experienced the most

challenging years in rainfall distribution. In addition, CV result identified 1994 as the most variable year with regards to rainfall distribution with a CV of 120% followed by 2015 with a value of 108% and then 1983 with a value of 107%. The lowest rainfall variable occurred in 1997 with a value of 84% followed by 1982 and 2013 with values of 88% respectively. The pattern of CV reported in the present study is consistent with (Udo-Inyang and Edem, 2012) in Akwa Ibom, Nigeria.

### **Normality Test**

The rainfall data over FCT for 34 years was tested for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests (Table 2). Kolmogorov-Smirnov and Shapiro-Wilk test the null hypothesis that the rainfall data is normally distributed, while the alternate hypothesis is that the rainfall data is not normally distributed. On this note, if the results of either test are significant (e.g.  $p < 0.05$ ), it implies rejecting the null hypothesis. This means rejecting the assumption of normality for the distribution or data set. For the present study, the Kolmogorov-Smirnov and the Shapiro-Wilk tests have p-value as greater than 0.05; it means we accept the null hypothesis that the rainfall data for FCT over 34 years was normally distributed. The result therefore means that it is not necessary to transform the rainfall data (Udo-Inyang and Edem, (2012)).

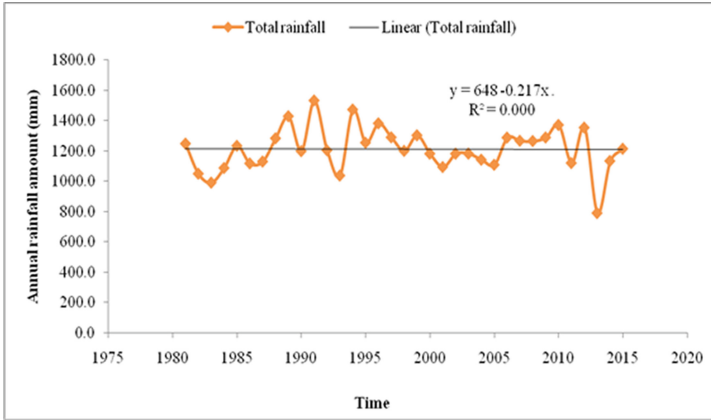
**Table 2.** Kolmogorov-Smirnov and Shapiro-Wilk tests of normality

	Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk		
	Statistic	Df	Sig.	Statistic	Df	Sig.
Total rainfall (mm)	0.095	35	0.200	0.975	35	0.607

### **Trend in Rainfall Amount**

The trend and annual variability in rainfall amount from 1981 to 2015 in the FCT shows that in 1981, the annual amount of rainfall recorded was 1,249 mm; this amount increased by 22.7% after 10 years to 1,532.7 mm in 1991 and thereafter it slightly decreased by 28.6% to 1,094.7 mm in 2001. Afterward, rainfall amount increased progressively and in 2010 it reached 1,371.7 mm. After this year, rainfall amount decreased to 1,121.1 mm in 2011 and suddenly increased to 1,354.3 mm in 2012 being the second highest during the 34-year period. It then decreased sharply in 2013 to 791.3 mm being the lowest rainfall amount recorded during the time period. The trend in rainfall amount in the FCT indicated that rainfall showed yearly variability with 1991 recording the highest amount followed by 1994 and then 1989, while the lowest rainfall amount was recorded in 2013. The study therefore shows that 1991 was the wettest year, while 2013 had the most rainfall deficit year. Furthermore, the information displayed in Fig. 3 showed that from 1981 – 2015; rainfall amount in the FCT showed a stationary trend despite the yearly variability in rainfall amounts. The straight line equation of the time series yielded  $y = 648 - 0.217x$  for the thirty four (34) years of data. The trend analysis indicated that the rainfall amount over 34 years neither showed an upward or downward trend. This is

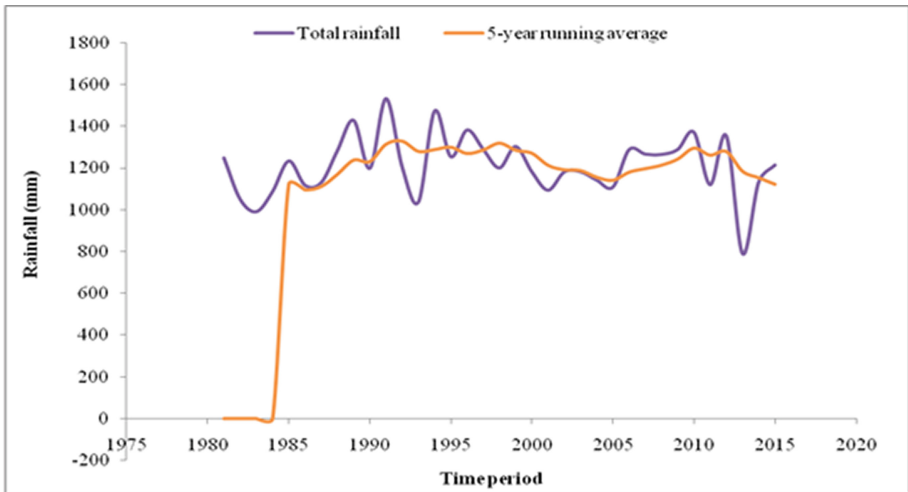
evident in that there was no improved rainfall in the study area as indicated in the Fig. 3. In all, the rainfall amount showed that from 1981 to 2015, there was no significant increase or decrease in rainfall amount.



**Fig. 3.** Trend in rainfall amount from 1981 to 2015.

**Trend in Rainfall Amount**

When a 5 year running mean was put through the annual total rainfall series (Fig. 4), fluctuations involving increasing trend were most prominent in the periods 1989 – 1992, 1994 – 1995 and 2008 – 2010. A fluctuation involving decreasing rainfall trend was prominent in the period 2000 – 2005 and 2011 – 2015. The 5-year running average of



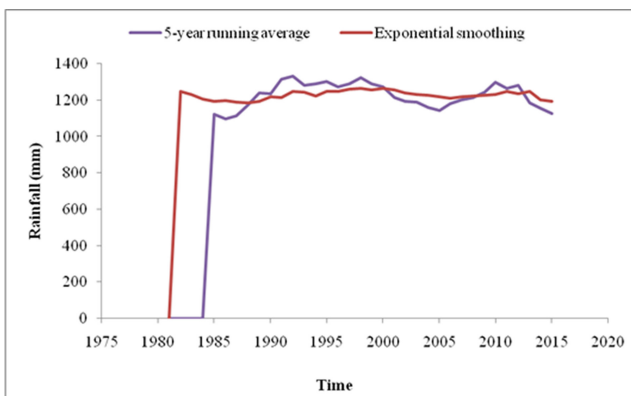
**Fig. 4.** Five year running average of rainfall from 1981 to 2015. Source: Researcher’s Analysis, 2017 .

rainfall in the area however showed that the 34 years period (1981–2015) of rainfall in Abuja was characterized by a decreasing rainfall in recent time, an indication that the climate of Abuja may not be becoming wetter. This is so as there are more periods of decreasing rainfall than increasing rainfall in the study period, this is also in agreement with Hassan, (2012).

In addition, the 5-year moving average shows rainfall in Abuja from 2011 to 2015 depicts a decline in annual rainfall. It also shows a fluctuating trend in rainfall pattern. Also, the 5- year moving average suggested a decline in rainfall and this is critical for crop growing mostly in the months of rain-fed agriculture. The decline in the amount of rainfall received does not show a distinct trend because there are fluctuations. The same conclusion was reached by Ati and Iguisi, (2007) for Guinea, Sudan and Sahel Savanna of Nigeria; and Abaje et al., (2010) for Guinea Savanna of Nigeria. These studies found decline in rainfall amount received. The result obtained also agrees with the study carried out in Kafanchan, Kaduna State, Nigeria by Abaje et al., (2010) when they stated that the 5-year running mean shows declining yield of annual rainfall in the area.

### *Time Series Analysis Using Exponential Smoothing*

Furthermore, Fig. 5 shows the exponential smoothing of annual rainfall in the study area. For this study, the smoothing constant  $\alpha$  was placed at 0.9; this was intended in order to remove the fluctuations and enable variability in rainfall pattern to be easily seen. The smoothing constant  $\alpha$  is not an arbitrary choice but generally falls between 0 and 1. Low values (smoothing constant  $\alpha$ ) are used when the underlying average tends to be stable, while higher values are used when the underlying average is susceptible to change. According to Ostertagová and Ostertag, (2011) and Ostertagová and Ostertag, (2012) the smaller the value for smoothing constant, the slower the response, but the larger the value, the more the fluctuations there are in a series. The graph as a result of the arbitrary smoothing constant of 0.9 resulted in the smoothing out of the peaks and valleys. The peak periods were 1995–1998 and 2010–2011, while periods with valleys were 1985–1989, 2002–2007 and 2014–2015. The graph however shows a decreasing pattern in rainfall amount.



**Fig. 5.** 5 year moving average and exponential smoothing.

**Standardized Annual Rainfall Anomaly Over Abuja** The Fig. 7 gives information on the standardized total annual rainfall anomalies for a period of 34 years (1981 – 2015). The result shows that 1991, 1994 to 1997; 1988 to 1989 and 2006 to 2010 were years with average rainfall with 1991 and 1994 showing the highest deviation of normal rainfall situation. This was a period of intense rainfall in the area. It also showed that 1982 to 1984, 1986 to 1987, 1992 to 1993, 2000 to 2005, and 2013 to 2014 were years with rainfall below normal with 2013 and 1983 recording the highest negative departure of normal rainfall condition. The periods, 2013 and 1983 experienced extremely low rainfall. This was the period according to Abaje et al. (2010) of intense drought that ravaged the Sudano-Sahelian zone of Nigeria. In addition, the information in Fig. 7 suggested an uneven distribution of the departures in rainfall from the mean with seventeen (17) anomalous situations (normal rainfall) on one side and eighteen (18) anomalous situations (abnormal rainfall or below normal) on the other side. This implies that rainfall in Abuja over the 34 years under review was below the normal rainfall condition. Implying decline in rainfall amount received in the area. Similar below normal rainfall was reported by Abaje et al. (2010) in Kafanchan, Kaduna State, Nigeria. The result obtained is also consistent with the findings of Ekwe et al. (2014) in Nasarawa State, when they observed rainfall fluctuations and general decline in recent times in the study area. This is also in line with the cycle of below average rainfall recorded between the years 1987–1990 and 2000–2005, Hassan (2012) recorded in his study.

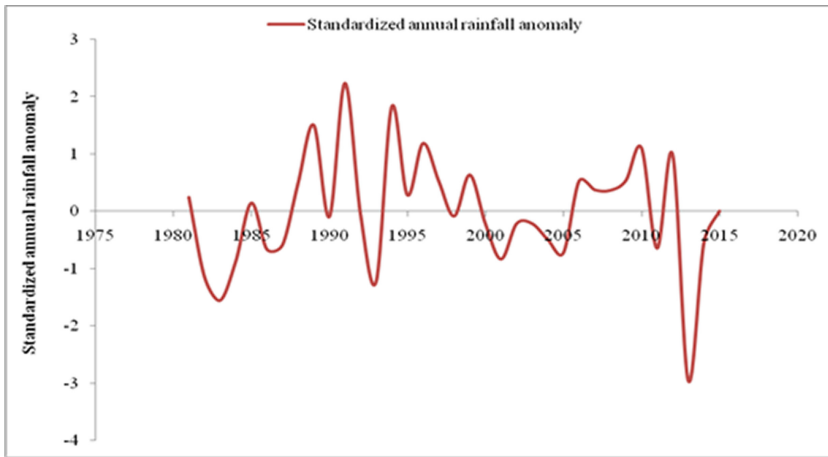
It also shows declining rainfall amounts as many of the years have their annual rainfall values below their long term mean. It further showed that the wettest years (years with the highest rainfall) were recorded in 1991, 1994 and 1989, while 2013, 1983 and 1993 were the driest years (years with the lowest rainfall). However, in five consecutive years, precisely 2011 and 2015, Abuja experienced fluctuations in rainfall conditions with more of below normal rainfall events in the area. The result corresponds to the Intergovernmental Panel on Climate Change [IPCC] projection cited in Akinsanola and Ogunjobi (2014) which stated that the coastal areas are prone to more wet years leading to the occurrence of flooding while region around the Sahel will experience more of drought as a result of reduction in the total precipitation.

The standardized total annual rainfall anomalies therefore indicates uneven distribution of departures in annual rainfall. This result somehow corroborates that of Enete and Ebenebe (2009) when they reported an uneven distribution of the departures in annual rainfall over Enugu from the mean with seven (7) anomalous situations on one side and eight (8) anomalous situations on the other side. Similar uneven departures were reported by Ekwe et al., (2014), as well as Abaje et al. (2010) in Nasarawa State, Nigeria. The result further showed that the pattern of rainfall in Abuja during the period under review is highly variable in temporal dimensions with inter-annual variability (Abaje et al. 2010); Udo-Inyang and Edem, (2012); Ekwe et al. (2014). In all, the result obtained implies that Abuja in the 34 years under review has passed through wet and dry sequences.

### ***Standardized Monthly Rainfall Anomaly Over Abuja***

The result in Table 3 and Fig. 7 shows the standardized total monthly rainfall anomalies for a period of 34 years. The Figure shows that May, June, July, August, September and October recorded rainfall amounts with positive deviation of normal rainfall situation,

while January, February, March, April, November and December had the highest negative departure of normal rainfall condition. The months of January and December recorded the highest negative departure of normal rainfall condition, while the month of August recorded the highest positive departure of normal rainfall condition. Similar rainfall condition and pattern was reported by Ekwe et al. (2014) in Nasarawa State when they observed that August recorded the highest amount of rainfall.



**Fig. 6.** Standardized annual rainfall anomaly over Abuja (1981 – 2015).

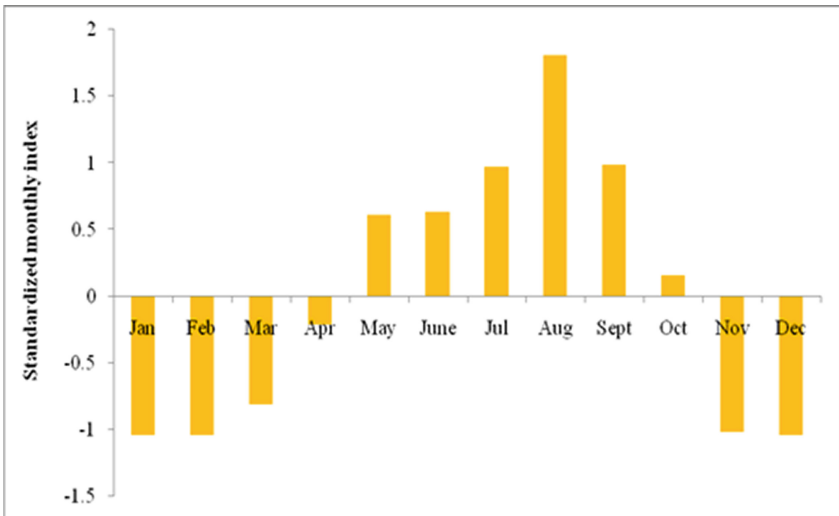
**Table 3.** Monthly rainfall and standardized monthly index

Months	Monthly rainfall (mm)	Standardized monthly index
Jan	89	-1.044
Feb	104.4	-1.039
Mar	859.1	-0.811
Apr	2830.1	-0.214
May	5563.4	0.613
Jun	5630.3	0.633
Jul	6750.3	0.973
Aug	9501.3	1.805
Sept	6809.4	0.990
Oct	4069.8	0.161
Nov	153.3	-1.025
Dec	92.2	-1.043

Source: Author’s field work.



Figure 6 unlike that in Fig. 7 suggests an even distribution of the departures in monthly rainfall from the mean with six (6) anomalous situations (normal rainfall) on one side and another six (6) anomalous situations (abnormal rainfall or below normal) on the other side. This implies that rainfall in Abuja over the past 34 years was normally distributed following the influence of ITD. It however shows increase in the annual rainfall due to increasing rainfall yields in the months of May to October having rainfall incidence with double maxima in July and September. This result is consistent with the findings of Ekwe et al. (2014) in Nasarawa State when they observed increasing rainfall yields in the months of June to September. Also, similar trend was reported by Udo-Inyang and Edem (2012) in Akwa Ibom State. The standardized anomalies results obtained in this study presented a fluctuating rainfall pattern across the years over Abuja which makes it difficult to easily forecast rainfall trend for a future season.



**Fig. 7.** Monthly rainfall standardized index.

The months of July, August and September as shown in Fig. 7 are periods of high rainfall intensity in the territory. These periods also coincide with the periods most residents experience flooding in the territory. The soils are saturated with water not allowing infiltration as such, coupled with all the other factors, which leads to flooded roads, houses and open spaces.

### **Standardized Precipitation Index (SPI)**

The standardized precipitation index stipulated by McKee et al., (1993) was further used to classify the rainfall amount received in Abuja over 34 years. Positive SPI values indicate greater than median precipitation, and negative values indicate less than median precipitation. Because the SPI is normalized, wetter and drier climates can be represented in the same way, and wet/dry periods can also be monitored using the SPI. The result in Table 4 showed that, 2.9% of the rainfall amount received fell in the category of

extremely wet, severely dry and extremely dry periods. The result further showed that 5.7% of the rains received during this period fell in the category of very wet, moderately wet and moderately dry, while a greater percentage (74.3%) of the rainfall received fell in the category of near normal. This goes to suggest that rainfall amount received in Abuja from 1981 to 2015 is near normal as a result of the frequent fluctuations. It also indicated that Abuja during the period under review experienced more of drought as a result of reduction in the total precipitation. Similar result was reported by Akinsanola and Ogunjobi, (2014) when they observed 24 years of near normal rainfall over Nigeria in the Guinea savanna zone with dry years more than wet years.

**Table 4.** Standardized precipitation index.

Standardized anomaly index	SPI	Frequency	Percent
2.0+	Extremely wet	1	2.9
1.5 to 1.99	Very wet	2	5.7
1.0 to 1.49	Moderately wet	2	5.7
−0.99 to .99	Near normal	26	74.3
−1.0 to −1.49	Moderately dry	2	5.7
−1.5 to −1.99	Severely dry	1	2.9
−2+	Extremely dry	1	2.9
Total		35	100

### Analysis of Significant Trend in Rainfall Amount Over 34 years

Attempt is made in this section to determine if there is a significant trend in rainfall amount over time. The approach also enabled the understanding of the rate of change that has taken place in 34yrs. However, before that was performed, the variable (time or year) was assigned numerical values. In achieving this, the first date being 1981 was assigned a value of 1, the second year (1982) a value of 2, and so on so that the last year being 2015 was assigned a value of 34. The analysis was carried out using linear regression. The test statistic for linear regression is the regression gradient. According to Kundzewicz and Robson (2004), linear regression is one of the most common tests for trend and, in its basic form, assumes that data are normally distributed. The idea here is that the t-statistic on  $\beta_1$  is tested to determine if it is significantly different from zero (Environmental Protection Agency (EPA), 2016). If the slope ( $\beta_1$ ) is non-zero, it means that there is a linear trend in rainfall over time. In doing so, the t-statistic on  $\beta_1$  is then tested to determine if it is significantly different from zero, but, when there is no trend, the slope ( $b_1$ ) is zero and the equation results in zero percent change (i.e.,  $\beta_1 = 0$ ) (National Nonpoint Source Monitoring Programme, 2011).

Data on rainfall amount was taken from 1981 to 2015. The linear trend for rainfall amount is mathematically defined thus:

$$Y = b_0 + b_1 t \quad (1)$$

Where:  $Y$  = linear trend forecast in period (rainfall amount)  $\beta_0$  = intercept of the linear trend line  $\beta_1$  = slope of the linear trend line (regression coefficient) and  $t$  = time period (1981 to 2015) The test statistic result showed that the slope of the trend ( $b_1$ ) is non-zero which entailed that there was a linear trend in rainfall amount over the 34 years under review, but the trend was not significant ( $t = 0.090$ ,  $p > 0.05$ ). The linear trend equation of rainfall over 34 years is given as follows:

$$Y = 101.404 - 0.018t \quad (2)$$

The slope of  $-0.018$  further indicated that for the 34 years, rainfall experienced a total decrease of about 1.8 mm. This decrease would have significant effects on crop production and yield as well as erosional losses experienced in the study area. This as already discussed in the preceding sections implies decline in rainfall amount received in the area. Similar observation in rainfall was reported by Abaje et al., (2010) in Kafanchan, Kaduna State, Nigeria.

### **Influence of Rainfall on Runoff**

The influence of rainfall on runoff is determined. In order to suitably perform this analysis, the logarithmic conversion method was employed to transform the variables to make them suitable for regression analysis (Rosenberg, 1997). According to Rosenberg (1997), logarithmic transformation of time series data provides a more appropriate and realistic results because it “flattens” the series of data, while the shape of the trend remains unchanged. The result of the bivariate regression analysis showed there was a very weak correlation (0.002) between rainfall and runoff.

## **3 Conclusions and Recommendations**

The trend in rainfall amount in the FCT indicated that, rainfall showed yearly variability with 1991 recording the highest amount followed by 1994 and then 1989, while the lowest rainfall amount was recorded in 2013. The study therefore showed that 1991 was the wettest year, while 2013 had the most rainfall deficit year. Despite this, the rainfall amount showed that from 1981 to 2015, there was no significant increase or decrease in rainfall amount Hassan, (2012). This is to conclude that flood incidences in the FCT are not necessarily caused only by rainfall. The runoffs from the rains too after analysis portrayed uneven distribution of departures in annual runoff events in the area. The result also showed that the pattern of runoff in Abuja during the period under review is highly inconsistent in temporal dimensions with inter-annual variability and indicated that Abuja in the 34 years under review has experienced decreasing runoff events due to the increasing dry sequence. The decrease in runoff amount over time in the FCT could be attributed to the decline in rainfall amount. In a related study, Daura, (1995) cited in Iwara, (2013) stated that runoff is a function of rainfall amount received over time. Decrease in rainfall amount, rainfall intensity and rainfall distribution over watersheds among others are known to affect runoff in an area. The flood here according to findings was caused by other factors other than rainfall alone. Some factors were cited like buildings constructed across the narrow floodplain, lack of adequate drainage facility,

land sealing, the pattern of drainage network, vegetation, basin shape and drainage area and other factors.

The research recommended that, there is an urgent need for enforcement of building standards and codes in the FCT to stop the indiscriminate approval and erection of structures in marsh land and water ways. There is a tendency to bend the rules as the memory of a flood event and its catastrophic consequences gradually fade away with time. Enforcement procedures and penalties need to be built into the process of approval. Governments should consider introducing strict penalties for defaulters' and approving officers that approved and signed the letter allowing them to erect such structures. They should also be strict on requirements such as surveyor certificates to verify that design elevations have been met, or inspector reports that flood-proofing measures have been implemented. There is also the urgent need to Start Campaign on Disaster Risk Reduction. The rainfall amount showed that from 1981 to 2015, there was no significant increase or decrease in rainfall amount. Runoff which is a function of rainfall amount received over time also decreased. The few flood experienced from this analysis were not given room to move freely, thereby causing havoc, though small. There is need to sensitize the people of the FCT on Disaster Risk Reduction and also take this awareness to our schools.

**Acknowledgement.** The authors deeply acknowledge the contributions of Professor Mallo I.I. Y and Professor Hassan S.M of the Department of Geography, The University of Abuja, Nigeria through which this research emerged.

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# Mineral Rent – Human Development Nexus: Experience from Selected Sub Sahara African Countries

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**Abstract. Purpose:** This study examines the relationship between the mineral rent-human development (HDI) nexus exists. To achieve this purpose, it is important to examine whether there is a relationship between mineral rent and a composite measure of elements of the human development index (life expectancy, education and national income per capita) (dependent variables) since human development encompasses a lot of economic variables that would reflect the impact of the mineral rent on the economy.

**Study Design:** the study adopted panel data of five countries (namely South Africa, Namibia, Democratic Republic of Congo, Botswana and Tanzania).) for 19 years from the year 2000 to 2019, making 95 observations. Fixed effect model was adopted to analyze the panel data of five resources rich countries from sub-Saharan Africa. The selection of the five countries was based on the fact that the first three are the top three countries (South Africa, Namibia and the Democratic Republic of Congo) leading in mining export in Africa. However, Tanzania and Botswana rank eighth (8th) and tenth (10th) respectively in mining exports have been carrying out similar reforms in the mining sector.

**Findings:** Findings revealed that the resource rent has a positive significant effect on human development. These results were confirmed by running the robustness test of the parameter estimates. We, therefore, concluded that resource endowment is a blessing rather than a curse in the selected sub-Saharan African countries.

**Limitations of the Study:** The study focused on five countries only from sub-Saharan Africa countries leaving some countries whose economy largely depends on the mineral, this was due to some missing information (data) in some of the years.

**Practical Implication:** The knowledge harnessed from the result of this study will create awareness and awaken policymakers in African countries with an abundance of mineral deposits and whose total export is dominated by mineral export.

**Social Implication:** since the finding contend that the mining rent is not a curse rather a blessing, this knowledge will help governments of the mineral exporting countries to use the economic benefit harnessed from mineral rent to improve social services (such as education and health services) in their countries to enhance the well-being of the society.

**Keywords:** Human development · Mineral rents · Sub-Saharan Africa

## 1 Introduction

In recent years economic development and mineral exports has been a major concern to many researchers. Hlavora (2015) argued that amount of minerals reserves of the country presents value of the scarce resources owned by that particular country. Economists believe that the value of resources endowed to the country presents one form of wealth possessed by the country. Generally, there has been debate on whether the relationship between the economic development of a country and resources is negative or positive. Under normal circumstances, it is obvious that amount of mineral resources of the country would attract foreign direct investment (FDIs) to that particular country hence led to economic development. According to Ericsson and Löf (2019) mining has made important economic contribution to several low and middle income countries endowed with mineral resources, as measured by mining contribution index (MCI). Ericsson and Löf (2019) further contended that ten among twenty countries where the mining contribution index score is higher have managed to move one or two steps as per world bank's classification between 1996 and 2016. This poses contradiction between the argument on whether the relationship that exists between economic development and mining development is negative or positive.

In many African mineral rich countries majority of rural population derive their livelihood based on agriculture or mining activities, particularly small scale mining activities. As contended in many literatures, natural resources development can provide important catalyst for economic growth and human development in general. Additionally, mining development also provides platforms for the transition from cottage industry production to factory production. Indeed, with the right handling and development of natural resources it is possible for a country to transform from a low-value economy that depends largely on exports of raw materials to a country that has labour-intensive manufacturing sector. Literature records that in many African countries development in mining sector has only to a limited extent acted as a catalyst for economic growth. It is reported that failure to adopt and implement the right growth promotion policies and lack of strong institutions in place are the root cause.

The main objective of this study is to examine the relationship between economic development and mineral rent using evidence from five sub Saharan African countries (South Africa, Namibia, Democratic Republic of Congo, Botswana and Tanzania). Selection of the five countries was based on the fact that the first three are the top three countries (south Africa, Namibia and Democratic republic of Congo) leading in mining export in Africa. However, Tanzania and Botswana rank eighth (8<sup>th</sup>) and tenth (10<sup>th</sup>) respectively in mining exports, it was also considered that the two countries (Tanzania and Botswana) have been carrying out some reforms in recent years with aim to improve contribution of the mining sector into economic development. Africa is gifted with abundant natural resources like arable land endowed with natural resources such as minerals (for example gold, aluminum, diamond, coal, copper, uranium, gas, and oil). Like other Natural resources, mining has dominated economic activities in many rural areas in African countries rich in minerals, due to the fact that majority of African countries lives in rural areas where small scale mining activities are of normal practices, it is important to examine whether the mineral rent-human development nexus exists in the selected countries. Unlike in the study by Yang et al. (2019a) , Kim and Lin (2017) and



Alexeev and Conrad (2011) where gross domestic growth (GDP) was used as a measure of economic growth, this study adopted human development (HD) as a measure of economic growth (dependent variables) since human development encompasses a lot of economic variables (including the GDP) that would reflect the impact of the mineral rent on the economy.

## 2 Literature Review

Literature presents that several studies examining relationships between the minerals or natural resources and economic development. According to Hlavora (2015) the relationships between the said variables has been of the negative, meaning dependence on the mineral resources is associated with lower than the average economic development. As contended in the study by Hlavora (2015) previous studies on the relationship between the natural resources and economic development shows negative results. However, in many s studies negative relationships is built on either Dutch disease or resource curse. Other researchers have gone far and explained how natural resources (including minerals) affect economic growth and pointed out other areas such as political and social indicators.

According to Ross (2001) Dutch disease theory explains whether there is existing relationship between the share of natural resources and political situations in the country. On the other hand Auty (1993) advocated resource curse concept where Auty argued that countries possessing larger amount of minerals exports tend to manifest lower economic growth compared to countries which are less dependence on minerals exports. He went further and considers even the potential situation in those countries which have significant minerals reserve. Though majority of previous studies explain negative results on the relationships between the minerals exports and economic development there are still some few studies which have shown the positive relationship between the minerals exports and economic improvement as contended in the concepts of resources curse. For example Roland (2006) holds that improvement in Russian economy disapproves the negative impact of mineral resources on economy as argued in the Dutch disease theory. Jerven (2010) argued that there is no existence of Dutch disease which implies of negative relationship minerals exports and economic improvement in Botswana. As it was argued by Ricardo (1817) foreign trade provide platform to attract foreign capital into the economy. Such increase of international provides earnings to the economy and establishes a room for improvement by increasing country's national income (Adenugba and Dipo, 2013).

## 3 Methodology

The relationship between resources endowment and economic development has been one of the interesting discussions in literature. One of the interesting discussions in literature is around the resource curse theory which encapsulates the state of resource rich countries having less economic growth and less development outcomes as compared to the resource poor counterparts.

This study extends the discussion by analyzing the nexus between the resource rent and economic development in 5 selected Sub – Saharan African countries. These countries include Botswana, Democratic republic of Congo, Namibia, Tanzania and South Africa. The study makes the use of a panel data from these countries which cover the period of 19 years from the year 2000 to 2019.

In literature a number of variables have been applied in measuring this relationship. These among others include, GDP as a measure of economic development as the dependent variable; natural resource abundance, institutional quality, investment in education, exchange rate and external debt as independent variables, Yang et al. (2019a) . For the purpose of this study, the dependent variable will be the Human Development Index (HDI) as a measure of economic development. This variable has been preferred over the use of GDP as a common measure of economic development because according to the United Nations Development Program (UNDP) “people and their capabilities should be the ultimate criteria for assessing the development of a country, not economic growth alone”. This variable was regressed against the key independent variable which was the natural resource rent (RR). Other independent variables which stood as control variables included Foreign direct investment (FDI) and exchange rate measured by the Official exchange rate (LCU per US\$, period average). The reason for including these control variables is that as suggested in literature they are directly linked to the economic growth of the country and thus they are connected to economic development. On one hand, more FDI and a favorable exchange rate are good for economic growth and development. However, a resource boom in a country may encourage more FDI and ultimately higher currency appreciations which may negatively impact economic development.

Table 1 presents the study variables and the hypothesized relationship between the dependent and the independent variables. The resource rent is our key independent variable and is hypothesized to have appositive relationship human development, ignoring the resource curse hypothesis, Yang et al. (2019b) . The FDI is also hypothesized to have a positive relationship with the dependent variable since increased foreign investment is likely to boost economic growth and consequently economic development. Lastly the exchange rate is hypothesized to have a negative relationship with human development. This is because the exchange rate volatility impacts the volume of international trade and in turn impacts the domestic economic development.

**Table 1.** Study variables description

Variable	Measurement	Expected causality
HDI	Human Development Index	Dependent variable
Rent	Mineral rents (% of GDP)	Positive
FDI	Foreign Direct Investment net inflows (% of GDP)	Positive
Exchange	Official exchange rate (LCU per US\$, period average)	Negative

Source: Authors computation

Therefore to estimate the relationship between our variables the following econometric model was specified and estimated.

$$Y_{it} = \beta_0 + \beta_1 Y_{it-1} + \beta_2 RR_{it-1} + B_3 FDI_{it-1} + B_4 EXC_{it-1} + \varepsilon_{it} \tag{1}$$

Where  $Y_{it}$  is the human development over year “t” in country “i” using the log of the human development index.  $Y_{it-1}$  is the lagged value of the log of human development index for country “i”,  $RR_{it-1}$  is the lagged value of the resource rent for country “i”,  $FDI_{it-1}$  is the lagged value of the log of foreign direct investment for country “i”,  $B_4 EXC_{it-1}$  is the lagged value of the official exchange rate for country “i” at time “t” on average and  $\varepsilon_i$  is the error term.  $\beta_0$  Is the intercept of the equation while  $\beta_1 \dots \beta_5$  are slope coefficients.  $\varepsilon_{it}$  Is a random error term and is assumed to be normally distributed with zero mean and constant standard deviation, ( $E(U_{it} \sim N(0, \delta^2))$ ). All the variables were estimated in their lagged form to take care of the possible presence of endogeneity among the variables, Yang et al. (2019b) .

