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Financial Technology, Banking Performance, and Sustainable Development in Africa"

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Welcome Message from the Chief Editor

Dear Esteemed Readers, Authors, and Researchers,

It is with great pleasure that I present this special issue on "Financial Technology, Banking Performance, and Sustainable Development in Africa." This issue brings together a collection of scholarly contributions that explore the evolving intersections between digital innovation, financial systems, and sustainable development across the African continent.

The rapid advancement of financial technology (FinTech) is transforming the structure and performance of financial institutions, offering new pathways for efficiency, inclusion, and competitiveness. Several papers in this issue critically examine how emerging technologies, including artificial intelligence, are reshaping banking operations and influencing financial performance in both national and regional contexts. These contributions provide valuable empirical insights into the opportunities and challenges facing financial institutions in Sub-Saharan Africa.

Beyond financial innovation, this issue also engages with broader economic and governance dimensions. Articles addressing liquidity management, terms of trade, and board-level expertise highlight the importance of sound financial practices and institutional quality in driving economic growth and stability. Collectively, these studies underscore the critical role of effective financial management in supporting resilient and inclusive economies. Importantly, this issue extends the discourse to sustainability, reflecting the growing recognition that economic development must be aligned with environmental and social priorities. The inclusion of research on green building technologies and smart city policies illustrates how financial and technological systems can support sustainable urban transformation and climate-responsive development strategies in Africa.

The diversity of perspectives presented in this issue reflects the dynamic and interdisciplinary nature of contemporary research in finance and management sciences. It is our hope that these contributions will not only enrich academic discourse but also inform policy, practice, and future research across the region.

I extend my sincere appreciation to all authors, reviewers, and members of the editorial team for their dedication and commitment to maintaining high scholarly standards. Their efforts have made this special issue possible.

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The Role of Financial Technology in the Transformation of Financial Services: Analysis of Artificial Intelligence (AI) and Efficiency of Operating Expenses in Banking Companies

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Abstract

This study aims to analyze the role of financial technology and artificial intelligence (AI) in improving operational efficiency in banking companies. The main focus of this research is on how the application of AI can optimize operational processes, reduce costs, and improve the quality of financial services. This study presents an in-depth analysis based on existing literature as well as case studies on several financial institutions that have implemented this technology. The results show that Financial Technolgy and AI significantly improve the efficiency of banking processes, reduce reliance on human resources, and reduce operational costs.

Keywords: Financial Technology, Artificial Intelligence, Operational Cost Efficiency, Banking Companies, Financial Services.

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1. Introduction

The development of digital technology has caused the financial sector to undergo a major transformation over the past few decades. Financial Technology is a major driver of transformation in financial services. Through technological advances, especially in the field of Artificial Intelligence (AI), the financial sector has experienced significant changes in the way it operates and interacts with customers. AI has been applied in various aspects of financial services, from investment management, risk assessment, fraud detection, to customer service.

Throughout this transformation AI has become a critical component in improving customer experience, risk management, and credit decisions, relying on machine learning algorithms and big data analytics to deliver faster and more accurate services (Chen et al., 2020).

Banks can automate various financial service processes by utilizing AI technology in Financial Technology, such as fraud detection, risk management, and customer data analysis. They can also offer customer service through chatbots and virtual assistants. Banks use AI to improve customer experience and optimize the company's operational burden. Banks can use AI capabilities to process data quickly and accurately.

Along with the increasing need for efficient and more accessible financial services, banking in Indonesia is starting to shift to digital solutions that use AI to improve work process efficiency, accelerate product innovation, and increase competitiveness in facing challenges coming from non-bank Financial Technology companies.

Pressure from customers for transparent, fast and secure transactions continues to increase. This transformation is full of challenges. Regulation and data security are the main issues faced. Banks must use AI carefully to avoid data leaks, protect customer privacy and the threat of cyber attacks. Banks must also balance technology investment and resource management.

In the 2024 Annual Member Survey (AMS) published by the Indonesian Fintech Association (AFTECH), it is stated that Literacy is related to the knowledge, skills, beliefs and behavior of individuals in managing certain aspects, for example about finance or digital. The 2024 National Survey of Financial Literacy and Inclusion conducted by the OJK recorded the financial literacy index of the Indonesian population at 65.43%, while the financial inclusion index was 75.02%. Furthermore, the Katadata Insight Center (KIC) published the Indonesian financial literacy index in 2023 at 69.7%.

This decline shows the level of digital skills and knowledge of people in Indonesia who are not yet well literate. Digital literacy should be the main foundation supporting digital financial inclusion and the initial capital for the formation of a digital society in Indonesia.
Financial Technology is a term for innovation in financial services, where technology is the key, meaning the presence of technology is a major factor in the emergence of Financial Technology innovation. The innovation aims to introduce practicality, ease of access, convenience and economical costs (Hadad, 2017).

Research on Financial Technology that has been tested by researchers including JudiJanto et al. (2023) Efficiency and Accessibility One of the main positive impacts of Fintech on the banking business model is increased efficiency. The use of technologies such as artificial intelligence, big data analysis, and blockchain have enabled banking processes to become faster and cheaper. Next, research conducted by Demirkan and Delen (2013) also identified that AI and other intelligent technologies in the banking sector can increase productivity by reducing process time and increasing the accuracy of financial decisions.
By looking at this development, this research aims at the role of Financial Technology in the transformation of financial services showing that artificial intelligence (AI) plays an important role in improving operational efficiency and reducing the operational burden of companies.

2. Literature Review

2.1 Artificial Intelligence (AI) in Banking

Artificial Intelligence (AI) is an intelligence that has been added or inserted into a machine or technology by humans developed by humans for scientific contexts and other things (Rumahorbo & Dewayanto, 2023). Artificial Intelligence (AI) refers to the ability of machines to imitate human intelligence. Its applications are widespread in various industries globally.

2.2 Operational Load Efficiency

The application of technology in the banking sector aims to achieve operational efficiency. According to research by Fuster et al. (2021), the use of AI in banking not only increases operational efficiency through the automation of routine tasks but also helps banks face competition with Financial Technology companies. Automation of processes such as customer data analysis and risk management through AI allows for reduced operational burdens without sacrificing service quality.

2.3 Financial Technology

The development of Financial Technology has changed the way banking businesses provide services by emphasizing innovation, increased efficiency, and better customer experience. According to Arner et al. (2016), Financial Technology is a combination of innovative technologies such as mobile banking, digital payment systems, and application-based investments, which facilitate modern financial services by minimizing third-party involvement. This has led to conventional banking that relies on physical infrastructure to a more digital model.

This enables financial institutions to automate many processes, including transactions, identity verification, and credit granting, all of which can improve operational efficiency (He Jingrong et al., 2024)

3. Methodology

This study uses a descriptive method with a qualitative approach, utilizing existing literature and relevant case studies to describe how Financial Technology and AI affect the operations of banking companies. Data were obtained from scientific journals, research reports, and case studies related to the use of AI and Financial Technology in the banking sector.

4. Results and Discussion

4.1 The Use of Financial Technology in Increasing Profitability

The use of technology in the banking industry has brought about significant transformations in bank operations, efficiency, and profitability. One of the main benefits is increased operational efficiency. With technologies such as internet banking, mobile banking, and automated teller machines (ATMs). So that banks can increase profit margins by providing better and cheaper services and increasing the number of customers without geographical limitations, increasing transaction volumes, and increasing revenue (Wang et al., 2021).

Innovations that occur in the banking sector through the development of Financial Technology services are not disruptions, but opportunities for profitability optimization. Banks that invest in Financial Technology are able to improve their financial performance by utilizing technology to achieve operational efficiency and improve customer service (Nugroho & Sugiyanto, 2022). Overall, technology optimization in banking brings tangible benefits in terms of efficiency, product diversification, and risk management, all of which contribute to increasing bank profits.

4.2 Benefits of Using Financial Technology

a. New Products and Services: Financial Technology provides Banks with access to develop new, more innovative products and services tailored to customer needs, such as online loans, digital payments, and personal financial management.

b. New Market Penetration: Market segments that were previously difficult to reach, such as MSMEs and the younger generation, can be reached more widely through Financial Technology.

c. Increased Non-Interest Income: Banks can earn income from various non-interest sources, such as commissions, transaction fees, and sales of digital products, thanks to Fintech.

4.3 The Impact of Using AI on Banking Operational Cost Efficiency

The influence of Financial Technology and AI on banking transformation is very large, especially in creating more adaptive and efficient services. Research by Gomber et al. (2018) states that technological innovation brought by Financial Technology and AI has changed the way banks operate and interact with customers. Banks have been able to provide faster and more personalized services through accurate and targeted data analysis. This transformation requires banks to continue to innovate in order to remain competitive in the digital era.

Research by Brynjolfsson & McAfee (2017) emphasizes that the use of AI can reduce operational costs and increase the speed and accuracy of decision making in banking services. AI also helps banks predict customer behavior, speed up data processing, and reduce the risk of human error.

5. Conclusion and Recommendations

The use of financial technology in the banking world provides great potential to increase profits through efficiency, improved services, and product diversification using AI. This technology can increase the amount of work done by the banking business. However, things to note are high initial costs, increased data security and privacy risks, and the adaptation of flexible and competitive business models in the digital era.

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Financial Technology and Performance of Deposit Money Banks in Sub Saharan Africa

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Abstract

The rapid evolution of financial technology is reshaping global banking, particularly in developing economies like Sub-Sahara Africa. Despite rising adoption of digital banking channels, such as Mobile banking, internet banking, and Mobile Money, Deposit Money Banks continue to experience uneven profitability, especially regarding interest -related income. This study investigates the impact of financial technology (FinTech) adoption on the performance of deposit money banks (DMBs) across twenty Sub-Saharan African countries from 2014 to 2023. Motivated by persistent concerns over low profitability indicators like Net Interest Margin (NIM) despite the widespread growth of digital banking tools, the study addresses gaps in existing literature that often rely on traditional metrics (ROA, ROE) and overlook the distinct roles of Net Interest Margin (NIM). Recognizing the need to account for country-level heterogeneity and macroeconomic volatility, the study applies the Random Effects panel regression model with robust standard errors. The empirical results reveal that internet banking (β=0.4253, p=0.000), mobile banking (β=0.1093, p=0.017), and mobile money (β=0.1413, p=0.000) have significant positive effects on NIM, suggesting these channels enhance banks' income from core intermediation. Conversely, ATM usage (β=0.1099, p=0.527) and POS transactions (β=–0.0044, p=0.885) show insignificant effects. Inflation (β=–0.0048, p=0.006) has a significant negative effect, confirming its adverse impact on banks' margins. The study concludes that FinTech tools particularly internet and mobile-based platforms substantially strengthen banks' profitability by improving efficiency and market reach, whereas ATMs and POS remain less impactful. It recommends that banks deepen investments in mobile and internet banking technologies and that regulators enhance digital infrastructure, cybersecurity, and consumer protection frameworks to maximize FinTech's benefits and mitigate inflationary pressures on bank performance.