Given the nature of our data which were panel data, Eq. 1 was estimated using two estimations. Firstly the *random effect* estimation which assumes the presence of an unobserved stochastic component in the error term was done. In the random effect estimation, the error term contains an unobservable component term which varies between countries but not within countries and an observable component which varies over countries and time. Secondly the regression equation was estimated using the two way fixed effect which allows each country to have its own intercept which varies across different time periods.

The most appropriate estimation model was then determined using the Housman specification test. In this we tested the null hypothesis that “the random effect was not appropriate” versus the alternative that “the random effect was the appropriate” model for estimating our regression equation. The results from this test showed that Prob > chi2 > 0.05 which implied that we failed to reject the null hypothesis that the random effect was not appropriate. This being the case we opted for the alternative which was the fixed effect estimation.

### 4 Results and Discussions

Before embarking into the presentation and discussion of the key findings of the study, the descriptive statistics of the variables used in the study are presented in Table 2.

**Table 2.** Descriptive statistics

Variable	Obs	Mean	Std. Dev	Min	Max	Nature
HDI	95	– .616	.214	– 1.1	– .317	Dependent
Rent	95	.482	1.895	– 9.003	2.971	Independent
FDI	95	.952	.87	– 1.472	2.543	Independent
Exchange	95	3.975	2.371	1.546	7.725	Independent

Source: Authors computation

**Table 3.** Matrix of correlations

Variables	(1)	(2)	(3)	(4)
(1) HDI	1.000			
(2) FDI	-0.281	1.000		
(3) Rent	0.102	0.033	1.000	
(4) Exchange	-0.087	-0.287	0.292	1.000

Source: Authors computation

Table 3 presents the important descriptive statistics which are important in explaining the main results for our study. Importantly, the total number of observation in our study was 95 as observed from the table. The standard deviations were generally small showing that the observations for each variable are not too scattered. Likewise the minimum and maximum values of each variable shows that there were no serious outliers when these are compared to the mean values of the variables.

The other important analysis was the correlation analysis among the variables of the study. Table 4 presents the matrix of correlation among the variables of the study. A cross – observation in the matrix shows that there were no variables which had a serious correlation exceeding 80% which could be an indication of multicollinearity.

To confirm the absence of multicollinearity, the variance inflation factor (VIF) was estimated and it was found that none of the correlations between any pair of the variables had a VIF value exceeding 10. As per the rule of thumb, any VIF exceeding 10 implies the presence of multicollinearity, (Gujarati, 2003). Therefore we verified the absence of multicollinearity in our variables.

**Table 4.** Fixed effects estimation results

VARIABLES	(1) HDI	(2) HDI	(3) HDI
Rent	0.0076*** (0.002)	0.0125*** (0.002)	0.0124*** (0.002)
FDI	0.0119*** (0.004)	0.0086 (0.005)	
Exchange	0.0523*** (0.007)		
Constant	0.3518*** (0.027)	0.5539*** (0.007)	0.5458*** (0.004)
Observations	95	95	95
R-squared	0.574	0.287	0.267
Number of id	5	5	5

Standard errors in parentheses.

\*\*\* p < 0.01, \*\* p < 0.05, \* p < 0.1

To achieve our research objectives, as directed by the houseman specification test, we conducted the fixed effects estimations to obtain the relationship between the dependent variable and the independent variables. Here we conducted three fixed effect estimations with the intention of testing the robustness of our results. In the first estimation we maintained all the variables including the control variables. In the second and third estimations the control variables were dropped to test for the robustness of the parameter estimates. The results remained the same for all the three estimations showing that our parameter estimates were robust.

The key variables in our analysis were the human development (HDI) and the mineral rent (Rent). From the table it can be seen that the mineral rent had a positive significant influence in determining changes in human development (HDI). The level of significance for this variable was 1%. In other words, the elasticity of human development with respect to changes in the mineral rent is 0.01 holding other variables constant. The results have remained the same throughout the second and the third estimations showing that our parameter estimates were robust.

Even though the mineral rent elasticity of human development is inelastic as revealed by the result, still the findings give an insight on the positive relationship between the two variables. The mineral rent has a positive significant influence on human development. In other words, as the mineral rent increases, holding other variables constant, human development also increase. This finding conforms to the argument presented by Ericsson and Löff (2019), where they argued that world development indicators have shown positive sign of progress to African mineral rich countries. This likely implies that the proceeds from the resource rent are injected into development programs that directly or indirectly impact the human development.

The other observations from our findings were the parameter estimates of the control variables. Both of the control variables showed a positive significant influence in determining the changes in human development. It was found that the foreign direct investment (FDI) was significant at 1% implying that the elasticity of human development with respect to changes in FDI was 0.01. It was also found that the average exchange rate was significant at 1% significance level. This could also be interpreted to mean that the average exchange rate elasticity of human development was 0.05. Findings in this study contradict with findings in a study by Lange (2003) which reported that resource-rich developing countries have performed worse economically than resource poor developing countries over the past 30 years, a phenomenon which is also known as the ‘resource curse’ (Sachs and Warner, 2001).

## 5 Conclusion and Policy Recommendations

The primary objective of this study was to ascertain the nexus between the natural resource rent and economic development in the selected sub Saharan African countries. The results of the study have revealed that there is a positive significant relationship between resource rent and economic development. This disapproves the resource curse hypothesis in the selected sub-Saharan African countries. The hypothesis suggests a negative relationship between the resource endowment and human development giving the reason that resource endowment reduces investment in other key sectors of the economy and hence causing a negative economic development, (Mohamed, 2020; Papyrakis

and Pellegrini, 2019). For the case of this study, the resource endowment measured by the resource rent is a blessing rather than a curse to the resource rich countries. This is likely because, with good management of the resource/mineral proceeds the countries can achieve more economic growth and consequently economic development.

Given this mining sector should contribute extensive economic benefits to mineral rich countries. This is very important particularly for low and middle income countries that lack alternative sources to support development. A well-developed mining sector could be attractive to foreign investors provided certain requirements are met – such conditions may include strong legal and policy framework, an adequate level of political stability, and well-defined property rights which could attract foreign investors to mineral rich mineral countries.

From these results we recommend that the resource rich sub Saharan countries should take advantage of their resource endowment. More efforts in the sustainable extraction of minerals are crucial for these countries to enjoy the blessings of their resources endowment. This can be enhanced by stable institutions and good policies focusing on the usage of the resources to create more economic growth and the ultimate human development.

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# Characterization Approach of Developed Oil Palm Fiber-Polymer Composites

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**Abstract. Purpose:** The purpose of this review paper was to expose researchers and industry players to standard procedure and techniques relating to the characterization of developed oil palm-polymer composites; to identify sample preparation procedures and techniques; as well as to identify the characteristics of oil palm fiber and polymer composite materials.

**Design/Methodology/Approach:** Content analysis was the opted methodology employed for this study, with specific reference to systematic review of manifest content. A systematic review was utilized to cover a period of eight years; from 2010 to 2017 from the Microsoft Bing database. The manifest contents of 22 out of 110 research papers were eventually chosen and manually coded for intensive review and analysis.

**Findings:** ASTM standards such as ASTM D 785 (Rockwell hardness); ASTM D 638 (tensile strength); ASTM D792 (specific gravity); ASTM D 4804 with modifications (flame propagation rate); water absorption technique; and Scanning Electron Microscope (SEM) were identified as some of the methods employed in characterizing oil palm and polymer composites. Polymers identified as matrix include Epoxy (EP), Polyester (PS) Linear Low-Density Polyethylene (LLDPE), High Density Polyethylene (HDPE), Poly (Butylene) Succinate (PBS), and Polypropylene (PP).

**Research Limitation/Implications:** Manual coding method employed has limitations in spite of the fact that computer-centered analysis could be more appropriate with high number electronic data sets by reducing time and avoid the need for employing several human coders to arrive at inter-coder reliability. The study was also limited by dwelling on only eight-year period from 2010 to 2017. Dealing with as many documents as possible, and more current research documents for that matter, could be more reliable to such research work.

**Practical Implication:** It is intended that the paper will guide both industry players and researchers as to the most suitable procedure and technique that should be adopted to characterize oil palm fiber-plastic composites during such composite development.

**Social Implication:** The knowledge obtained in this paper when applied will facilitate sustainable development by making use of waste vegetal fibre and polymer waste through efficient and effective characterization techniques by recycling these materials to produce new composite materials.

**Originality/Value:** This study is novel for the reason that it establishes the fact that different specimen preparation techniques may be employed by researchers in the development of oil palm fiber and polymer composites depending on the type of polymer matrix and the type of desired composite characteristics; and that specific standards are available in characterizing oil palm and polymer composites.

**Keywords:** Charge compression fiber · Grinding molding

## 1 Introduction

This review is necessitated considering the perpetual interest of researchers and industry players with reference to oil palm fiber and polymer composites in engineering applications of materials (Ahmed and Jones 1990). It has been found that by adding fibers to polymers properties such as stiffness, fracture toughness, reduction of coefficient of thermal expansion, and improvement of creep resistance could be improved (Jabbar 2017; Lin et al. 2016). Resource scarcity and environmental awareness have also contributed to the increasing interest in the use of bio-based materials such as Oil Palm Fiber and Polymer Composite (OPF-P) in various engineering applications Väisänen et al. (2016). Oil Palm Mesocarp Fiber (OPMF) and Oil Palm Empty Fruit Bunch (OPEFB) fiber are considered in this paper.

Other factors that have further encouraged the desire to improve the necessity to OPF-P composites research and applications include compulsive legislative laws and policies He et al. (2013) as well as financial and commercial implications Carus et al. (2015). Though all these factors have influenced the interest of OPF-P composite manufacture, it appears the principal and overriding elements have been found to be resource scarcity and environmental concerns. Both legislative and commercial interests have arisen due to the need to save scarce resource and protection of the environment. Over half a century beginning from the 20<sup>th</sup> Century, the challenges relating to plastic waste disposal have been costly to deal with, particularly, with regards to environmental pollution and degradation as well as public health. The issue of global warming and the consequential effects of flooding, extreme weather conditions of heatwaves and cold freezing, hurricanes, tornadoes and stormy weather conditions have been experienced in many parts of the world. The challenge of greenhouse gas emissions arising from plastic burning or incineration and noxious gases from vehicles that convey plastic products due to burning of petroleum-based fuel in vehicle combustion chamber has equally become a burden on the environment and humanity as well. Though more crude oil discoveries are being made it appears the rate of consumption of petroleum consumption does not commensurate with the rate of a crude oil find.

The instability of crude oil price in the global environment and the occasional but unbearable hikes of petroleum price, demands that new and comparable engineering material resource need to be explored elsewhere. These are, but the principal reasons for which natural fiber plastic composites have come into play as a new engineering resource material. In countries where the palm oil tree is a found oil palm fiber has become a target natural fiber for plastic composite formation. Thus, as organic waste, OPF finds new but innovative and applicable use in creating new materials with plastics,



which have become environmental and public health burden, in the form of OPF-P composite materials. Comparably, Natural Fiber-Plastic Composites (NFPCs) such as Oil Palm Fiber-Polymer composites may offer a manifold of benefits with conventional thermoplastic composites such as carbon fiber, E-glass and Kevlar in terms of density, processing time, and processing temperature. Nevertheless, NFPCs are limited due to their inherent thermal and moisture instability arising from the presence of cellulose in the structure of the vegetative fiber.

Another deficiency of OPF-P composite, and for that matter NFPCs, is the weaker bonds between vegetative fiber and polymer at the molecular level. This condition arises as a result of the ingrained hydrophobic characteristics of natural vegetative fiber that degenerate the bond between fiber filler and polymer matrix, which in effect, determines the general behavior of the composite material. In spite of these limitations, a careful selection of natural fiber and plastic, treatment and sample preparation have been found to be useful in reducing, if not circumventing these drawbacks. Though these four elements are all useful in ensuring the desired properties of composite, it appears the final process in the development of the composite; i.e. sample preparation appears to be the most prominent since without which a fiber with the desired characteristics, a plastic with known properties, and the best selection of fiber treatment media would all come to naught; since the beneficial properties would be less than compensate for a better sample preparation technique. The aim of this study was to investigate the techniques in the characterization of oil palm-polymer composites. The specific objectives were to review literature on approaches employed in sample preparation of OPF-P composite materials as adopted by researchers; to examine the sample preparation materials, identify specimen preparation procedures, and finally, to establish the characterization elements and equipment of OPF-P composite development.

## 2 Methodology

This study selected content analysis as the study methodology, with specific emphasis on systematic review of manifest content. Content analysis is the study of documents which might be texts of various formats, words, pictures, audio or video. It is used to examine arrangements in information communication in a systematic way (Alan (2011)). This method employs previous research documents to be reviewed to establish research gap with reference to the study under consideration. Hence the five-step procedure proposed by Denyer and Tranfield (2009) to systematically review literature was utilized. The procedure includes the formulation of questions on the study, selection of required documents, assessment of the selected documents, analysis and finally, documentation of the result.

To achieve the objectives of the study and to identify the current and appropriate academic research work connected to characterization approach of developed oil palm fiber and polymer composites, a systematic review was utilized to entail a period of eleven years; from 2012 to 2021 from the Microsoft Bing database. The Microsoft Bing database contains reputable number of research documents globally. The eight year span between 2010 and 2017 was justified due to the fact that a relatively higher portion of current research work in the subject area, were studied within the period.

An elaborate search on the Microsoft Bing was performed by employing the “title-abstract-keyword” procedure. The keywords for the search involved “charge calculations”; “compression molding”; “grinding”; “heat blending”; “oil palm fiber” and “polyethylene (PE)”. The search yielded 63,235 documents. Upon further sifting employing the keywords “tensile strength”; “hardness”; “impact”; “compression”; flexural properties; “water absorption”; “microstructure” and “thermo-gravimetric”, 3065 documents were obtained. Furthermore, restrictions were made using the keywords “materials technology”; “material science”; “composites”; and “materials engineering”, with specific application to article documents. Research titles were sifted again to yield 110 publications. Upon analysing further, 22 of the 110 research documents were finally selected and manually coded for detail review and analysis of the manifest contents (Lee, Kim, and Yu 2001). The next section of this paper presents the results obtained.

### 3 Findings and Discussion

Many researchers have conducted various studies on the potential of utilizing oil palm fiber, particularly oil palm empty fruit bunch fiber, and oil palm mesocarp fiber, as reinforcement material for non-renewable polymer composites (Aldousiri, Alajmi and Shalwan 2013; Eng et al. 2014; Ewulonu and Igwe 2012; Ewulonu and Igwe 2012; Ghazilan et al. 2017; Khalil et al. 2012; Mahjoub et al. 2014; Mohammed, Ansari and Pua 2015; Nasution, Pandia and Sinaga 2015; Olusunmade et al., 2016; Shinoj et al. 2011; Sosu, Hasford and Dadson 2011; Then et al. 2013; Yousif 2010). This section reports on the methods applied by various researchers to prepare oil palm fiber-polymer composite materials from material acquisition to characterization.

#### 3.1 OPF-Epoxy (EP) Blend

In an effort to determine the mechanical properties of short random oil palm fiber reinforced epoxy composites, Yousif (2010) used oil palm empty fruit bunch (OPEFB) fiber and  $1.15 \text{ g/cm}^3$  density epoxy matrix. A Retsch model grinder was employed to chop fiber into 10 mm to 20 mm length. Composites with 5%, 10%, 15% and 20% volume fraction fiber loading were fabricated by hand lay-up method. Composites were molded using 200 mm (length, L)  $\times$  150 mm (width, W)  $\times$  3 mm (thickness, T). Epoxy resin and hardener were initially mixed in a ratio of 4:1 to constitute the base matrix. After fibers were spread into mould epoxy resin was added to cover the fiber. The report, unfortunately, failed to report whether heat was applied to the composite or not, mold material was also not stated. The mixture in the mold was compressed until a thickness of 3 mm was achieved. A curing period of 24 h at 34–30 °C room temperature condition was used. STM standard D638 and D790 respectively were finally used for tensile and flexural tests. Tensile strength, Young’s modulus, elongation at break, flexural strength and flexural modulus of composites were determined. Scanning electron micrograph was used to determine the microstructure of composites.

Composites fabricated from oil palm fiber (OPF) and epoxy matrix have been found to be useful in producing automobile parts and construction components (Mohammed, Ansari and Pua 2015). The presence of moisture in lignocellulose fiber is, however, a

challenge in the application of plant fiber in general for such purposes. However, chemical treatment of fiber surface is a means by which this challenge could be circumvented if not reduced. In trying to investigate this phenomenon a study was carried out by Mohammed et al. (2015). Three different and separate treatments; alkaline, silane and acetylation, were used; as sodium hydroxide, triethoxy (ethyl), silane coupling agent and acetic acid respectively. Brand of epoxy and hardener were 8950-1A and 8950-1B respectively. Fibers were prepared from oil palm empty fruit bunch as waste material after oil palm fruits used for oil extraction were removed from the bunch. Fibers were ground and sieved by a motorized sieve shaker to obtain 300 to 600  $\mu\text{m}$  size fibers (Yousif 2010).

Alkaline treatment involved soaking 5% concentration alkaline solution at 29 °C for two hours; filtering out treated fibers; washing with distilled water to ensure total removal of sodium hydroxide; and finally drying fiber at 50 °C for 48 h in an oven. Silane treatment also involved soaking fiber in triethoxy (ethyl) silane coupling agent solution (alcohol-water mixture at 60:40) with pH adjustment of 3.5 – 4.0 for 2 h; washing with distilled water at room temperature; filtering to eliminate soluble impurities; and finally drying fiber at 50 °C for 48 h in an oven: The acetylene treatment was carried out through immersion of fiber for 2 h at 50 °C. Fibers were then washed with distilled water at room temperature; soluble impurities removed by filtration, and finally dried in an oven at 51 °C for 24 h (Yousif 2010).

Composite fabrication proceeded by mixing epoxy resin with a hardener in a ratio 2:1. After thorough mixing, treated fiber (30 wt%) was distributed mixed and stirred thoroughly to ensure uniform distribution and minimal air entrapment. An Aluminium mold of dimension 200 × 200 × 14 mm<sup>3</sup> was prepared to receive the fluid mixture at room temperature for 24-h curing. A universal testing machine (model No. 8801 UK, Instron) was used for the tensile test. In accordance with ASTM D 638, dumbbell-shaped specimens of 13 mm × 3 mm cross-section, and length 50 mm, were prepared for tests. At ambient temperature, load cell and crosshead speed were 10kN and 5 mm/min respectively. Average values were taken for 5 specimens each, relying on Blue Hill V.2.5 software. In addition to tensile strength, tensile modulus and elongation at break were determined. The microstructure of specimen were further determined by Scanning Electron Microscope (SEM) (employing Hitachi S-3400N) through observation of fracture ends of the specimens. Microscope operating conditions for accelerating voltage and magnification were 15 kV and 500 × respectively. To ensure better image resolution, fracture specimen samples (and to avoid electrostatic charging) were coated with gold before observation (Yousif 2010).

Oil palm empty fruit bunch fiber-reinforced epoxy composites were tested for tensile strength and modulus of elasticity characteristics by Ghazilan et al. (2017). Zeepoxy HL002 TA/B epoxy resin pellets; and carded, combed, intermixed and tangled OPEFB fiber, using electrical motor carding machine, were used as composite ingredients. The mold consists of 400 mm × 400 mm bottom stainless steel plate; 300 mm × 300 mm upper stainless steel plate; and four 200 mm × 5 mm flexible resin stoppers. Mylar sheet, as a releasing agent was placed on each side of the mold plate. Epoxy resin and hardener were mixed thoroughly depending on fiber-matrix volume fraction proportions. By stacking layers of OPEFB fiber on the bottom plate, the epoxy-hardener mixture was placed on fiber layers to impregnate into a composite material. Vacuum bagging material

was then placed on top of the composite and covered by the upper component of mold. The purpose of the vacuum bag was to enclose the lay-up in a secluded space. Sealant tape was then used to seal the edges of the mold. A vacuum pump finally draws out the air in the secluded space creating an airtight vacuum bag best suited for storage purpose. Curing was subsequently performed. Tensile characterization was adopted to determine tensile strength and modulus of elasticity. Specimens were prepared in accordance with ASTM D 638 standards. Tensile strength was obtained as the quotient of maximum load to average cross-sectional gauge length area of the specimen. Modulus of elasticity was also obtained as the quotient of the difference in stress corresponding to the section on the straight line obtained by extending the initial linear portion of the stress-strain curve, on one hand, to the corresponding difference in strain value on the other (Ghazilan et al. 2017).

### 3.2 OPF-Polyester (PS) Blend

Yousif (2010) conducted a study on oil palm fibers; both fruit and bunch oil palm mesocarp fiber (OPMF) and oil palm empty fruit bunch (OPEFB) fiber) as reinforcement of polyester matrix. Both fruit and bunch fiber were extracted by first crushing fruit bunches to remove palm fruits. Bunch fibers were then extracted from empty fruit bunch. Oil palm fruits were also crushed and washed to separate mesocarp fiber from oil, soil, and seeds. To ensure clean wash, this procedure was repeated for three times. At room temperature of 28 °C, extracted fibers were dried for 48 h and cut to 10–20 mm length. Fibers were then soaked in 0.1% NaOH solution for 24 h and finally dried in an oven at 40 °C for 24 h. Both bunch and mesocarp fiber composites were fabricated using the hand-layup method. The dimensions of metal mold was 120 mm × 120 mm × 20 mm. Mold surface was coated with a thin layer of wax to facilitate easy removal of cast composite. After randomly arranging the fiber into the mold and pressed into a mat, a composite block was fabricated by impregnating the fiber mats with polyester resin – 2% hardener. At 24 °C composites were cured for 24 h. It was observed that low volume fraction of fibers (below 30%) could not be easily fabricated since fibers appeared to float during the curing process thus rendering composite formation inefficient. The volume fraction of fiber between 35% and 65% were therefore selected (Yousif 2010).

During the fabrication process, the required quantity of fibers was put in the mold and pressed before pouring the liquid matrix into the mold. A steel roller was used to uniformly distribute fiber to enhance composite homogeneity. The best block out of five fabricated for each fiber type (bunch and fruit) was selected for testing. Blocks were machined into three samples for tensile, compression and flexural experimentation (Yousif 2010).

Single fiber pull-out experimentation of specimens was also prepared separately. A metal mould of 50 × 10 × 10 mm<sup>3</sup> dimension was employed in this regard. Pieces of rubber were placed at both ends of the mould to prevent resin leakage prior to resin solidification. Both ends of the fiber were placed into the middle plane of the rubbers. As a releasing facilitator, the wax layer was applied on mold walls. A 2% polyester hardener was gently stirred and poured into the mould. At 24 °C environmental temperature, prepared samples were cured for 24 h. The pull-out test was conducted using a 100Q standalone Universal Test System at a loading speed of 1 mm/min. Embedded fiber was

cut by drilling a hole through the specimen to ensure the required embedded length (20 mm) was obtained (Yousif 2010).

Experimentation involving tensile, compression and flexural characteristics of composites were conducted at room temperature by employing WP300 PC Aided Universal Material Test machine provided with data acquisition system. The tensile test was performed by using a few specimens to determine appropriate grip forces. This was to ensure fracture prevention of specimen arising from gripping forces. Simultaneous measurement of load and strain were made by subjecting load incrementally at a constant rate of 2 mm/min until fracture. Applying a crosshead movement rate of 1 mm/min, the three-point flexural tests were used for the bending tests. Tests were repeated thrice for each type of composite and volume fraction. Scanning Electron microscopic was used to observe the microstructure of composites and each fiber type (Yousif 2010).

### 3.3 OPF-Linear Low Density Polyethylene (LLDPE)

Dynamic mechanical properties (fiber-matrix interactions) of oil palm fiber (bunch) and low linear density polyethylene (LLDPE) bio composites were determined by Shinoj et al. (2011). Palm oil milling sequence was employed to strip off palm fruits. Fresh fruit bunches (FFBS) were treated with steam at a pressure of 294 kPa for 1 h. Fruits were then stripped to yield the empty fruit bunches (EFBs). Empty fruit bunches were dried using electrically forced convection cabinet heat drier at 60 °C. Moisture content was reduced from 65–70% (w.b) to 35–40%. A mechanical decorticator was employed to subject bunches to shear and impact forces through rotating beaters to extract fibers. Field impurities (soil, etc.) were removed by washing fibers in distilled water; after which content was dried in a hot air oven at 50 °C for 48 h and then stored in air-tight cabinets. Powdered LLDPE of 0.938 gcm<sup>-3</sup> density; 3.3 g (10 mm)<sup>-1</sup> melt-flow index; and 126.5 °C melting point were used in the experimentation (Shinoj et al. 2011).

Composites were prepared by immersion of fibers in 5% (ww-1) NaOH technical grade alkali solution for one hour. Traces of NaOH were then removed by washing fiber in distilled water. Five percent concentration NaOH was used in accordance with recommendations by earlier studies. In a hot air oven, washed fibers were further treated at 50 ± 1 °C for 48 h. A laboratory grinder was used to shred fibers and then sieved into three distinguished fractions. ASTM standard test sieves was used to categorize fractions into 20–40 (425–840N); 40–80 (177–425N) and 80–200 (75–177N). A Baker Perkins Saginaw-Michigan USA ribbon rotating blender was then employed to mix OPFB and LLDPE at a rotating speed of 40 rpm for 10 min. Mixture composite was poured into a 200 mm × 200 mm and 3 mm thickness mould. A hydraulic press compression mold facility with water cooling system preheated the composite at 150 °C; heated the mixture in the mould at 850 kPa pressure for 12 min; and cooled (mold) for 15 min under atmospheric pressure. A DMA-242 NETZSCH model dynamic mechanical analyzer was employed to scan 55 × 10 × 3 mm<sup>3</sup> rectangular specimens to determine storage modulus, loss modulus and damping parameter ( $\epsilon'$ ,  $\epsilon''$  and  $\tan \delta$ ) of composites. Fiber-matrix interactions were finally determined by theoretical methods (Shinoj et al. (2011).

Olusunmade et al. (2016) studied the mechanical properties of oil palm mesocarp fiber-linear low-density pure polyethylene (OPMF-LLDPE) composite. Pure polyethylene was obtained for the study in the form of pellets while fiber was acquired from

oil palm processing mill after extracting palm oil from oil palm fruits. The oil palm mesocarp fiber was washed with water and detergent solution to render fiber clean of palm oil and other soluble impurities. This was to ensure adequate adhesion between fiber and polyethylene matrix. The fiber was then dried in the sun; pulverized with a 300 micron sieve. Composite was prepared by adopting a hand lay-up method. The electronic weighing balance was adopted to weigh plastic and fiber. Fiber loading was varied from 5 wt% to 25 wt% in steps of 5 wt% and mixed with plastic. Aluminum mold was employed to heat the fiber-plastic mixture for 20 min at 150 °C. The mixture was thoroughly mixed to attain homogeneous blend. The mold was further heated for another 10 minutes with an electric heater. The mold was of male and female type (top and bottom), connected by two hinges (Olusunmade et al. 2016).

To safeguard adequate and efficient compression a G-clamp was adopted to hold the female and male parts of the mold together until blend flows out through provided orifice on male (top) part and male and female interface of walls. The mold and its content were allowed to cool at room temperature after which clamp was loosened to remove the casts composite. Mold content was then removed and cut for specimen tests. The tensile test was carried with Instron 3369 (universal Testing Machine to determine tensile strength, tensile modulus and elongation at break. Hardness test was also performed according to Brinell standard, while the impact strength test was carried out by the Izod principle. The study failed to report on any standard. No surface modification or treatment was also employed for fibers. A  $295 \times 210 \times 6 \text{ mm}^3$  dimension mold was used. Specimen sizes were however not stated in the report. Ordinary flat plate electronic heater was adopted during the heating process (Olusunmade et al. 2016).

### 3.4 OPF-High Density Polyethylene (HDPE)

Ewulonu and Igwe (2012) investigated the properties of oil palm empty fruit bunch (OPEFB) fibre-high density polyethylene (HDPE) composite with maleic anhydride-g-polyethylene (MAPE) to compact the blend. Spikelets from OPEFB were removed from the bunch, washed thoroughly with water and sun-dried. They were then reduced to a fine powder. Three sieves were used to categorize fiber sizes into 0.50 mm, 0.21 mm and 0.300 mm. High density polyethylene with melt flow index (MFI) of 2.16 dg/mm and density of  $0.946 \text{ g/cm}^3$  was obtained for experimentation. It was first heated to melt and mixed with fiber filler, ensuring homogeneity of mixture in the injection molding facility by selecting appropriate quantities of OPEFB and HDPE. Two distinguished composites were prepared: first, preparing HDPE-OPEFB composites; and second, preparing HDPE-OPEFB with MAPE composites. The three particle sizes were each prepared with both latter and former composites. Using injection molding technique sheet composites were fabricated at 150 °C for both sets. MAPE quantity applied to the latter composite varied between 1 to 6 wt% with the fixed base quantity of HDPE (800 g) and OPEFB (8 g). Rockwell Hardness (ASTM D 785); tensile strength (ASTM D 638); specific gravity (ASTM D792); flame propagation rate (ASTM D 4804 with modifications); and water absorption (cold water (24h); hot water (2 h) characteristics were determined by standard methods (Ewulonu and Igwe 2012).

### 3.5 OPF-Poly (Butylene) Succinate (PBS) Blend

In another experimentation that aimed to determine tensile, flexural and impact properties of the composite, oil palm mesocarp fiber (OPMF) and oil palm empty fruit bunch (OPEFB) fiber were each fabricated into separate composites with poly butylene succinate matrix (Then et al. 2013). The fibers were then dried in an oven at 5 °C. The drying process was to remove fiber impurities such as palm oil and soil. Dried fibers were then ground using 150–300 µm sieve size. Fibers were each sealed and stored in polyethylene bags, separately, according to fiber type: OPEFB or OPMF. At 120 °C and 50rpm rotor speed, a Brabender internal mixer blended PBS with OPMF and OPEFB fiber. Prior to the blending, OPMF, OPEFB fiber and PBS were dried in a 60 °C temperature oven. Blending was proceeded by first placing PBS pellets into the mixing chamber for 2 min to melt. Fibers were then added and allowed to mix with PBS pellets for 13 min at 120 °C and 150 kg/cm<sup>2</sup>. Compound material was compressed for 5min by a hydraulic hot press. Compressed composites were then cold-pressed at 30 °C for another 5 mm. fiber loading was varied from 1 to 70 wt% at 10 wt% intervals for both OPMF and OPEFB fiber separately (Then et al. 2013).

Flexural and tensile tests of bio-composites were conducted by a Universal Testing Machine (Instron 4302) at 25 °C and 1 kN load cell. Specimens were prepared according to ASTM D790 and D638–5 standards. The flexural test was performed with 48 mm support span length and 1.3 mm/min crosshead speed. Crosshead speed for the tensile test was 5 mm/min. Properties tested include elongation at break and flexural modulus. ASTM D256 standard was applied with Izod impact tester for the impact test at 25 °C with 7.5 J pendulum energy content. Average values for five specimens were recorded for all tests performed. After coating specimen with gold by a Bio-rad coating system, a JOEL JSM-6400 scanning electron microscope operated at 15 kV and 200–300 × magnification, scanned samples for surface morphological characteristics. PBS was of density 1.26 g/cm<sup>3</sup> and melting point –115 °C. Oil palm mill fiber materials were used to prepare the composites (Then et al. 2013).

### 3.6 OPF-Polypropylene (PP) Blend

In a separate study, the effect of maleic-anhydride-g-polypropylene (MAPP) on impact strength and thermal degradation of oil palm empty fruit bunch (OPEFB) fiber and waste polypropylene composite was studied by Nasution et al. (2015). OPEFB fiber was obtained from oil palm processing mill after removal of oil palm fruits for palm oil production polypropylene was obtained as plastic packaging cups waste manufactured from pure polypropylene (wPP from pPP). Waste polypropylene (wPP) packaging cups were collected, cleaned and washed to remove soil and other contaminants. Waste cups were then dried and cut into 1 × 1 cm pieces. Cut pieces of polypropylene were grafted into maleic anhydride to form maleic-anhydride-g-polypropylene synthesis matrix. While OPEFB fiber content was fixed, the content of wPP and MAPP were varied in percentage. The wPP percentage reduced as MAPP proportion increased. Before then, OPEFB was treated chemically with acetic acid. Oil Palm empty fruit bunch fiber was in 50% acetic acid; stirred for 1 h; filtered through filter paper to separate and clean solution of solid materials such as soil and dirt; washed several times with distilled water, and dried



for 24 h at 80 °C. Twenty milliliters of acetic acid was used to dissolve 1 g of fiber. At 190 °C fabrication of composites was obtained (Nasution et al. 2015).

In the process, the mixture was introduced into an extruder and hot-pressed at 190 °C to 5 mm for impact test. Preheating was done in the hot press for 5 min before 5 min compression. This was followed by cooling for another 5 min before impact test was conducted in accordance with ASTM D 256. Unfortunately, the study did not state the type of equipment used for testing the impact strength. Thermogravimetric analysis of composites was done employing Perkin-Elmer Pyris 6 TGA analyzer under the following conditions: 50–80 °C heating temperature; the heating rate of 20 C/min; and nitrogen-air flow of 50 ml/min (Nasution et al. 2015).

## 4 Conclusion

From the foregoing, the following observations were deduced. Oil palm fibre-plastic composites studies have become popular in recent times due to various advantages and benefits that accrue from their usage and applications. Palm oil fibres have a relatively high specific strength, low weight, free formability and comparable fatigue and corrosion resistance. However, its limitations include high moisture absorption and high anisotropic characteristics. For improved chemical and physical characteristics of fiber-plastic matrix composites, surface modification of fiber is required. Chemical treatment of fibers includes alkaline, silane and acetylene. Charge calculations of palm oil fiber and polymers were based on weight and volume. Initial washing of water-detergent solution of fiber to clean off soil and dirt is also required during composite fabrication. Metals such as stainless steel and Aluminium may be preferred as the mold material to avoid contamination of composite with rust. The hinged mold of male and female parts could also be used. Fiber-plastic mixture may be heated depending on the type of plastic and composite expected. Fibers may be grafted by another material while a hardener may also be introduced into the plastic resin. Polymers identified include Epoxy (EP), Polyester (PS) Linear Low-Density Polyethylene (LLDPE), High Density Polyethylene (HDPE), Poly (Butylene) Succinate (PBS), and Polypropylene (PP). Various researchers have used standardized procedures as against non-standard approach during experimentation. ASTM standards such as ASTM D 785 (Rockwell hardness); ASTM D 638 (tensile strength); ASTM D792 (specific gravity); ASTM D 4804 with modifications (flame propagation rate); Scanning Electron Microscope (SEM); and water absorption technique were identified.

While fibers could be obtained from oil palm milling entities, plastics were in most situations obtained purely from manufacturers (chemical). The standard procedure includes the type of equipment used for composite preparation: composite preparation (mixing, casting); measuring equipment; and measurement. Mechanical properties determined to characterize composites include tensile strength, modulus of elasticity, impact strength, compression strength, elongation at break and flexural strength. Water absorption, microstructure and thermo-gravimetric properties could also be determined. Equipment's usually implored for mechanical characterization were Universal Testing Machine; Izod Impact Equipment; and Bend Testing Machine (3-point bending). Chemical surface treatment was also found to be fundamentally employed. Though chemical



surface modifications could be employed, physical or biological treatments may also go a long way to improve upon the characteristics and properties of fabricated composites. Exploring characteristics of hybrid composites of OPMF-polyethylene composites with palm kernel shell as hybrid reinforcement material as a new area of study may be an interesting avenue of research within oil palm tree cultivated regions of the world such as West Africa in general and Ghana in particular.

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# The Dilemma of Using English Language in Tanzanian Higher Education

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**Abstract. Purpose:** This paper investigated the dilemma of using the English Language in Tanzanian higher education. Specifically, the study examined the attitude of learners and instructors toward the usage of EL as a medium of instruction (MoI) and communication.

**Design/Methodology/Approach:** The study adopted a cross-sectional survey in which one hundred (100) students and twenty (20) instructors ( $n = 120$ ) from the College of Business Education - Dodoma Campus were surveyed using a questionnaire. Qualitative data were captured using focus group discussion and observation methods. Proportionate stratified and purposive sampling techniques were employed in sample selection. Content analysis was employed as a qualitative data analysis method while descriptive statistics were employed for quantitative data analysis.

**Findings:** The findings show that students' attitude was not supportive toward the usage of EL as MoI and communication in Tanzanian higher education. The findings further show that instructors use a mixture of English and Kiswahili during instruction and communication with learners.

**Research limitation/Implication:** The study was limited to one higher education institution. Its implication is a source of biasness and to it is recommended the inclusion of more than one higher education institution in future.

**Practical Implication:** The Ministry of Education, Science and Technology and higher education management should re-rethink about closing the skill gap in EL usage since the usage of EL as MoI is a policy issue that requires compliance and not otherwise.

**Social Implication:** The study findings imply that there is an existence of mismatch between labour market requirements for graduates with good mastery in EL and the actual reality of graduates with inadequate mastery in EL.

**Originality/Value:** The originality of this study is embedded in unfolding the dilemma of using EL in Tanzanian higher education which today is a puzzle since the MoEST, higher education management and development partners in education are silent on the situation.

**Keywords:** Dilemma · English language · Higher education · Tanzania

## 1 Introduction

The Sustainable Development Goals (SDGs) point out that quality education is one of the SDGs that aims at ensuring that it is provide to all people. High quality education is for liberation and consequently is aimed at poverty reduction if such education is integrated in economic activities, creativity and innovation. The English language has established itself as a universal Lingua franca in this period of extraordinary globalization, despite the decelerating worldwide debates on English as an international language (Coleman 2006). Worldwide, the need of using EL as Medium of Instruction (MoI) in higher education (HE) has increased (Coleman 2006, Coetzee 2004, Crystal 2004). Graddol (1997) argued that one of the serious observed trends in education worldwide is teaching of increasing academic programmes in HE using English as MoI. The option of using EL has been interpreted in various dimensions: in some situations, it is viewed as a component of an increasingly developing socio-economic agenda; while others argue, it focuses on the idea of having one universal common serviceable language (Marsh 2006). Instructors and students in higher institution encounter challenges when interacting using EL as MoI in learning process. Numbers of studies have been conducted to identify these challenges, their causes and ways of intervention. Although these studies come up with valuable findings which have, in a way helped to formulate measures for interventions but most of them have been conducted to address challenges of using EL as a MoI in primary and secondary education. Nevertheless, the challenges of using EL as a MoI and communication tool in higher learning institutions in Tanzania still persist and at times intensify as they remain understudied.

In Tanzania, the system of education is guided by the policy with bilingual application, which compels students to learn both English and Kiswahili in different weight depending on the level of the learner. At primary level of education Kiswahili is used as a MoI, in secondary level of education it is a subject, and at tertiary level of education it is an optional course (URT, National website). In Tanzania, EL is very important since it is the language which connects Tanzania and other parts of world technologically, politically, administratively as well in commercial arena.

Worldwide, EL apart from being a great concern of educational system, it has also been found being necessary as job requirement in several countries (Doğançay-Aktuna 1998). In Tanzania, it has been revealed that students in secondary level of education and higher levels are irresponsibly prepared in using EL as MoI (Majenga 2015). Hence, instructors and students alike through struggle try to ensure that they communicate using the language that they have little mastery. As the result, Kiswahili has been always used informally as MoI since both students and instructors frequently switch to it with the concern that it is the language they are familiar with during expression discussion. A number of efforts have been taken by the Government to fuel use of EL effectively as a MoI from secondary to tertiary levels. Such efforts include development of education policy (URT 1995), essay writing competitions, administration of examinations, assignments and tests. Despite the Government's efforts taken, to date there is ineffective use of EL as MoI and communication and learners-instructors attitude toward usage of EL in Tanzanian HE has not been rigorously explored; something which calls for an academic

inquiry. This study focuses specifically to explore the dilemma of using EL in Tanzanian HE taking the College of Business Education – Dodoma Campus as an institution selected for study.

## 2 Theoretical Framework

Two theories were used to underpin this study. The first theory was the theory of self-efficacy (TSe) which was developed by Albert Bandura (1986) considering self-efficacy as special capability of human; this is because, via this kind of own-referent thinking, human beings gauge and modify the way they think and behave. These personality assessments comprise insights of self-efficiency which is trust in individual's abilities for organizing and implementing the paths of acts essential in managing forthcoming circumstances. The theory put forward four major tactics for efficacy progress: Mastering of learning activity addresses that the focus of building up competence is on emerging fitness during learning. Another one is imitation which is thoroughly linked to modeling whereas learners replicate the model for attaining competence. Another one is modeling in which its primary role aims at fast-tracking mastery by imparting learners with models to copy, luckily, at large human behaviour is acquired via close observational modeling. Finally, self-regulation as human behavior emphasizes on performing a certain action. Such beliefs of individual aptitude bring about behavioural effect. They always tend to affect individual's preferences and the progressions of actions people perform. In connection to this study, the theory of Self-efficacy is relevant in ways that learners gain mastery from the surrounding environment. For learners to use EL effectively, lecturers and management team must assume the role modeling in many ways such as fluent use of EL in teaching, instructing, communication and giving learners' chances to do by themselves using EL. Moreover, they have to change their attitudes towards the use of EL so as to inspire learners to change their attitudes towards the same.

Further, the second theory was adopted to give learners exposure to the learning environment, the aspect which was not covered in the first theory. This theory was the Operant Conditioning Theory which was developed by Skinner (1974) with the focus that whenever a hungry organism demonstrates behaviour that results such organism to be served with food, such behaviour is strengthened by repetitive actions consequently, the chance of the behaviour to recur is maximized (Skinner 1974). The relevance of this theory to this study is that when students in higher education are exposed to a certain environment; say using or not using EL, their behaviour will be strengthened by that action accordingly and consequently it is most likely to happen repetitively and become a behaviour. Accordingly, learners' and instructors' attitudes are more likely to be affected by the newly developed behaviour. For example, using or not using EL in the class room during learning-teaching process and even outside class room environment.

## 3 Research Methodology

This study adopted cross-sectional research design survey with the reason that the design permits collection of data at one specified time (Kothari 2009). According to Hulley et al. (2013) a cross-sectional study entails that the variables are all measured at a single point

in time with no structural distinction between predictors and outcomes. This research design was sought suitable due to of limited time and financial recourses to complete the study timely. The study was restricted to Dodoma Region at the College of Business Education (CBE). CBE was selected with the reason that the researcher was familiar with the college environment since she worked at CBE on part time basis. This facilitated easy availability of data and reduced unnecessary costs associated with difficulties to data accessibility. The population of the study was three thousand hundred and eighty-four (3,084) CBE students ranging from National Technical Award Level 4 (Certificate), National Technical Award Level 5 (Diploma-I), National Technical Award Level 6 (Diploma-II), National Technical Award Level 7 (Bachelor-I and II) and National Technical Award Level 8 (Bachelor-III) (CBE-Dodoma Campus, 2015). Further, this study involved population of sixty (60) academic staff. Since the population existed in strata based on NTA Levels (educational programmes), proportionate stratified sampling was considered suitable. Final subjects were randomly selected from each stratum. Members of management team as key informants (KIs) were purposefully selected since they were believed to be rich in information. One hundred and twenty (120) respondents were involved in the study (Table 1). Saunders, Lewis and Thornhill (2007) recommend that the sample size of 30 is statistically suitable for analysis. Therefore, 120 sample size in this study was considered statistically sufficient to carry out the analysis.

**Table 1.** Sample size determination

Respondents	Population			Sample size		
	Male	Female	Total	Male	Female	Total
NTA Level 4	185	169	354	6	6	<b>12</b>
NTA Level 5	264	236	500	8	8	<b>16</b>
NTA Level 6	497	574	1071	15	20	<b>35</b>
NTA Level 7	466	407	873	15	13	<b>28</b>
NTA Level 8	183	103	286	5	4	<b>9</b>
<b>Sub-total</b>	<b>1595</b>	<b>1489</b>	<b>3084</b>	<b>49</b>	<b>51</b>	<b>100</b>
<b>Instructors</b>	<b>50</b>	<b>10</b>	<b>60</b>	<b>17</b>	<b>3</b>	<b>20</b>
<b>Total</b>						<b>120</b>

Source: CBE-Dodoma Campus (2015)

Primary data were collected with the aid of questionnaire survey, focused group discussions (FGD) and observation methods. Questionnaires with open and closed ended questions were designed for both instructors and students. 5-point Likert Scale questions were used to measure of students’ and instructors’ attitude toward EL usage as MoI and communication. The questionnaire was pre-tested before it was fully administered to respondents. Questions with ambiguous and multiple answers were rephrased and some were omitted. Similarly, questions with important answers which were missing were added. Qualitative data analysis was carried out using content analysis whose steps

involved examination, categorization, tabulation and recombination of the evidences for the problem under investigation (Yin 2014). In the course of analysis, researchers worked hard in understanding respondents' opinions from FGD, made interpretation and presented them in the required manner (Charmaz 2006). The descriptions and observed issues were compared and contrasted with existing body of knowledge (Majenga 2015). In some cases where responses were found to unclear during data analysis, some respondents were contacted using mobile phone to give more clarifications. Quantitative data were analyzed descriptively in which frequency, percent, mean scores and standard deviations were computed and presented in tables. To ensure credibility of data, reliability test and validity were established. Cronbach's Alpha was performed as the reliability test. Triangulation was adopted to ensure high degree of validity of data in which several methods of collecting and analyzing data were employed (Golafshani 2003). In this regard, questionnaire, observation and FGD data collection methods were employed. Before embarking to full questionnaire administration, pre-testing of questionnaire was performed to 10 students and 5 instructors from neighbouring institution to increase validity.

## 4 Findings and Discussion

### 4.1 Results from Reliability Test

Cronbach's Alpha (Table 2) for attitude of students-instructors toward EL usage as MoI and communication was computed as reliability test. Normally, coefficients of Cronbach's Alpha ranges between 0 and 1 whereas results approaching to 1 indicate higher reliability (Majenga 2015). Interpretation for magnitude of coefficient Alpha with 0.9 and above has high reliability and its interpretation is very good or excellent. Those with the coefficient of Alpha ranging from 0.80 to 0.89 are good while an Alpha value ranging from 0.70 to 0.79 is suitable. Those ranging from 0.60 to 0.70 bring about question mark and poor for those ranging from 0.50 and 0.60 while unacceptable for coefficient of Alpha with values less than 0.50 (Lawson 2014). Initially, some variables under the study yielded low values of Chronbach's Alpha. This necessitated the researcher to thoroughly re-clean data and re-tested for reliability. Therefore, the variables in this study yielded Chronbach's Alpha of 0.786 implying acceptable reliability. Many previous studies have used Cronbach's Alpha to measure reliability and validity of research instruments (Mashene and Kumburu 2020, Mungai 2013, Tundui 2012).

**Table 2.** Reliability results

Variables	Cronbach's Alpha	N of items
Attitude of students-instructors toward EL usage	.0786	8

## 5 Students' Attitude Toward Using EL as a MoI and Communication

The findings generally (Table 2) indicate that students had negative attitude (Overall mean score = 2.38) toward EL usage in communication in both classrooms and outside the classrooms. This is because the mean score of 2.38 is below the average score (neutral point) of 3.0 implying learners in Tanzanian HE are at risk since they attempt examinations in English language and upon their graduation all interviews are carried out using English language. As the result, this situation poses a great dilemma of having graduates who fit less in the education that intensifies the use of EL throughout delivery and in the labour market when seeking jobs. These findings are in harmony with Majenga (2015) and Mtallo (2015) which established that use of EL in Tanzania as a MoI is still not unsuccessful. Specifically the findings show only one (Mean = 4.65) variable that is instructors who teach using a mixture of English and Kiswahili languages was liked by students since its mean score was above the average score of 3.0. These findings inform that learners are motivated to learn when instructors use the mixture of English and Kiswahili languages. These findings are supported by those of Majenga (2015) and Mtallo (2015) which indicated that most of instructors in higher education in Tanzania employ code-switch between English and Kiswahili languages during communication with students. These findings contradict with the theory of self-efficacy (Bandura 1986) which suggests that learners imitate the model to achieve mastery. In this case, lecturers are the models in using EL fluently in communication in order to influence learners accordingly. Additionally, these findings are consistent with those of Rutalemwa and Tegeza (2010) which showed that there a serious need for Tanzania to maximize leaning environment for bilingual in English and Kiswahili and this will help to shape citizens accordingly.

**Table 3.** Attitude of Students toward EL Usage as a MoI and Communication (n = 100)

Variables	Mean	Std. deviation
Instructors who teach using EL fluently	2.97	1.141
Instructors who teach using Kiswahili fluently	2.73	1.196
Instructors who teach using a mixture of English and Kiswahili	4.65	0.642
Answering questions asked by instructors using EL in classroom	3.00	0.899
Asking questions to instructors using EL during learning process	2.91	0.900
Participating in class discussions conducted by instructors using EL	3.01	1.000
Conducting group discussions for group assignments using EL	2.75	0.936
Communicating with my fellow students using EL	2.74	1.07
<b>Overall score</b>	<b>2.38</b>	<b>0.973</b>

Regarding other variables under the study, the findings (Table 3) show the mean scores were less than the average mean score of 3.0 i.e. instructors who teach using



EL fluently (Mean = 2.97), instructors who teach using Kiswahili (Mean = 2.73), answering questions asked by instructors using EL in classroom (Mean = 3.00), asking questions to instructors using EL during learning process (Mean = 2.91), participating in class discussions conducted by instructors using EL EL (Mean = 3.01), conducting group discussions for group assignments using EL (Mean = 2.75) and communicating with my fellow students using EL (Mean = 2.74). These findings imply that teaching and learning process is a dilemma since learners' participatory is limited if English language is made mandatory as MoL fluently. The findings of this study are similar in nature with those of Mosha (2019) which indicated that students in higher education in tanzania experience difficulties in grasping learning contents presented using English language. The reasons for this situation from the study were that learners had limited English vocabularies and their background to English language from primary schools was poor. Further, quantitative findings from this study were supported by the summarized qualitative findings (Table 4).

**Table 4.** Summary of students' qualitative findings

Variables	Qualitative findings
Instructors who teach using EL fluently	<i>"...We feel unhappy with instructors who teach using EL fluently..."</i>
Instructors who teach using Kiswahili fluently	<i>"...We admire instructors who teach using Kiswahili language fluently..."</i>
Instructors who teach using a mixture of English and Kiswahili	<i>"...We enjoy and feel free in classroom sessions whose instructors use code-switch between EL and Kiswahili language..."</i>
Answering questions asked by instructors using EL in classroom	<i>"...To be honest we hardly answer questions asked by instructors using EL in classroom, in most cases we remain silent when asked..."</i>
Asking questions to instructors using EL during learning process	<i>"...We feel ashamed to ask questions to instructors using EL during learning process; mostly we don't ask questions..."</i>
Participating in class discussions conducted by instructors using EL	<i>"...To be honest, we speak in low voices using a mixture of EL and Kiswahili language during discussions conducted by instructors using EL and sometimes we remain quiet..."</i>
Conducting group discussions for group assignments using EL	<i>"...In most cases we use Kiswahili language mixed with EL during group discussions for our assignments outside classrooms..."</i>
Communicating with my fellow students using EL	<i>"...To be sincere, most of our communication is in the Kiswahili language; the language which we are used to it since we were children ..."</i>

## 6 Instructors' Attitude Toward EL Usage as a MoI and Communication

The findings (Table 5) show that all instructors (100.0%) have positive attitude toward teaching using mixture of English and Kiswahili languages fluently. These findings give surprise as they connote a dilemma in higher education. It was expected instructors to demonstrate role modeling culture on usage of EL, instead, they act in a controversial manner. The quantitative findings from this study were exhibited with qualitative findings from observation which gave evidence in all ten (10) observation events made instructors were observed communicating fluently with students and among themselves using the mixture of EL and Kiswahili language or the Kiswahili Language. Qualitative findings from FGD complimented quantitative findings from this study "...we are facing a very difficult situation since when you ask students questions using EL they will either remain silent or ask you to allow them to use Kiswahili language. This situation forces lecturers to use a mixture of EL and Kiswahili language in order to make teaching-learning effective...". FGD held in Dodoma City on 8<sup>th</sup> April, 2015. These findings are in harmony with those of Mtallo (2015) which revealed that code-switch is predominant in Tanzanian education system as instructors and learners are involved.

**Table 5.** Instructors' attitude toward EL Usage as MoI and Communication (n = 20)

Variables	Negative	Moderate	Positive	Total
Teaching using EL fluently	15.0%	5.0%	80.0%	100.0%
Teaching using Kiswahili language	60.0%	25.0%	15.0%	100.0%
Teaching using mixture of English and Kiswahili languages fluently	0.0%	0.0%	100.0%	100.0%
Answering questions asked by students using EL in classroom	0.0%	20.0%	80.0%	100.0%
Asking questions to students using EL during learning process	0.0%	15.0%	85.0%	100.0%
Guiding students in classroom discussions using EL	20.0%	0.0%	80.0%	100.0%
Communicating with students using EL outside classroom	40.0%	10.0%	50.0%	100.0%
Communicating with other instructors using EL	40.0%	25.0%	35.0%	100.0%
Communicating with non-academic staff using EL	75.0%	25.0%	0.0%	100.0%

To large extent the findings (Table 5) further indicate that instructors have positive attitude toward EL usage as MoI and communication. Empirically, teaching using EL fluently (80.0%), answering questions asked by students using EL in classroom (80.0%), asking questions to students using EL during learning process (85.0%) and guiding students in classroom discussions using EL (80.0%). These findings imply that instructors in

most cases were struggling to ensure that usage of EL is honoured. However, the circumstances and fear to let students get lost along the teaching-learning process necessitated instructors to lessen efforts of EL usage as MoI and communication. These findings are in congruence with those of Majenga (2015) and Mosha (2019) which pointed out that instructors in higher education were reluctant in EL usage with fear that students would not capture learning contents presented in EL.

Surprisingly, instructors as role models demonstrated negative willingness to communicate with non-academic staff using EL as empirically evidenced by 75.0%. These findings suggest a pronounceable dilemma of using EL in Tanzanian higher education. One would expect to witness instructors and non-academic staff to act as role models via their communications, but the reality has been in a reverse fashion. Further, the findings were a bit surprising as instructors indicated 40% of unwillingness to communicate with students and among themselves using EL. These findings imply that if instructors' readiness to use EL as means of communication is questionable, then, students' motive to adopt EL as a communication tool is frustrated.

## 7 Conclusion

The study concludes that Tanzanian higher education institutions do not use EL effectively in communication but rather use the mixture of EL and Kiswahili. This is attributed by inadequate guidance and emphasis by instructors to students, poor students' background, instructors' unwillingness to demonstrate role modeling and laxity of higher education management to implement usage of EL as MoI and communication. Furthermore, the study concludes that the attitude of students towards EL usage as MoI and communication is negative. Moreover, the attitude of instructors toward EL usage in communication was negative since most of them were observed to use mixture of EL and Kiswahili when communicating with students. Generally, the conclusion drawn from the findings of this study is that the dilemma is highly pronounced among Tanzanian higher education due to use of the mixture of EL and Kiswahili as MoI; something which contradicts Tanzanian Education Policy. Based on the study findings, the practical implication is that Tanzanian higher education produce graduates who can hardly compete in free labour market. This situation needs intervention from higher education management by reviewing their curricula and institute communication skills in EL to be treated as the core subject and taught in all years of study. Similarly, higher education management should provide regular training to instructors on importance of EL as MoI. The findings further suggest social implication in a way that Tanzania higher education institutions have acquired the culture of using mixture of languages as MoI; something which needs intervention from the Ministry of Education, Science and Technology by issuing government circular for compliance of using EL.

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# Assessing Postgraduate Students' Satisfaction with Management Services in Residences of Higher Education Institutions for Lifelong Learning Opportunities

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**Abstract.** Student residences are fundamental in Higher Education Institutions and contribute towards achieving academic goals. The purpose of this study is to determine the level of postgraduate students' satisfaction with management services in HEI residences and how the quality of the features influences their satisfaction. In HEIs, learning and research are considered principal activities. A quantitative research approach was used, and a questionnaire survey was conducted in the Gauteng Province of South Africa, targeting postgraduate residences. The data gathered were analyzed using the five points Likert scale, including the Mann-Whitney U test. The findings revealed that postgraduate students were satisfied with electricity supply, water supply, rent payment and refuse disposal. However, the Mann-Whitney U test revealed no significant difference in how South African and International postgraduate students view their level of satisfaction with management services. The study also revealed that the quality of management services has an impact on satisfaction. This study will assist housing providers and HEIs to better their management skills and find ways to improve service delivery, and cater for postgraduate students' needs.

**Keywords:** HEI · Management · Residences · Services · Students

## 1 Introduction

Education is one of the most important elements in any country as it helps individuals contribute positively to the economy and innovation collectively. It is for this reason that postgraduate students are of vital importance to contributing to the body of knowledge, the economy and innovation through research. The students' residential experience goes hand-in-hand with the educational experience. Thus, student residences must be given much attention as they are a primary need in Higher education institutions (HEI).

Adama, Aghimien and Fabunmi (2018) mentioned that students need residences that are comfortable for them to carry out their primary function in the HEI. While Hassanain (2008) also concurs that for students to perform well in their academic endeavours they need to be satisfied with the surrounding and the place they reside in.

In higher education institutions (HEIs), learning and research are considered principal activities. For this reason, support such as recreational facilities, medical services, and accommodation is essential not only to students but also to staff members and contribute towards the core objectives of the HEI (Mohammad et al. 2012). According to Ekpoh (2018), services offered by universities such as transport, library, health facilities and hostels are aimed at ensuring that students can succeed in their academic pursuits. Thus, management plays a vital role in ensuring that the core services are reached and not compromised. The core services would include electricity and water supply in which, according to Danso and Hammond (2017), students' satisfaction lies within social amenities such as water and electricity supply. For entities such as student residences to be functional, management services are needed to ensure that day-to-day services are rendered and meet occupants' needs and expectations. Therefore, understanding customer expectations is key as gaps in service quality can be identified faster by referring to the customer's perspective.

Student residences are fundamental in Higher Education Institutions and contribute towards achieving academic goals. One basic need required by postgraduate students is the availability of a well-functioning accommodation that will meet their expectations and needs. For this reason, management services provided in student accommodations are well orientated and managed to provide services that exceed the customer's expectations. Sanderson and Edwards (2016) mentioned that the theory of customer relationship management (CRM) is based on good customer service, which results in customer satisfaction. The way management attends to matters has a significant impact on the level of satisfaction with services rendered. Any services being rendered or offered to students must be satisfactory and of the best quality. According to Nimako and Bondinuba (2013), customers have priorities they attach to different dimensions of accommodation quality. They further emphasized that it is important to constantly improve quality based on customers' perceptions to have a clear understanding of which aspects of service quality are most important. A vast body of knowledge addresses satisfaction with students' accommodation, and only a few regarding postgraduate students. Thus, the significance of this study to uncover the satisfaction of postgraduate students with management services provided in residences in HEIs. This study was undertaken to evaluate the level of satisfaction of postgraduate students with management services in student residences to establish key factors that contribute to satisfaction.

## **2 Factors Affecting Satisfaction with Residences**

Student residences are built to house students temporarily till the completion of their studies. Regardless of the residences being temporary, they need to be able to provide students with the best experience ever. Muslimet al. (2012) pointed out that student residences allow student affairs administrators to impact and support students' educational experience at HEIs. According to Jiboye (2009), satisfaction with residences has gone

far beyond physical and structural adequacy but incorporates different amenities and the residence's overall functionality. According to Hughes et al. (2021) quality issues arise due to a combination lack of skilled labour and the resultant lack of quality control.

A study by Aigbavboa et al. (2014) conducted a study to evaluate students' satisfaction with the university hall of residences. They define residential satisfaction as occupants/users receiving a good quality service, which meets and exceeds their level of expectations (Aigbavboa et al. 2014). Mohit et al. (2010), cited by Aigbavboa 2014, define satisfaction as a positive experience conveyed by occupants when their housing needs meet their expectations of the housing features and services provided and neighbourhood features. From the above-mentioned definitions, it is clear that satisfaction can be deduced from the concept of quality services provided, including fulfilling occupants' expectations. According to Navarez (2017) students' satisfaction is of great importance in HEI's as it continually strives to improve the learning environment for students and ensure that their needs and expectations are met. With this being said, student residential satisfaction affects one's judgment of their functionality in a specific environment. For this reason, Aigbavboa et al. (2014) mentioned that occupants tend to make an immediate comparison of their previous to their present dwelling place, which ultimately impacts residential satisfaction. Residences should be able to provide students with the best experience, even though they are temporary. Thus, to attain residential satisfaction, basic facilities and services need to be provided (Tsedzah and Obuobisa-Darko 2015). According to Eke et al. (2014), residential satisfaction is not only for the occupants but also for anyone who has a business in the building, members of the public and visitors. For this reason, good and proper student housing conditions are important factors for performance and health in all aspects.

Student residences go beyond just providing accommodation but has several factors that somewhat influence satisfaction. According to Thomsen (2007) aspects such as the façade of a building, the residence's entrance, materials and colours in the residence used, have a determining effect on students' satisfaction. For this reason, the appearances of the student residences are as important as the facilities provided and offer a feeling of home, which ultimately contributes to students' level of satisfaction. Khozaei (2010) emphasized some predictors of students' satisfaction with residences, namely: cleanliness and neatness of the residence, security, activity programmes provided while staying at the residence, being able to provide inputs into decision-making in the activities and governing rules made in the residences. While Waziri et al. (2013) also identified four factors that are considered to be major contributors to satisfaction in student residences. The factors constitute of structural components, dwelling features, neighbourhood and the environment and lastly management services. Furthermore, a study by Salleh et al. (2011) addressed tenant satisfaction with housing and the relationship with rent arrears. The study revealed that satisfaction is related to rent arrears and a major contribution to tenants' low satisfaction is due to poor management services. Thus, it is imperative to consider all factors when assessing students' satisfaction with residences and ensure the utmost level of total fulfilment. Monitoring the building quality features is of great importance. It also assists management in doing repair works where needed, having a clear understanding of what occupants need, and offering the best quality service for their occupants.

### 3 Management Services Provided in Residences

For student residences to function to its full capability, management services are required at all times. Management ensures that day-to-day services rendered meet the occupants' level of expectations and needs. These services rendered by management may affect the level of satisfaction with the occupied residence. According to Wanie et al. (2017), a positive relationship with residence managers, including the system and management practices, can equally assess and determine the level of satisfaction in student residences. Based on Wanie et al. (2017), the core problem of dissatisfaction in student residences is influenced by management. Problems such as students being billed for imaginary usage of electricity and water; rent increments which do not match the quality of services provided; caretakers inflating meter readings so that students pay more; and the overall maintenance of the residences in which there are health hazards and factors such as toilets, showers and sinks are not in good working conditions. The manner in which management attends to issues has a significant impact on the students' satisfaction. Thus, attending to issues promptly builds a good relationship with occupants, which yields satisfaction and eliminates dissatisfaction.

According to Mohammad et al. (2012), Facilities Management (FM) encompasses people, the process and procedure for achieving the institution's cooperate goal. Residence management can be defined as the process of ensuring that students respect the rules that govern the residence and ensuring good student accommodation with good quality that meets their needs (Wanie et al. 2017). For this reason, customer service should not be overlooked as it has a significant influence on satisfaction. Mohammad et al. (2012) and Gronroos (1984) mentioned that the key to success in service quality is understanding customer expectations as any gaps between customer expectations and service quality can be identified by referring to the customer's perspective. To achieve satisfaction in student residences, basic facilities need to be provided, including quality services from management (Tsedzah and Obuobisa-Darko 2015; Newman et al. 2020). According to Jasinskas et al. (2016), quality is a determining factor of service provided to a customer and a profitable success to a service provider. They further emphasized that service providers main focus should be on the quality of response to matters in order to provide expected services to customers. Thus, the services provided by management should focus entirely on satisfying customers and ensuring that their expectations are met. Anand et al. (2018) coincide that service quality is an important factor in measuring customer satisfaction. It is without doubt that management services do influence students' satisfaction. Thus, it is important that residence managers build a positive relationship with students through the use of good services that meet all expectations and needs.

### 4 Research Methodology

A quantitative research approach was deployed using a convenience sampling technique. A questionnaire survey was conducted in the Gauteng Province of South Africa, in Johannesburg targeting postgraduate residences situated on-campus. The questionnaires were distributed to a total of 120 postgraduate students, and only 96 were returned resulting to an 80% response.



The questionnaire was divided into two sections, in which the first section covered the demographic information of the respondents, and the second section focused on the factors that determine postgraduate students' satisfaction with management services and how the quality of the management services affect satisfaction. Data gathered were analyzed using the five-point Likert scales, which one measured the quality and the other satisfaction. The Mann-Whitney U-test was employed in testing whether there is a significant difference between South African and International postgraduate students' level of satisfaction with management services in residences. A reliability test was conducted using Cronbach's alpha coefficient.

## 5 Findings and Discussion

### 5.1 Background Information of Respondents

The findings of the study revealed that from the total population sampled, 51% were females and 49% were males. The majority of the respondents were between the ages of 21–25 with percentage of 41.7%, followed by 26–30 with a percentage of 34.4%, above 30 with 22.9%, and 16–20 with a percentage 1.0%. The respondents ethnic group revealed that 94% were African, 3% were Indian, 2% were Coloured, and 1% were Asian. Regarding the respondent's qualification they were enrolled for, 39.6% were enrolled for Honours degree, followed by Doctorate with 31.3% and Masters with 29.2%. The findings also revealed that 38.5% were from an urban area, followed by 35.4% from a township, 24.0% from a rural area and 2.1% from an informal settlement. Based on the findings regarding the respondent's nationality, 62% were South African students, and 38% were international students. The respondent's residence occupied was 44.8% from Student Town, 24.0% from Lesedi, 19.8% from Faranani, 7.3% from Takalani and 4.2% from Faranani Extension (Admin flats).

### 5.2 Postgraduate Students' Satisfaction with Management Services

To achieve the aim of this study, the paper assessed both the quality of management services and the satisfaction of post-graduate students with these services.