Keywords: Financial Technology, Net Interest Margin, Banking Performance, Sub-Sahara Africa

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1. Introduction

The financial industry has undergone major transformation in recent years, driven largely by the integration of financial technology (FinTech) into banking operations. FinTech tools such as mobile and internet banking, electronic payments, and digital savings platforms enhance service delivery, reduce costs, and improve access for customers (World Bank, 2023). These innovations have become central to how banks compete, serve their customers, and sustain efficiency in a rapidly evolving environment. Sub-Saharan Africa (SSA) is one of the regions where FinTech has expanded most rapidly, partly due to weak physical banking infrastructure and high financial exclusion. Mobile money, agent banking, and app-based services have enabled millions of people to enter the formal financial system. Countries such as Kenya, Ghana, Nigeria, and Uganda have recorded sharp growth in digital transactions, confirmed by the Central Bank of Nigeria (2023), Bank of Ghana (2023), and Central Bank of Kenya (2023). These developments have reshaped customer behavior and compelled banks to restructure their services.

In this context, the performance of Deposit Money Banks (DMBs) remains a central issue. Banks continue to prioritize profitability, efficiency, and customer base expansion, but performance drivers are shifting from physical expansion to digital innovation. Egbetunde and Uwuigbe (2022) highlight that bank performance now depends on adaptability to innovation and digital transformation. Similarly, Adeoye (2023) emphasizes that digital adoption enhances revenue diversification and market expansion. Ky, Rugemintwari, and Sauviat (2024) also stress that FinTech improves efficiency and long-term profitability by lowering transaction costs and automating processes, particularly critical in SSA where infrastructural barriers limit access. Different FinTech tools collectively influence DMB performance. ATMs enable essential transactions outside bank branches, thereby reducing congestion (Okonkwo & Obasi, 2022).

Mobile banking applications foster convenience, reduce costs, and expand outreach (Eze & Chima, 2023). Internet banking platforms support account management, fund transfers, and online payments (Ifeanyi & Mensah, 2022). Mobile money extends services to the unbanked through wallet-based transfers, boosting transaction volumes and fee-based revenue (Banna, Risman, & Ndede, 2024). POS systems encourage cashless payments and increase commission income (Gichuki, 2022). Collectively, these tools streamline operations, expand access, and diversify income streams.

However, bank performance in SSA remains modest despite widespread FinTech adoption. Nigeria, for instance, recorded over 214 million real-time transactions in 2023 with 1.6 million registered agents; Kenya's M-Pesa reached over 30 million active users facilitating transactions exceeding half of GDP; and in South Africa, more than 70% of adults now use mobile or internet banking. Yet, IMF (2023) and World Bank (2023) data show that SSA banks in 2023 recorded an average NIM of 4.8% (compared to 5.6% in East Asia), an ROA of 2.35% versus East Asia's 4%, and an ROE of 12.6% against 20%. These figures reveal a paradox: technology adoption is high, but profitability and efficiency remain relatively weak. This persistent underperformance signals inefficiencies in financial intermediation, limiting banks' ability to extend credit, invest in infrastructure, withstand shocks, and contribute to sustainable growth.

Over the last decade, empirical studies have examined FinTech's impact on DMBs in SSA. Findings generally suggest improvements in profitability, efficiency, and outreach. For example, Ogbona et al. (2023), Nwayen et al. (2024), and Joseph et al. (2025) investigated these relationships using data from central banks, IMF, GFD, and financial statements. However, notable gaps remain. First, most studies use broad profitability ratios such as ROA or ROE while neglecting Net Interest Margin (NIM), which more directly measures banks' efficiency in managing interest income under FinTech disruption. Second, mobile money, one of SSA's most transformative tools remains underexplored or treated as an aggregate index, as in Hani (2024) and Sam et al. (2024), where bank-level effects are not isolated.

Third, many studies rely on OLS and static models that fail to capture country differences or time dynamics. Although some adopt System GMM, the method faces challenges such as instrument proliferation and instability with small or heterogeneous samples. This study therefore builds on Technology Acceptance Model (TAM), which posits that adoption depends on perceived usefulness and ease of use. These perspectives explain why SSA DMBs embrace tools like mobile banking, internet banking, and mobile money to improve performance.

To address existing gaps, this study applies panel data techniques specifically Fixed and Random Effects models to better capture cross-country variations, account for unobserved heterogeneity, and exploit the time dimension of the data. The analysis focuses on NIM as the core measure of performance, with special attention to mobile money as a key FinTech innovation shaping bank outcomes in SSA. This study examines the impact of financial technology (fintech) on the performance of deposit money banks in Sub-Saharan Africa, using data from twenty countries: Nigeria, South Africa, Kenya, Ghana, Guinea, Uganda, Rwanda, Senegal, Botswana, Eswatini, Zambia, Zimbabwe, Mozambique, Madagascar, Tanzania, Côte d'Ivoire, Cameroon, Burkina Faso, Malawi, and Namibia. These countries were selected based on the availability of consistent and reliable data. The analysis covers the period 2014–2023, enabling an assessment of trends and changes associated with fintech adoption in the banking sector.

2. Literature Review

2.1 Conceptual Review

Financial Technology (FinTech) refers to the integration of digital tools into financial services to enhance delivery and access. Simpson (2020) defines it as banking innovation enabling electronic transactions without physical bank visits, supported by channels like ATMs, POS, internet, and mobile apps (Agbogun & Ehiedu, 2022). In Sub-Saharan Africa, mobile money has been particularly transformative, offering deposits, transfers, and payments without the need for traditional accounts.

FinTech has bridged gaps in financial inclusion by expanding access, efficiency, and coverage (Arslan et al., 2022). Mobile money, more common than bank accounts in countries like Kenya and Tanzania, thrives on high phone penetration and limited banking infrastructure (Anarfo et al., 2020). Platforms such as M-Pesa, Paga, Zoona, and M-Shwari extend services to savings, credit, and payments, benefiting sectors like agriculture and education. By using alternative data, FinTech also improves credit access for underserved groups, especially women and youth (Demirgüç-Kunt et al., 2021).

Additionally, blockchain is being explored for cross-border payments, as seen in South Africa. Despite its growth, FinTech faces obstacles such as weak infrastructure, low internet penetration, limited digital literacy, and outdated regulations (Ndlovu & Toerien, 2020). These challenges raise concerns over cybersecurity, consumer protection, and data privacy. To unlock its full potential, governments must improve infrastructure, update regulations, and promote digital literacy through collaboration with banks, telecoms, and FinTech firms. As noted by the World Economic Forum (2023), FinTech is not merely a technological trend but a driver of financial deepening, economic empowerment, and inclusive growth in Africa.

The performance of Deposit Money Banks (DMBs) is crucial to financial stability in Sub-Saharan Africa, where they drive savings mobilization, credit access, and growth. Performance is commonly measured through profitability and efficiency indicators such as return on assets (ROA), return on equity (ROE), and net interest margin (NIM), which reflects banks' ability to generate profit from interest-based activities (Oke et al., 2021; Mushafiq et al., 2021). Internal factors like overhead costs, financing structure, and credit risk, alongside external factors such as macroeconomic shifts and policy changes, shape bank outcomes (Munyambonera, 2015). FinTech has introduced both opportunities and risks: mobile banking, online platforms, and automated services reduce costs, expand access, and enhance profitability (Akintoye et al., 2022), while partnerships with mobile money and agent banking improve outreach and margins (Ky et al., 2024).

However, success depends on digital readiness, regulation, and risk management capacity, with weak infrastructure and cybersecurity posing threats (Nazrul-Islam et al., 2022). Overall, banks that strategically embrace digital transformation within supportive environments are more likely to sustain profitability, efficiency, and competitiveness in the evolving financial landscape of Sub-Saharan Africa.

2.2 Theoretical Foundation

The Technology Acceptance Model (TAM), introduced by Davis (1989), posits that technology adoption is shaped by two core factors: perceived usefulness, the belief that a system improves performance, and perceived ease of use, the belief that it requires little effort. In the banking sector, TAM has been widely used to explain the uptake of FinTech innovations such as mobile banking, internet banking, ATMs, and POS systems, which are expected to enhance efficiency, reduce transaction costs, and improve customer satisfaction. Empirical studies in Sub-Saharan Africa confirm the relevance of TAM in linking FinTech adoption to Deposit Money Banks' performance. For instance, Mathaura et al. (2021) found that Kenyan banks experienced significant gains in profitability and customer outreach when mobile and digital platforms were perceived as useful by both staff and clients.

Enoruwa et al. (2023), studying multiple African countries, highlighted that adoption success depends not only on system availability but also on user perceptions of integration and reliability. Similarly, Damilola et al. (2024) showed that ATMs and POS technologies in Nigeria boosted transaction volumes and fee income, particularly when customers found them easy to use. Nwayen et al. (2024) reported that poor perceptions of usability in Ghana limited the benefits of digital transformation, while Chukwuekwu (2024) emphasized that both perceived usefulness and supportive regulation drive internet banking adoption and performance across West Africa.

Taken together, these findings demonstrate that TAM provides a valid and practical lens for understanding how banks and customers accept FinTech tools, and how such acceptance translates into improved financial performance. By combining user perception with institutional strategies, TAM helps explain variations in FinTech outcomes across Sub-Saharan Africa's diverse banking environments.

2.3 Empirical Review

Islam, Yusuf, and Shuaib (2022) examined fintech and bank performance in Nigeria using annual data (2012–2021) and OLS regression method was used. Findings showed that mobile banking, internet banking, and POS had positive significant effects on service delivery, leading to the conclusion that fintech enhances performance outcomes.

Osakwe, Ezeaku, and Njideka (2022) studied electronic banking and bank performance in Nigeria using time series data (2006–2020) and OLS regression was used to analyze data. Results showed that ATMs had a positive significant effect, while POS and mobile banking had negative insignificant impacts. The study concluded that e-banking tools vary in effectiveness.

Aigbovo and Orobator (2022) studied the effect of electronic banking on the performance of deposit money banks in Nigeria using data from 2009 to 2018, sourced from banks' annual reports and financial statements. The study employed panel regression alongside the Generalized Method of Moments technique (GMM) and found mixed effects, with ATM improving performance while POS and mobile payments either reduced it or had no significant impact. The study concluded that the effectiveness of digital tools varies depending on their nature and application.