In assessing the quality of management services, both the South African and International students have similarities in how they view the quality of management services in postgraduate residences. With reference to Table 1, electricity supply was ranked the highest with a mean score of 3.90 for South African students and 4.25 for International students, followed by water supply with a mean score of 3.78 and 4.22. Time of rent payment was ranked third by International students with a mean score of 3.69, and measures taken with non-rent payment was ranked third by South African students. According to Sanderson and Edwards (2016), the theory of customer relationship management (CRM) is based on good customer service, which results in customer satisfaction. The quality of management services of the above-mentioned variables show how important service delivery is to students. As reported by Jiboye (2009), satisfaction with residences has gone far beyond physical and structural adequacy but incorporates different amenities and the overall functionality of the residence.

The findings revealed that postgraduate students were least satisfied with the response to reporting of defect with an overall mean score of 2.94, followed by attendance to complaints with a mean score of 2.85, and lastly timely repair services with mean score of 2.76. As opined by Jasinskis et al. (2016, p. 560), which support the study's findings, service providers should focus mainly on the quality of response to matters to provide expected services to customers. Wanie et al. (2017) also noted that a positive relationship with residence managers including the system and management practices can equally be used to assess and determine the level of satisfaction in student residences. Thus, the relationship management has with students, and the quality of services does have a determining factor in students' satisfaction. Based on the Mann-Whitney u-test it revealed that there is a significant difference in how postgraduate students view the quality of management service regarding electricity supply and water supply (Table 2).

**Table 1.** Quality of management services

Management services	South African		International		Overall		Mann-Whitney	
	Mean	Rank	Mean	Rank	Mean	Rank	Z	Sig.
Electricity supply	3.90	1	4.25	1	4.03	1	-2.073	0.038**
Water supply	3.78	2	4.22	2	3.95	2	-2.298	0.022**
Time of rent payment	3.55	4	3.69	3	3.60	3	-0.654	0.513
Measures taken with non-rent payment	3.58	3	3.61	4	3.59	4	-0.383	0.702
Refuse/garbage disposal	3.52	5	3.50	5	3.51	5	-0.116	0.907
Policy compliance	3.45	6	3.42	9	3.44	6	-0.248	0.804
Security of the building	3.35	7	3.47	7	3.40	7	-0.428	0.669
Friendliness of management	3.28	8	3.50	5	3.36	8	-0.824	0.410
Enforcement of rules by management	3.20	10	3.39	10	3.27	9	-0.691	0.490
Cleanliness of the residence	3.23	9	3.22	13	3.23	10	-0.056	0.956
Overall services provided by management	3.12	11	3.39	10	3.22	11	-1.132	0.258
Quality of repairs	3.08	12	3.44	8	3.22	11	-1.489	0.136

(continued)

**Table 1.** (continued)

Management services	South African		International		Overall		Mann-Whitney	
	Mean	Rank	Mean	Rank	Mean	Rank	Z	Sig.
Building hygiene	3.00	13	3.28	12	3.10	13	-1.270	0.204
Room selection	2.95	14	3.19	14	3.04	14	-0.935	0.350
Service delivery	2.93	15	3.17	15	3.02	15	-0.942	0.346
Planning and provision of entertainment	2.87	16	3.06	16	2.94	16	-0.695	0.487
Response to reporting of defects	2.87	16	3.03	17	2.93	17	-0.53	0.596
Attendance to complaints	2.75	18	2.83	18	2.78	18	-0.191	0.848
Timely repair services	2.72	19	2.83	19	2.76	19	-0.228	0.819
<b>GROUP MEAN</b>	<b>3.22</b>		<b>3.39</b>		<b>3.28</b>			

**Table 2.** Quality of management services: Mann-Whitney U-test

	Quality of Management services
Mann-Whitney U	137.500
Wilcoxon W	327.500
Z	-1.256
Asymp. Sig. (2-tailed)	0.209
Exact Sig. [2*(1-tailed Sig.)]	.212 <sup>b</sup>

In the assessment of postgraduate students' satisfaction with management services, nineteen variables were assessed. Table 3 revealed the following variables were ranked the highest, namely electricity supply with a mean score of 4.04, water supply with a mean score of 3.92, time of rent payment with a mean score of 3.63 and measure is taken with non-rent payment. However, the following variable ranked the lowest: response to reporting of defects with a mean score of 2.94, attendance to complaints with a mean score of 2.85 and timely repair services with a mean score of 2.76. With reference to the two nationalities, they ranked the same variable the highest which is electricity supply and ranked timely repair services the lowest. It is evident from the findings of the study that basic amenities such as electricity and water supply are essential. As highlighted by Danso and Hammond (2017) students' satisfaction can be achieved by providing social amenities such as water and electricity supply. Tsedzah and Obuobisa-Darko (2015), further emphasized and supported the study's findings that satisfaction

can be achieved through the provision of basic facilities, including quality services from management. Table 4 reveals no significant difference in how South African and International postgraduate students view their level of satisfaction with management services since the Mann-Whitney test has a p-value of 0.314, which is above the 0.05 threshold.

**Table 3.** Level of satisfaction with management services

Management services	South African		International		Overall		Mann-Whitney	
	Mean	Rank	Mean	Rank	Mean	Rank	Z	Sig.
Electricity supply	3.97	1	4.14	1	4.03	1	-1.005	0.315
Water supply	3.78	2	4.14	1	3.92	2	-1.704	0.088
Time of rent payment	3.58	4	3.69	3	3.63	3	-0.715	0.474
Measures taken with non-rent payment	3.58	4	3.61	4	3.59	4	-0.344	0.731
Refuse/garbage disposal	3.62	3	3.56	6	3.59	4	-0.06	0.952
Policy compliance	3.48	6	3.50	8	3.49	6	-0.218	0.828
Security of the building	3.47	7	3.42	9	3.45	7	-0.384	0.701
Quality of repairs	3.23	11	3.61	4	3.38	8	-1.815	0.070
Friendliness of management	3.23	11	3.53	7	3.34	9	-1.098	0.272
Enforcement of rules by management	3.32	9	3.36	11	3.33	10	-0.175	0.861
Cleanliness of the residence	3.37	8	3.25	14	3.32	11	-0.298	0.766
Overall services provided by management	3.25	10	3.39	10	3.30	12	-0.536	0.592
Building hygiene	3.12	13	3.28	13	3.18	13	-0.685	0.493
Room selection	3.08	14	3.31	12	3.17	14	-0.749	0.454
Service delivery	2.92	15	3.19	15	3.02	15	-1.27	0.204
Planning and provision of entertainment	2.88	17	3.08	17	2.96	16	-0.784	0.433
Response to reporting of defects	2.83	18	3.11	16	2.94	17	-1.067	0.288

(continued)

**Table 3.** (continued)

Management services	South African		International		Overall		Mann-Whitney	
	Mean	Rank	Mean	Rank	Mean	Rank	Z	Sig.
Attendance to complaints	2.90	16	2.78	19	2.85	18	-0.515	0.606
Timely repair services	2.70	19	2.86	18	2.76	19	-0.519	0.604
<b>GROUP MEAN</b>	<b>3.28</b>		<b>3.41</b>		<b>3.33</b>			

**Table 4.** Satisfaction with management services Mann-Whitney U-test

	Satisfaction with Management services
Mann-Whitney U	146.000
Wilcoxon W	336.000
Z	-1.008
Asymp. Sig. (2-tailed)	0.314
Exact Sig. [2*(1-tailed Sig.)]	.325 <sup>b</sup>

## 6 Conclusion and Recommendation

Postgraduate students' satisfaction goes along with the quality of service. The level of satisfaction with management services has been established through the questionnaire results, which revealed that, postgraduate students are more satisfied with electricity supply, water supply, time of rent payment, and measures taken with non-rent payment. These factors have proved to be significant in determining the level of postgraduate students' satisfaction with management services. The study's findings also revealed that a positive relationship with residence managers, including the management practices put in place, can equally be used to determine the level of satisfaction with management services. The students were least satisfied with the response to reporting of defects, attendance to complaints and the timely repair services. This reflects that management's maintenance culture is also an attribute in determining satisfaction regarding management's services. Regarding the two nationalities, the International students proved to have a higher level of satisfied as compared to the South African students. Overall, postgraduate students are satisfied with the management services provided to them in residences. Even though that is the case, it would be beneficial for managers to have a repair service book or something similar in which it will enable them to attend to issues timeously. Students do not want to be frustrated or be in a residence that does not function fully with all necessities. Thus the quality of repair works is of great importance. This study will contribute to the body of knowledge regarding postgraduate students and bring relevant information to assist residence managers and residence developers in focusing on matters that impact satisfaction. This will also assist in preventing repetition

of existing mistakes and propel a higher level of satisfaction. The study was limited to public HEI's thus, further research can be extended to private HEI's. This will assist in comparison, if there any different mechanisms or similarities in addressing satisfaction with management services. This will give insight of how to better services provided and the level satisfaction.

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# Ionizing Radiation Measurements at the Redeemer's Health Centre, Redemption Camp, Ogun State, Nigeria

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**Abstract.** The radiation dose levels inside and in the vicinity of the X – ray room at the Redeemer's Health Centre, Mowe, Ogun State, Nigeria were determined using a handheld radiation survey metre (PRM – 900). The radiation dose rates recorded for a period of 7 days for 10 min each at five different locations, which included the X – ray room, entrance of the X – ray room, patients waiting area, reception and main entrance in the hospital were within the range of 0.070  $\mu\text{Sv/hr}$ –0.120  $\mu\text{Sv/hr}$  when the machine was switched off. When the machine was switched on, the measured radiation dose rates were 0.090  $\mu\text{Sv/hr}$ –0.140  $\mu\text{Sv/hr}$  and 0.090  $\mu\text{Sv/hr}$ –0.190  $\mu\text{Sv/hr}$  respectively during the peak and off- peak periods. Both the daily and the annual effective doses at the various locations were found to be within the recommended ICRP limits for both radiation workers and the public thus implying a good containment of the radiation being emitted by the X – ray machine at the health centre.

**Keywords:** Dose rate · Ionizing · Peak · Radiation · Radiation workers

## 1 Introduction

Radiations travel in forms of energy through space or in form of particles of matter or wave. They can be produced either by radioactive decay of unstable atoms (radionuclide) or by the interaction of a particle with matter. Radioactive decay is spontaneous and random, and the type of radiation emitted depends on the specific radionuclide, Dindar et al. (2015).

Human beings are exposed to background radiation that seems both from natural and man- made sources. In general, approximately 85% of the annual total radiation dose of



any person comes from natural radio-nuclides of both terrestrial and cosmogenic origin (Belivernis et al. 2010, UNSCEAR 2000). According to the World Health Organisation (2016), Medical use of radiation accounts for 98% of the population dose contribution from all artificial sources, and represents 20% of the total population exposure.

Ionizing radiation emanating during usage of radioactive facilities in hospitals and medical research institutes have been of great concern because of the detrimental effects of high exposure. Due to the circumstances in which their work is carried out, healthcare workers using radioactive sources are occasionally subjected to the risk of exposure to ionizing radiation that may involve doses higher than the limits recommended for occupational workers. In addition, indoor and outdoor patients who require ionizing radiation treatments could be exposed to ionizing radiation in excess of the annual recommended limits owing to improper containment of the radioactive sources or extended stays more than necessary around the radioactive sources whenever they are in use. Unfortunately, not all these health workers or patients have means of checking up how much of the radiation they have been exposed to. As such there is need for a regular monitoring of the environmental radiation especially around where these sources are being used so as to ensure that both health workers and the public are not at any radiation risk arising from undue exposure to ionizing radiation.

In this study, the indoor and outdoor radiation dose owing to the use of x-ray machine in a Health Centre were measured in order to determine radiation dose being received by both patients and health personnel following the continual exposure to emission from the x-ray machine.

## 2 Methodology

The study was carried out at the Redeemer's Health Centre of the Redemption Camp - the international headquarters of the Redeemed Christian Church of God (RCCG) in Mowe, Ogun State of Nigeria. The specific locations within the Health Centre where measurements were carried out included the main entrance, the reception, the patient waiting area, the entrance to the X – ray room and the X – ray room.

A hand- held radiation survey metre (PRM -9000) which is suitable for the detection, measurement and monitoring of broad spectrum as well as low energy radionuclide was calibrated electronically using a pulse generator “relative” to Cs-137, with a maximum error that did not exceed 5%. The metre was preset to measure the hourly dose rates for a period of 10 min at each of the designated points. The background radiations at the chosen locations were measured for seven days when the X-ray machine was OFF; afterwards, the measurements were repeated during both peak, between 1pm and 4pm and off -peak periods, between 10am to 12 noon when it was ON.

### 2.1 Annual Effective Dose

The annual effective mean dose rate was calculated following the hourly dose rates measured at the various locations Eq. 1 (Marilyn and Maguire 1995)

$$D = \sigma \times \mu \times 24 \times 365 (\mu\text{Sv}/\text{yr}) \quad (1)$$

where  $D$  is the annual dose rate in micro sievert per year,  $\sigma$  = dose rate in micro sievert per hour and  $\mu$ , the occupancy factor is 0.3 (assuming that a worker spends an average 8 h in the hospital each day).

### 3 Results and Discussion

Tables 1 and 2 show the radiation dose rates and the corresponding annual effective doses respectively at the designated points within the Redeemer’s Health Centre.

**Table 1.** Radiation dose rates ( $\mu\text{Sv/hr}$ ) at Redeemer’s Health Centre

S/N	Location	Day	Machine off	Machine on (off peak)	Machine on (peak)
1	Inside X – ray room	1	0.080	0.110	0.170
		2	0.070	0.230	0.190
		3	0.100	0.320	0.170
		4	0.070	0.120	0.170
		5	0.070	0.180	0.180
		6	0.070	0.300	0.170
		7	0.080	0.110	0.190
		<b>Mean</b>	<b>0.077</b>	<b>0.196</b>	<b>0.177</b>
2	Entrance of X – ray room	1	0.110	0.110	0.110
		2	0.100	0.110	0.110
		3	0.080	0.140	0.120
		4	0.100	0.100	0.120
		5	0.100	0.120	0.110
		6	0.100	0.100	0.100
		7	0.100	0.100	0.120
		<b>Mean</b>	<b>0.099</b>	<b>0.111</b>	<b>0.123</b>
3	Patient waiting area	1	0.100	0.090	0.090
		2	0.100	0.090	0.110
		3	0.100	0.130	0.090
		4	0.120	0.100	0.090
		5	0.120	0.140	0.100
		6	0.110	0.110	0.120
		7	0.120	0.130	0.100

*(continued)*

**Table 1.** (continued)

S/N	Location	Day	Machine off	Machine on (off peak)	Machine on (peak)
		<b>Mean</b>	<b>0.110</b>	<b>0.113</b>	<b>0.100</b>
4	Reception	1	0.140	0.120	0.130
		2	0.120	0.120	0.120
		3	0.140	0.120	0.140
		4	0.130	0.090	0.120
		5	0.140	0.140	0.130
		6	0.140	0.090	0.140
		7	0.140	0.120	0.120
		<b>Mean</b>	<b>0.136</b>	<b>0.114</b>	<b>0.129</b>
5	Main entrance	1	0.100	0.090	0.100
		2	0.080	0.100	0.100
		3	0.110	0.090	0.100
		4	0.080	0.100	0.090
		5	0.100	0.100	0.100
		6	0.100	0.100	0.100
		7	0.100	0.100	0.110
		<b>Mean</b>	<b>0.096</b>	<b>0.097</b>	<b>0.100</b>

**Table 2.** Annual effective dose ( $\mu\text{Sv}$ ) at Redeemer's Health Centre

S/N	Location	Day	Background dose	Effective dose	
				(Off-peak)	(Peak)
1	Inside X – ray room	1	233.60	321.20	496.40
		2	204.40	671.60	554.80
		3	292.00	934.40	496.40
		4	204.40	350.40	496.40
		5	204.40	817.60	525.60
		6	204.40	876.00	496.40
		7	233.60	321.20	554.80
		<b>Mean</b>	<b>225.26</b>	<b>613.20</b>	<b>517.26</b>

(continued)

**Table 2.** (continued)

S/N	Location	Day	Background dose	Effective dose	
				(Off-peak)	(Peak)
2	Entrance of X – ray room	1	321.20	321.20	321.20
		2	292.00	321.20	321.20
		3	233.60	408.80	350.40
		4	292.00	292.00	350.40
		5	292.00	350.40	321.20
		6	292.00	292.00	321.20
		7	292.00	292.00	350.40
		<b>Mean</b>	<b>287.83</b>	<b>325.37</b>	<b>333.71</b>
3	Patient waiting area	1	292.00	262.80	262.80
		2	292.00	262.80 <sup>a</sup>	321.20
		3	292.00	379.60	262.80
		4	350.40	292.00	262.80
		5	350.40	408.80	292.00
		6	321.20	321.20	350.40
		7	350.40	379.60	292.00
		<b>Mean</b>	<b>321.20</b>	<b>329.54</b>	<b>292.00</b>
4	Reception	1	408.80	350.40	379.60
		2	350.40	350.40	350.40
		3	408.80	350.40	408.80
		4	379.60	262.80	350.40
		5	408.80	408.80	379.60
		6	408.80	262.80	408.80
		7	408.80	350.40	350.40
		<b>Mean</b>	<b>396.29</b>	<b>333.71</b>	<b>375.43</b>
5	Main entrance	1	292.00	262.80	292.00
		2	233.60	292.00	292.00
		3	321.20	262.80	292.00
		4	233.60	292.00	262.80
		5	292.00	292.00	292.00
		6	292.00	292.00	292.00
		7	292.00	292.00	321.20
		<b>Mean</b>	<b>279.49</b>	<b>283.66</b>	<b>292.00</b>

The mean background dose rates ( $\mu\text{Sv/hr}$ ) recorded in various locations of interest at the health centre when the x-ray machine was not in use was between 0.077 and 0.136. The results compare favourably to those carried out within the x-ray buildings of four general hospitals in Lagos State (Adekoya et al. 2021).

The least value was recorded inside the X- ray room which indicates that some external sources of radiation apart from the x-ray machine might be contributory to the level of radiation at the Health Centre. As expected, the mean dose rate was higher inside the X-ray room compared to all other locations when the machine was switched ON, since the x-ray machine is installed in there.

A comparison of the dose rates of other locations of interest outside the x-ray room when the machine is OFF and when it is in use show approximately equal values except at the reception. This implies a good containment of the emission of radiation from the x-ray machine in the x-ray room. This assertion is also true at the reception area, the recorded dose rates notwithstanding. The higher dose rate at the reception when the x-ray machine is OFF compared to the values when it is ON strongly corroborates the earlier submission that some other sources of ionizing radiation might be present within that vicinity.

The computed mean annual effective doses ( $\mu\text{Sv}$ ) show a range of values from 283.66–613.20 and 292.00–517.26 during the off -peak and peak periods respectively when the machine is in use. The risk of exposure to radiation is greatest in the x-ray room as expected and least at the patients' waiting area and main entrance. Individuals who stay at the reception are more likely to be exposed to ionizing radiation compared to others who stay in any of the other locations outside the x-ray room.

The annual set limit of exposure to ionizing radiation by the International Commission for Radiation Protection (ICRP) is 1 mSv and 20 mSv (European Commission 1999, ICRP, 2005; EPA 2014) for the public and radiation health workers respectively. The computed annual doses in all the locations of interest at the Redeemer's Health Centre are far below these limits thus implying that the public and the radiation workers at the Health Centre are at no radiological risks.

## 4 Conclusion

Notwithstanding the present safety of both occupational workers and the public from ionizing radiation associated with the use of X – ray machine at the Redeemer's Health Centre, there is need for proper monitoring of environmental dose around the Centre. For a better approximation of the radiation dose rates, there is need to conduct this research over a much longer period than just seven (7) days. A thermo – luminescence dosimeter (TLD) is also recommended in place of a hand- held survey metre for more accurate measurements of the absorbed dose to both radiation workers and the public.

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# Effect of Teachers' Motivation Strategies on Customer Service in Tanzania

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**Abstract. Purpose:** The paper established the effect of secondary school teachers' motivation strategies on customer service in Dodoma City of Tanzania. Specifically, the study (i) assessed the strategies used by private secondary schools' management in motivating teachers and (ii) established how motivational strategies affect customer service in private secondary schools.

**Design/Methodology/Approach:** The design for this study was cross sectional using a sample of 60 secondary school teachers. Four heads of the respective secondary schools and eight students as key informants were interviewed as key informants. Region, district and wards were purposefully selected. The final sample from strata of four schools adopted random selection. Content analysis best fitted in analyzing qualitative data whereas motivation strategies were determined using descriptive statistics. Logit model was employed in establishing how teachers' motivation strategies affect customer service.

**Findings:** The findings show that salary, job security, participation, promotion, recognition and working environment had positive significant effect on customer service.

**Research Limitation/Implication:** This study was confined to secondary schools from Dodoma City and not from other cities and the sample size was limited to 60 due to short period of time. The implication of this limitation is that biasness was likely to happen and it is proposed in future to be extended to other cities with an increased sample size.

**Practical Implication:** The Ministry of Education, Science and Technology (MoEST) and key development partners in education sector should make sure that public and private teachers' motivation is improved using improved salaries, employee job security, participation, promotion, recognitions, promotion and working environment.

**Social Implication:** MoEST and other development partners in education sector should work hard to improve social well-being of teachers and students by integrating the component of customer service in the school curricula since students are customers and deserve good customer service.

**Originality/Value:** The novelty of study is routed from the integration of customer service which is the business concept and teachers' motivation among secondary schools. This integration justifies that apart from education being social service; it is the business opportunity for investors in education sector.

**Keywords:** Customer service · Motivation strategies · Teachers · Tanzania

## 1 Introduction

Elsewhere globally, the issue of acceptable customer service has resulted into customer satisfaction. In most cases, good customer service is the outcome of motivated employees. For instance, Yin and Han (2016) focused on teachers' motivational issues in Hong Kong. In Indonesia, studies of Dias et al. (2021) and (Razinkina et al. 2017) revealed significant positive effect existed on the performance of teachers. These findings imply that whenever teachers are motivated accordingly, they like their jobs and consequently their teaching performance is enhanced through delivery of acceptable standard of customer service. The study of Benic and Opic (2017) in Croatia showed that satisfaction of students is the function quality of teacher-student relationship, the relationship which is engineered by good customer service demonstrated by teachers. In India, private sector over represent education sector by over 60%, private schools demonstrated higher level of customer service than that of their counterpart public schools (Sheikh 2017). Among the reasons that were given for private schools to demonstrate higher level of customer service than public schools was the result of better motivation strategies used by the private sector. Accordingly, Atkinson (2011) argued that organizations that provide high standard of customer care are characterized by provision of superior products which match with value for money (VFM) customers pay and they offer satisfactory post-sales services and they have employed right people who are friendly with high level of training in handling customers. This means that, service organizations are required to heavily invest in people who render services to customers. This investment starts from recruiting right people and also making thorough training to equip staff with relevant knowledge, skills and attitude to serve customers. In the study of Kursunluoglu (2011) when determining effect of customer service on satisfaction and loyalty of customers, it was established that customer service was the determinant of customer satisfaction and loyalty. These findings implied that whenever high standard customer service is rendered to customers there is likelihood of such customers to be satisfied with the service and consequently become loyal to the organization and its products.

In African countries, the study of Ali and Dahie (2016) in Somalia showed that teaching career is the least paid job despite many hours involved in teaching per day. As the result, teachers' morale is low due to low motivation. In Ghana, Shafiwu and Salakpi (2013) found increased students' dropout tendencies which are the result of low teachers' motivation. The findings from these studies imply that work motivation fuel commitment among teachers and consequently trigger sound customer service to their students. For instance, high dropout cases were due to teachers being less committed due to inequity compensation. Similarly, in Kenya inadequate motivation among secondary school teachers has negatively affected students' performance (Wambugu et al. 2018, Nyakundi 2012). The findings from these studies generally showed that high students' performance is the result of strong relationship that exists between teachers and students. This relationship is the result of acceptable customer service which is the function of well-motivated teachers.



In Tanzania like in other African countries, teachers' payment is solely salary; it excludes payments such as rent allowance, transport allowance and teaching allowance (Makinge 2014). As the result, absence of allowances to top up on their salaries creates the situation that reduces teachers' morale, consequently impairs their concentration to take care of their students. The study of Lyimo (2014) and Mruma (2013) revealed unfriendly work conditions including low salaries paid to Tanzanian teachers. Findings also exposed shortage of materials for delivery in classroom, inadequate office working tools and lack of recognition which was accompanied with inadequate participation were interrupting teachers' ability to practice high level of customer service. Like any other service organizations, the issue of customer service to secondary school students requires special attention and its route cause also need to be traced as well. Many previous studies in secondary schools have given much attention on establishing the link between motivation for teachers and performance of students academically (Mganga 2016, Makinge 2014, Mruma 2013). Out of these studies, little attention has been directed to draw up the linkage between motivation strategies and customer service. Further, few studies in Tanzania have tried to address students' satisfaction, have mainly focused in higher education but not in secondary school (Mashenene 2019, Mashenene et al. 2019). In view of this therefore, determining the effect of motivational strategies for teachers on customer service was required the gap existed.

## 2 Theory Underpinning the Study

This study was underpinned by the Maslow's hierarchy of needs theory founded in 1954. The theory depicts five stages of human needs; physiological, safety, belongingness, esteem and self-actualization needs (Maslow 1954). One's need when satisfied is no longer motivator as it activates the second needs. Therefore, if one need is being satisfied then a person can seek for the next need and so on. The five stages of Maslow's hierarchy of needs is applicable to schools, employers and teachers; for example, physiological needs are important for survival as sustain life and include food, water, sex and shelter. The teachers' needs are to be well paid good salary to fulfill the basic needs as mentioned before. Hence, teachers who are paid low are likely to be de-motivated at work, a situation that leads to absenteeism. Security or safety needs means the need for self-protection including stability and free from anxiety. This means teachers should live harmoniously both at home and work place hence there should be no firing out; a friendly working environment should be developed. Needs for esteem is another stage in the theory which means a desire for recognition for work well done through praise and rewards. Self-actualization is the fifth stage of the hierarchy. At this stage, teachers are helped by the management to realize their own needs and develop potentials and capabilities. This stage is useful for teachers as it helps them in realizing their potentials and work hard towards achieving the goals by setting manageable targets in their respective subjects.

## 3 Methodology

The design for the study was cross sectional as it was intended to observe the phenomenon under the study area once a time but also this kind of research design was

economical in terms of time and money. Dodoma city was selected the location for the study, the city was selected because is the most growing city in the country with increased rate of establishment of secondary schools and is the capital city of Tanzania. The population of Dodoma urban district is 410,956 (NBS 2012). Dodoma City had 19 private secondary schools and 37 public secondary schools which make a total of 56 secondary schools (Dodoma City Council 2019). The study focused on private secondary schools in Dodoma City due to the reason that private schools are the ones that provide better of motivation packages compared to public secondary schools (Mashenene 2008). The population (N) under this study was 242 private secondary schools’ teachers in Dodoma City and selection of four private secondary schools for the study was made purposefully. To obtain relevant schools for the sample, the researcher in consultation with the District Education Officer (DEO) selected private secondary schools in Dodoma City based on ease of accessibility. Teachers as final subject were randomly obtained since the teachers’ list from each school was obtained from school management. To select students and heads of private secondary schools purposive selection was implemented since the selected individuals were sought to have relevant information required. Sixty (60) secondary teachers was determined as sample size (Table 1). This sample size was proportionately computed using standard formula established by Huysamen from which it was obtained through vertical summation of sample size from each school. Mruma (2013) adopted similar Huysamen formula to estimate sample size for the study.

**Table 1.** Sample size determination

School	N	Computed sampling fraction	n
St. Peter Claver High School	68	$\frac{1}{4} \times 68 = 17$	17
Maria De Mattias School	48	$\frac{1}{4} \times 48 = 12$	12
Huruma Secondary School	65	$\frac{1}{4} \times 65 = 16$	16
Jamuhuri Secondary School	61	$\frac{1}{4} \times 61 = 15$	15
<b>TOTAL</b>	<b>242</b>	<b>60</b>	<b>60</b>

Sixty (60) questionnaire administration to secondary school teachers who were selected proportionately from four strata followed by random selection took place. Four (4) heads of secondary schools and four (08) secondary school students were purposefully selected as key informants and they were interviewed using interview guide. Content analysis Content analysis best fitted in analyzing qualitative data whereby data that were recorded by using voice recorders, note books and photos were transcribed and thereafter themes were formulated out of them. Further, arguments were built on

the established theme and intensive discussions were made followed by comparing and contrasting qualitative findings with already existing body of knowledge elsewhere globally. To assess strategies used by private secondary school management in motivating teachers, descriptive statistics were employed whereby mean scores were computed and after computation of mean scores ranking of such mean scores followed. Determination of the effect of teachers' motivation strategies on customer service, binary logistic regression as an econometric model was used. Logistic regression model was chosen because customer service as dependent variable was managed dichotomously (0, 1) whereas independent variables subjected to factor analysis to generate factors as scores with index. The equation for logit model was expressed;

$$(Y = 1) = \beta_0 + \beta_1Sa + \beta_2Js + \beta_3Pa + \beta_4Pro + \beta_5Re + \beta_6We + \varepsilon$$

Whereby; Y= Students' customer care  
 $\beta$ =Coefficients estimated from the model  
 Sa = Salary  
 Js = Job security  
 Pa = Participation  
 Pro =Promotion  
 Re = Recognition  
 We =Working environment,  
 $\varepsilon$  = Error term

## 4 Findings and Discussion

### 4.1 Motivation Strategies Employed by Schools' Management

Table 2 presents the findings which show that good remuneration (Mean = 4.6133) was one of the motivation strategies used by private secondary schools' management. The implication of these findings reveal that the salaries paid to private secondary school teachers are enough to meet their daily living expenses. These findings are supported by Maslow theory (1954) which argued that, wherever home needs of human being such as good salaries enable them to satisfy physiological needs they tend to work hard and being motivated to struggle for higher needs. As one of the teachers commented that:

*"...the salaries we receive from private secondary schools are sufficient to meet our daily life expenses and also enable us to build house for living and take our children to good school..."* FGD conducted on 10/05/2019.

**Table 2.** Motivation strategies employed by school management

Items	Mean (M)	Rank (R)
Remuneration	4.6133	1
Job security	1.9875	6
Participation	4.5333	3
Promotion	4.5667	2
Recognition	4.4778	5
Working environment	4.5083	4

Another motivation strategy as indicated in Table 2 above, used by school management was good working environment ( $M = 4.5083$ ) implying that, a good working environment motivates employees and trigger them to work very hard. The results in Nyakundi (2012) indicated coherence with results of the current study by unfolding that working environment is very important to be considered by school management because a good working environment motivates more teachers to work hard. These findings are also supported qualitatively as one of the respondents exhibited:

*“...to be honest most of the private secondary schools have good working environment as they provide good offices with good furniture, good teaching tools which facilitate us to conduct our daily activities smoothly hence motivate us to work hard as we feel the job is good...”* interview with the student on 16/05/2019.

Recognition was another motivation strategy used by private school management to motivate teachers as the results pointed out that ( $M = 4.4778$ ) implying that teachers who demonstrate a high degree commitment were highly recognized by private school management. These findings are supported by Taylor (2011) who emphasized that when employers appreciate the work well done by the employees, this act makes the particular teacher to feel that his/her contribution is valued, and therefore, he/she is encouraged to perform even more. The qualitative results from qualitative data supported these results:

*“...In our school, we have good working condition which actually makes teachers to feel energetic and encouraged to stay in the same school without shifting to another school though the issue of job contracts and salary is somehow still a challenge....”*FGD conducted on 14/05/2019.

The findings reveal that participation ( $M = 4.5333$ ) was among of motivational strategy employed by school management to motivate workers to work hard. This implies that teachers' opinions were used by the school management. Interview from teachers presented an evidence of support;

*“...to increase the level of teachers' motivation, our school management should ensure that all teachers are fully involved/participated to discuss all matters that affect them either directly or indirectly which eventually boost their working morale...”*interview conducted with a form three teachers on 14/05/2019.

The results indicate that promotion ( $M = 4.5667$ ) implying that private secondary schools promotes teachers who demonstrated high degree of commitment, which means probably that majority of the teachers were promoted than the few even if they showed a high degree of commitment. This study concurs with the study of Zalwango (2014) which commented that promotion was among the important motivation strategy by Tanzanian school management.

The results for job security ( $M = 1.9875$ ) implied high risk to work with such schools since low mean score justify low job security as any time teachers could be fired by violation of procedure. This implies that, teachers were probably under fear condition that might bring to retardation of the activity of exercising acceptable customer service to students. This study was supported by Gobena (2018) who concluded that, right teachers in terms of qualifications working under jobs with low security generally have reduced morale for teaching. This implies that job insecurity in Private secondary schools is still a problem since workers are not given work contracts, something that makes them to feel de-motivated. One of the teachers commented that:

*"...In order to increase teachers' morale in our school, the school management should work hard to revise the job contracts and improve the existing salary scale as this will motivates teachers, hence, students will be served with high customer care..."* FGD conducted on 14/05/2019.