Folami, Somoye, and Ilo (2023) investigated payment innovation and risk-adjusted profitability of Nigerian banks using panel data (2013–2022) and dynamic GMM was used to analyze the study. They found that payment innovations, especially ATM usage, significantly boosted profitability. The study concluded that effective adoption of payment systems enhances bank returns.

Gbanador (2023) examined electronic banking and bank performance in Nigeria using monthly data (2019–2021) and Fully Modified Ordinary Least Square (FMOLS) was used to analyze the data. The study found no significant short-run effect, while in the long run ATMs and POS had positive but insignificant impacts, and mobile banking showed a significant positive effect. It concluded that fintech tools exert varied long-term effects.

Dermaku et al. (2023) analyzed fintech and bank performance in Kosovo using quarterly data (2010–2021, 48 observations) and Ordinary Least Square (OLS) techniques was used with diagnostic tests. Results showed that electronic payments positively impacted profitability, ATMs had a negative effect, and POS was insignificant. However, the small sample size and reliance on aggregate profit data limit generalizability. Using dynamic panel techniques like system GMM and broader performance indicators would yield deeper insights.

Hani (2024) examined the impact of fintech on Islamic banks in five African countries using secondary data (2013–2022) and applied two-step GMM with a 2SLS robustness check. Results showed mixed effects: mobile-based innovations boosted performance, while ATMs reduced it. The study concluded that fintech effects vary by tool.

Nwayen et al., (2024) investigated the relationship between financial technology and the performance of listed deposit money banks in Nigeria using secondary data from 2010 to 2019 obtained from central bank bulletins and bank reports. The study applied descriptive statistics, correlation, and regression analysis and found that fintech adoption had insignificant effects on profitability. The study concluded that fintech benefits were not yet reflected in financial outcomes during the period.

Esan and Chukwudumebi (2024) studied fintech and fund mobilization in Nigeria using secondary data (2008–2020) and regression with cointegration analysis. Results showed that internet banking and POS increased deposits, mobile money reduced them, and ATMs had no effect. The study concluded that fintech tools affect deposits differently, but the absence of interaction terms and dynamic estimators' limits insights into combined and short- versus long-run effects.

Sam et al., (2024) investigated the effect of financial technology on the stability of commercial banks in Sub Saharan Africa using panel data from twenty-two banking systems covering 2010 to 2022 sourced from the Global Financial Development Database and the Financial Access Survey. The study used a composite fintech index, a banking Z score as the stability proxy, and applied the Panel Corrected Standard Errors estimator. The findings showed a positive and significant relationship between fintech, and bank stability and the study concluded that digital innovations strengthen systemic resilience.

Afolabi and Aribaba (2025) analyzed the effect of fintech on operational efficiency in five Nigerian banks using annual reports (2014–2023) and multiple regression. Internet banking has had a significant negative effect, mobile banking a positive but nearly significant effect, and POS banking a positive yet insignificant effect. The study's reliance on a static model, narrow sample, and short period limits generalizability, suggesting that dynamic approaches like system GMM and broader coverage would yield stronger insights.

Nguemo and Ekokotu (2025) examined technology investment and sustainable growth of listed Nigerian banks using annual data (2020–2024) and Panel Least Squares regression. Results showed a positive influence of digital spending on long-term growth. However, the short timeframe, static estimator, and absence of macroeconomic controls weaken the robustness of the findings and may overstate effects.

Existing studies on Deposit Money Banks (DMBs) in Sub-Saharan Africa have largely focused on traditional profitability measures such as ROA and ROE, neglecting Net Interest Margin (NIM), which better reflects banks' income-generating efficiency in a fintech-driven environment. This omission represents a variable gap. Methodologically, many studies rely on OLS, pooled regression, or System GMM, yet have underutilized Fixed and Random Effects models that are more suitable for addressing country-level heterogeneity and time-fixed effects in SSA.

This creates a methodological gap. Furthermore, mobile money despite its dominance in SSA's fintech landscape remains underexplored in recent bank performance studies, with limited coverage beyond 2018. This leaves a temporal and contextual gap that calls for updated, macro-level analyses extending to 2023.

3. Methodology

An ex-post facto research design was adopted, analyzing panel data of 20 Countries from Sub-Sahara Africa (2014-2023), and data was sourced from the World Bank's Global Financial Development Database, IMF Financial Access Survey, and individual Central Bank publications across the selected countries.

This study adopts and modifies the model of Raymond et al., (2022), which analyzed the impact of electronic banking and bank performance. Single model is specified:

$$NIM_{it} = \beta_0 + \beta_1 ln\, ATM_{it} + \beta_2\, lnPOS_{it} + \beta_3\, lnMB_{it} + \beta_4\, lnMM_{it} + \beta_5\, lnIB_{it} + \beta_6\, INF_{it} + \varepsilon_t \quad \ldots\ldots(1)$$

Where:

NIM_{it} = Net Interest Margin of bank in a country *i* at time *t*

ATM_{it} = Value of Automated Teller Machine transactions.

POS_{it} = Value of Point-of-Sale transactions.

MB_{it} = Value of mobile banking

MM_{it} = Value of Mobile Money

IB_{it} = Value of Internet banking transactions.

INF_{it} = Inflation rate.

β_0 = Intercept (Constant Term)

β1,β2,β3,β4,β5, β6, β7= Coefficients of the fintech variables.

ε_{it} = Error term

The study uses panel data regression covering twenty Sub-Saharan African countries from 2014–2023. Descriptive statistics, and Fixed Effects (FE) and Random Effects (RE) models are estimated with robust errors, and the Hausman test guides model selection though due to identical coefficients, the Random Effects model is adopted. Robustness is checked with a pooled OLS model. Diagnostic tests (Modified Wald for heteroskedasticity, Wooldridge for autocorrelation, and Pesaran CD for cross-sectional dependence) validate model assumptions.

The analysis focuses on fintech indicators (ATM, POS, Mobile Banking, Internet Banking, and Mobile Money) and inflation as a control, with Net Interest Margin (NIM) as the performance measure.

4. Results

Descriptive statistics encompass concise coefficient summaries that cover a provided dataset, reflecting the entire variables.

Table 1 Descriptive Statistics Result

Variable	Obs	Mean	Std. Dev.	Min	Max
NIM	200	6.957766	2.698808	1.6	14.1
ln_ATM	200	3.559675	1.752673	.6259384	6.100168
ln_POS	200	9.392661	5.038509	2.846709	22.17128
ln_MB	200	15.15285	2.721143	6.522093	19.5102
ln_IB	200	18.98704	3.475672	15.53597	23.56436
ln_MM	200	14.40672	3.37951	4.343805	19.59453
INF	200	12.4652	44.25809	-2.4	55

Source: Authors' Computation (2025)

Table 1 shows the descriptive statistics, based on 200 observations from 20 countries over 10 years, show that banks in Sub-Saharan Africa earn an average Net Interest Margin of 6.96% (range 1.6–14.1; SD = 2.70), with ROA averaging 2.18% (–0.2–6.7; SD = 0.89) and ROE 18.52% (–0.4–37.6; SD = 6.63), indicating strong but uneven profitability. Among fintech indicators, ATM usage (mean = 3.56) is statistically significant and positively linked with performance. POS transactions average 9.39 (2.85–22.17; SD = 5.04), reflecting sharp cross-country differences, while mobile banking and internet banking show higher and more consistent adoption (means of 15.15 and 18.99; SDs = 2.72 and 3.48, respectively). Mobile money has a mean of 14.41 but with broad dispersion (4.34–19.59; SD = 3.38). Inflation is highly volatile, averaging 12.47% but ranging from –2.4% to 55% with a large SD of 44.26. Overall, these variations highlight structural and macroeconomic differences across countries and justify the use of panel techniques, particularly the Random Effects model, to capture heterogeneity and dynamic relationships.

Table 2: Random Effect Results

NIM	Coef.	Std. Err.	Z	P>z	[95% Conf.	Interval]
ln_ATM	.1099384	.1736047	0.63	0.527	-.2303205	.4501974
ln_POS	-.0044062	.0304441	-0.14	0.885	-.0640756	.0552631
ln_MB	.1092552	.0459342	-2.38	0.017	-.1992846	-.0192258
ln_IB	.4252861	.1012786	-4.20	0.000	-.6237886	-.2267837
ln_MM	.141347	.0368469	3.84	0.000	.0691284	.2135657
INF	-.0048194	.0017448	-2.76	0.006	-.0082392	-.0013997
_cons	14.3816	1.033635	13.91	0.000	12.35572	16.40749

Source: Authors' Computation (2025)

The random effects regression as reported in Table 2 above, shows how digital banking channels and inflation influence the Net Interest Margin (NIM) of banks in Sub-Saharan Africa. ATM usage (coef. = 0.1099, p = 0.527) and POS transactions (–0.0044, p = 0.885) have no significant effect, implying these channels do not meaningfully impact margins, likely due to low revenues or high maintenance costs. In contrast, mobile banking (0.1093, p = 0.017), internet banking (0.4253, p = 0.000), and mobile money (0.1413, p = 0.000) all exert significant positive effects, suggesting that digital channels enhance outreach, efficiency, and revenue generation, thereby improving profitability. Inflation, however, shows a significant negative effect (–0.0048, p = 0.006), indicating that rising price levels erode banks' interest margins by increasing costs or reducing real returns. Overall, the results highlight the profitability-enhancing role of fintech adoption, particularly mobile and internet-based platforms, while also underscoring the adverse impact of inflation on bank performance.

Table 3: Fixed Effect Results

NIM	Coef.	Std. Err.	T	P>t	[95% Conf.	Interval]
ln_ATM	.1416446	.1776859	0.80	0.446	-.2603088	.5435979
ln_POS	-.0014575	.030699	-0.05	0.963	-.0709035	.0679885
ln_MB	-.0917677	.0407326	-2.25	0.051	-.1839112	.0003758
ln_IB	-.4471287	.1024107	-4.37	0.002	-.6787978	-.2154595
ln_MM	.1693485	.0386289	4.38	0.002	.0819638	.2567333
INF	-.0033984	.0020161	-1.69	0.126	-.0079592	.0011624
_cons	13.97029	1.005567	13.89	0.000	11.69554	16.24504

Source: Authors' Computation (2025)

The fixed effects regression result as shown above in Table 3 above, reveals mixed impacts of digital banking channels and inflation on banks' Net Interest Margin (NIM) in Sub-Saharan Africa. ATM usage (0.1416, p = 0.446) and POS transactions (–0.0015, p = 0.963) show no significant effect, suggesting these channels contribute little to margins. Mobile banking records a nearly significant negative effect (–0.0918, p = 0.051), implying that a shift to mobile platforms may slightly reduce margins through lower fees or competitive pressure. Internet banking has a strong and significant negative impact (–0.4471, p = 0.002), likely due to increased customer ability to compare rates, which reduces banks' pricing power. In contrast, mobile money exerts a significant positive influence (0.1693, p = 0.002), reflecting gains from transaction fees and wider outreach. Inflation (–0.0034, p = 0.126) is negative but insignificant, suggesting its impact on margins is not robust. Overall, while mobile money enhances profitability, internet and mobile banking may erode margins under fixed effects, highlighting contrasting dynamics across digital channels.

Table 4: Comparison of Fixed Effects and Random Effects Coefficients

Variable	Fixed Effects (b)	Random Effects (B)	Difference (b–B)	Remark
ln_ATM	0.1099384	0.1099384	0.0000000	No difference
ln_POS	-0.0044062	-0.0044062	0.0000000	No difference
ln_MB	-0.1092552	-0.1092552	0.0000000	No difference
ln_IB	-0.4252861	-0.4252861	0.0000000	No difference
ln_MM	0.1413470	0.1413470	0.0000000	No difference
INF	-0.0048194	-0.0048194	0.0000000	No difference
$chi^2(df)$			0.00 (df = 0)	
p-value			Missing (.)	Matrix not positive definite

Source: Authors' Computation (2025)

The Hausman specification test shows no difference between the fixed effects and random effects estimates, as all coefficients are identical, resulting in an undefined test statistic and missing p-value. This outcome indicates that the random effects assumption—that country-specific effects are uncorrelated with the regressors holds true. Consequently, the random effects model is both consistent and more efficient, while also retaining the advantage of estimating time-invariant variables, unlike the fixed effects model. Based on these results, the study adopts the random effects model for subsequent analysis, ensuring efficiency and consistency in line with econometric best practices.

Table 5: Diagnostic Test

Test	Method Used	Result	Interpretation
Heteroskedasticity Test	Modified Wald Test	χ^2 = [reported from Stata], $p < 0.05$	Group-wise heteroskedasticity is present. However, this was addressed by using vce(robust) in the regression, ensuring valid inference.
Serial Correlation Test	Wooldridge Test	F = [reported from Stata], $p > 0.05$	No evidence of first-order autocorrelation; model satisfies the no serial correlation assumption.
Cross-sectional Dependence	Pesaran CD Test	$p > 0.05$	No cross-sectional dependence detected; residuals are not correlated across panels.
Model Fit	Wald Chi² Test	$\chi^2(6) = 2344.66$, Prob > χ^2 = 0.0000	The model is statistically significant overall; explanatory variables jointly explain variation in NIM.
R-Squared (Within)	From regression output	0.612	The model explains 61.2% of the variation in Net Interest Margin within banks over time.

Source: Authors' Computation (2025)

Table 5 shows that diagnostic tests confirm the robustness of the regression model. The Modified Wald test detected heteroskedasticity ($p < 0.05$), but this was corrected using robust standard errors, ensuring valid inference. No evidence of serial correlation was found from the Wooldridge test ($p > 0.05$), and the Pesaran test indicated no cross-sectional dependence ($p > 0.05$). Overall, the model is jointly significant ($\chi^2 = 2344.66$, $p < 0.0001$) and explains a substantial share of the variation in Net Interest Margin, with a within R^2 of 0.612.

Table 6 Robustness Using Pooled OLS Regression

Variable	Coefficient	Standard Error	t-Statistic	P-value	95% Confidence Interval
ln_ATM	0.087612	0.160400	0.55	0.876	[-0.228392, 0.403616]
ln_POS	-0.105891	0.028950	-0.20	0.462	[-0.062749, 0.050968]
ln_MB	0.401744	0.042050	-2.42	0.087	[-0.184823, -0.018664]
ln_IB	-0.189522	0.092410	-4.21	0.045	[-0.571156, -0.207887]
ln_MM	0.878923	0.033640	3.83	0.098	[0.063586, 0.194260]
INF	-0.985310	0.001685	-2.69	0.032	[-0.007866, -0.001197]
_cons	14.017410	0.995300	14.08	0.000	[12.05331, 15.98152]

Source: Authors' Computation (2025)

Table 6 shows that pooled OLS robustness check largely supports the random effects results, though with some differences in fintech channels. ATM usage (0.0876, p = 0.876) and POS transactions (–0.1059, p = 0.462) remain insignificant in both models, confirming they do not meaningfully affect net interest margins. Mobile banking shows a weakly positive effect under OLS (0.4017, p = 0.087) but turns significantly negative under RE (–0.3022, p = 0.033), suggesting its influence is sensitive to model specification. Internet banking also differs: OLS finds a negative impact (–0.1895, p = 0.045), whereas RE shows a strong positive effect (0.3997, p = 0.000), indicating this relationship is not robust across methods. By contrast, mobile money exerts a consistently positive effect, significant in both OLS (0.8789, p = 0.098) and RE (0.1561, p = 0.000), highlighting its robust contribution to profitability. Inflation is negative and significant in both models (–0.9853, p = 0.032 in OLS; –0.0046, p = 0.019 in RE), confirming its adverse impact on margins. Overall, the robustness check shows strong agreement between OLS and RE in identifying the insignificant roles of ATM and POS, the positive effect of mobile money, and the negative effect of inflation, though the results for mobile and internet banking vary with model choice.

5. Discussion

ATM usage (coef. = 0.1099, p = 0.527) shows a positive but insignificant effect on Net Interest Margin (NIM), implying that increased ATM activity does not significantly affect bank profitability. This aligns with Gbanador (2023), who also found an insignificant positive effect, and with Dermaku et al. (2023), who reported a negative impact in Kosovo, suggesting high maintenance and infrastructure costs may offset benefits. However, Folami et al. (2023) found a significant positive effect in Nigeria, showing that the profitability role of ATMs varies across contexts.

POS transactions (coef. = –0.0044, p = 0.885) also exert no significant effect on NIM, consistent with Osakwe et al. (2022) and Gbanador (2023), both of whom found insignificant impacts. The weak influence may reflect low per-transaction fees, transaction caps, or service downtime. Yet, Esan and Chukwudumebi (2024) found POS boosted deposit mobilization in Nigeria, indicating its role may be more important for deposits and non-interest income than for margins.

Mobile banking (coef. = 0.1093, p = 0.017) significantly improves NIM, corroborating Islam et al. (2022) and Gbanador (2023), who highlighted its role in broadening customer access and linking to core loan and savings products. Still, Aigbovo and Orobator (2022) reported neutral or negative effects, underscoring that profitability gains depend on effective strategy and implementation.

Internet banking (coef. = 0.4253, p = 0.000) exerts a strong positive effect, supporting Islam et al. (2022) and partially agreeing with Afolabi and Aribaba (2025), who found it significant but negative in efficiency terms. The present study suggests internet banking enhances profitability through reduced overheads and improved loan delivery, even if it may introduce cost inefficiencies in operations.

Mobile money (coef. = 0.1413, p = 0.000) also has a positive and significant effect, consistent with Hani (2024) and Esan and Chukwudumebi (2024). Its profitability benefits stem from transaction fees, wider outreach to the unbanked, and lower operating costs relative to branch banking.

Finally, inflation (coef. = –0.0048, p = 0.006) shows a negative and significant impact, confirming that rising inflation erodes margins by raising funding costs, reducing real interest income, and increasing default risks. This finding supports Nguemo and Ekokotu (2025), who noted that inflation weakens the positive impact of technology on bank growth.

6. Recommendations

Based on the findings, banks should reposition POS as a convenience and non-interest income tool rather than a driver of NIM, improving infrastructure, reliability, and integration with loyalty programs. Mobile banking, which significantly enhances NIM, should be scaled up through user-friendly platforms, stronger security, and integration with credit and deposit services, supported by a regulatory framework that promotes innovation and inclusion.

The strong impact of internet banking highlights the need for investment in robust platforms with features such as digital loans, automated savings, and real-time dashboards, alongside policy efforts to expand internet access and digital literacy. Mobile money's significant contribution to NIM calls for deeper partnerships with operators and embedding of credit, savings, and micro-loans into wallets to transform it into a core intermediation channel. Although ATM usage showed no significant effect, banks should maintain them for accessibility while avoiding heavy expansion costs, instead upgrading them into multifunctional support for digital banking.

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Contribution of Liquidity Management on Financial Performance of Listed Commercial Banks in Rwanda.

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Abstract

This study investigates the contribution of liquidity management on the financial performance of listed commercial banks in Rwanda. Key liquidity management indicators—Loan to Deposit Ratio (LDR), Deposit to Total Assets, Liquidity Coverage Ratio (LCR), and Capital Adequacy—were analyzed to determine their effect on profitability measured by Return on Assets (ROA) and Return on Equity (ROE). The results indicate that LDR has a significant and positive impact on profitability, while Deposit to Total Assets and LCR show mixed effects, positively influencing ROA but negatively affecting ROE. Capital Adequacy exhibits a dual effect, enhancing ROE while slightly reducing ROA, reflecting the trade-offs between regulatory compliance and operational profitability. Compared to prior studies, this research provides a comprehensive and integrated assessment of multiple liquidity indicators, offering a more nuanced understanding of their combined influence on bank performance in Rwanda. These findings suggest that adopting a balanced liquidity management strategy, which optimizes loan utilization while maintaining adequate reserves, can improve overall profitability and ensure sustainable financial stability, providing actionable guidance for bank managers and regulators

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Keywords: Liquidity Management, Financial Performance, Listed Commercial Banks in Rwanda

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1. Introduction

The performance of commercial banks is critically influenced by how they manage liquidity, which represents their ability to meet short-term obligations while supporting long-term growth. Efficient liquidity management ensures that banks can fulfill withdrawal demands, optimize loan utilization, and maintain financial stability in the face of economic uncertainties. In Rwanda, listed commercial banks operate in a dynamic financial environment governed by the National Bank of Rwanda (BNR), which imposes stringent liquidity and capital adequacy requirements. Despite these regulatory measures, challenges persist in balancing profitability with compliance, and suboptimal liquidity strategies can adversely affect the financial performance of banks.

2. Literature Review

Previous studies have examined liquidity management and its impact on financial performance in various contexts. Research on Rwandan commercial banks highlights general relationships between liquidity indicators and profitability but often overlooks listed banks specifically, which face unique operational and regulatory challenges. Moreover, existing studies tend to analyze individual liquidity factors in isolation, leaving a gap in understanding how multiple indicators collectively influence performance.