## 5 Effect of Motivation Strategies on Students Customer Service

Table 3 shows that an overall fitness of the model was found to be significant statistically ( $p = 0.000$ ) implying fitness of model in predicting motivation strategies to affect customer service. Nagelkerke  $R^2$  found to have the value of 0.267 which suggest that independent variables considered in the model predicted 26.7% of variance in customer service. The Nagelkerke  $R^2$  value produced information of the magnitude of change for dependent variable predicted by the model. Normally, Nagelkerke  $R^2$  is pseudo  $R^2$  statistical value in its interpretation and not the actual  $R^2$  value as interpreted for the case of multiple regression model (Pallant 2011).

Findings (Table 3) indicate existence of positive (0.731) and significant ( $p < 0.1$ ) effect on customer service, implying that any rise in unit of salary will result into 73.1% rise in customer service. The odd ratio (OR) with 1.392 value further justifies the contribution as likelihood for salary to alter customer service is 1.4 times. These results are coherent with those of Orassa (2014) which revealed that the healthcare workers' were motivated with good pay and that why they liked the job. In connection to salary, the findings (Table 3) show existence of positive (1.563) and significant ( $p < 0.005$ ) effect on customer service, suggesting that any unit rise in unit of job security result into 156.3% increase in customer service with the odd ratio of 3.669 which indicate the likelihood of job security to alter customer service was 3.7 times. These findings are in coherence with those of Mangaleswarasharma (2017) which revealed that job security in terms of provision of job contracts to workers catalyzed their productivity, reduced job stress, improved overall performance and minimized rate of employee turnover. Further, the findings (Table 3) show existence of positive (0.692) and significant ( $p < 0.001$ ) effect on customer service, implying that any increase in unit of employee participation will lead

**Table 3.** Logit results

Variables	B	S.E	Exp (B)
Salary	0.731*	.381	1.392
Job security	1.563**	.278	3.669
Participation	0.692*	.350	1.149
Promotion	1.861**	.348	3.423
Recognition	1.313**	.333	3.467
Working environment	1.166***	.407	3.210
Constant	8.082	9.135	0.000
Chi-square	30.2112***		
Hosmer and Lemeshow $-\chi^2$	4.113(8) (p = 0.787)		
Cox & Snell R <sup>2</sup>	0.154		
Nagelkerke R <sup>2</sup>	0.267		
-2 Log Likelihood	189.231		

Notes: Dependent variable: Customer service (1 = high level of customer service, 0 = otherwise). \* denote 10%, \*\* denote 5% and \*\*\* denote 1% level of significance respectively

to 69.2% increase in customer service, connoting that any unit rise in employee participation will lead to 114.9% increase in customer service. The OR with 1.149 value signifies contribution of employee participation in altering customer service is 1.5 times. These finding are in accordance to those of Nyakundi (2012) which revealed that teachers' participation in decision making is a corner stone for employee motivation.

The findings (Table 3) in a similar way show existence of positive (1.861) and significant ( $p < 0.1$ ) effect on customer service, connoting that any unit rise in employee promotion is likely to cause 186.1% rise in customer service. The value of odd ratio of 3.423 further informs that the likelihood of employee promotion to influence acceptable customer service was 3.42 times. The findings in Nyakundi (2012) found that promotion of employees demonstrated remarkable employee morale. Similarly, the findings (Table 3) indicate existence of positive (1.313) and significant ( $p < 0.05$ ) effect on customer service, signifying that any change in unit of employee recognition will result into 131.3% change in customer service. The OR of 3.467 informs that the contribution of employee recognition to bring about good customer service was 3.5 times. The theory of Maslow (1954) supports the findings in this study as it depicts that recognition of human being is the determinant of the struggle to higher needs. The study of Lai (2012) further support findings in this study by unfolding that teachers' recognition for good work done make teachers feel that their inputs are noticed by employers and this the energizer for them to keep on working hard. The findings (Table 3) also show the existence of positive (1.166) and positive ( $p < 0.1$ ) effect on customer service, connoting that any unit of improvement in working environment will result into 116.6% increase in customer service. The odd ratio value of 3.210 illustrates that the likelihood of improved working environment to alter customer service was 3.2 times. The study findings in Nyakundi (2012) as cited in Macfie (2002) argued that it is the responsibility of school management

to cultivate good working environment for teachers which in future bring high level of employee satisfaction.

## 6 Conclusion

In its conclusion, the study established that good salary, high level of job security, high level of employees' participation, clear promotional procedures, recognition of teacher and availability of conducive working environment were strategies for motivating teachers in private secondary schools in Tanzania. Practically, the findings bring a call to the MoEST to make sure that public and private teachers' motivation is improved using the strategies established in this study. The study further concludes that employee job security, participation, promotion, recognitions, promotion and working environment had positive significant effect on customer service. Social implication of the study findings is that MoEST and other players in education system to make sure that public and private teachers' motivation is improved using these strategies. If this is well implemented by MoEST and other players teachers will feel that their social well-being is improved, as the result they will be motivated to render high standard of customer service.

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# Perceived Quality of NMB Bank PLC E-Banking Services in Tanzania

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**Abstract. Purpose:** Investigation of customers' perception on quality of NMB Bank PLC e-banking services in Dodoma city of Tanzania was performed. The study worked on; (i) determination of levels of customers' perception on electronic NMB and (ii) establish how customers' perception and quality of electronic NMB Bank relate.

**Methodology:** Cross sectional study was undertaken with involvement of a sample of 93 NMB Bank customers. NMB Bank customers who use e-banking services were randomly selected whereby key informants were purposively chosen. Collection of data was done with the use of questionnaire survey, interview, focus group discussion (FGD) and review of documents. The analysis of qualitative data was undertaken with the use of content analysis. Levels of customers' perception were determined using descriptive statistics by computing means and standard deviation. Logit model established how perception of customers and quality of NMB Bank e-banking services relate.

**Findings:** The findings indicated that perception of customers on NMB Bank PLC e-banking services was generally positive. The logit results indicated that security, trust, networks, cost and time were statistically significant relationship with quality of electronic NMB services.

**Research Limitation/Implications:** The research was undertaken to one bank, NMB and excluded other banks and its focus was in one city; something in future needs to be taken care of by extending the study to cover other banks with consideration of rural setting.

**Practical Implications:** The study concluded that the level of customers' perception on NMB Bank PLC e-banking service was positive. The study recommends that NMB Bank PLC management should improve the Bank's network infrastructure. Social implication from these findings is that the bank should improve investment in public awareness/education about e-banking services to create understanding on the developed technologies and economic growth for individual, the bank and the nation at large.

**Keywords:** Customers' perception · E-banking · Service quality · NMB Bank PLC · Tanzania

## 1 Introduction

Working environment and patterns of living today's world cannot overlook adoption information technology (IT) (Khater et al. 2016). As the matter of facts, the growth of IT and its application in the emerging economy and elsewhere in the world has necessitated several changes in bank operations including adoption of e-banking services which are far traced from the mid of 1990s ((Ajanthan 2018, Ditto 2017). In the global perspective, the study of Reddy and Reddy (2015) in Pakistan found that adoption of e-banking has added value to bank operations and has boosted customer satisfaction level and has made redundant the traditional banking operations. Mukhtar (2015) in UK established that technology and its application is growing with accelerating speed and it has aided changes in various industries globally. Hasandoust and Saravi (2017) in Northern Tehran further depicted that the trust of customers for a bank largely is routed from e-banking services rendered with acceptable quality. The study of Ditto (2017) and Kaur et al. (2016) in India revealed that the future bank growth is predicted by the quality of IT the industry opts to go for; the growth of IT has created several opportunities that enterprises need to exploit profitably and maximize satisfaction of customers. Generally, the presented studies from global orientation connote that satisfaction of customers with services offered by service providers among them being banks is the function of adoption of IT. Now days as it has been presented by previous studies from global angle, banks are competing to heavily invest in IT with the aim of enhancing the level of satisfying customers and remain competitive in the industry and attain their profit maximization goal.

In African countries like in other countries in the rest of the world, IT has revolutionary changed operations of several sectors among them being banking sector. For instance, Mwiya, Chikumbi, Shikaputo, Kabala, Kaulung'ombe and Siachinji in Zambia emphasized that the technology with bumper benefits and ease to use gives customer trust which eventually result into attitude of customers becoming positive for such technology. Dhurup et al. (2014) in South Africa established that banks should integrate e-banking strategy in the main corporate agenda for improved quality of service delivery. Kiragu (2017) in Kenya pointed out that great profits were made by banks that opted for e-banking in serving customers. In South Africa, Maduku learnt that the trust customers build on a bank is the key determinant for the option to use bank electronically aided services. Generally, the body of knowledge visited in Africa pin point that delivery of banking services using e-banking strategy superimposes the traditional bank operations that have been meagerly contributing to improved level of customer satisfaction.

In Tanzania, most of banks including NMB Bank use automated banking service delivery strategy. A number of previous studies have undertaken on e-banking services since when it was adopted for the first time in Tanzania. However, mainly such studies have focused on the adoption of mobile phone banking in NMB Bank service delivery, its associated benefits and challenges in NMB service (Mashenene and Mkende 2019). Several initiatives have been put in place by the government of the United Republic of Tanzania to curb identified challenges. Such initiatives among others were establishment of the legal frameworks (policies and Acts). These frameworks include the 2003 policy for National Information and Communications Technologies, the 2006 Act No. 4 of the

Bank of Tanzania and the 2006 Act No. 5 of the Banking and Financial Institutions and 2015 cybercrimes Act (URT 2015, URT 2006a, URT 2006b, URT 2003). Despite government initiatives and the NMB Bank management to curb the established challenges, to date studies with the focus of establishing how customers perceive NMB Bank e-banking services are hardly found in the existing literature. Therefore, this study work on establishing how customers of NMB Bank perceive service quality for e-banking it offers.

## 2 Theories Underpinning the Study

Attitude Theory (AT) Ajzen (1975) underpinned the study. AT The attitude theory advocates that when an individual forms positive attitude on a certain product, there is great likelihood that such individual to buy or make use of that product. Generally, such attitude on an object is expectedly to form behavior of the said individual toward the object (Ajzen and Fishbein 1980). From AT, its relevance can be drawn in this way; perceptions and attitude toward something are interrelated concepts and in most cases they are measured using similar constructs (Mashene 2016). It is from this argument, attitude forms behaviour for an individual to use or not to use. In this regard, as customers perceive valuable NMB Bank e-banking services they build up behaviour to transact and continue transaction with the bank. Since predictor was variables developed from attitude and perception, AT was unable to suffice measurement of dependent variable which was quality of bank electronically aided services. SERVQUAL model formulated by Parasuraman et al. (1988) was added appropriately as the second theory in underpinning the study. Tangibility, reliability, assurance, responsiveness and empathy were dimensions in the SERVQUAL model that are used when measuring quality of the service.

## 3 Methodology

The study involved eligible customers of NMB Bank in Dodoma city who have transacted with NMB Bank for a period of six months. This city was the location chosen for the study with reasons of increased number of NMB Bank in Dodoma city after the government has shifted its headquarter to Dodoma from Dar-es Salaam city. The transfer of the government also has resulted into rapid rise in population of Dodoma city, consequently, increased transactions with the bank. NMB Bank branches have increased from 3 (before 2015) to 6 (after 2015); namely Dodoma, UDOM, Mazengo, Makole Business Centre, Kambarage and Bunge branch. The design for the research opted was cross-sectional; the design was sought suitable since the research plan aimed at gathering data one time point (Mashene and Mkende 2019, Kothari 2013).

In this study 17,000 registered customers using e-banking services formed population (N) for the study. The population also included 68 NMB Bank staff and 4 branch managers in Dodoma City. Staff and managers from two NMB branches namely Kambarage and Bunge were excluded since they were newly established during the period of study. The sample of 93 NMB Bank customers estimated by Yamane (1967) formula formed sample size for the study. Initially, the sample size was estimated to be 100 NMB Bank customers who transact using e- Banking. However, during the field work, only 93(93%) respondents returned useful questionnaires (Table 1).

**Table 1.** Sample size determination

S/n	NMB Bank PLC braches	NMB customers
1	Dodoma Branch	24
2	UDOM Branch	24
3	Mazengo Branch	24
4	Makole Business Centre	21
	<b>Total</b>	<b>93</b>

The researcher first obtained lists of NMB Bank customers who use e-banking services from the bank management. Since customers were distributed in four branches, then the four branches were regarded as separate strata. Non-proportionate of sample in the strata was considered appropriate followed by random selection from each stratum. Key informants of one NMB Bank staff from each of the four branches were purposefully selected making a total of four staff. The selection of the staff was based on the belief that the selected staff had adequate and relevant information related to the topic under investigation. Further, four NMB Bank branch managers from each branch were purposefully included. Methods adopted in collecting data comprised of interview, survey, focus group discussion (FGD) and review of NMB recent documents from 2016 to 2019. Qualitative data analysis was made possible using content analysis that required transcription of data which were captured in hard copy and in electronic form. Transcription was thereafter followed by categorization of transcripts in accordance to themes. Determination of level of perception of customers on bank electronically provided services, descriptive statistics in form of central tendency was performed and findings were tabulated. Establish of the relationship between customers’ perception and quality of NMB Bank e-banking services, logit model. The logit was appropriate since quality of NMB Bank e-banking services as dependent variable was a dummy variable (1 = high quality, 0 = otherwise) which emanated from factor analysis. Factor analysis was used to formulate index scores for independent variables (trust, security, network cost and time). The logit equation was formulated as follows;

$$Pr (y = 1) = \beta_0 + \beta_1 Tr + \beta_2 Se + \beta_3 Ne + \beta_4 Co + \beta_5 + \epsilon_i$$

Where;

Pr = is the probability function (to link the expectation of y to linear predictor)

y = Quality of e-banking services (1 = If NMB customers perceived quality, 0= Otherwise)

$\beta_0$  = Constant

Tr = Trust

Se = Security

Ne = Network

Co = Cost

Ti = Time

## 4 Findings and Discussion

### 4.1 Reliability Test

To ensure that data collected had acceptable reliability, Cronbach Alpha (Table 2) was performed as the test for reliability. The results indicated that values of Cronbach Alpha were within the range between 0.760 and 0.913; the range which signifies a high degree of reliability (Mashene 2016).

**Table 2.** Test for reliability

Variables	Cronbach's Alpha ( $\alpha$ )	Number of items
Trust	0.793	3
Security	0.841	3
Network	0.760	3
Cost	0.801	3
Time	0.778	4
Quality of e-banking services	0.913	5

## 5 Descriptive Statistics Results

### 5.1 Perceptions of Customers on E-Banking Services

Table 3 shows that mean score for all variables predicted NMB Bank customers' perception was above the average with a mean score of 3.5212, inferring positively perceived services provided electronically by the bank. Security construct was perceived by customers being positive ( $M = 3.6380$ ), implying that NMB customers perceive e-banking services to be safe to use during transaction. The results from this study correspond with those of Joseph and Stone which revealed that security is considered as one of key determinants for bank customers to opt for e-banking services.

**Table 3.** Perceptions of customers on e-banking services (n = 93)

Variables	N	Mean	Std. dev.
Security	93	3.6380	0.9611
Trust	93	3.667	0.9581
Network	93	3.7132	0.94507
Cost	93	2.8459	1.1215
Time	93	3.7419	1.0098
<b>Overall mean</b>		<b>3.5212</b>	<b>0.9991</b>

Findings (Table 3) generally show NMB Bank mean score of customers’ perception on trusting electronically delivered services was 3.67 implying a high perception on trust. These findings concur with the findings by Kumbhar who indicated that customers trust is one of the dominant factors militating against the growth and development of ATM services. Table 3 further indicates that bank trust as a construct was high with a mean of 3.667, implying that NMB Bank is likely to retain existing customers and acquire new customers since customers already have built adequate trust with the bank. Assertion by Dhurup et al. (2014) matched with the results of this study in a way that customers trust banks that assure them with protect customers’ transactions and personal information with the bank. Findings in Table 3 indicate that NMB bank network is highly perceived by customers (M = 3.7132), connoting that the ability of bank network in terms of connectivity and performance satisfies customers. The results correspond with the findings of Lee and Moghavvemi (2015) which emphasized that strong bank network ubiquitously win the competition due to enhanced level of customer satisfaction.

Findings in Table 3 show that cost charges by NMB Bank during use of e-banking services was perceived low (M = 2.8459) since it was below the average score. Impliedly, customers perceive such charges being user friendly and make them continue transacting with the bank. Findings in Rosu (2011) tied with findings in this study in a way that opting for e-banking services minimizes costs for customers to transact with the bank. Table 3 shows NMB Bank customers perceive time they spend when transacting using e-banking is short since agreement was above average score (M = 3,7419), giving implication that customer were satisfied with the time they spend to perform transactions with NMB Bank. Findings from Lichtenstein and Williamson (2016) and Guriting and Ndubisi inform that e-banking is the time saver and source of convenience for customers who use it.

## 6 Logistic Model Results

### 6.1 Model Description

The logit results (Table 4) show on Omnibus test being significant ( $p \leq .001$ ) as it was measured by Chi-square ( $\chi^2 = 31.736$ ) (Rath (2018). Table 4 further shows values for Cox & Snell R Square  $R^2 = 0.089$  whereas Nagelkerke  $R^2 = 0.118$ , Nagelkerke

$R^2$  suggests that logit model on the study variables accounts for 11.8%. The values of Cox & Snell  $R^2$  and Nagelkerke  $R^2$ , Nagelkerke  $R^2$  should inform that they are just Pseudo values sufficient for logit model and they are interpreted differently from  $R^2$  in multiple regression model.

## 7 Model Results

Findings in Table 4 shows existence of positive (0.047) and significant ( $p = 0.043$ ) relationship between security and e-banking services, implying that any increase in unit of security will result into 4.7% rise in perceived quality of e-banking services. The odd ratio (OR) with 1.107 value signifies that the contribution of security in changing perceived quality of e-banking services was 1.1 times. These findings were supplemented with qualitative one;

*“...NMB Bank PLC offers the best quality on e-banking services that is why many customers and other stakeholders enjoy our services. Basically, NMB Bank PLC comprises of advanced technologies which help much on the security, accessibility, reliability, and trust; something which gives staff and customers’ confidence to work with it and enjoy the services...” (Interview held with NMB Bank PLC Branch Manager on 15<sup>th</sup> May 2019).*

**Table 4.** Logit model results

Variables	B	S.E	Sig	Exp(B)
Security	.047	.017	.043	1.107
Trust	.056	.019	.011	1.015
Network	.048	.016	.002	1.003
Cost	.037	.004	.032	1.001
Time	.042	.003	.041	1.002
Chi-square	31.736 ( $p = .000$ )			
Hosmer and Lemeshow $-\chi^2$	6.362(8) ( $p = .676$ )			
Cox & Snell $R^2$	.089			
Nagelkerke $R^2$	0.1184			
-2 Log Likelihood	212.302			

Findings (Table 4) indicate existence of positive (0.056) and significant ( $p = 0.011$ ) relationship between trust and e-banking services, implying that any rise in unit of trust

will lead to 5.6% rise in perceived quality of e-banking services. The OR value of 1.015 notifies that the contribution of trust in changing perceived quality of electrically delivered bank services was 1.0 times; this contribution is high to bring about noticeable change. Findings in Table 4 further reveal existence of positive (0.048) and significant ( $p = 0.002$ ) relationship between network and e-banking services, implying that any unit improvement in network will produce 4.8% increase in quality of electronically delivered bank services. The OR with value of 1.003 suggests that the contribution of network to alter quality of services provided by banks electronically was 1.0 times.

The findings in Table 4 indicate existence of positive (0.037) and significant ( $p = 0.032$ ) relationship between cost and e-banking services, implying that any rise in unit of cost will lead to 3.7% rise in quality of services delivered online by banks. The OR of 1.001 indicates high contribution of cost in influencing quality of services delivered electronically was 1.0 times. Similarly, results in Table 4 indicate existence of positive (0.042) and significant ( $p = 0.041$ ) relationship between time and quality of bank online services, implying that any rise in unit of time will lead to 4.2% rise in perceived quality of e-banking services. The OR of 1.002 indicates high contribution of time in influencing quality of online delivered services was 1.0 times.

## 8 Conclusion

The conclusion drawn from study findings is that NMB Bank PLC customers demonstrated positive perception toward quality of bank electronically supported services. The study further concludes that security, trust, network, cost and time were key determinants of bank's e-banking perceived service quality. The findings give practical implication to NMB Bank PLC Management to heavily invest on e-banking security, trust and network which consequently will reduce cost and time to customers. This can be achieved through improvement of fund for the purchase of bank facilities like CCTV camera, information data base, computers, software programs for the effectiveness of security, timely service provision, increased trust and reduced operational and administration cost as the way forward to meet the quality of e-banking in the Banking industry especially NMB Bank PLC. Social implication from these findings is that the bank should improve investment in public awareness/education about e-banking services to create understanding on the developed technologies and economic growth for individual, the bank and the nation at large.

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# Organisational Factors Influencing Vendors' Participation in Public Electronic Procurement System in Ilala District, Tanzania

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**Abstract. Purpose:** This paper examined the organisational factors influencing vendors' participation in public electronic procurement system (PEPS). Ilala District, Tanzania. The governmental aspects were used in this study as mediator for direct and indirect on organisational factors influence for vendors' participation in PEPS.

**Methodology:** The paper applied sample 300 vendors and three key informants, cross-sectional research design and content analysis for qualitative while Partial Least Square-Structural Equation Modelling (PLS-SEM) was used for quantitative. The study tested four alternative hypotheses, to examine direct and indirect influence of organisational factors influence toward vendors' participation in PEPS.

**Findings:** The paper results found a strong significant direct effect at  $p < 0.05$  for the organisational aspects like training, willing to change, top management support and skilled human resources influencing vendors' participation in PEPS. The findings also found an indirect linkage between organisational factors and governmental aspects for vendors' participation in PEPS.

**Research Implications:** The paper focused to the organisational factors with mediating of governmental aspects on influence to vendors' participation in PEPS. It proved that organisational with or without mediation have influence for vendors' participation in PEPS.

**Practical Implication:** This has implication for attraction vendors to participate because indicators for what should be done by regulators and system's controller where documented for more assured competitive vendors' database, hence value for money.

**Social Implication:** The knowledge advanced by this study will help regulators, system controllers, policy-makers, vendors on the organisational factors and governmental aspects for vendors' participation in PEPS.

**Originality:** This paper proved that vendors' participation in PEPS can be influenced by both organisational factors and governmental aspects. This study has been quite different from previous researchers' focus with theoretical triangulation and Resource Based view theory arguments highlighted only internal factors for organisations to be competitive.

**Keywords:** Mediating · Organisational factors · Participation · Public electronic procurement · Vendors

## 1 Introduction

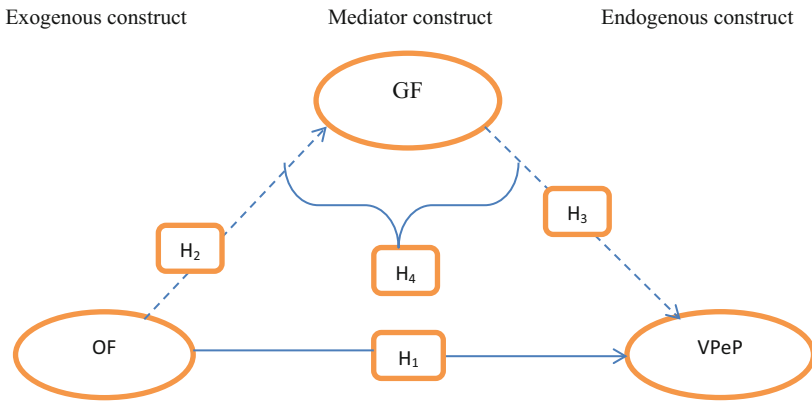
Globally, service delivery improvement by governments through public procurement has become an important agenda due amount budget set for this activity. Experience form using public procurement noted to have political landscape and institutional problem, therefore recommended innovation for the use of clear procurement procedures, national strategy, necessary expertise and legal framework (Li et al. 2020). According to Dello and Yoshida (2017) public procurement which was done manually found to be very ineffective, which lead to corruption, delays on project completion, costs inflated, lack of transparency in its operation and provision of poor quality of services and supplies. To cater those challenges of manual procurement system, the Information and Communications Technologies (ICT) has opened new possibilities for governments to introduce what so called public electronic procurement (World Bank 2016). The public e-procurement implementation in developed countries has brought benefits such as cost reduction, efficiency; reduction of the procurement process, reduction of corruption level, enhanced compliance and standardisation of procurement (Tutu *et al.* 2019, Vaidya and Campbell 2016). The expected benefits of e-procurement transaction have been considerable just after the adoption of this technology, public procurement expenditure reduced by 5–20% once properly encouraged participation of private sectors (vendors) (European Commission 2012).

In the globalisation era, vendors' participation in public e-procurement system is becoming critical for improving public e-procurement success rates by meeting the intended objectives like transparency, quality improvement, time management, costs reduction, paperwork system reduction, and improving efficiency and effectiveness in the operation (Ujakpa *et al.* 2016). It is also documented that, among other benefits of vendors' participation in public e-procurement system is allowing advanced and qualified suppliers from developed countries to trade with developing countries (Dhaoui 2019, Eei *et al.* 2012, Sharabati *et al.* 2015). Further apart from benefits, scholars also documented organisational factors measurements lead vendors to adopt of e-procurement system which are organisational culture, willing to change, top management support, ethical practice, training for practitioners, resources and business nature, however, all those organisational indicators lead vendors to adopt e - procurement system for firm level use (Daoud and Ibrahim 2019, Suliantoro and Ririh 2019, Naik and Bobade 2018). The current study had focus to examine the influence of these organisational factors for vendors' participation in public e-procurement system mediated by governmental factors measured by system bylaws, reliable procurement procedures, government leadership, bureaucratic control and administrative practices (Premathilaka and Fernando 2018, Gutierrez *et al.* 2015).

Scholars like Shouran *et al.* (2019), Zhou et al. (2018), Irma *et al.* (2016) and Cousins *et al.* (2011), anticipated organisational factors that lead vendors to adopt an e-procurement system for their own use like Information Technology (IT) literacy and infrastructures, financial aspects, managerial support and legal preparedness. Furthermore, Aqeel and Asim 2019, De Coninck *et al.* (2018), Seo et al. (2018), Lynn and Davis (2016) and Thiga and Makau (2016), also revealed that, top management support,

presence reliable procurement procedure, training to vendors, reliable database influence vendors' adoption for technology (e-procurement system) for individual firms' use. Aforementioned scholars given a little attention on how these organisational factors can influence vendors' participation in public e-procurement system. Therefore, this study examined organisational factors influence on vendors' participation in public e-procurement system.

In Tanzania, Dello and Yoshida (2017) study proved that, manual public procurement was ineffective, which lead to corruption, delays in public projects completion, costs inflated, lack fairness, lack of transparency and provide poor quality services/supplies. The introduction of e-procurement is expected to be a catalyst to rectify these shortfalls observed from manual procurement system and relative advantages like transparency, paperless system, corruption free and usefulness were documented (Shatta et al. 2020). Ngussa *et al.* (2020) found that, merchandise management (vendors) where one key drive for best public procurement performance. Tanzania through PPRA invested efforts to integrate public procurement functions and its proceedings among vendors and Procuring Entities (PEs) into public e-procurement system. However, there is reluctance on the vendors' side, results the use incompetent suppliers in government projects due to lack reasonable numbers of qualified vendors in the database for procurement competitions (URT 2018, Mlinga 2018). Therefore, the current study adopted organisational factors mediated by governmental aspects to examine how it influences vendors' participation in public e-procurement system (Fig. 1).



**Fig. 1.** Construct model. Key: ———> Direct Influence (OF: Organisational Factors to VPeP (Vendors' Participation). - - -> Indirect Influence (OF via GF (Governmental Factors) to VPeP)

The Endogenous constructs were guided by Diffusion of Innovation (DOI) theory by Rogers (1983), for relative advantages which are profits maximisation, increase market share, enhance trust and contract control. Furthermore, Rahman *et al.* (2019) documented factors influencing e-procurement implementation in the organisation which were selling efficiency, improved savings, increased job performance, increased productivity and management improvement. The Diffusion of Innovation (DOI) theory also catered for

exogenous construct aspects like training, top management, willing to change, database capacity for quick retrieval and mediating construct which was governmental aspects like administrative practice, by laws for the system, reliable procurement procedures, equal access for both big and small vendors, these both stand as resources and capabilities for vendors' participation in public e-procurement system. Abdul and Lyimo (2019) also revealed factors influencing adoption of e-procurement in institutions which were top management support, suppliers' capacity and information systems infrastructure. This paper adopted post-established organisational factors to examine they are influencing for vendors' participation in public e-procurement system. According to Suliantoro and Ririh (2019), Thiga and Makau (2016) and Li *et al.* (2015), revealed organisational factors influencing adoption of e-procurement in the respective organisation such as top management support, e-security, information sharing, business to business experts and change management. The current study adopted the same organisational factors to examine their influence toward vendors' participation in public e-procurement system. Prayudi *et al.* (2019) and Kaliannan *et al.* (2009), revealed the uptake for vendors to public e-procurement system is very low, hence the current study used governmental factors (administrative practice, by laws, procurement procedures and equal access to all vendors) been mediators to organisational factors on their influence toward vendors' participation in the system.

Likewise, Daoud and Ibrahim (2019) and Shukla *et al.* (2016) revealed the importance of e-procurement like access to a wider market, control of malpractice, time saving, reduction of business costs, maximize transparency and streamlining the procurement process, but postulated that, only 27% Jordan firms (vendors) participated in the public e-procurement system. Seo *et al.* (2018) also found vendors' willingness to participate in public e-procurement is limited; hence call for the investigation of organisational factors affecting vendors' participation in the system. Furthermore, Isaac *et al.* (2015), revealed a major limitation for organization' e-marketing (similar to e-procurement system) uptake been confidentiality and trust, worrying the information leaked to rivals, hence strongly recommended government and others stakeholders to intervene the process by providing awareness programs to SMEs (vendors). Therefore the governmental factors influencing vendor participation in public e-procurement system need to be researched.

Furthermore, challenges for public e-procurement system implementation documented to be: stakeholders' behaviours (vendors), leader's behaviour, leadership shortcoming, unskilled personnel, lack of training, resistance to change, organisational power and politics and public e-procurement value creation (Mohungoo *et al.* 2020). The current study focus was to use the same challenges (organisational factors) to examine their influence toward vendors' participation in public e-procurement system while being mediated by the government itself. Lumsden (2015), under the study of Technological-Organisational-Environmental (TOE) factors influence managers' decision to adopt cloud computing, the study revealed for organisational factors necessity for legal regulation, service linkage and best vendor identification (procedures), which from the current study termed as governmental factors used for mediating purpose for the influence on vendors' participation in public e-procurement system. From the facts narrated, the current study need to fill the existing knowledge gap, therefore these alternative hypotheses were hypothesized and tested:

*H1. Organisational factors influence vendors' participation in public e – procurement system,*

*H2. Governmental factors influence vendors' participation in public e-procurement system.*

*H3. Organisational factors associated with governmental factors.*

*H4. Organisational factors once mediated by governmental factors influence toward vendors' participation in public e-procurement system.*

## 2 Theoretical Guidance

The study was guided by Diffusion of Innovations (DOI) Theory by Rogers (1983). The choice of this theory was justified by need of resources for participation and the requirement for advantages motives for the diffusion of the newly established innovation system which will support vendors to participate in public e-procurement.

### 2.1 Diffusion of Innovation (DOI) Theory

Diffusion of Innovations Theory by Rogers (1983), was used to evaluate the dissemination of innovations. The innovation process for adoption by organisation passes first knowledge of an innovation for forming an attitude towards the innovation, to a decision to adopt or reject given innovation, to the implementation of the new idea”, and that the awareness of characteristics of an innovation has an impact upon the intention of the individual to use the technology (Rogers 1983). The Innovation diffusion is communicated through certain channels over time, among the members of a social society as “*an idea, practice, or object that is perceived as new by an individual or other unit of adoption*”. Innovation distribution is dependent upon the relative complexity (knowledge for practitioners by training), advantage (relative usage which will create willing for change), trialability and observability (to justify management support aspect, the innovation to allow testing for approval and the results being visible), compatibility (perceived values, need and reliability to justify the need for database capacity aspect, which assure availability required information timely). Diffusion theory suggests that an innovation that offers higher relative advantages, compatibility, triability, observability and lower complexity will be disseminated earlier, therefore it will justify vendor' participation in public e-procurement system.

## 3 Methodology

The study was conducted in Ilala District, Dar Es Salaam; the study area was selected because of having 1110 vendors out 9740 countrywide (11.4%), who were eligible in public e-procurement system's participation (URT 2018). The study collected quantitative data through a structured questionnaire (5 Likert scale format) which was administered by the researcher. Qualitative data were collected through interview with key informants; the interview was guided by the key informants guide. The study adopted cross-sectional research design, because the design allows the use of a variety of analytical techniques, the use of different methods for data collection and its ability to allow

data management due interaction of variable over one-another (Flick 2011, Creswell 2009).