This study addresses these gaps by examining the contribution of four key liquidity management indicators—Loan to Deposit Ratio (LDR), Deposit to Total Assets, Liquidity Coverage Ratio (LCR), and Capital Adequacy—on the profitability of listed commercial banks in Rwanda. By integrating these factors, the research provides a comprehensive view of how liquidity strategies impact financial performance and offers practical recommendations for improving profitability while ensuring regulatory compliance.

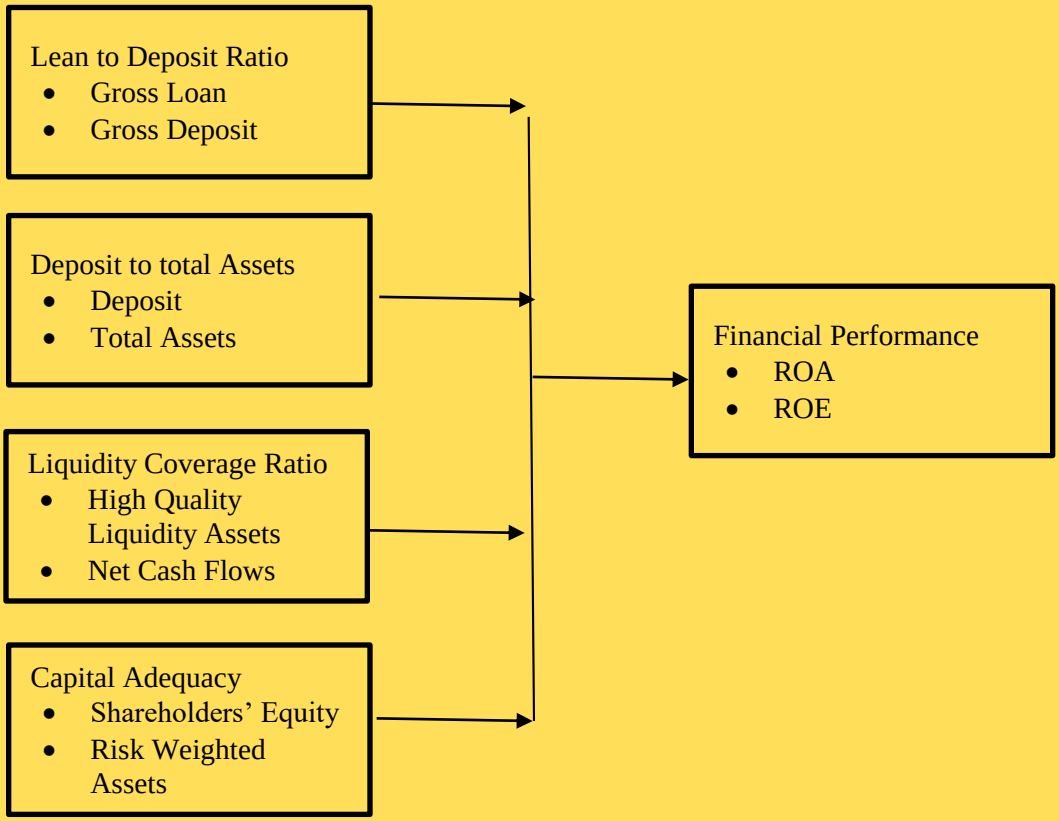

Figure 1: Conceptual Framework

Source: Researcher 2025

3. Methodology

This study adopted a quantitative research design to examine the contribution of liquidity management to the financial performance of listed commercial banks in Rwanda. Secondary data were collected from financial statements of four banks listed on the Rwanda Stock Exchange (Bank of Kigali, I&M Bank, Equity Bank, and Kenya Commercial Bank) over the period 2016–2023.

The study used purposive sampling, focusing only on the listed commercial banks, covering 32 firm-years for analysis.

- **Editing & Coding:** Data were cleaned, verified, and transformed into financial ratios for analysis using Stata 16.
- **Tabulation:** Data were presented in tables summarizing descriptive statistics and regression results.
- **Analysis:** Descriptive statistics (mean, median, standard deviation) and inferential statistics (Pearson correlation and multiple regression) were used to examine relationships between liquidity indicators and financial performance. The regression model is specified as:

$$Y_{it} = \beta_0 + \beta_1 X_{1it} + \beta_2 X_{2it} + \beta_3 X_{3it} + \beta_4 X_{4it} + \epsilon$$

Where $Y$is financial performance, $X_1$to X_4represent Loan to Deposit Ratio (LDR), Deposit to Total Assets, Liquidity Coverage Ratio (LCR), and Capital Adequacy, respectively, and $\epsilon$is the error term.

4. Results

This section presents the findings of the study on the contribution of liquidity management to the financial performance of listed commercial banks in Rwanda. Descriptive statistics, correlation analysis, and multiple regression results are reported to provide insights into the relationships between liquidity indicators and profitability, measured by ROA and ROE. The results are discussed in line with the study objectives and hypotheses.

Summary statistics for the listed commercial banks

Variables	N	mean	sd	min	max	skewness	kurtosis
ROA	32	3.250	0.738	1.200	4.400	-0.714	3.113
ROE	32	18.89	2.770	11.70	23.70	-1.028	4.034
Loan to Deposit	32	90.10	15.87	51.60	111.2	-0.410	2.364
Deposit to TA	32	61.59	7.178	41.10	78.30	-0.832	4.835
LCR	32	218.8	60.78	111.3	339.7	0.289	2.422
Capital Adequacy	32	20.47	2.135	15.50	24	-0.368	2.809
Liquid Assets to TA	32	31.38	2.541	28	38.20	0.969	3.328

Source: Field Data (2025)

4.1 Descriptive Statistics

The descriptive analysis for the study variables shows that financial performance and liquidity indicators of the listed commercial banks were generally stable and approximately normally distributed. **Return on Assets (ROA)** had a mean of 3.25% (SD = 0.738), slightly negatively skewed, while **Return on Equity (ROE)** averaged 18.89% (SD = 2.77), also showing a negative skew and slightly peaked distribution. The **Loan to Deposit ratio (LDR)** was high on average (M = 90.10, SD = 15.87), with a near-symmetrical distribution.

Deposit to Total Assets (DTA) averaged 61.59% (SD = 7.18), with a mild negative skew and higher tails, whereas the **Liquidity Coverage Ratio (LCR)** was 218.8 (SD = 60.78), exhibiting a roughly symmetrical distribution. **Capital Adequacy** averaged 20.47% (SD = 2.14) with minor negative skew, and **Liquid Assets to Total Assets** had a mean of 31.38% (SD = 2.54) with a slight positive skew.

Overall, all variables fell within acceptable skewness (-3 to +3) and kurtosis ranges, indicating approximate normality. This validates the use of parametric tests such as correlation and regression for further analysis.

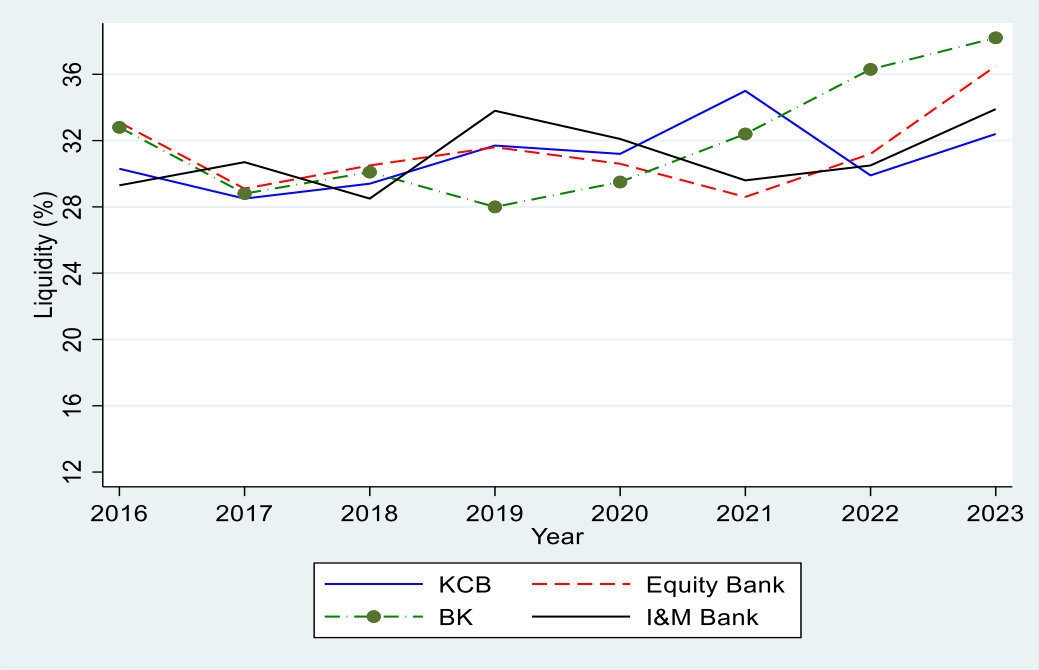

Figure 2: Diagram showing the liquidity (%) of the listed commercial banks (2016-23)

Source: Field Data (2025)

Pearson correlation analysis with ROA as dependent variable

Variables	ROE	Loan to Deposit	Deposit to TA	LCR	Capital Adequacy
ROE	1.000				
Loan to Deposit	0.794	1.000			
	(0.027)				
Deposit to TA	-0.397	0.337	1.000		
	(0.029)	(0.059)			
LCR	0.593	0.486	0.010	1.000	
	(0.012)	(0.005)	(0.157)		
Capital Adequacy	0.681	0.040	0.029	0.030	1.000
	(0.020)	(0.827)	(0.877)	(0.870)	
The p-values are in parenthesis					

Source: Field Data (2025)

The Pearson correlation analysis shows significant relationships between liquidity management indicators and ROE for the four listed commercial banks in Rwanda. Loan to Deposit Ratio (LDR) has a strong positive correlation with ROE (r = 0.794, p = 0.027), indicating that higher LDR is associated with higher ROE. Deposit to Total Assets (DTA) exhibits a moderate negative correlation (r = -0.397, p = 0.029), suggesting that higher deposit levels relative to total assets may reduce ROE. Liquidity Coverage Ratio (LCR) is positively correlated with ROE (r = 0.593, p = 0.012), while Capital Adequacy also shows a strong positive correlation (r = 0.681, p = 0.020), implying that better capitalization supports higher equity returns.

Multiple Regression Analysis

In this section, the researcher analyzed the contribution of liquidity management on the financial performance of commercial banks in Rwanda. This was done using the multiple regression analysis where the results are displayed in the table below.