The simple random sampling technique was used to select 300 vendors (were vendor’s managerial personnel considered as respondent) after random generated number done (with the help of Microsoft excel) from the vendors list obtained at Government Procurement Service Agency (GPSA) database Financial Year (FY) 2018/2019. A purposive sampling technique used to sample three (3) Key Informants form the empowered public institutions (Public Regulatory Authority, Government Procurement Service Agency and Medical Stores Department) to develop and control the system, these institutions were selected due to the richness of information on public e-procurement system (Tanzania National electronic Procurement System (TANePS)). The minimum sample size reached by the use of Cochran’ finite population formula (Cochran 1977). To get  $n_0$  from infinite first:

$$n_0 = \frac{z^2pq}{e^2} = \frac{(1.96)^2(0.5)(0.5)}{(0.05)^2} = 384 \tag{1}$$

Where  $n_0$  = Infinite sample size,  $z$  = selected critical value,  $p$  = estimated proportion of attribute,

$q = 1-p$ ,  $e$  level of precision. Assuming  $p = 0.5$ , taking confidence level as  $+0.5$ ,  $p = 0.5$ ,  $q = 1-0.5 = 0.5$ ,  $e = 0.05$ ,  $z = 1.96$ .

The finite population formula (Cochran 1977) was used to determine sample size for vendors:

$$n = \frac{n_0}{1 + (n_0 - 1)/N} = \frac{384}{1 + (\frac{384-1}{1110})} = 286 \tag{2}$$

A questionnaire was developed without ambiguity in concepts and terms used and pre-tested using the sample size of 30 respondents (vendors) as a rule of thumb at Ubungo District (which is not actual study area) (Saunders *et al.* 2016). Internal consistency reliability was tested by using Cronbach Alpha, at pilot stage internal consistency reliability was 0.972 which was above minimum required threshold of 0.7, hence allowed the final questionnaire to be developed; also the respondents were informed about the confidentiality which will be observed. Face validity was done by involving procurement experts from College of Business Education and Moshi Co-operative University. A total of 26 items from 29 items were involved with loading above 0.5 were Organisational factors 9 items, governmental aspects 10 items, vendors’ participation aspects 7 items were assessed. For the purpose of the used software (SmartPLS 3.0 for PLS-SEM) require results from positive to negative (Hair 2016), Likert scale statements developed ranging from 1 to 5 (ranging from 1 = strongly agree; 2 = agree; 3 = neither agree nor disagree; 4 = disagree; 5 = strongly disagree) to examine the organisational factors influence on vendors’ participation in public e-procurement system.

Quantitative data were analysed by using the Partial Least Square Structural Equation (PLS-SEM), which was appropriate for testing hypothesis in the model. The study assessed reliability, item loading, convergent and discriminant validity by clearly observing the indicated threshold: Cronbach’s Alpha > 0.7, outer loading > 0.5, Average Extracted Variance (AVE) > 0.5 and composite reliability (CR) > 0.5. The qualitative



data analysis was done by using content analysis (thematic approach) after stage-wise tasks where by data were recorded, transcribed, categorised, axial coded and grouped into themes relating to organisational factors influencing vendors' participation in public e-procurement system.

PLS-SEM analysis tools was chosen due to its flexibility which permit examination of complex associations, capability to combine linear regression and factor analysis, estimate constructs which are formatively or reflective, free from model fit and ignore assumptions hence remove error measurement problems (Hair *et al.* 2016, Wolf *et al.* 2013). The PLS-SEM analysis method used as a prediction-oriented technique was capable to carry Confirmatory Factor Analysis (CFA) with the provision of reliable and valid outer loading which guide on which indicator to drop and which one retains for results interpretation (Afthanorhan 2013). The PLS-SEM analysis involve two main stages (Chin 2010) which were: (1) The assessment of the measurement model like discriminant validity, internal consistency and item reliability of the measures (Formative measurement model for this study) and (2) the assessment of the structural model for path analysis determinants.

### 3.1 Reliability, Validity and Multicollinearity Test

The Variance Inflation Factor (VIF) was inspected on assessing the multicollinearity problem. Table 1 depicted the VIF results are all below 10, meaning that the problem of multicollinearity does not exist (Chin 2010). The widely measurement used to measure reliability was Cronbach's Alpha as per social sciences (Loewenthal and Lewis 2018, Bonett and Wright 2015, Cronbach 1951). Reliability of data was used to assess the internal consistency for all 26 aspects through Cronbach's Alpha and was significant at an Alpha of 0.925 and reliability as per constructs was significant as indicated in Table 1 where all constructs' reliability tested scored above 0.7 indicates a strong consistency among constructs aspects (Prajogo and Sohal 2003).

The two aspects were used to measure Construct validity which was discriminant and convergent validity. These measures used to examine the variance of the shared latent variable and their differences between each other's (Alarcón *et al.* 2015). In order to overcome traditional Cronbach's Alpha (CA's) deficiencies, the Composite Reliability (CR) was applied. The CRs threshold accepted in the study was above 0.80 and all observed as per Table 1 results shown. The Average Variance Extracted was used to measure convergent validity and the acceptable threshold should be above  $AVE > 0.5$  (Fornell and Larcker 1981). The current study results observed the acceptable threshold for convergent validity see Table 1.

Discriminant Validity requires the square root of Average Variance Extracted (AVE) being greater than the correlations for the given constructs (Fornel and Larker 1981). Hence it was tested and found the square root of AVE for all constructs as shown diagonally in Table 2 were greater for all model's constructs than the construct correlations, therefore, proved that, no problem with discriminant validity for the applied model's constructs.

**Table 1.** Factor loading, reliability, multicollinearity, average variance extracted and composite reliability

Construct	Indicator	Factor loading	VIF	Cronbach's alpha	AVE	Composite reliability
OF	OFVPeP1	0.541	1.288	0.838	0.519	0.874
	OFVPeP10	0.674	1.673			
	OFVPeP11	0.745	1.789			
	OFVPeP12	0.618	1.619			
	OFVPeP3	0.706	1.733			
	OFVPeP4	0.612	1.448			
	OFVPeP5	0.720	1.716			
	OFVPeP6	0.532	1.476			
	OFVPeP8	0.768	1.936			
GF	GFVPeP1	0.625	2.076	0.932	0.622	0.942
	GFVPeP10	0.777	3.050			
	GFVPeP2	0.815	3.291			
	GFVPeP3	0.741	2.219			
	GFVPeP4	0.812	2.822			
	GFVPeP5	0.809	2.477			
	GFVPeP6	0.820	2.701			
	GFVPeP7	0.845	3.569			
	GFVPeP8	0.831	3.287			
	GFVPeP9	0.792	3.130			
VPeP	VPeP2	0.759	1.861	0.852	0.532	0.888
	VPeP3	0.801	2.091			
	VPeP4	0.750	1.828			
	VPeP5	0.684	1.494			
	VPeP6	0.760	1.890			
	VPeP7	0.712	1.712			
	VPeP1	0.626	1.380			

OF1: Electronic procurement strategy; OF3: Willing to change; OF4: Ethical Practice; OF5: Top management support; OF6: Agreements on new standards and procedures; OF8: Skilled human resources; OF10: Management Style; OF11: Training for practitioners; OF12: Database Capacity; GF1: Government leadership; GF2: Administrative Practice; GF3: Legal and policy framework; GF4: Bureaucratic control; GF5: By laws for the system; GF6: Policies for Public-Private partnership; GF7: Reliable Procurement procedures; GF8: Access of information for policy making; GF9: Equal access for SMEs and big enterprise; GF 10: Presences of PeP-contract management; VP1: Maximize Profit; VP2: Increase Market share; VP3: Maximize trust; VP4: Help contract control; VP5: Require small investment and accessible solution; VP6: Help in production planning; VP7: Help on inventory management

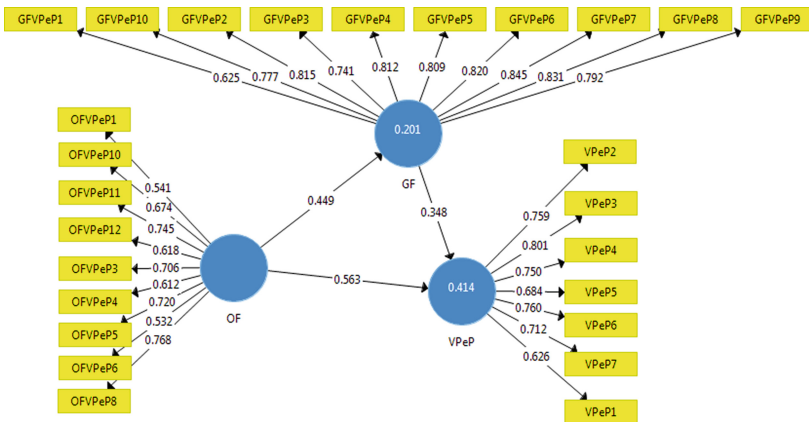
**Table 2.** Discriminant validity test for measurement model in PLS-SEM

	GF	OF	VPeP
GF	0.789		
OF	0.449	0.662	
VPeP	0.531	0.563	0.729

GF: Governmental Factors, OF: Organisational Factors, VPeP: Vendors' Participation e-Procurement

### 4 Findings and Discussions

The structural model was assessed by using two measures: coefficient of determination (R square-R<sup>2</sup>) and significance level (t-test) with estimated path coefficient (β). The PLS-SEM method used to confirm influence between the constructs with the model by testing hypothesis model. The significance of paths for respective model was determined by actual testing. Therefore, the squared multiple correlation (R<sup>2</sup>) in each construct was assessed. Then the paths' significance was also evaluated in each construct.



**Fig. 2.** The PLS-SEM model results

The statistical results in Fig. 2 for the theoretical model tested showed significance to hypothesized influence of organisational factors was supported with acceptable loading for all measurement above 0.5. The results indicated that organisational factors had both direct and indirect influences towards vendors' participation in public e-procurement system and the hypothesized influence appeared to be in real life due to the fact that, training give knowledge for anything new but also top management must approve anything to incorporated in the organisation structure.

Chin (2010) suggested that R<sup>2</sup> values around to 0.190 are weak, values ranging from 0.200 to 0.333 are moderate and values 0.35 are substantial. The Fig. 2 for this study showed that, 20.1% (0.201-R<sup>2</sup>) of the variance in governmental factors is explained

by organisational factors. The 41.4% (0.414-R<sup>2</sup>) in vendors’ participation aspect were explained by both organisational factors and governmental factors. The R<sup>2</sup> values fall under the moderate and substantial category as per Chin (2010) hence depleted good results.

**Table 3.** The Partial least squares (PLS-SEM) results for hypothesis model test

Constructs	$\beta$	T-value	P-value	Remark
GF → VPeP	0.348	5.006	0.000	Supported
OF → GF	0.449	5.865	0.000	Supported
OF → VPeP	0.563	6.038	0.000	Supported
OF → GF → VPeP	0.156	3.680	0.000	Supported

GF: Governmental Factors, OF: Organisational Factors, VPeP: Vendors’ Participation e-Procurement

In PLS-SEM, paths’ significance for the measurement model was tested by using the bootstrapping method. This bootstrap method because it is an alternative way to get better approximations for a true small sample properties (according to Chin’s (1998) good sample size for bootstrapping is 500 samples and also used as a technique for testing the study hypothesis (Schmidheiny and Basel 2012). According to Hair *et al.* (2011) the critical t-values for two-tailed test, t-value > 1.65 (significant at 0.1 level), t-value > 1.96 (significant at 0.05 level) and t-value > 2.58 (significant at 0.01 level). Table 3 indicated the hypothesis test, and standardised path coefficient results. The result revealed that, all the independent constructs are positively significant to the dependent constructs VPeP (GF  $\beta = 0.348$ , t-value = 5.006, p 0.01; OF  $\beta = 0.563$ , t-value = 6.038, p 0.01; OF-GF  $\beta = 0.156$ , t-value = 3.680, p 0.01) and GF (OF  $\beta = 0.449$ , t-value = 5.865, p 0.01).

Alternative hypothesis (H<sub>1</sub>) were supported in Table 3, once the results revealed that organisational factors (mainly were top management support, willing to change, training to practitioners and skilled human resources) has a positive influence with vendors’ participation in public e-procurement system. This implies that for vendors to participate in public e-procurement system, vendors’ employees must be trained, vendors’ top management must be supportive but also allow change for better, but also, human resources involved in vendors’ procurement process must skilful, hence guidelines and procedures observed perfectly for better participation in the system. The training practice to vendors for participation in the system was supported by key informants interviewed and this statement quoted:

*We as a mandated government agency for the system, our priority for attracting vendors to participate in the system is training, although it is heavy duty, but we must do it (PPRA, TANEPS personnel, 8<sup>th</sup> May, 2019)*

This view is also confirmed by another Key Informant interviewed from another institution:

*Yes, Being Knowledgeable of Public e-procurement System as Vendor, Will Motivate to Participate and Use It (MSD, TANEPS Personnel 7th May, 2019)*

The main argument for this key informant was how training can influence vendors' participation in the system. The study conducted by Bahaddad *et al.* (2018), Muganda *et al.* (2018) and Thiga and Makau (2016) concurred with the current study by proving that organisational readiness (willing to change), training for employees (IT knowledge and skills) and top management support were significant and supportive for adoption and implementation in e-procurement system which was also decision on acceptance to existing technology, the only different was focus of the study.

Furthermore, the top management support was the second organisational aspect with great influence for vendors' participation in the system, the key informant supported by this argument:

*Vendors' top management must be supportive and willing to register; we have no other mechanism than letting them know the importance of being the part of the system, because no way they can do business with government anymore (MSD, TANEPS personnel 7<sup>th</sup> May, 2019)*

*The integration between public e-procurement system and vendors' systems, depend much managerial commitment from respective vendor organisation. Third party software integration is the biggest issue; management willing must be guaranteed (GPSA, TANEPS personnel 7th May, 2019)*

The current study concurred with study done by Suliantoro and Ririh (2019) argued that, supportive leader (top management support), knowledge sharing (training) and change management (will to change) were influenced vendors' usage of an e-procurement system.

Alternative hypothesis two (H<sub>2</sub>), for the organisational aspects influence of governmental aspects on driving vendors to participate in public e-procurement system also supported and proved that organisational aspects can be influenced governmental aspects of vendors' participation in the system. This implies that for every unit increase in organisational aspects, its effects would contribute a unit increase in governmental aspects of supporting the vendors' participation. And more importantly the effects of organisational factors on governmental factors is significant ( $p < 0.001$ ). Thus, hypothesis stated that, organisational factor has positive significance of governmental factor was supported.

Alternative hypothesis three (H<sub>3</sub>) was also supported once results found a positive influence on governmental aspects (mainly bureaucratic control, bylaws for the system, reliable procurement procedures, administrative practice and access of information for policy making) for vendors' participation in public e-procurement system. This implies that, for the organisation to be attracted on acceptance of new technology, the government has its duties to fulfill, due to the fact that, the government is the one responsible to put regulation and policies in place which guide public procurement operations. Furthermore, once the bureaucracy was controlled and procurement procedures are reliable, vendors will be attracted to do business with government due assurance of not tie-up the capital and increase competitiveness base. But also, by government giving vendor's full

information on how they can participate in the procurement policy making, this act will make vendors more willing to do business with government and being one of its agenda.

Lastly, alternative hypothesis four ( $H_4$ ) was also supported due to the study results found a positive influence on organisational factors mediated by governmental aspects for vendors' participation in public e-procurement system. This implies that, once the government set by laws for the system, easy administrative practice, put reliable procurement procedures in place and provides equal access for both small and medium sized enterprises and big companies and then organisational factors can influence vendors' participation in public e-procurement system. According Key Informant's interviewed; he supported the intervention of government by saying:

*I think when government initiatives on implementing public e-procurement system by vendors were well supported; participation rate must improve due to the fact that, vendors have nothing to do with establishing laws and regulation on behalf of government agencies (MSD, TANEPS personnel 7th May, 2019)*

This argument from key informant implies that, there were strong influence between mediated organisational factors and vendors' participation in public e-procurement system. The results proved wrong, Baron and Kenny tests, which claim that there is no direct effect but mediation is strongest when there is an indirect effect in the equation, where the truth is, the strength of mediation should be measured by the magnitude of the indirect effect and not by the lack of the direct effect (Zhao *et al.* 2010). The study results imply that, organisational factors have a strong influence for vendors' participation in public e-procurement system once mediated by governmental factors than direct effects.

#### **4.1 Theoretical Implications of the Study Findings**

The Diffusion of Innovation theory (DOI) assumed by having the relative advantages (benefits/requirements) in place, acceptance of given innovation been maximised. The current study supported the theory by having training, top management support, skilled human resources and willing to change been significant and influencing vendors' participation (diffuse) in the new innovation (public e-procurement system). Therefore, this theory was clearly supported by the study findings and when organisational aspects aforementioned mediated by governmental measurements which are bureaucratic control, system bylaws, procurement procedures, government leadership, policies for partnership, contract management and information for policy making have a strong contribution to vendors' participation in public e-procurement system.

### **5 Conclusion and Recommendations**

The study found significant and direct influence for the organisational indicators which are training, top management support, willing to change and skilled human resources on vendors' participation in public e-procurement system. In addition, the direct influence was found statistically significant cause the p-value < 0.05 which implied the influence exists in actual life of vendors' participation. For organisational aspects having statistically significant for the direct influence on vendors' participation in the system

suggest the existence of partial mediation. The study results also found an indirect linkage between organisational factors and governmental aspects for vendors' participation in public e-procurement system. Therefore, for organisational factors and governmental factors having direct and indirect influence toward vendors' participation in public e-procurement system, it is concluded that, internal organisations characteristics and governments intervention are very vital for vendors to participate in the system, hence cooperation between these key partners is highly encouraged for the public e-procurement system successful implementation. The study recommends that Public Procurement Regulatory Authority should continue to train vendors on how to participate and practical benefits for the system usage. The study also recommends vendors' top management procure infrastructure required for participation in the system but also should employ skilled human resources who can meet public procurement procedures requirement for participation in public e-procurement system. Lastly, since there is indirect influence for organisational factors via governmental aspects aforementioned, the study then recommend PPRA should update system bylaws and reduce unnecessary bureaucratic control for easy vendors' participation in public e-procurement system.

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# Covid-19 Consequences, Lessons and Opportunities for Addressing SDG 11: Evidence from Yilo Krobo Municipality of Ghana

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**Abstract. Purpose:** This paper explores the consequences of the Covid-19 pandemic as far as some aspects of SDG 11 are concerned. From the experience of the pandemic, the paper further explored lessons and opportunities for addressing some aspects of SDG11.

**Design/Methodology/Approach:** The study adopted a qualitative approach, interviewing 12 participants consisting of 7 Assembly Members and 5 local governance officials. Random and purposive sampling techniques were used and Qualitative Content Analysis was used for the data analysis.

**Findings:** The paper identified loss of income to the Municipal Assembly and high cost of goods as general consequences of the pandemic. In the area of transportation, less movement and fewer vehicles were experienced. This provided lessons for managing vehicular traffic and opportunities for developing other means of transportation. Positive consequences on waste management and sanitation were observed and this presented opportunities for waste management.

**Research Limitation/Implications:** The study adopted a qualitative approach. Hence some of the findings are contextual and cannot be extended to a larger population.

**Practical Implication:** The study provides practical evidence for management of waste and provision of mass public transport as elements of SDG11.

**Social Implication:** This study presents evidence for transformative policies that seek to address transportation and waste management problems.

**Originality/Value:** This study contributes to the literature on the consequences of Covid-19 in rural settlements.

**Keywords:** Covid-19 · SDG 11 · Human settlement · Transportation · Waste management and sanitation

## 1 Introduction

Making cities and human settlements inclusive, safe, resilient and sustainable is projected in the Sustainable Development Goal 11 (SDG11). The targets of SDG 11 include

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ensuring access to adequate, safe and affordable housing and transportation and basic services. While the inclusion of SDG 11 in the SDGs represent a global policy shift from the Millennium Development Goals (MDGs) by focusing on cities and human settlements in all economies, it also represents an opportunity to address issues of other human settlements such as slums and rural areas (Croese et al. 2021, Fukuda-Parr 2016). The SDG 11 also makes provision for addressing several other basic services and safety concerns of human settlements such as waste management and sanitation, flooding and pollution of all kinds (Croese et al. 2021). The need to increase access to basic services to make human settlement safer, more resilient and inclusive is eminent as a result of communities transforming into urban forms.

The experience of the Covid-19 pandemic revealed the realities of the need to address concerns of cities and human settlements such as sanitation and congestion at food markets (Asiamah and Steel 2020). This saw local authorities taking drastic measures to sanitise market places and decongest the food markets through the establishment of satellite and neighbourhood markets to reduce overcrowding at the main markets (Asante and Mills 2020). Following the experience of Covid-19, studies justify rethinking the development and planning of cities and human settlements (Bereitschaft and Scheller 2020).

There is a consensus that the onset of the Covid-19 pandemic presents a setback to the achievement of the SDGs. The United Nations (2020) reports that before the pandemic, the world was not on track in achieving many of the SDGs. Several authors hold the view that the pandemic is a setback in the attainment of SDG 11 in particular and highlight the negative consequences of the pandemic.

Nerini et al. (2020), indicates that the pandemic has particularly had a severe impact on vulnerable populations mostly found in poor and densely populated urban areas. With Covid-19 being a contagious disease, movement especially within urban areas poses an issue of public health concern. Public transportation especially becomes challenging as it is economically efficient and effective when the means of transport can transport commuters in large numbers at short distances. This becomes impossible with the onset of Covid-19 (Bereitschaft and Scheller 2020).

Though a public health crisis, the pandemic has a potential effect on food security and could turn into a food crisis. This can be averted if the State intervenes to protect the most vulnerable, and mitigate the impact on agriculture and food systems (FAO 2020). Covid-19 has challenged an already structurally weak agrifood system, particularly in Africa. The closures of markets coupled with limited points of sale for foods results in loss of income opportunities for stakeholders in the agricultural supply chain while this has a resultant effect on food prices (Durizzo et al 2021).

Likewise, the volume and composition of waste generated during this pandemic have significantly changed. The sudden increase in the wearing of facemasks coupled with improper disposal practices has created a new environmental challenge for waste managers particularly in developing countries (Peng et al. 2020, W.H.O 2020). According to a WWF report, “if just 1% of the masks were disposed of incorrectly and dispersed in nature, this would result in as many as 10 million masks per month polluting the environment” (Italy WWF 2020). Fragmentation of the macro plastic in the mask could occur due to various abiotic and alter the mobility and bioavailability of pollutants that

are adsorbed on them. The occurrence of such bioaccumulation of microplastic in a major food web exposes humans to great health risks (Saadat et al. 2020).

Other studies on Covid-19 and the environment shows great gains in environmental indicators. For instance, there has been a drop in carbon dioxide (CO<sub>2</sub>) emissions and traffic congestion (Aletta and Osborn 2020). Also, in Europe, nitrogen dioxide (NO<sub>2</sub>) emissions significantly dropped over France, Italy, Spain and UK, during the lockdown periods compared to the same period in 2019 (Solberg et al. 2021). The International Labour Organisation (2020) reports that tens of millions of workers are forgoing transportation altogether and working from home relying on telecommunication, particularly broadband and cellular services. This serves as an opportunity to reduce vehicular and human congestion in central locations of human settlements where a conglomerate of economic activities occurs. It is of little wonder that environmental quality assessment has received more attention in research following the onset of the Covid-19 pandemic (Sharifi and Khavarian-GarmsirHamidi 2020).

While the literature presents a divided opinion on the consequences of the Covid-19 pandemic on the progress of SDG 11, it has exposed more than ever the importance of the resilient dimension of cities and human settlements. It, therefore, presents lessons and opportunities for proper planning of human settlements to propel the success of SDG 11. So far, studies on SDG 11 and Covid-19 pandemic have focussed mainly on cities and urban settlements (Croese et al. 2021, Koch and Krellenberg 2018) while neglecting rural settlements. This paper focuses on rural settlements and comprehensively addresses some of the less researched targets of SDG 11. It further offers solutions for implementing in the areas of transportation, waste management and sanitation and public spaces.

## 2 Underpinning Theories – Vulnerability and Resilience Theories

The pandemic brings to reality the inequalities and related socioeconomic deprivation in developing countries -such as Ghana (Tavares and Betti 2021). It has exposed historical gaps in communities and a major lesson is an importance of prioritizing the most vulnerable groups and harmonizing national efforts. It also presents a good opportunity to reflect on the effectiveness of policies on basic services such as health, transportation etc.

The vulnerability theory holds that all individuals are exposed and susceptible to dependency as a result of their embodiment (Rodgers 2021). The proponent of the theory (Albertson Fineman 2008) argues that the acknowledgement of this condition as a necessary and integral element of the human condition implies an expanded role for the State. Herring (2016) contributes to the theory by suggesting a shift in institutional arrangements which foster exclusion and disadvantage to arrangements that make provision for state responsibility and provisions for all to reduce the vulnerability shocks. Governments, therefore, have an important role to play in reducing the vulnerability of its citizens to the Covid-19 pandemic. There is a need for strategic and concerted coordination of policy responses to tackle the pandemic and its aftermath.

Resilience theory is becoming increasingly popular in interdisciplinary research (Van Breda 2018) with its interest in how adversities such as Covid-19 impact people. Masten (2015) describes resilience as the latent or demonstrated capacity of a dynamic system to

adapt successfully to disturbances that endanger its function, survival, or development. Resilience theory for this study is how well cities adjust to significant adversities. The resilience theory also offers some insights on the response of communities to changes relating to bottlenecks in public services and also follows the Covid-19 experience. The resilience theory is cross-cutting and emphasizes concepts frequently used in the evaluation of the SDGs. Although it originated from the disciplines of biology and ecology it is applied to other disciplines (Liang and Li 2020). In ecology and biology, its application relates to the extent to which renewable resources can be used or polluted with the ecosystem structure and function remaining intact (Alberti 1996). In developing the concept of resilience, Holling (1973) attempted to merge ecology and systems theory within socio-ecological systems and in later works related the behaviour of ecological systems to socio-natural systems such as human settlements (Holling et al. 2001). Resilience theory has been used in studies relating to human settlements as it explores ways to respond better to changes in human settlements following increasing population size and pandemics (Harrison et al. 2001). Human settlements are categorized as being resilient when they can absorb, recover and prepare for future shocks (economic, environmental, social & institutional) as well as promote sustainable development, well-being and inclusive growth.

### 3 Methodology

A qualitative approach was employed in the study. The narrative design was used in the qualitative aspect of the study. The Yilo Krobo Municipality in the Eastern Region of Ghana was purposively selected for the study due to fact that no such study has been done in this area since the onset of the pandemic. The municipality which has an area of about 805 square kilometres, (4.2% of the total land area of the Eastern Region) is situated approximately between latitude 6°.00'N and 0°.30'N and between longitude 0°.30'W and 1°.00'W. Narratives of Assembly Members, as well as the Local Governance Officials located in the Municipal Assembly (MA) and the Regional office, were obtained through in-depth interviews, each taking an average of 30 min. 63 Assembly Members are consisting of 60 males and 3 females. Seven Assembly Members were randomly selected from the list. The communities were demarcated into large, medium and small communities. Two Assembly Members were randomly selected from each community and a female was randomly selected out of the three females. Three Officials were purposively selected from the MA, namely the Municipal Director, the Development Planner and the Physical Planner. Two Officials were also purposively selected from the Regional Office, namely the Director of Community Development and Community Development Officer.

Data were collected utilizing face-to-face interview sessions. The researchers ensured the participants were willing to participate in the research. Participants who were not willing to participate were exempted from the research.

Data were analysed using qualitative content analysis (QCA). The type of QCA adopted is what is known as the Conventional QCA (Hsieh and Shannon 2005). With this type of QCA, the study starts with an observation and the codes are defined during data analysis. Although the theoretical framework helped in explaining the phenomena under

study, the codes were not necessarily derived from the theories. The analysis was more data-driven than concept-driven. The analysis began with the selection of the text material and building the coding frame. This was done for each research question and first for the Assembly Members followed by the Local Governance Officials. After each group, there was re-coding to ensure the subcategories are mutually exclusive and the main categories are unidimensional. This was done again to ensure the appropriate categories and sub-categories are used and also to enhance consistency. The segmentation into coding units was then carried out. The main analysis followed which led to the results.

## 4 Findings and Discussion

### Consequences, Lessons and Opportunities from the Experience of Covid-19

This section presents findings on the consequences of Covid-19 as far as implementing SDG 11 is concerned. Lessons and opportunities for addressing problems concerning transportation, waste management and sanitation and air pollution were drawn from the consequences.

#### 4.1 Consequences of Covid-19

Ghana experienced a partial lockdown of the Greater Accra and parts of the Ashanti Regions and their environs for a period of one month spanning from March ending to April ending 2020. Although there was no lockdown in the Yilo Krobo Municipality, certain measures were taken to prevent the spread of the Covid-19 virus. This includes closure of some markets, running shifts at some markets and office places. Also, the number of passengers in commercial vehicles was reduced to allow social distancing. Schools were closed before the lockdown period and several months thereafter. Also, although there was no lockdown in the study area, it received a spillover of the lockdown effect as traders in the study area could not move to Accra and Kumasi for trading activities. Similarly, traders from Accra and Kumasi could not also move to the study area. These had consequences on the communities. Some measures were taken by the government of Ghana to encourage hand washing. One of such measures was to provide access to water and electricity at no cost for a period of three months to reduce the negative financial consequences on Ghanaians.

Participants narrated the financial consequences and those related to aspects of SDG 11 understudy. These are further classified as negative, positive and bifurcated consequences. Bifurcated consequences have both negative and positive sides. Table 1 presents the categories and subcategories derived from the data.

The negative financial consequences are the loss of revenue to the MA and the high cost of commodities. During the period of closure of markets and lockdown, there were fewer movements of vehicles and these road tolls and revenues from trading activities were lost. This implies a loss of funds for development activities including the implementation of SDG 11. Another negative consequence to community members is the high cost of goods, especially imported goods. Prices went up drastically during the lockdown period. Taking insights from the resilience theory, this shows a lack of resilience

**Table 1.** Consequences of Covid-19 pandemic on the Yilo Krobo Municipality

Main Categories	Subcategories	Elaborations/Exemplars
Financial consequences (negative)	Loss of revenue to the MA	<i>For me it affected everything. Even revenue for the Assemblies. They couldn't collect what they expected according to their projections. Markets were closed. How do you take tolls? It affected every aspect of our lives...</i> -Regional Official 1
	High cost of commodities	<i>The financial implication is a bother to me..... And people were also increasing their prices astronomically. And so the same thing you used to buy before, now you cannot buy. So you can't buy because the money is not enough. Prices of things were up. Everything went up....</i> -Regional Official 2
Transportation (positive)	Less traffic, fewer vehicles	<i>But during the lockdown....cars stopped going and cars stopped coming on the highway to Accra....so the place became vacant and there was less traffic.</i> -Regional Official 2
Transportation (bifurcated)	Reduction in the number of passengers	<i>Well, it is comfortable but only that the drivers complain.</i> -Municipal Official 1  <i>The passengers...I will say they were happy but the drivers were losing because they were using the passengers for their budget. So the car owners and the drivers were not so happy but the passengers were happy because it means more space and comfort.</i> -Regional Official 1
Waste management and sanitation (negative)	Littering of nose masks	<i>the nose masks that we use....you know there is now a campaign that we should stop using the disposable one because it has littered all over the place. When you go to the beaches they are there and it is all over the place.</i> -Municipal Official 3  <i>It was that bad. It was that bad because the service providers, some of them had to lay the workers off so they couldn't come as frequently as they should.</i> -Regional Official 1
Waste management and sanitation (positive)	Improvement in cleanliness	<i>is that what I have gathered about Covid-19 is that personal hygiene has improved a bit</i> -Municipal Official 3  <i>...when you go to some communities there were very clean areas and the water was flowing. The air was cleaner.</i> -Regional Official 1  <i>I think when it comes to waste management at the lorry station it rather reduced because people were not there in numbers.</i> -Regional Official 2  <i>Yes, those times were a bit better than now. Because people were afraid to come out so all the littering was done in the homes. So during that time, it was a bit better.</i> -Assembly Member 4  <i>I mean on the environment, the refuse and everything... that has also come down because people did not go round to be dumping whatever they were carrying around the place</i> -Assembly Member 5
Air pollution	Reduction in vehicular pollutants	<i>.....transport was not running that much so air pollution has come down.</i> -Assembly member 2  <i>The pollution was less in town. There was less population in town.</i> -Regional Official 1

in the system. Price volatility is a strong precursor of financial shocks which require regulation. Since price regulation is not feasible in informal markets, the consequence is a financial burden to consumers.

The consequence on transportation was positive as there was less traffic and less vehicular movement. This reduced the traffic situation in some communities that experience vehicular traffic. The reduction in cars on the road also meant a reduction in vehicular emissions in the atmosphere. The number of passengers in commercial vehicles was also reduced and this had a positive consequence but it was a disadvantage in disguise to the drivers who lost income.

The finding indicates visible positive consequences of Covid-19 on the waste management and sanitation aspect of SDG 11. While there was an improvement in personal hygiene and cleanliness of the environment, the concern of littering the environment with nose masks was also narrated. The improvement in air pollution from vehicular emission also reduced. Overall, the outcomes on the environment were positive.

From the findings, the negative consequences considering the aspects of SDG 11 under study are minimal. The support by the State helped to reduce the negative consequences. Access to free water encouraged hand washing with soap and also reduced the financial burden on community members. This study gives credence to the vulnerability theory. Notwithstanding, the gravity of the pandemic was not so significant to create serious negative consequences.

## 4.2 Lessons and Opportunities

### 4.2.1 Transportation

The commercial road transport system in Ghana is primarily operated by private individuals. The common vehicles used for short journeys are *taxis* and minibuses or shuttles known as *trotros* while buses are used for long-distance journeys. The government provides mass transportation for short distances which is insufficient and does not cover every jurisdiction. Consequently, there is a gap in the provision of mass transportation for short distances. Drawing from the consequences of Covid-19 to transportation, codes derived as lessons for addressing transportation problems include the use of mass public transport, the development of alternative transport systems, the pooling of vehicles and the broadening of roads. Some of the quotes from participants giving credence to these findings are as follows:

*The mass public transport system should also be encouraged. Here is the case we don't have mass public transport and there is always private transport. If there were mass public transport which is comfortable, convenient and affordable, people will be willing to join rather than driving all by themselves to a place*

-Regional Official 2

*...For me, if you look at what happened in Covid, we had fewer cars in town. It means that the cars are parked. If we have a reliable mass public transport system it means that most of us will park our cars and we will get that same experience. There will be less traffic and the carbon emission will reduce...*

-Regional Official 1



This finding suggests that when public transport is comfortable, safe and reliable, it will attract patronage and this will help reduce vehicular traffic on the roads. Many of the existing public commercial vehicles operated by private individuals are in a deplorable state and not comfortable and convenient to passengers. This presents an opportunity to improve upon the state of the existing public commercial vehicles and also take measures to reduce congestion in these vehicles.

Another finding as an opportunity is the development of alternative transport systems such as rail transport for addressing transportation problems. The quotes of one participant below give credence to this finding.

*Look at our train system. Nigeria has worked on their rail line. Look at Nigeria our neighbour...we always compare ourselves to them. India, their train system is working. You go to South Africa and it is working. Why is ours not working? There used to be a train system from Tema to Accra but it is not working anymore.*

- Regional Official 1

Participants also revealed other environmental benefits that will be derived from the use of public transport including the willingness to patronize public mass transport.

*So if the public mass transport was working, there will be less traffic, there will be less pollution, let's talk about climate change.*

*If we have a reliable public transport system it means that most of us will park our cars and we will get that same experience. There will be less traffic and the carbon emission will reduce*

-Regional Official 1(female)

#### **4.2.2 Waste Management and Sanitation**

From the experience of an improvement in cleanliness as a result of the pandemic, a participant elicited lessons of continuous cleanliness. The quotes which support this finding are as follows:

*So we shouldn't take it that as a result of the outbreak before we will keep our environment clean. We should always keep our environment clean..... which means we are capable of keeping our environment clean all the time.*

-Assembly Member 4 (female)

Another participant saw the opportunity to introduce an attractive waste recycling system to maintain the cleanliness of the environment.

*So waste management, we should do more recycling. Whether it is liquid waste, solid waste, whatever, we should do more recycling. And it should be attractive. In Holland, when you use cans, they have a vending machine, you put it in and you are given money. For me, it is attractive because if I know I will get money from it, I will not put it in the Zoomlion bin.*

*-Regional Official 1*

To boost recycling, waste segregation at the source should be mandatory with stiffer punishment for offenders since the usage of landfills and waste dumps sites promote material and energy loss. The government could equally develop innovative packages and incentives such as tax reliefs for waste management stakeholders. This will encourage private investments in recycling techniques. There is equally the need for clear guidelines on the bearer of the cost of waste recycling. This calls for a discussion and implementation of the Extended Producer Responsibility policy in Ghana.

## **5 Conclusion and Policy Implications**

The Covid-19 pandemic and the ensuing lockdown in the Greater Accra Region and parts of the Ashanti Region has both negative and positive consequences on human settlements. This paper explored these consequences as in-depth interviews were carried on Assembly Members and local government officials in the Yilo Krobo MA. The paper further derived the lessons and opportunities for addressing some aspects of SDG 11 namely waste management and sanitation, transportation and air pollution. The Covid-19 pandemic had a negative consequence on the financial inflows due to a slowdown in activities from which the Assembly derive revenues such as tolls, fees, property rates and tax revenues. There was less movement and less traffic in the study area during the lockdown period although there was no lockdown in the study area. This has a consequence on the reduction of emissions in the environment. The lessons drawn from this experience include the use of public mass transport and the pooling of vehicles to reduce road traffic. The paper presents opportunities for upgrading the state of existing public commercial vehicles and the development of alternative means of transportation such as the rail system.

The consequence of the pandemic for waste management and sanitation was predominantly positive although there was a concern about littering the environment with nose masks. The positive consequences were the improvement in the cleanliness of the environment. This presents a lesson of the possibility of keeping the environment clean. Participants derived opportunities for waste management through waste recycling and implementing attractive measures to encourage consumers to participate in this.

The real experience of less vehicular traffic and congestion in the capital town of the Municipality presents the need to manage vehicular traffic and provide public transport which is convenient, affordable, reliable and safe. Aggressive policies on public mass transport are needed to fill the gap in demand by short-distance commuters. The existing government services are not adequate to cover all communities. Policies to encourage private stakeholder participation in this market is needed. Also, policies are required to upgrade the state of public transportation provided by private individuals. The condition of some *taxis* and shuttles are so deplorable and this makes the use of public transport unattractive. Authority is needed to monitor the activities in this space to achieve

the target of providing safe, affordable, reliable and convenient mass transportation. Aggressive policies are also needed to support the adoption and enforcement of waste segregation. The enforcement of sanctions for inappropriate waste disposal is needed.

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# Challenges Saddling the Adoption of Blended Learning in Technical Universities

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**Abstract. Purpose:** This study ascertains if the challenges found to be saddling the adoption of blended learning in institutions of higher learning in other countries are relevant challenges saddling the adoption of blended learning (BL) by Technical Universities (TUs) in Ghana using Takoradi Technical University (TTU) as a case study and determine the relative influence of each of the challenges.

**Design/Methodology/Approach:** The Delphi technique was employed with a sample size of 15 heads of departments. Questionnaire aided in data collection. Analysis was done using descriptive statistics; outcome presented in tables.

**Findings:** Consensus was reached on fourteen challenges. High cost of data bundles in Ghana, the existence of inadequate legal provisions promoting blended learning as a means of course delivery and examination, and no direct financial support for lecturers for using their data for online delivery of courses were unique to this study.

**Research Limitation/Implications:** The study was limited to TUs focusing on the experience from TTU.

**Practical Implication:** The study identifies the challenges saddling the adoption of BL in TTU which when addressed will enhance the delivery of quality education in TTU thereby addressing sustainable development goal four which focuses on quality education.

**Social Implication:** The findings will help in policy formulation geared towards the implementation of BL in institution of higher education in Ghana.

**Originality/Value:** It applies the saturation theory and the Delphi technique in determining the challenges saddling the adoption of blended learning by TUs while also serving as the reference literature for future studies.

**Keywords:** Blended learning · Education · Higher learning

## 1 Introduction

Learning in institutions of higher learning involves the process of acquiring new intellectual abilities, skills, and knowledge, which can be used to solve problems successfully (Anthony et al. 2020). In the past, the teaching paradigm was face-to-face (traditional

model), however in the recent past Blended learning (BL) is gaining much recognition and acceptance in institutions of higher learning. Thus, researchers such as Ross and Gage (2006); Norberg et al. (2011), and Graham et al. (2013) have predicted that pretty soon blended learning will become the “new traditional model” or the “new normal”, in the delivery of courses in institutions of higher learning. But that notwithstanding, it appears the presence of the COVID-19 pandemic has hastened BL adoption in institutions of higher learning across the globe and Ghana is no exception to this. In Ghana, both Technical and Traditional Universities have adopted blended learning in the delivery of courses in the era of the COVID-19 pandemic. However, whereas studies abound with regards to the framework for the adoption of blended learning in institutions of higher learning with a classic example being the study by Graham et al. (2013), little is known of studies that bring to the fore the challenges that Technical Universities face following the adoption of BL in delivery of courses. More so, whereas many studies have investigated BL at the individual course level, for example, Halverson et al. (2012), little is known of studies that studied BL at the institutional level (see Graham et al. 2013). Hence, the relevance of this current study is also embodied in conducting the BL study at the institutional level.

Furthermore, it is evidenced in previous studies that BL has been studied either from the educational perspective, pragmatic perspective, holistic perspective, corporate training, or chief learning officer perspective (Kaur 2013). In consonance, knowing the perspective also helps to make a more meaningful meaning out of the findings of previous studies. Given this, the current study followed the educational perspective of BL. According to the educational perspective of BL, BL means replacing a portion of the traditional face-to-face time with online activity. Its primary focus is to integrate two separate teaching paradigms, the synchronous (classroom), and the asynchronous (online) (Kaur 2013). In agreement, Graham et al. (2013) argued that BL is a mixture of online and traditional face-to-face delivery where the online portion effectively replaces some of the face-to-face (in-person) contact time instead of complementing it. Subramaniam and Muniandy (2019) further informed that BL adopts a combination of online-mediated and face-to-face instruction to help lecturers to achieve pedagogical goals in training learners (Subramaniam and Muniandy 2019). Studies on BL in the past have shown that the BL approach enhances students’ learning (Edward et al. 2018; Ghazal et al. 2018), and offers opportunities for professional collaboration, in addition to improving the time adeptness of lecturers (Guillén-Gámez et al. 2020; Owston et al. 2019). However, it is the percentage of the blend between the online and classroom sessions that have varied across institutions, programmes, cultural and national settings (Anthony et al. 2020).

Takoradi Technical University, like other Technical Universities, has been legally created by the Technical Universities Acts 2016 (Act 922) as amended to provide hands-on technology-based training to learners and churn out graduates that meet the expectations of the industry (Dwomoh and Luguterah 2020). Until the COVID-19 pandemic, BL seems to be an unpopular vocabulary among lecturers or facilitators and learners or students in Technical Universities. But with the new era of living with the COVID-19 pandemic, BL has been the popular teaching and learning approach adopted by Technical and Traditional Universities in Ghana. In The first semester of the 2020/2021 academic year, the BL approach adopted by TTU was 34%–66% (one week face-to-face (34%)

and two weeks online (66%) for every three weeks). This was the BL approach the entire university followed for the semester even to the extent that there was also, the option of administering mid-semester examinations online. The online lectures were done via google classroom (a cloud-based learning management system). However, in the second semester of the 2020/2021 academic year all lectures have been largely face-to-face and the google classroom appears to have been reduced to the posting of learning materials and course contents for learners/students). This current situation regarding blended learning appears not different from all the Technical Universities in Ghana. Thus, threatening the survival and growth of BL as a means of delivering courses in Technical Universities in Ghana. It is against this backdrop that this current study seeks to find answers to the following research questions:

1. What are the challenges saddling the adoption of blended learning by Technical Universities in the delivery of courses in Ghana?
2. What is the relative influence of each of the challenges saddling the adoption of blended learning in the delivery of courses in Ghana?

This current study addresses the two research questions as it seeks to ascertain if the challenges found to be saddling the adoption of blended learning in institutions of higher learning in other countries are relevant challenges saddling the adoption of blended learning by Technical Universities (TUs) in Ghana using Takoradi Technical University (TTU) as a case study and determine the relative influence of each of the challenges.

Though the current study used Takoradi Technical University as a case study it does not seek to generalise its findings to represent what is prevailing in all the Technical Universities in Ghana. However, with the great resemblances of Takoradi Technical University with all Technical Universities in Ghana, this case study will offer some valuable findings that will be of enormous help to Technical Universities in Ghana.

In achieving the aim of the current study, the following objectives guided the current study: to identify the challenges saddling the adoption of blended learning in the delivery of courses in Takoradi Technical University; to determine the relative influence of each of the identified challenges saddling the adoption of blended learning in Takoradi Technical University.

## 2 Theoretical Basis of the Study

This study was underpinned by Giddens' structuration theory. The theory argued that human actions are influenced by social structures and agency (self-centred factors) (Giddens 1984). According to Dube and Scott (2018), human beings create the structures which in turn, constrain or enable them. The structures are not limited to social structures but include, economic and cultural structures. Oppong (2014) affirmed that structures encapsulate external forces such as resources, rules, and social systems/macro and agency include capability to make a difference/ micro. Thus, extrinsic and intrinsic challenges (Lameras et al. 2012). By applying the saturation theory to the study of challenges saddling the adoption of blended learning in Technical Universities, there exist an array of challenges relating agency (intrinsic) and structures (extrinsic).

## 2.1 Challenges Saddling the Adoption of Blended Learning: A Review of Existing Literature

According to Kaur (2013), the challenges saddling the adoption of blended learning are embodied in technical challenges, organizational challenges, and instructional design challenges. Technical challenges include ensuring learners and lecturers can successfully use the technology whereas organizational challenges include overcoming the idea that blended learning is not as effective as traditional classroom training. Instructional design challenges include ensuring participant commitment and follow-through with “non-live” elements, and the challenge of how to teach. Political instability, lack of funding, intermittent power supply, unreliable internet service, remote access challenges, lack of basic training in the use of technology, lack of policy on blended learning, and internet connectivity challenges according to Hossain (2013) are the challenges that have characterized the adoption of blended learning in Bangladesh.

Lameras et al. (2012) argued that acceptance of the system, motivation, skill level, and time management, are key intrinsic challenges to the adoption of blended learning (Lameras et al. 2012). On the contrary, Bakir et al. (2016) asserted that teachers’ beliefs and initial reluctance with online learning, technology skills, and access to technology explain the challenges to the adoption of blended learning. Piper (2010) opined that insufficient funding had been a major challenge to the adoption of blended learning. This view was affirmed in a related study in Bangladesh when Hossain (2013) argued that among others, funding challenges pose an enormous threat to the adoption of blended learning and institutions that do not see blended learning as an investment but a cost element risk not venturing into blended learning at all and the benefits associated thereof eludes them. Thomas and Stratton (2006) found a lack of knowledge and ability to integrate the technologies into teaching practices on behalf of teachers to be a major challenge to the adoption of blended (Thomas and Stratton 2006). In a related study, non-confidence in the technology being used and unwillingness to use the technology by lecturers were identified to have saddled the adoption of blended learning (Anderson 2008).

Hence, with regards to the challenges saddling the adoption of blended learning, several views have been advanced in previous studies. The lack of consensus in the views of authors could be attributed to the underpinning theoretical perspective of previous studies amidst social-cultural settings. Thus, a synthesis of the various views will present a more comprehensive framework to guide the current study.

## 3 Methodology

This study employed a two-stage approach to research. Firstly, literature was reviewed which aided in identifying the challenges saddling the adoption of BL in institutions of higher learning in some national and cultural contexts as well as the operational definition of BL to place the study in the perspective. The second stage was validating the challenges saddling the adoption of BL in TUs in Ghana using Takoradi Technical University as a case study. The Delphi method was employed at this stage. The Delphi method (a qualitative instrument) was used to solicit the views of Heads of Departments in Takoradi Technical University as to the extent that the identified challenges to the



adoption of BL in institutions of higher learning are saddling the adoption of blended learning in Takoradi Technical University. In all, 15 out of the 23 Departments' Heads completed a three-round Delphi process. This sample size of 15 informed Heads of Departments was consistent with similar Delphi studies (Ameyaw et al. 2016; Somiah 2018). Hence the sample size was deemed adequate. According to McKenna (1994), the Delphi respondents are supposed to be informed individuals concerning the issue being investigated. They are called expert panellists or experts. Hence, the use of Heads of Departments as respondents in this current study. The Heads of Departments in TTU are informed with regards to BL adoption in their departments because they have experienced BL and directly supervised the implementation of BL in their departments. They have been the first point of contact if lecturers and students had any challenge with the BL approach adopted by the institution.

Further, the Delphi method was employed following the principle that forecasts from a structured group of persons are more accurate than forecasts from unstructured groups (Rowe and Wright 2001; Ameyaw et al. 2016). Additionally, it is suitable for studies that aim to solicit views from a group of respondents in an attempt to build consensus in the respondents' views and to predict the likelihood of a future event (Lang 1995). According to Miller (1993) and Hanson et al. (2005), the Delphi method is a qualitative methodology and seeks to establish consensus in research respondents' views through rounds of survey (Miller 1993; Hasson et al. 2000). It uses structured questionnaires in collecting data from respondents (Aigbavboa 2014; Ameyaw et al. 2016).

Concerning this study, the common criteria for selecting the respondents was that respondents should have had experienced BL and are involved in the delivery and supervision of the BL model adopted by Takoradi Technical University at the departmental level. The Google Classroom is a cloud-based learning management system that TTU has employed under its BL model. Again, the respondents were carefully selected to represent a broad spectrum of opinions on the issue being examined (see Loo 2002; Aigbavboa 2014; Tilakasiri 2015). Subsequently, after each round of the Delphi survey, a statistical estimate of the respondents' views was computed and analyzed using the interquartile deviation, median, standard deviation, and mean. The adopted scale for measuring consensus was:

1. Strong consensus - median 9–10, mean 8–10, interquartile deviation (IQD)  $\leq 1$  and  $\geq 80\%$  (8–10);
2. Good consensus - median 7–8.99, mean 6–7.99,  $1.1 \leq \text{IQD} \leq 2$  and  $\geq 60\% \leq 79\%$  (6–7.99); and
3. Weak consensus - median  $\leq 6.99$ , mean  $\leq 5.99$ , and  $\text{IQD} \geq 2.1 \leq 3$  and  $\leq 59\%$  (5.99).

The scale was based on a 10-point level of agreement scale where 1 and 2 represent no level of agreement; 3 and 4 represent a low level of agreement; 5 and 6 represent a medium level of agreement; 7 and 8 represent a high level of agreement; 9 and 10 represent a very high level of agreement (Aigbavboa 2014). Ethically, the identity of the respondents was kept confidential in this study.

## 4 Findings and Discussion

### 4.1 Respondents’ Demographics

To situate the findings of the study, the demographics characteristics of the panel of experts were solicited (Table 1).

**Table 1.** Respondents’ demographic characteristics

Respondents’ demographics characteristics	Frequency (n = 15)	Percentage (%)
<i>Gender</i>		
Male	13	86.7
Female	2	13.3
<i>Level of education</i>		
Master’s Degree	13	86.7
Doctorate Degree	2	13.3
<i>Work experience</i>		
5 years or less	3	20
6–10 years	2	13.3
11–15 years	5	33.4
16–20 years	3	20
Over 21 years	2	13.3

In this study, male respondents dominated with an 86.7% score whereas female respondents accounted for 13.3% with only 20% of the respondents having a work experience of 5 years or below in the university. All the demographic characteristics of the respondents suggest that the respondents have experienced the BL model adopted by TTU.

**Objective One:** *To identify the challenges saddling the adoption of blended learning in the delivery of courses in Takoradi Technical University;*

Concerning objective one, literature was reviewed and some challenges saddling the adoption of blended learning in institutions of higher learning within some national and cultural contexts were identified. Subsequently, respondents’ views were sought on whether or not the identified challenges saddle the adoption of blended learning in Takoradi Technical University. The analysis was presented in a form of a table.

As shown in Table 3, a strong consensus was reached by the respondents on fourteen (14) challenges to be relevant challenges saddling the adoption of BL in TTU. Each of the 14 challenges attained a group median of eight (8). Moreover, the values of IQD showed a strong consensus in the views of the respondents as all the IQD values were less

than one (1). The values of standard deviation affirmed a high degree of consistency and non-variability in the views of the respondents. Respectively, all the values of standard deviation were less than one (1). Thus, based on the strong consensus in the views expressed by the respondents in the Delphi study, this study advances that 14 challenges have saddled the adoption of BL by TTU. The 14 challenges are unreliable internet service, lack of clear-cut national policy for blended learning, lack of motivation for lecturers and students, high cost of data bundle in Ghana, poor internet connection within the university and its environments, lack of internet connectivity in remote areas of Ghana, lack of clear-cut formal policy on blended learning in Technical Universities, the existence of inadequate legal provisions promoting blended learning as a means of course delivery and examination in Ghana, low commitment levels on the part of lecturers to blended learning, inadequate training in the use of the learning management system for blended learning, inadequate financial commitment to blended learning, lack of political commitment to blended learning, unwillingness on the part of learners to use the learning management system, and no direct financial support for lecturers for using their data for online delivery of courses (see Table 2).

**Table 2.** Challenges saddling the adoption of blended learning in Takoradi Technical University

SN	Challenge(s) saddling blended learning	Author(s)
1	Unreliable internet service	Consistent with (Hossain 2013)
2	Lack of clear-cut national policy for blended learning	Consistent with (Hossain 2013; Moskal et al. 2013)
3	Lack of motivation for lecturers and students	Consistent with (Lameras et al. 2012)
4	High cost of data bundle in Ghana	Unique to Ghana study
5	Poor internet connection within the university and its environments	Consistent with (Hossain 2013; Moskal et al. 2013)
6	Lack of internet connectivity in remote areas of Ghana	Consistent with (Hossain 2013; Moskal et al. 2013)
7	Lack of clear-cut formal policy on blended learning in Technical Universities	Consistent with (Graham and Robison 2007)
8	The existence of inadequate legal provisions promoting blended learning as a means of course delivery and examination in Ghana	Unique to Ghana study
9	Low commitment levels on the part of lecturers to blended learning	Consistent with (Kaur 2013)
10	Inadequate training in the use of the learning management system for blended learning	Consistent with (Hossain 2013)
11	Inadequate financial commitment to blended learning	Consistent with (Piper 2010; Hossain 2013)
12	Lack of political commitment to blended learning	Consistent with (Hossain 2013)
13	Unwillingness on the part of learners to use the learning management system	Consistent with (Anderson 2008; Bakir et al. 2016)
14	No direct financial support for lecturers for using their data for online delivery of courses	Unique to Ghana study

Among the 14 challenges eleven (11) were consistent with the challenges saddling the adoption of blended learning in institutions of higher learning in some national and contexts whereas three (3) challenges were peculiar to the Ghana study. The three peculiar challenges were the high cost of data bundles in Ghana, the existence of inadequate legal provisions promoting blended learning as a means of course delivery and examination, and no direct financial support for lecturers for using their data for online delivery of courses (see Table 2).

**Objective two:** *to determine the relative influence of each of the identified challenges saddling the adoption of blended learning in Takoradi Technical University.*

With regards to objective two, the individual mean score of the challenges saddling the adoption of blended learning by Takoradi Technical University was ranked. The result is presented in a form of a Table (see Table 3).

**Table 3.** Relative influence of the challenges saddling the adoption of blended learning in Takoradi Technical University

Challenges .... is a challenge saddling the adoption of blended learning by Takoradi Technical University	Median (M)	Mean ( $\bar{x}$ )	Standard deviation ( $\sigma_x$ )	Interquartile deviation (IQD)	Mean scores ranking (R)
Lack of motivation for lecturers and students	8	8.20	0.41	0.00	1 <sup>st</sup>
Unwillingness on the part of learners to use the learning management system	8	8.20	0.41	0.00	1 <sup>st</sup>
Inadequate financial commitment to blended learning	8	8.20	0.41	0.00	1 <sup>st</sup>
Lack of clear-cut national policy for blended learning	8	8.13	0.35	0.00	4 <sup>th</sup>
Lack of clear-cut formal policy on blended learning in Technical Universities	8	8.13	0.35	0.00	4 <sup>th</sup>
Unreliable internet service	8	8.00	0.65	0.00	6 <sup>th</sup>
High cost of data bundle in Ghana	8	8.00	0.38	0.00	6 <sup>th</sup>

(continued)

**Table 3.** (continued)

Challenges ... is a challenge saddling the adoption of blended learning by Takoradi Technical University	Median (M)	Mean ( $\bar{x}$ )	Standard deviation ( $\sigma$ )	Interquartile deviation (IQD)	Mean scores ranking (R)
Poor internet connection within the university and its environments	8	8.00	0.38	0.00	6 <sup>th</sup>
Lack of internet connectivity in remote areas of Ghana	8	8.00	0.38	0.00	6 <sup>th</sup>
The existence of inadequate legal provisions promoting blended learning as a means of course delivery and examination in Ghana	8	8.00	0.65	0.00	6 <sup>th</sup>
Low commitment levels on the part of lecturers to blended learning	8	8.00	0.38	0.00	6 <sup>th</sup>
Inadequate training in the use of the learning management system for blended learning	8	8.00	0.38	0.00	6 <sup>th</sup>
Lack of political commitment to blended learning	8	8.00	0.00	0.00	6 <sup>th</sup>
No direct financial support for lecturers for using their data for online delivery of courses	8	8.00	0.65	0.00	6 <sup>th</sup>

Relatively, three challenges were jointly ranked first as saddling the adoption of BL in TTU. The challenges were lack of motivation for lecturers and students which supports the study by Lameris et al. (2012), inadequate financial commitment to blended learning which supports the study by Piper (2010) and Hossain (2013), and unwillingness on the part of learners to use the learning management system which affirms the study by Anderson (2008) and Bakir et al. (2016). Each of the challenges recorded a mean score of (8.20). Also, a lack of clear-cut national policy for blended learning with a mean score of (8.13) emerged fourth. According to Hossain (2013), the absence of a national policy on BL impedes the adoption of BL. This is also consistent with the study by Moskal et al. (2013) when the authors asserted that national policy on BL is a major challenge to the adoption of BL in developing countries. Also emerging fourth was the Lack of clear-cut formal policy on blended learning in Technical Universities, which is consistent with the study by Graham and Robison (2007) that institutional policies have been a challenge saddling the adoption of blended learning.

Further, nine of the challenges with each recording a mean score of (8.00) were jointly ranked sixth. They include *no direct financial support for lecturers for using their data for online delivery of courses* which was unique to this study. *Lack of political commitment to blended learning* affirms the study by Hossain (2013) which revealed that lack of political will is a crucial challenge saddling the adoption of blended learning. *Inadequate training in the use of the learning management system for blended learning* aligns with the study by Hossain (2013). According to Hossain (2013), lack of training in BL is a challenge saddling the adoption of blended learning. Also, *the existence of inadequate legal provisions promoting blended learning as a means of course delivery and examination in Ghana* was found to be unique to this Ghana study. *Low commitment levels on the part of lecturers to blended learning* affirms the view of Kaur (2013) that lack of positive attitude on the part of senior members in institutions of higher learning has saddled the adoption of blended learning. More so, *unreliable internet service* affirms the argument by Hossain (2013) that unreliable internet service is a challenge to BL. *The high cost of data bundles in Ghana* was a challenge unique to this current study. *Poor internet connection within the university and its environments* support the study by Hossain (2013) and Moskal et al. (2013), and *lack of internet connectivity in remote areas of Ghana* agrees with the study by Hossain (2013) and Moskal et al. (2013). Hossain (2013) and Moskal et al. (2013) in a separate study argued that the lack of internet in remote areas is a challenge to the adoption of blended learning.

## 5 Conclusion

This study seeks to ascertain if the challenges found to be saddling the adoption of blended learning in institutions of higher learning in other countries are relevant challenges saddling the adoption of blended learning in Technical Universities (TUs) in Ghana using Takoradi Technical University (TTU) as a case study and determine the relative influence of each of the challenges. The study employed the Delphi method and concluded that fourteen challenges saddle the adoption of BL by TTU. Theoretically, it advances that the challenges saddling the adoption of BL by TTU are embodied in unreliable internet service, lack of clear-cut national policy for blended learning, lack of

motivation for lecturers and students, high cost of data bundle in Ghana, poor internet connection within the university and its environments, lack of internet connectivity in remote areas of Ghana, lack of clear-cut formal policy on blended learning in Technical Universities, the existence of inadequate legal provisions promoting blended learning as a means of course delivery and examination in Ghana, low commitment levels on the part of lecturers to blended learning, inadequate training in the use of the learning management system for blended learning, inadequate financial commitment to blended learning, lack of political commitment to blended learning, unwillingness on the part of learners to use the learning management system, and no direct financial support for lecturers for using their data for online delivery of courses. Ranking the challenges by their respective mean score, three challenges jointly emerged first with an individual mean score of 8.20. Two challenges recorded a mean score of 8.13 and ranked 4<sup>th</sup> whereas nine challenges jointly emerged 6<sup>th</sup> with a mean score of 8.0. The practical value of this study is that it identifies the challenges saddling the adoption of BL in TTU which when addressed will enhance the delivery of quality education in TTU thereby addressing sustainable development goal four which focuses on quality education. In addition, the study applies the saturation theory and the Delphi technique in identifying the challenges saddling the adoption of BL in TTU, a methodology no existing study had applied in identifying the challenges saddling the adoption of BL in TTU thereby serving as the reference literature for future studies. It has also revealed 3 challenges peculiar to the Ghana study only. It informs stakeholders and policymakers in policy formulation geared towards BL adoption in institutions of higher learning in Ghana. It is recommended that effective collaboration between TTU, government and education stakeholders is essential in addressing the challenges saddling BL in TUs in Ghana since the unravelled challenges are diverse and multifaceted.

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# Assessment of Risk of Development Project in Tanzania

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**Abstract. Purpose:** This paper introduces the study about assessment risks of development project under Dar es Salaam Maritime Gateway Project. Specifically, the study intended to determine Value at Risk (VAR) invested in Dar es Salaam Maritime Gateway Project.

**Methodology:** The study employed an explanatory sequential mixed method whereby a judgmental sampling technique was used to collect secondary information to the key informants. The Microsoft excel 2007 was a tool used to analyze data gathered in this study.

**Findings:** The study revealed that the stimulated that it will be a low value at risk of the project in the next coming years including 2021.

**Policy Implication:** It's then recommended that the Dar es Salaam Maritime Gateway project should allow opinion of professional personnel on the issue of risks estimation. For instance, this report proposes the value at risk of the project in the next coming years through the simulation process.

**Keywords:** DMGP · Monte Carlo · Project · Risk · Tanzania

## 1 Introduction

Development organizations are different in size and orientation but most share the regular goal of helping people and befitting the society. Development projects can be financed by the governments, and others are financed by institutions like World Bank. Usually development projects support development activities such as welfare support, health, education, small financial loans and environmental protection (Siles 2018). The aim of international organization like World Bank and Governmental and Non-Governmental organizations (NGOs) is to improve standard of living conditions in developing countries (Robert 2003). In order to ensure effective and sustainability of development projects organizations need to support project management by creating flexible framework with practices and competencies of technical personnel (PM4DEV 2020).

The real estate development is a triangulation process that it might be complicated, too long and risky. So, it might take years to complete the project from the initial stage through construction to the final stage (Formigle 2016). Consequently, projects with high risks profiles can commensurate financial or social returns and discouraging investors

from discouraging project from launching (Tekolste et al. 2016). Considering time value for money in any development project is inevitable and it's crucial when estimating reruns and risks of the project. Project managers can function on accounting or finance professional for the calculations but they must take in mind that money available today is worth more than money available later (Brown 2007).

In Tanzania, there are five (5) development projects namely; Kikonge Dam and Hydropower Project, World Bank's Tanzania Rural Electrification Expansion Program, Nordic Development Fund's Sustainable Charcoal Business Development Fund, Dar es Salaam Maritime Gateway Project and USAID's Tusome Pamoja (The Borgen Project 2016). Among all these projects, this study will be conducted in DMGP. The DMGP is located at the business city of Tanzania (Dar es Salaam), the major aim of this project is to improve the effectiveness and efficiency of the port of dar es salaam for the benefit of public and private stakeholders (World Bank 2019).

A lot of studies are not conducted in Tanzania but also estimating risks is not the same as the organization are with different objectives and methods used in estimation. The major topics also are not the same as this study based on development project in Tanzania whereby the risk is analyzed using Monte Carlo Simulation. Determining risks in DMGP is an essential study to be conducted in Tanzania hence it will convey the presence of organization position in terms of profit and loss.

## 2 Literature Review

Project management involves a series of activities such as project planning, project execution and project monitoring and evaluation (Suda et al. 2015). Project management can be defined as planning, monitoring and control of all aspects of a project and the motivation of all those involved in it to achieve the project objectives on time at specified cost, quality, and performance (Atkinson 1999). It is the art or science of converting idea into reality reflection what is needed at right time. Project management is difficult to define though a standard accepts the concept of Roger Atkinson of the Iron Triangle which is cost, quality and time which is still working to date. Consequently, the project which has met those parameter of cost, quality and time but has not met the needs of customers, not liked by sponsors and does not show effectiveness is characterized as failed project (Atkinson 1999).

Risk management plays a crucial part in every stage of implementation of each project as every part from initial stage to final stage contains marginal risk with different magnitude (Junkes et al. 2015). Consequently, the process of risk management starts with assessment and evaluation. A risk event may be considered as a likelihood occurrence that affects a project positively or negatively, while uncertainty occurs when there is no sufficient and clear information available to decision makers, reducing confidence on evaluating alternatives and their risks, thus, resulting to decision-making dilemma (Kopacz et al. 2017; Qazi and Simsekler 2021). Uncertainty is lack of objective discrete distributions associated with the events that are not susceptible to accrual science. Moreover, this concept can be presented in three generic groups (Helliari et al. 2002): uncertainty about the prices and components of investment, uncertainties regarding the deadlines for implementing the schedule and uncertainties regarding the occurrence of events.