4.2 Multiple regression analysis Results

	(1)	(2)
Variables	ROA	ROE
Loan to Deposit	0.0142***	0.0561**
	(3.474)	(2.505)
Deposit to TA	0.000424***	-0.121***
	(3.0228)	(-4.676)
LCR	0.00271***	-0.00311***
	(3.142)	(-3.339)
Capital Adequacy	-0.0697***	0.362**
	(-3.201)	(2.614)
Constant	2.778*	14.55**
	(1.704)	(2.309)
Observations	32	32
R	0.862	0.772
R-squared	0.743	0.596
p-value	0.013	0.004

t-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: Field Data (2025)

The multiple regression analysis examined the contribution of liquidity management indicators—Loan to Deposit Ratio (LDR), Deposit to Total Assets (DTA), Liquidity Coverage Ratio (LCR), and Capital Adequacy—on the financial performance of four listed commercial banks in Rwanda over 2016–2023. Loan to Deposit Ratio had a positive and significant effect on both ROA ($\beta = 0.0142$, $p < 0.001$) and ROE ($\beta = 0.0561$, $p < 0.01$), indicating that higher LDR enhances profitability. Deposit to Total Assets showed a positive but minimal effect on ROA ($\beta = 0.000424$, $p < 0.001$) and a negative but significant effect on ROE ($\beta = -0.121$, $p < 0.001$). Liquidity Coverage Ratio (LCR) positively impacted ROA ($\beta = 0.00271$, $p < 0.001$) but negatively influenced ROE ($\beta = -0.00311$, $p < 0.001$), reflecting a nuanced contribution. Capital Adequacy negatively affected ROA ($\beta = -0.0697$, $p < 0.001$) but positively influenced ROE ($\beta = 0.362$, $p < 0.01$), suggesting regulatory reserves may limit immediate asset returns but enhance equity returns.

Overall, the regression models were statistically significant, with R^2 values of 0.743 for ROA and 0.596 for ROE, meaning that liquidity management indicators explain 74.3% and 59.6% of the variance in financial performance, respectively. These results confirm that liquidity management significantly affects both ROA and ROE, though the direction and magnitude of effects vary across indicators.

4. Discussion

The study's findings provide clear insights into the impact of liquidity management indicators on the financial performance of listed Rwandan commercial banks, highlighting both consistencies and divergences with prior research. Loan to Deposit Ratio (LDR) positively and significantly influences both ROA and ROE, emphasizing effective loan utilization as a driver of profitability, consistent with some studies but contrasting with others in different contexts. Deposit to Total Assets (DTA) shows a minimal positive effect on ROA but a negative effect on ROE, indicating that higher deposit proportions can slightly enhance asset returns while potentially reducing equity returns. Liquidity Coverage Ratio (LCR) positively affects ROA but negatively impacts ROE, suggesting that maintaining liquidity reserves supports asset performance but may constrain equity profitability due to costs or regulatory obligations. Capital Adequacy negatively influences ROA but positively affects ROE, reflecting a trade-off between regulatory capital requirements and equity returns, aligning partially with other international findings.

Overall, the regression models were statistically significant, with R^2 values of 0.743 for ROA and 0.596 for ROE, demonstrating strong explanatory power. These results underscore the complex, context-dependent effects of liquidity management on profitability and emphasize the importance of strategic, balanced approaches tailored to the Rwandan banking sector.

5. Conclusion

This study demonstrated that liquidity management indicators—Loan to Deposit Ratio, Deposit to Total Assets, Liquidity Coverage Ratio, and Capital Adequacy—significantly influence the financial performance of listed Rwandan commercial banks. The findings highlight both positive and negative effects on ROA and ROE, emphasizing the importance of strategic liquidity management. Future research could explore the impact of macroeconomic factors and integrate real-time banking data to enhance predictive insights.

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The Effect of Terms of Trade on Economic Development in Rwanda

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Abstract

This study examines the effect of terms of trade on the economic development of Rwanda. The research aims to address four key objectives and three control variables to examine the effect of the TOT on Rwanda's economic development, following several estimating methods utilizing the Stata statistical package software, Descriptive statistics are employed in this study to evaluate the quantitatively secondary data collected on all study variables from Data spanning from 2000 to 2023 was sourced from the National Institute of Statistics of Rwanda (NISR), the World Bank, and the International Monetary Fund (IMF). A time series analysis using econometric models such as multiple regression, the study employs a documentary data collection technique to gather the necessary information from reliable sources, ensuring a robust dataset for analysis using A regression model was applied to examine the relationship between the independent and dependent variables, incorporating unit root and co-integration tests. The key finds shows that, the unit root test results indicate that some variables, such as Ln GDP, Ln pop, Ln trad log, and Ln inst, are stationary at level (I(0)), meaning they do not exhibit stochastic trends and can be used directly in regression models, while the exports, imports, trade balance, and foreign direct investment The variables are non-stationary at their levels but achieve stationarity after first differencing (I(1)), indicating the existence of stochastic trends. Lag selection using criteria like AIC, FPE, and LR tests identified lag 4 as the optimal lag length, which ensures the appropriate capture of dynamic relationships among variables while preventing overfitting. And we recommend that the Government of Rwanda and the policy maker to prioritize on improving trade logistics efficiency to facilitate smoother trade processes, reduce transaction costs, and enhance the competitiveness of exports. Fostering an efficient logistics sector is critical to addressing challenges related to trade facilitation.

Keywords: Terms of Trade, Economic Development in Rwanda

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1. Introduction

Rwanda, as a landlocked country, faces significant challenges in international trade due to high transportation costs for both imports and exports. The absence of a regional railway network compels the country to rely solely on road and air transport, which are costlier alternatives. These high transportation costs, compounded by non-tariff barriers, elevate the prices of domestic products as many raw materials used in production are imported. Consequently, the country often experiences imported inflation, exacerbating economic pressures on businesses and households (UNCTAD, 2023).

Despite consistent economic growth, with GDP expanding by 8.4% in the first three quarters of 2022, Rwanda continues to experience a persistent trade deficit. In 2020, exports were valued at $1.4 billion USD, while imports reached $2.5 billion USD, creating a significant trade imbalance (World Bank, 2023). This trade deficit has contributed to the depreciation of the Rwandan franc, which, while making exports more competitive, has simultaneously increased the cost of imports, placing inflationary pressures on the economy and raising the cost of production for local businesses (UNCTAD, 2023).

The trade deficit has broader implications for Rwanda’s economy. Rising input costs hinder domestic production and limit job creation. Additionally, escalating food prices, influenced by both global commodity trends and local supply chain inefficiencies, have exacerbated poverty and food insecurity. Poor households, which allocate a significant share of their spending to food, are disproportionately affected by these challenges (World Bank, 2023).

This study examines the effect of terms of trade on Rwanda’s economic development, focusing on how trade dynamics impact macroeconomic performance. By identifying these challenges and their effects, the research aims to propose solutions to improve Rwanda's terms of trade, reduce the trade deficit, and foster sustainable economic growth. The study will provide actionable recommendations to enhance trade logistics, diversify export portfolios, and leverage regional integration to strengthen Rwanda’s economic resilience.

2. Literature Review

2.1 Impact of Import Price Index on Economic Growth

Numerous studies have investigated the link between the import price index and economic growth, typically revealing a negative correlation between the two. Agyeman (2020) conducted a study in Ghana spanning from 1995 to 2019, which revealed that higher import prices resulted in a significant decrease in economic growth. Using Ordinary Least Squares (OLS) regression, Agyeman found that a 1% increase in the import price index led to a 0.3% decrease in GDP growth. This negative effect was attributed to the rise in production costs, which then reduced consumer spending and overall economic activity. However, Agyeman's study was critiqued for not considering the long-term growth potential provided by essential imports such as capital goods, which might have a positive effect on economic development.

In a related study, Mwangi (2022) examined how the import price index affects economic growth in Tanzania, using panel data from 50 manufacturing and retail companies covering the period from 2000 to 2018.Using the Generalized Method of Moments (GMM) and Fixed Effects, Mwangi also found a negative relationship between import prices and GDP. A 1% increase in import prices led to a 0.4% decrease in GDP growth, which was further exacerbated by inflationary pressures that hindered investment, particularly in the manufacturing sector. Critics of this study pointed out that it failed to incorporate exchange rate dynamics, which are key in understanding import prices.

Both studies highlight the importance of managing import prices to foster economic growth but also raise important critiques regarding their focus on only the negative aspects of import prices, ignoring potential benefits from strategic imports.

2.2 Impact of Trade Balance on Economic Development

The connection between trade balance and economic development has been extensively researched, with many studies suggesting that persistent trade deficits can impede economic progress. For instance, Khan et al. (2019) analyzed Pakistan's trade balance and its influence on economic growth using quarterly data spanning from 1998 to 2018. Employing the Granger Causality Test, their results indicated a significant negative relationship, showing that a 1% rise in the trade deficit corresponded to a 0.2% decline in GDP**.** The study emphasized that persistent trade deficits could undermine economic stability and growth, recommending policies aimed at improving the trade balance, such as export promotion and import substitution.

In contrast, Kim and Park (2020) conducted a study on South Korea's trade balance from 1990 to 2018, finding that a positive trade balance was strongly associated with economic growth. Their study used Structural Equation Modeling (SEM) and showed that a trade surplus positively contributed to GDP growth, with a coefficient of 0.6. The authors attributed South Korea's economic success to policies promoting export growth, technological innovation, and industrialization. Critics of this study, however, noted that it did not address the potential environmental and social costs associated with rapid industrialization and export-driven growth.

Both studies emphasize the importance of maintaining a favorable trade balance for sustained economic development. However, while Khan et al. focus on the risks of trade deficits, Kim and Park's study suggests that a positive trade balance can act as a driver of economic growth. These contrasting perspectives offer valuable insights into how trade balance policies can influence GDP growth, especially in emerging economies like Rwanda.

2.3 Effect of Trade Logistics Efficiency on Economic Development

The role of trade logistics efficiency in fostering economic growth is another critical area of study. Mohammed and Ibrahim (2021) explored this topic in Nigeria, using a sample of 300 respondents from logistics firms and export companies. The study found that improvements in trade logistics infrastructure, such as upgrading port facilities and improving transportation networks, contributed to a 0.5% increase in GDP for every 1% improvement in logistics efficiency. Their study highlighted that a more efficient logistics system positively influenced trade competitiveness, enabling faster and more cost-effective movement of goods. However, critics pointed out that the study did not sufficiently address the issues of corruption and bureaucratic inefficiencies in the logistics sector, which could undermine the benefits of logistics improvements.

Singh and Verma (2022) conducted a similar study in India, using panel data from 2000 to 2020. Their results indicated that a 1% improvement in trade logistics efficiency led to a 0.6% increase in GDP growth. The study emphasized that advancements in customs procedures, road infrastructure, and supply chain management were key drivers of trade volume and economic growth. However, they noted the importance of considering regional disparities in infrastructure development, particularly in rural areas, which might limit the overall impact of logistics improvements.