Study conducted by Jiang and Ruan 2010 on investment risks assessment on high-tech Projects Based on Analytic Hierarchy Process and BP Neural Network revealed that, investment risks assessment of projects is a more complex process which involves numerous factors and it is not entirely the linear relationship between influencing factors and measurement result. Consequently, projects are faced with interrelated risk in which one leads to another risks.

Risks in projects evolves from the day of converting ideas to execution. Previously, project team were using traditional risk management approach whereby they respond to risk after occurring where hedging and insurance were the best option(Liu et al. 2017). Moreover, treating each risk class in a discrete silo generates inefficiencies due to lack of coordination between the various risk management and raises supervision problem (Meidell and Kaarbøe 2017; Shad et al. 2019). Consequently, traditional risk management approach failed to endorse success on quality projects. Basing on continuous failure of projects, a new model called enterprise risk management (ERM) was introduced whereby risk is assessed on every stage of project execution activities (pre and post project risk management) (Hoyt and Liebenberg 2011). Risk is now handled at individual level and there is study in how risk relate to one another to the organisation by holistic approach.

Even though risk management is one of the greatest needs in project management, it is recognized that little has been done in this respect (Raz et al. 2002; Ibbs and Kwak 2000; Zwikael and Globerson 2006; Zwikael and Sadeh 2007). It has been perceived risk management is a post action after implementation of the project and not the duties of project managers rather it was taken as duties of financial managers (Fadun 2013). Consequently, nowadays project management has two parts namely soft part and hard part implicating social behavior and technical issue which then believed to be areas of risk occurrence.

Study conducted by Keshk et al. 2018 on Special studies in management of construction project risks, risk concept, plan building, risk quantitative and qualitative analysis, risk response strategies revealed that, both qualitative and quantitative risk assessment techniques are necessary and risk management team is required to continue its work in any project until end of project because risks may arise at different stages of project life cycle. Moreover, risks vary from project types and size.

According to researchers in project and risk management theory have identified two theories on how to handle risk. One being frequency theory or the frequency approach to risk assessment which is explained by adaptation by Ekung et al. 2015. This approach is concerned with the frequency of risk occurrence and how it relates with other key variables parameters, which eventually include other risks. The other approach is the life cycle theory, which studies several possible developments of the project with time during its life cycle. However Ekung et al (2015) observed that the life cycle approach is most regularly used in construction projects and the need to apply the frequency approach is compulsory for many projects. For example, one must study how interest rate risk is associated with default risk (financial risks) the study in the life cycle is incomplete because it is difficult to determine frequency of occurrence and how it correlates to each other.

Allied with this approach, Bakker et al. (2012) emphasized the importance of risk identification as the most influential process in terms of numbers as well as in the strength of communications effects, followed by risk reporting, risk registration and risk allocation, risk analysis, and finally risk control. In this view, according to work by Besner and Hobbs (2006), sharing information about project risk with project' stakeholders, constitutes an important practice for management.

Several risks are found to affect projects, more ever researchers have created various frameworks of project risks applicable to the development projects. Consequently, most basic framework of project risks is embodied by three components of risks and was formulated and accepted. (Amoatey and Danquah 2018; Ekung et al. 2015) This framework recognizes a construction project risk as it categorizes risks as financial risks, material/equipment risks and people risks.

Among these three categories, our study will deal with financial risk where it is defined as probability of not achieving the desired financial needs due to uncertain constraints. Moreover, VaR is the ratios which determine and provides an indication that on the near future the project will be having financial constraints using Monte Carlo simulation approach.

### 3 Methodology

There are different types of research design such as case study, cross-sectional, survey, experimental, longitudinal, archival, and others (Magigi 2013). This study employed an explanatory sequential mixed method. According to Creswell (2012), asserts that explanatory sequential research is the design whereby researcher first analyses quantitative results by gathering participants' views, then a researcher build up on data through identifying instrument that fits and follow qualitative approach.

The sampling unit of this study was an institution of Dar es Salaam Maritime Gateway Project. Hence the study analysis based in calculation of estimated risks basing on secondary information, then the sample procedure is biased because the research is based on secondary data. Therefore, this study used only non-probability sampling technique in sampling selection. Sampling procedure implies the technique or process to be used by the researcher in choosing the items for the sample (Kothari 2015). The researcher used judgmental sampling techniques in selecting Dar es Salaam Maritime Gateway Project stakeholders toward the project.

This study used only secondary information as one of the type of data collection. Also, the study employs a documentary review as a data collection method in order to review the secondary information of the area of the study. In this study only secondary data were collected. Secondary data are data that were already collected, written and sometimes analyzed by other researchers and authors. In this case, the researcher collected secondary data through documentation method, the data obtained from various records and publication such as journals, minutes meeting, books, newspaper, magazines, as well as searching the library literature was used for the development project. In this study, secondary data were collected to obtain a series of estimated return and risks from the past years of the project.

The researcher collected secondary data by using document review method. By reading the available documents in the Dar es Salaam Maritime Gateway Project and

policies regarding investments, DMGP documents and records, other manuscripts related to investment issues.

In this study, Microsoft excels 2007 used as the tool for data analysis. To determine risk arising in Dar es Salaam Maritime Gateway Project Microsoft excel was performed to calculating risks by using Monte Carlo simulation formulas for standard deviation. The normal distribution curve was sketched through scatter curves in the Microsoft excel 2007. Also, the software was used to subtract, add and multiply all calculation necessary to this study.

## 4 Findings and Discussion

### 4.1 Computation of Value at Risk (VaR) in Dar es Salaam Maritime Gateway Project (Monte Carlo Simulation)

The computation of value at risk by using Monte Carlo simulation was determined by using historical time data. The following below are procedures for computing VaR by using Monte Carlo simulation in the historical information of the Dar es Salaam maritime gateway project.

The first procedure is to determine the time horizon (t) for the analysis and dividing it equally into the small-time periods; therefore  $dt = t/n$ . for the Dar es Salaam maritime gateway project  $dt = 1$  year as the project estimate its profit, investment and other cost for the 1 year basis (Table 1).

**Table 1.** DMGP return on investment in four years (US\$ million)

	2016	2017	2018	2019
Profit	–	–	18.6	43.3
Investment	191.5	191.5		
ROI	0	0	9.7%	22.6%

*Source: (Researcher analysis 2020)*

Therefore, the following equation used as the standard asset model to simulate the path of an asset price from the 1<sup>st</sup> year as defined below;

$$R_i = (S_{i+1} - S_i)/S_i = \mu \Delta t + \sigma \epsilon \sqrt{\Delta t}.$$

Where:

$R_i$  is the return of the asset on the 1th year

$S_i$  is the asset price on the 1th year

$S_{i+1}$  is the asset price on the  $i + 1$ th year

$\mu$  is the sample mean of the asset price

$\Delta t$  is the time step

$\sigma$  is the sample volatility (standard deviation) of the asset price

$\epsilon$  is a random number generated from a normal distribution.

Therefore, the asset price on the first year of the Dar es Salaam maritime gateway project ( $S_i$ ) which is 2016 was \$191.5 million. Likewise, the asset price on the  $i + 1$ th year of the project which is 2017 was \$191.5 million hence the project didn't get the profit on the first year. So, through this description the return of the asset on the first year ( $R_i$ ) was 0, that means no return on asset (Table 2).

In the next year (2017) the asset price on the first year of the Dar es Salaam maritime gateway project ( $S_i$ ) which is 2017 was \$191.5 million. Likewise, the asset price on the  $i+1$ th year of the project which is 2018 was \$210.4 million hence the project got the profit on the first year of \$18.9 million. So, through this description the return of the asset on the first year ( $R_i$ ) was as follows;

$$R_{2017} = (S_{2018} - S_{2017}) / S_{2017}$$

$$R_{2017} = (\$210.4 - \$191.5) / \$191.5$$

$$R_{2017} = \$0.0989.$$

Also in the next year (2018) the asset price on the first year of the Dar es Salaam maritime gateway project ( $S_i$ ) which is 2018 was \$210.4 million. Likewise, the asset price on the  $i+1$ th year of the project which is 2019 was \$253.7 million hence the project got the profit on the first year of \$43.3. So, through this description the return of the asset on the first year ( $R_i$ ) was as follows;

$$R_{2018} = (S_{2019} - S_{2018}) / S_{2018}$$

$$R_{2018} = (\$253.7 - \$210.4) / \$210.4$$

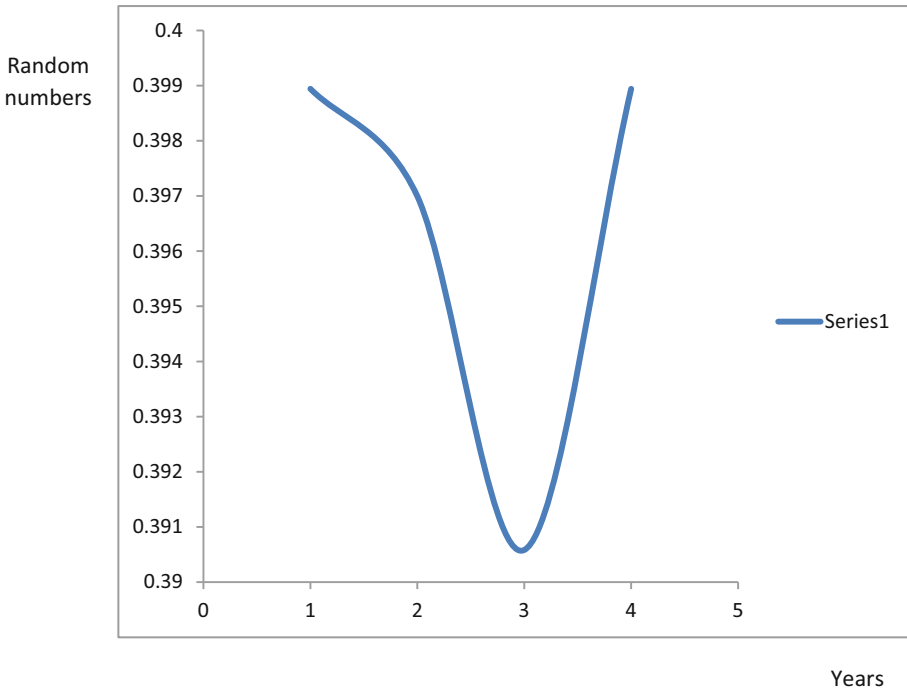
$$R_{2018} = \$0.2058.$$

**Table 2.** Presentation of return of asset based on the neutral assumption of the year '2019'

Year	2016	2017	2018	2019
Return of asset	\$0	\$0.0989	\$0.2058	\$0
Normal distribution (A1,0,1,0)	0.398942	0.396996	0.390583	0.398942

Therefore, if the return of the asset (Dar es Salaam maritime gateway project) is neutral that means there will be a large Value at Risk hence as presented below. This is supported by study conducted by Torikian and Kumral 2014 on analyzing the reproduction of correlations in Monte Carlo simulations in mine projects. The graph has anticlockwise shape of the normal distribution of the return of asset.

Figure 1 is the sketch of random number from the random number generator, which was updated from the price of the asset at the end of the first-time increment.



**Fig. 1.** The neutral assumption curve on return of asset

The computation of value at risk by using Monte Carlo simulation based on the assumption of return of asset if the base year its price will depend on the coming year which for one way or another its price is undefined due to lack of information of that project, therefore; after determining the value at risk if the return in 2019 and above is neutral (0) from then on, the following below table if when the return of asset is positive (+) (Table 3).

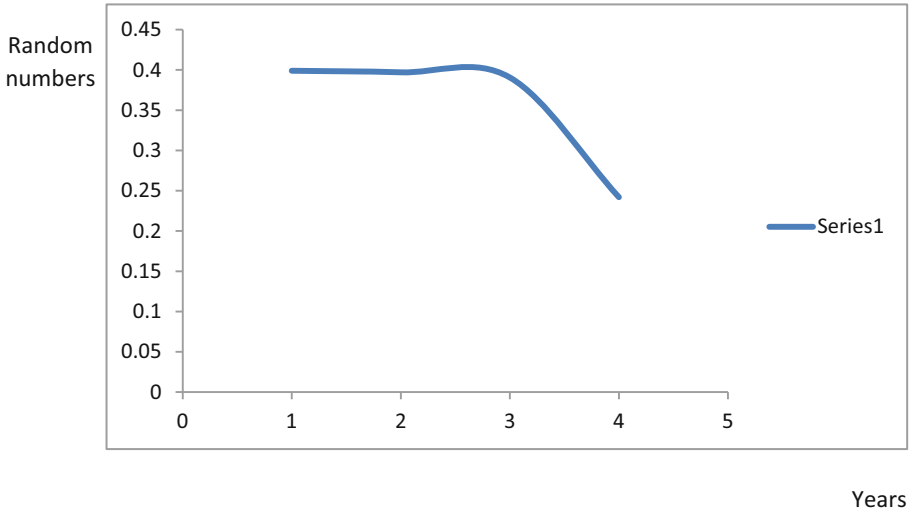
**Table 3.** Presentation of return of asset based on the positive assumption of the year ‘2019’

Year	2016	2017	2018	2019
Return of asset	\$0	\$0.0989	\$0.2058	\$1
Normal distribution (A1,0,1,0)	0.398942	0.396996	0.390583	0.241971

Figure 2 shows the simulation of return of asset of dare s salaam maritime gateway project based on the positive assumption for year 2019 and above. Therefore, the graph



show the clockwise curve of the normal distribution which mean there is a low value at risk of this project in the next coming years including 2020. This assumption is supported by the real situation of the profit accumulated from this project in 2019. Therefore, there is high possibility of accessing low value at risk in Dar es Salaam maritime gateway project in the next coming years.



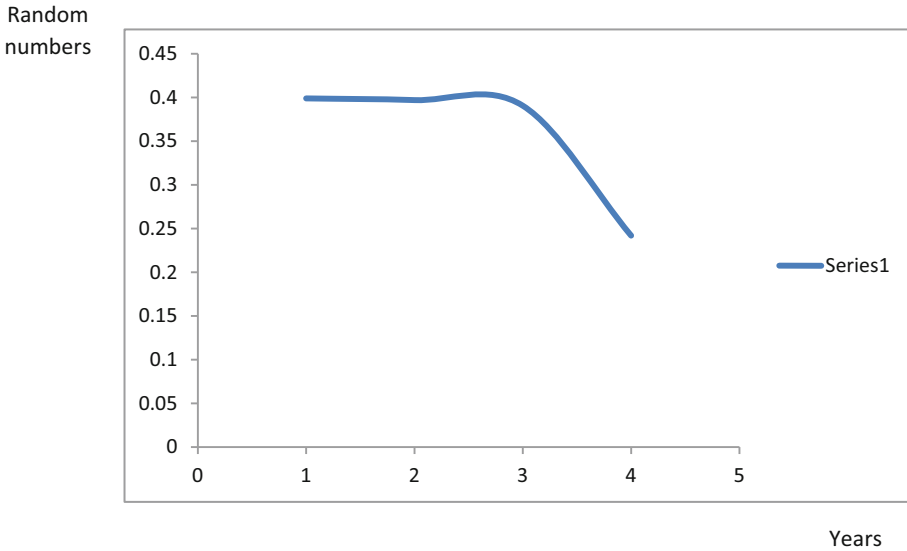
**Fig. 2.** Positive assumption on return of asset

After the positive and neutral assumptions on return of asset in the next coming years the following is the presentation of negative assumption of return of asset in the coming years. So, if the assumption of the return on asset in the concept of normal distribution the standard deviation is also negative (-1) Table 4.

**Table 4.** VaR based on negative assumption on return on asset

Year	2016	2017	2018	2019
Return of asset	\$0	\$0.0989	\$0.2058	\$-1
Normal distribution (A1,0,1,0)	0.398942	0.396996	0.390583	0.241971

Figure 3 indicates there will be low return of asset if the assumption is negative. Therefore, if the return on asset in the coming year will be negative therefore there will also be a minor value at risk due to the following reasons; the collapse of the business, it's difficult to acquire negative return of the asset once the business started to generate profit, and in general this assumption seems to be difficult to exist.



**Fig. 3.** Negative assumption on return of asset

## 5 Conclusion

This paper presents the findings and discussion on determination of Value at Risk (VaR) invested in Dar es Salaam Maritime Gateway Project (DMGP). The study revealed that through the normal distribution, the graph show the clockwise curve of the normal distribution which meaning there is a low value at risk of this project in the next coming years including 2020. This assumption is supported by the real situation of the profit accumulated from this project in 2019. VaR has become a necessary implementation in any professional corporate risk management as it use a time period of the expected output, the dollar amount of VaR (portfolio, assets, etc.) and particular normal market condition (or confidence interval to determine percentage of loss from such investment. VaR is not only applicable in exploring the market risk but also in managing all other types of risk. This is due to the fact that, risks are interdependent as one risk may influence the other. Consequently, VaR is primarily designed for both risk management and regulatory purposes.

Therefore, there is high possibility of accessing low value at risk in Dar es Salaam maritime gateway project in the next coming years. It is very easy for individuals or societies to understand and bring into the financial market to measure the risk of a company. Also, it makes the risk much easier to clarify. It can be concluded that using Monte Carlo methods to simulate financial circumstances is a much better approach to model real world situations in comparison with analytical models that do not factor unpredictability.

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# The Optimization of Site Layout on Construction Sites for Efficiency in the Ghanaian Construction Industry

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**Abstract. Purpose:** Many projects in Ghana experiences delay and even abandonment due to improper initial work management plans, which includes site layout planning. The paper aims at the optimization of site layout on construction sites for efficiency in the Ghanaian construction industry.

**Methodology:** The research design is quantitative and purposive sampling techniques to 100 respondents comprising 35 Site Supervisors, 22 Quantity Surveyors, 18 General Foremen, and 12 Safety officers who have practised and are been involved in an ongoing construction project and 87 sets of questionnaires were received.

**Findings:** A total of 10 factors were also identified as factors influencing effective site layout plans on construction sites. Based on the findings of the analysis, it was ascertained that site layout plans have a significant positive impact on construction sites in the Ghanaian construction industry.

**Research Limitation/Implications:** The study focused on the optimization of site layout on construction sites for efficiency in the Ghanaian construction industry.

**Practical Implication:** The impacts were discovered to be linked to work efficiency. This study brings to the fore the merits of utilizing an effective site layout plan as well as factors to be considered in achieving an effective site layout plan as far as construction is a concern. The availability of a site layout plan should be one of the factors used to select a contractor for any project in Ghana.

**Originality/Value:** The novelty of this study also lies in the factors that contribute to the efficiency of the construction sites in Ghana.

**Keywords:** Construction · Layout · Productivity · Site · Ghana

## 1 Introduction

Efficient use of site space can have a significant impact on the productivity, safety, and security of the site, which in turn can affect the cost and schedule of the project. The front-end planning of the layout of construction sites referred to as site layout planning has received the attention of researchers in recent decades (Mincks and Johnston 2010).

Contractors may guarantee that their productivity and profitability are maximized by using proactive site planning, lean construction concepts, and a variety of other factors that influence project delivery on the job site (Bamfo-Agyei et al. 2018).

Planning the site layout of construction projects is a crucial task that has a significant impact on cost, productivity, and safety (Archer 2016). Elbeltagi and Hegazy (2002) said that the output rate of productivity expected and estimated is mainly affected by inefficient site layout planning in most construction projects. Efficient management of construction resources can lead to higher productivity which can help to achieve cost and time-saving. The location of temporary facilities and equipment is coupled with the sequence of construction activities at the site. Poor planning of the temporary facilities layout could potentially lead to work delays, temporary material storage, multiple handling of materials resulting in schedule delays, loss of time and money, and unsafe working conditions (Mincks and Johnston 2010).

Bamfo-Agyei et al. (2020) argued that restricted spaces, particularly in urban development locales, have been a challenge to a successful site layout plan, and a layout plan which does not legitimately address the wellbeing and security needs of the workforce compromises on productivity. Calis and Yuksel (2010) noted that site layout planning as a major aspect in the construction process has been treated lightly. In most cases, the sites look untidy and disorganized, driving to site mishaps and posturing security issues. This brings to the fore the pertinence of site layout planning as an imperative handle of development administration that cannot be underestimated. It is against this background that this paper aims at the optimization of site layout on construction sites for efficiency in the Ghanaian construction industry.

## 2 Theories Underpinning the Study

In as much as a lot of construction projects are going on in Ghana, many preliminary criteria have to be met to ensure the smooth execution of construction projects. One of these preliminary criteria is site layout planning. Archer (2016) concurred by stating that for a project to be completed, it is fundamentally dependent on the efficiency of the site layout planning. This is because, site planning is directly linked to the cost, time, productivity and security outcomes of every construction project (Farnaz and Mohsen 2015).

The importance of site planning cannot be overemphasized in the construction industry. Many researchers over the years have conducted studies relating to site planning mainly in the areas of temporary facilities constraints, sizing and mapping of construction sites and determination of facility location (Je-Chian Lin et al. 2013). Furthermore, Whitman et al. (2021) revealed that many construction stakeholders from various companies, both big and small, deemed site planning as very important. Although the concept of site planning is quite old, the Ghanaian construction industry continues to face problems in that area. Archer (2016) reinforced this statement by highlighting that numerous construction projects in Ghana experienced delay and even abandonment due to improper initial work management plans, which principally included site planning. An extensive literature search conducted by the researcher brought to light, the lack of in-depth research work on construction site planning as a major cause of this problem in Ghana.

## 2.1 Definitions of Site Planning

As established earlier on, many studies have been conducted on on-site planning with scopes all around the world. Accompanying these studies are various opinionated definitions developed by various researchers in an attempt to explain site planning. This study will highlight some definitions.

Whitman et al. (2021) defined site planning as a decision-making process carried out to effectively locate temporary facilities within the boundaries of a given construction site. They further listed some temporary facilities as project trailers, material laydown yards and cranes.

Another definition by Elbadr (2016) described site planning as the determination of the optimum location of objects on the construction site to minimize travel distances and maximize safety. The objects cited in the definitions consist of temporary facilities such as batch plant and tower cranes and working areas.

Yahya and Saka (2014) also defined site planning as the process used to find the best arrangement of the temporary facilities according to multiple objectives that may conflict with each other and be subjected to logical and resources constraints.

Schwabe et al. (2016) and Raj (2020) agreed in explaining site planning as a decision-making process carried out at the start of a construction project to allocate and arrange important resources such as temporary facilities to improve site safety and productivity. The definitions developed by the researchers all concur showing that the concept of site planning is universally uniform.

## 3 Factors to be Considered in Achieving an Effective Site Layout Plan

For an effective and efficient site layout to be achieved, certain factors have to be considered in the planning and implementation of a site layout plan. These factors when properly addressed will aid in the smooth running of any construction process.

### 3.1 Plot Size and Shape

The size and shape of the plot should be assessed during the planning of the site layout. It is common knowledge that the size of the plot will determine what type and the number of temporary facilities can be accommodated on the site (Archer 2016). A site with limited space needs proper planning, in that temporary facilities that are more necessary should be located on-site. This is because site space is a very precious and finite resource in this instance (Whitman et al. 2021). Where there is the luxury of space, the layout plan can have all the necessary facilities that will aid in the construction process.

### 3.2 Location of Project

The location of the project will to some extent determine the outcome of the final site layout plan. How far or closer it is will also tell the kind and size of temporary facilities to be provided. In some project locational situations, special arrangements for temporary

facilities should be made. However, these arrangements should be planned in such a way that they do not interfere with each other as it might cause great inconveniences (Je-Chian Lin et al. 2013). In extreme project locational cases where construction projects are situated far away from industrial centres and/or civilization, special on-site facilities must be provided. Archer (2016), mentioned some of the special site facilities as batch plant, maintenance workshops, warehousing, site accommodations for the workforce and even recreational centres. Furthermore, extra arrangements should be made for areas where there is no electricity, water or telecommunication service.

### **3.3 Information Signs**

Signage as a form of communication should be of utmost consideration during the planning of the site layout. It should be visible and in clear language that is easy to understand, indicating what to do and what not to do on-site, to prevent unnecessary hits and falls resulting in accidents and injuries. There should be a site map that will show details of the project; this should be exhibited boldly in the site Engineers or project Managers' office and also posted at the entry point. Strategically traffic regulatory signs should be located to direct traffic on the site to prevent accidents as much as possible (Vaidya and Seethraaman 2011).

### **3.4 Security**

The security of the site should be of prime consideration to the site planner if the project should end successfully. Archer (2016) established that providing and maintaining appropriate levels of site security benefits both the owner and contractors, as it will protect the site, reduce the potential for theft and restrict entry to only authorized personnel. The whole site should be fenced and the entrance strategically located with guard posts to check the ins and outs movement of all personnel and vehicles to check to pilfer. The whole site should be illuminated at night to prevent intruders to the site.

### **3.5 Accommodation and Craft Change-Houses**

The principle in providing workers accommodation on site is to ensure the welfare of workers throughout the entire duration of the construction project (Yaman et al. 2020). Therefore, some form of accommodation should be provided for all categories of personnel involved in the project on-site, especially when the project is large and has a long duration for completion. On a small or restricted site, accommodation for only the site engineer and the security should be considered, and arrangements should be made for other workers nearby. Furthermore, craft change-houses should be provided for workers to change, keep clothes, bath and relax during breaks. The space should have toilet facilities for their convenience (Archer 2016).

### **3.6 Utilities (Electricity, Water and Telecommunication)**

Haggerson (2018) advised that during site planning, all utilities deemed important to the success of the construction project should be located and harnessed to the advantage of



the project. In instances where important utilities cannot be located or are non-existent, provisions should be made to introduce these utilities to the site. For example; in areas where water is a problem, arrangements can be made for tanker services or a borehole can be sunk to provide water. Furthermore, in areas with no power supply, a generator plant can be installed to provide electricity.

### **3.7 Positioning of Construction Materials**

Material handling makes up about one-third of all construction operations (Archer 2016). Therefore the effective materials location planning can immensely reduce travel times on-site, thus increasing productivity and reducing the overall duration of the construction project (Madeh 2020) Furthermore, the use of proper equipment for material handling and planning will minimize multiple handling which will result in direct cost and time savings.

### **3.8 Site Accessibility**

In planning for site accessibility, Madeh (2020) stated that an examination of existing roads leading to and away from the construction site had to be carried out. This is because good planning is needed to effectively link the site roads to existing roads nearby without causing traffic congestions on or off the site. Roads within the site are needed to allow work to flow easily. Spaces for parking vehicles are to be provided. The easy movement will keep the morale of the equipment and vehicle drivers high, thus increasing the overall productivity output of workers and reducing site vehicular accidents (Vaidya and Seethraaman 2011).

### **3.9 Nature of Project**

It was highlighted previously that construction projects come in three main types namely; residential building projects, non-residential building projects and engineering construction projects. With building projects (residential and non-residential) and some types of engineering projects, where most of the activities are executed in one designated site area, Archer (2016) advised that a centralised site plan system should be considered. However, for other construction projects such as transportation projects (railways and highways), where construction is constantly on the move, thus making Archer (2016)'s advice impractical, an improvised site plan can be adopted to make sure the construction project runs smoothly (Vaidya and Seethraaman 2011).

### **3.10 Construction Methods**

The choice of construction methods is to be considered in the event of site layout planning. This is because the choice of construction methods can singlehandedly eliminate the need for some temporary facilities (TFs) whiles introducing the need for other temporary facilities. Researchers such as Akintoye (2013) and Banton and Berry-Johnson (2021) supported this statement. They explained saying that these construction methods

could eliminate the need for work and numerous material storage areas on-site as compared to the traditional method of construction. Thus, making construction methods, a viable consideration in site planning.

## 4 Methodology

The research design is quantitative and purposive sampling techniques to 100 respondents comprising 35 Site Supervisors, 22 Quantity Surveyors, 18 General Foremen, and 12 Safety officers who have practised and been involved in 20 construction projects on Cape Coast Metropolis. 87 sets of questionnaires were received. Data were statistically analyzed using descriptive statistics that comprise frequencies, and mean scores and factor analysis was also used.

## 5 Findings and Discussion

This section focus on the factors influencing effective site layout plan on construction sites. Ten factors were identified as having a positive effect on site layout plans on construction sites in Ghana. Table 1 indicates the factors under consideration in this study.

**Table 1.** Factors influencing effective site layout plan on construction sites

Variable	Mean	Std. deviation
Nature of project	4.183908	0.842598
Choice of construction method	4.16092	0.819438
Availability of road or access and exist to the construction site	4.137931	0.878323
Access to utilities e.g. electricity, water, telecommunication	4.149425	0.86976
Information signs	4.114943	0.85488
Positioning of construction materials	4.114943	0.881664
Location of project	4.218391	0.813052
Plot size and shape	4.172414	0.780681
Adequate security measures put in place	4.08046	0.942762
Accommodation and Craft change-houses)	4.149425	0.800127

*Source:* Field data (2021).

As shown in Table 1, it can be observed that some indicator variables recorded high mean values considering a neutral point of 2.5. The location of the project recorded the highest mean score of 4.218391 which suggest that most respondents agreed with the factor. Other indicators with high mean value include; Nature of project, Choice of construction method, Availability of road or access and exist to the construction site, Access to utilities e.g. electricity, water, telecommunication, Positioning of Construction

Materials, Plot size and shape, Information signs, Adequate security measures put in place and Accommodation and Craft change-houses.

This however suggests that most of the respondents agreed with these factors. However, Information signs recorded the highest standard deviation (0.942762) depicting that it is the indicator with the most varied choices while variable Plot size and shape recorded the least standard deviation (0.780681) showing that it is the indicator with the most consistent choices considering the Likert scale.

### 5.1 Analysis of Kaiser-Meyer Olkin Measure of Sampling Adequacy

An overall KMO measure of 0.734 for this data indicates that the correlation matrix is appropriate for factor analysis. Since the value is greater than 0.6, it suggests that patterns of correlation are relatively compact and therefore factor analysis should yield distinct and reliable factors.

### 5.2 Analyses of Bartlett’s Test of Sphericity

**Table 2.** KMO and Bartlett’s test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.897
Bartlett’s test of sphericity	Approx. chi-square	2604.448
	df	153
	Sig.	.000

Table 2 shows Bartlett’s test of Sphericity data of 2604.448 and p-value was 0.000 with sample size  $n = 87$ , indicator variables  $p = 18$ . This shows that Bartlett’s test of Sphericity is sufficient for this data.

**Table 3.** Regression

	Estimate	Std. err	z-value	P(> z )	Std. lv	Std. all
Site layout plan ~ Effect (work efficiency)	0.424	0.063	6.696	0.000	0.671	0.671

Source: Field data

Table 3 indicates the p-value of 0.000 of site layout plan in influencing work efficiency suggested that site layout has a significant positive effect on work efficiency on construction sites. In Ghana’s construction industry, we may conclude that site layout has a favourable effect on efficiency.

## 6 Discussion

The findings of this study's analysis are consistent with existing theories. In the Ghanaian construction industry, site layout plans do have a significant positive impact on construction sites.

The study identified that the size and shape of the plot will influence the type and number of temporary facilities that can be accommodated on the site. The final site layout plan will be influenced to some extent by the project's location. This augments the findings of Archer (2016), Je-Chian Lin et al. (2013) and Whitman et al. (2021) which indicated that a location with limited space necessitates careful planning, with the most essential temporary facilities being located on-site. This is because, in this case, site space is a very valuable and limited resource. The layout plan might include all of the necessary amenities to aid in the construction process. The goal of providing workers with on-site housing is to assure their safety and well-being throughout the building project.

The study also identified the project's nature as a factor to consider when planning a site. This is consistent with the findings of Archer (2016) and Vaidya and Seetharaman (2011). Archer (2016) recommended that a centralised site plan system be considered for building projects (both residential and non-residential).

It was discovered that in the event of site layout planning, the choice of construction methods must be addressed as it is an important factor that must be addressed for effective site planning. This is because the choice of construction methods might minimize the need for some temporary facilities while simultaneously raising the necessity for others this is also confirmed the findings of Archer (2016).

## 7 Conclusion

This study revealed ten factors that influencing effective site layout plan on construction sites includes; location of the project, nature of the project, choice of construction method, availability of road or access and exist to the construction site, access to utilities, positioning of construction materials, plot size and shape, information signs, adequate security measures put in place and accommodation and craft change-houses. It was discovered that having a site layout plan had a positive impact on construction efficiency.

In the Ghanaian construction industry, site layout plans do have a significant positive impact on construction sites. The impacts were discovered to be linked to work efficiency. The size and shape of the plot will influence the type and number of temporary facilities that can be accommodated on the site. The final site layout plan will be influenced to some extent by the project's location. In the event of site layout planning, the choice of construction methods must be addressed. This is because the choice can minimize the need for some temporary facilities (TFs) while also allowing for the introduction of other temporary facilities on site.

Those in charge of overseeing construction projects should demand a site layout plan before the project begins; the availability of a site layout plan should be one of the factors used to select a contractor for any project in Ghana.

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