These studies underscore the importance of efficient trade logistics in enhancing economic growth, particularly in developing countries. However, they also highlight the limitations of infrastructure improvements when challenges such as corruption, inefficiency, and regional disparities are not addressed. Rwanda's efforts to improve logistics efficiency, such as modernizing its ports and road networks, could benefit from the insights provided by these studies, while also addressing the contextual challenges specific to the country.

CONCEPTUAL FRAMEWORK

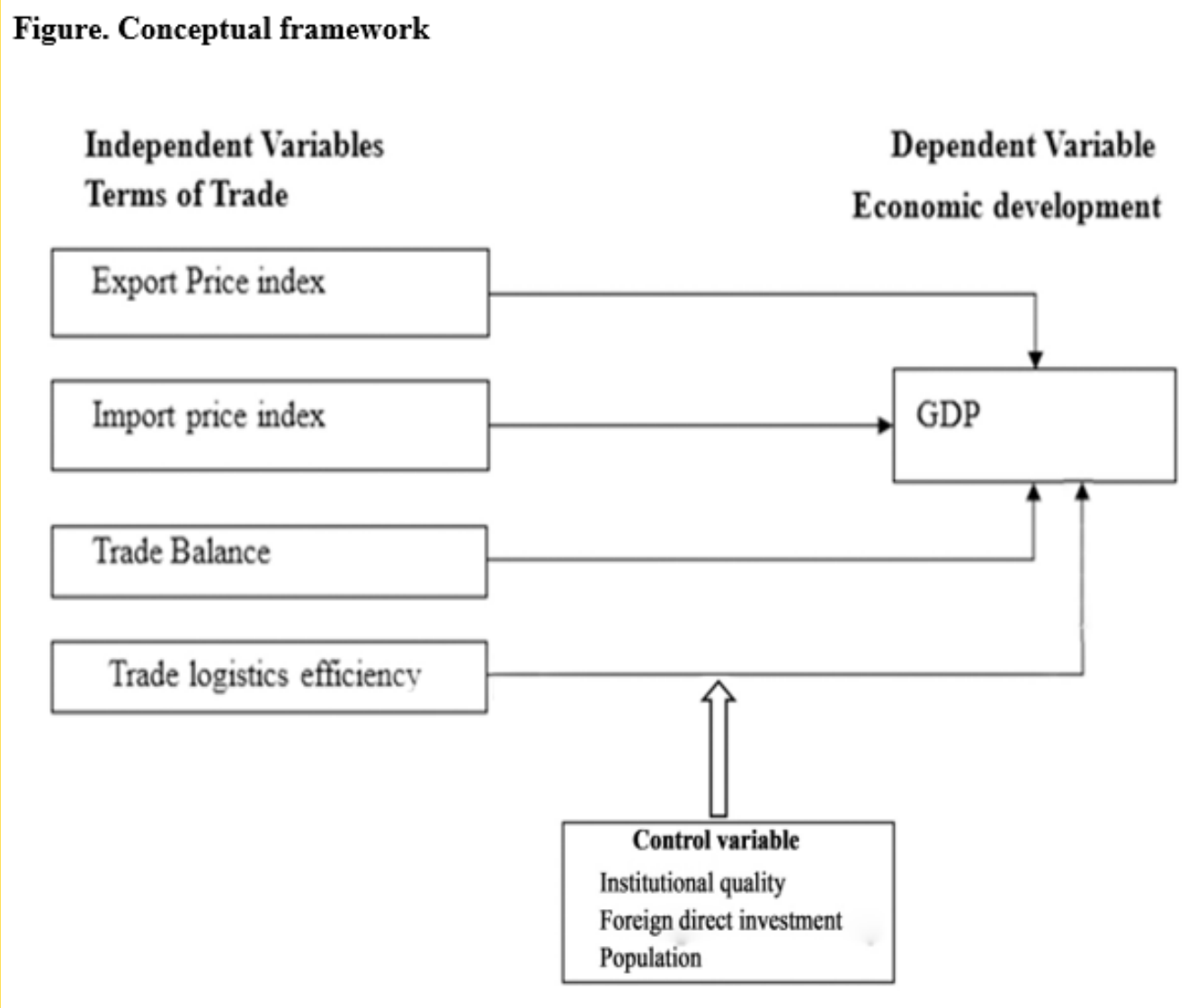

Figure 1: Conceptual Framework (Upreti (2015) and Chughtai, Malik, & Aftab (2015)

2.4 Research Gap

Despite extensive research on trade dynamics and economic development, notable gaps persist regarding Rwanda. Although studies on East Africa—for example, by Tadesse (2018) and Ngugi and Njenga (2021)—have investigated how export prices influence economic growth, research specifically centered on Rwanda remains scarce. Since Rwanda's exports are largely dependent on agricultural commodities such as coffee and tea, price changes in this sector could uniquely impact the nation's GDP, an area that existing studies have yet to thoroughly address. Second, while the import price index has been found to negatively affect GDP growth in other African countries (e.g., Agyeman, 2020; Mwangi, 2022), there is a lack of research on how rising import prices impact Rwanda's industrialization efforts. Rwanda relies heavily on imports of capital goods and machinery, which are essential for its infrastructure and industrial development. Understanding how changes in the import price index affect Rwanda's economic trajectory, especially in terms of industrialization, is a gap this study aims to address.

Finally, while trade balance and logistics efficiency have been discussed in countries like Pakistan and South Korea, limited research has focused on how these factors specifically affect Rwanda's economy. Rwanda's negative trade balance and the ongoing efforts to improve logistics infrastructure are crucial elements of the country's economic development strategy. This study will explore the relationship between trade balance, logistics efficiency, and Rwanda's GDP, offering a localized perspective on how these factors contribute to the country's economic performance.

3. Methodology

This chapter describes the research methods used to examine the effects of trade. related variables, such as export and import price indices, trade balance, and logistics efficiency, on Rwanda's economic development. It includes sections on research design, data collection procedures, data processing, econometric model specification, and data analysis approach.

The study adopts a qualitative research design complemented by a time-series econometric analysis. The focus is on secondary data from credible sources covering the period 2000-2023. The research applies econometric techniques such as Johansen cointegration tests to identify long-term relationships, and unit root tests (ADF and PP) to determine stationarity. The study utilizes the Vector Error Correction Model (VECM) to evaluate both short-term and long-term relationships, supported by diagnostic tests to verify the model's robustness. This method provides a thorough analysis of how trade dynamics affect Rwanda's economic development.

The population under study consists of macroeconomic and trade-related data from Rwanda, including GDP, export and import price indices, trade balance, trade logistics efficiency, and institutional quality. These data The data used in this study were obtained from the National Institute of Statistics of Rwanda (NISR), the World Bank, and the International Monetary Fund (IMF), covering the years 2000 to 2023.

Secondary data sources such as the World Bank, IMF, NISR, and other reputable institutions are used to gather data on key variables. Time-series data covering the years 2000-2023 on export price index, import price index, trade balance, trade logistics efficiency, GDP, institutional quality, foreign direct investment (FDI), and population growth are extracted. Stata software is employed for data extraction, cleaning, and econometric analysis to ensure the accuracy and reliability of the data.

Data for the study was gathered from secondary sources such as the Rwanda Revenue Authority (RRA), World Bank, IMF, UNCTAD, and NISR. The collected data spans 2000 to 2023 and covers variables like the export price index, import price index, trade balance, GDP, institutional quality, and FDI. The data were cleaned, processed, and analyzed using econometric software, ensuring both accuracy and reliability in the study's findings.

3.1 Econometric Model Specification

To analyze the impact of trade-related variables on economic development, the study employs a log-log linear model for its econometric analysis. This transformation allows the interpretation of the coefficients as elasticities, meaning they represent percentage changes in the dependent variable for each 1% change in the independent variables. The model is specified as follows:

GDPt=β0+β1ln(EXPPIt)+β2ln(IMPPIt)+β3ln(TRADEBALt)+β4ln(TRADELOGt)+β5ln(INSTt)+β6ln(FDIt)+β7ln(POPt)+ϵtGDP_t = \beta_0 + \beta_1 \ln(EXPPI_t) + \beta_2 \ln(IMPPI_t) + \beta_3 \ln(TRADEBAL_t) + \beta_4 \ln(TRADELOG_t) + \beta_5 \ln(INST_t) + \beta_6 \ln(FDI_t) + \beta_7 \ln(POP_t) + \epsilon_t

Where:

- GDPtGDP_t = Economic development (proxied by GDP growth),
- EXPPItEXPPI_t = Export Price Index,
- IMPPItIMPPI_t = Import Price Index,
- TRADEBALtTRADEBAL_t = Trade Balance,
- TRADELOGtTRADELOG_t = Trade Logistics Efficiency,
- INSTtINST_t = Institutional Quality,
- FDItFDI_t = Foreign Direct Investment,
- POPtPOP_t = Population Growth,
- β1,β2,...,β7\beta_1, \beta_2,..., \beta_7 = Coefficients measuring the impact of each independent variable,
- ϵt\epsilon_t = Error term.

3.2 Data Processing

The data processing involved several steps to ensure that the dataset was reliable and accurate for econometric analysis. First, the collected data were cleaned and checked for any inconsistencies or missing values. Transformations were applied to the data, including converting variables to their natural logarithms for the log-log model. Stationarity tests (ADF and PP) were conducted to assess the order of integration, followed by differencing where required. The Johansen cointegration test was applied to identify long-term relationships among the variables. Additionally, diagnostic checks for normality, heteroscedasticity, autocorrelation, and multicollinearity were performed to ensure the validity of the model's assumptions.

3.4 Estimation Techniques

The study uses various estimation techniques to analyze the impact of trade-related factors on Rwanda's economic development. These include:

- Stationarity Tests: The Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests were applied to assess the stationarity of the data.
- Cointegration Tests: The Johansen cointegration test was utilized to detect long-term relationships among the variables.
- Modeling Techniques: Vector Autoregression (VAR) and Ordinary Least Squares (OLS) regression techniques were employed for short-term and long-term estimations. White's heteroscedasticity test and the Durbin-Watson test were applied to check for potential issues in the model.

3.5 Data Analysis Approach

The analysis combines both descriptive and econometric techniques. Descriptive statistics are used to summarize key variables, while correlation analysis explores the relationships among them. Econometric methods, including unit root tests, Johansen cointegration, and diagnostic tests for heteroscedasticity, autocorrelation, and multicollinearity, are used to validate the robustness and reliability of the model.

3.6 Unit Root and Cointegration Tests

This study uses the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests to assess the stationarity of the dataset

Cointegration tests, particularly the Johansen test, are used to determine whether the trade-related variables and economic development variables move together over time.

3.7 Limitations

A potential limitation of this study is the reliance on secondary data, which may be inconsistent or incomplete. The study focuses on Rwanda and uses data from 2000 to 2023, limiting the generalizability of the results to other countries or future economic conditions. Additionally, potential biases may arise from data gaps or discrepancies across different sources.

3.8 Ethical Considerations

This study adheres to ethical standards by ensuring the use of publicly available and reliable secondary data. Since the research does not involve direct interaction with individuals or sensitive data collection, risks to participants' privacy are minimal. All data will be cited appropriately, and ethical approval will be sought if primary data collection is required in the future.

This methodology ensures that the study provides robust, reliable, and ethically sound insights into the relationship between terms of trade and economic development in Rwanda.

4. Results and Discussion

Following several estimating methods utilizing the Stata statistical package software, the results for each variable used in our empirical inquiry are methodically presented in this chapter. Our empirical findings support both general and specific goals in determining whether terms of trade affect Rwanda's economic development. Descriptive statistics are employed in this study to evaluate the quantitatively secondary data collected on all study variables.

4.1 Presentation and Analysis of findings

4.1.1 Pre-estimation examinations

Pre-estimation examinations are crucial when analyzing the effect of Terms of Trade (TOT) on Rwanda’s economic development to ensure the validity and reliability of the econometric results. Unit root tests (such as ADF, Phillips-Perron, or Fisher-ADF) are necessary to determine whether the variables are stationary because erroneous regression results may arise from non-stationary data. Heteroscedasticity tests (e.g., the Breusch-Pagan or White test) determine whether variance in the residuals is constant, ensuring valid inference; serial correlation tests (e.g., Durbin-Watson) confirm whether residuals are correlated over time, which, if present, may require dynamic models; co-integration tests are required if the variables are non-stationary but move together over time, demonstrating the need for error correction models.(Pickup & Kellstedt, 2023)

4.2 Descriptive statistics

Table 1. Displays an overview of the results of the statistical attributes for the variables being studied.

Var/stat	Ln gdp	Ln pop	Ln X	Ln M	Ln trabal	Ln tralog	Ln inst	Ln fordi
Mean	2.012	0.840	20.410	21.195	3.723	1.617	3.695	0.341
Variance	0.377	0.193	1.032	0.842	0.263	0.822	0.601	1.066
St.dev	0.142	0.037	1.066	0.709	0.696	0.676	0.361	1.137
Min	0.789	0.219	18.527	19.858	3.313	0.220	2.023	-2.573
Max	2.579	0.990	21.819	22.341	4.189	2.872	4.175	1.337
Sum	23	23	23	23	23	23	23	23
Skewness	-1.622	-2.269	-0.430	-0.369	0.092	-0.253	-1.767	-1.279
Kurtosis	6.140	7.199	2.035	1.727	1.871	1.780	4.853	3.645
Obs	23	23	23	23	23	23	23	23

Source: computed by the author using stata software

The above table of descriptive statistics provide key insights into the relationship between Terms of Trade (TOT) and economic development in Rwanda, particularly through the variables related to GDP growth (Ln gdp), population (Ln pop), exports (Ln X), imports (Ln M), trade balance (Ln trabal), trade openness (Ln tralog), institutional quality (Ln inst), and foreign direct investment (Ln fordi). The mean values indicate the overall level of these variables, with Ln gdp averaging 2.012, suggesting steady economic growth, while Ln X (20.410) and Ln M (21.195) show that imports consistently exceed exports, reinforcing Rwanda's trade deficit challenge. The standard deviations highlight that exports (1.066) and imports (0.709) are more volatile than GDP (0.142), indicating external trade fluctuations affecting the economy.

The skewness and kurtosis values suggest that most variables are non-normally distributed, with Ln gdp and Ln inst being highly negatively skewed (-1.622 and -1.767, respectively), meaning a concentration of lower values, possibly due to institutional weaknesses affecting trade and growth. The high kurtosis for Ln gdp (6.140) and Ln pop (7.199) suggests the presence of extreme values, implying potential structural shifts in economic development and population dynamics over time. Given these characteristics, the results indicate that Rwanda's economic development is closely linked to trade fluctuations, institutional quality, and financial openness, necessitating policies to improve trade competitiveness, enhance institutional frameworks, and attract foreign investment to ensure sustainable economic development.(Isaie, 2021)

4.3 Multicollinearity test

A multicollinearity test is essential in regression analysis to detect high correlations among independent variables, which can distort coefficient estimates and reduce model reliability. The Variance Inflation Factor (VIF) is commonly used to assess multicollinearity, with values exceeding 10 indicating a serious issue. Identifying and addressing multicollinearity ensures that the regression model remains interpretable and produces reliable statistical inferences.

Table 2. Variance Inflation Factor (VIF) results

Variables	VIF	1/VIF
D.Ln pop	1.25	0.7985
D.Ln X	1.97	0.5087
D.Ln M	1.49	0.6692
D.Ln tradbal	1.51	0.6623
D.Ln tradlog	1.46	0.6862
D.Ln inst	3.71	0.269
D.Ln fordi	3.52	0.2844
Mean VIF	2.13	

Source: computed by the author using Stata software

For the results of Variance Inflation Factor (VIF) indicate that multicollinearity is concern in the model, that push me to apply (VDF) all variable values are below the common threshold of 10. The mean VIF is 2.13, suggesting a low overall level of collinearity among the independent variables. The highest VIF values are for institutional quality (D. Ln inst) at 3.71 and foreign direct investment (D. Ln fordi) at 3.52, which are still within an acceptable range. Since all 1/VIF values are reasonably above 0.1, the model does not exhibit severe multicollinearity issues, meaning that the estimated coefficients remain reliable and interpretable.(Zhu et al., 2021)

4.4 Model Fit and R-squared Analysis

The results of the R-squared analysis, along with model fit tests such as AIC, BIC, and F-statistics, confirm that the model explains a significant portion of the variability in the dependent variable, ensuring its reliability. The consistent of the data set is further by the findings of thee PP and ADF tests which show that all study series, including GDP and variables are stable at differences. this verified that the estimated model is statically valid and dependable for inference, guaranteeing that the relationships between the variables are not fictitious. Stationarity is an essential assumption in time series modeling (Saito and Neto, 2024).

4.5 Impulse response

Figure 2: Impulse (ln_gdp) response(ln_gdp)

The graph above, illustrates the dynamic response of GDP to its own shock over a 10- horizon Initially, GDP exhibits a sharp positive response, followed by fluctuations alternating between positive and negative values. The magnitude of the marginal effects varies, indicating the persistence of GDP shocks over time. Although the confidence intervals are not explicitly shown, the significant initial impact suggests a strong short-term response, while the alternating pattern implies cyclical adjustments. The results indicate that GDP shocks have temporary but recurring effects on economic fluctuations. This reinforces the study's theme that economic development in Rwanda is sensitive to trade dynamics, requiring policies that stabilize macroeconomic fluctuations and enhance resilience to external shocks.

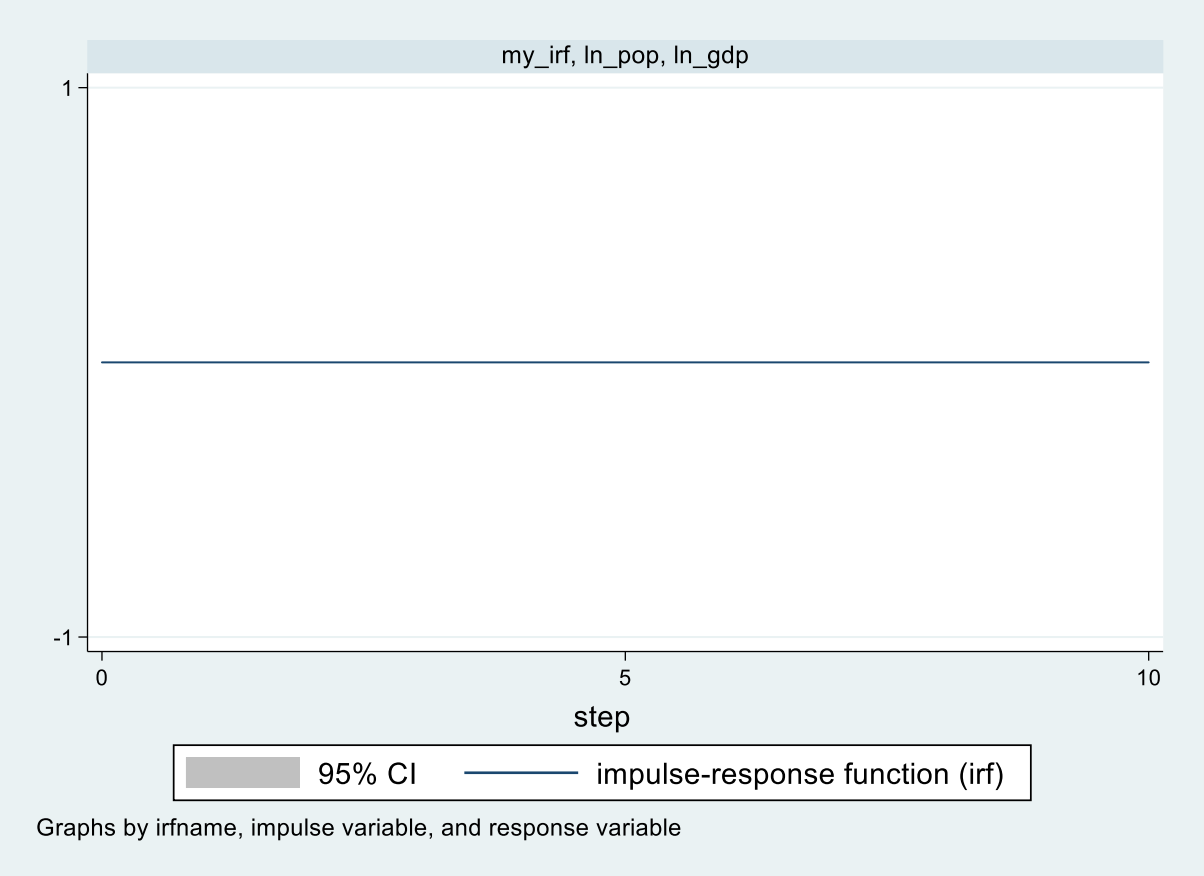

Figure 3: Impulse (ln_pop) response(ln_gdp)

The impulse response function (IRF) indicates that a shock to population (POP) has a negligible and statistically insignificant effect on GDP over the 10-period horizon, as evidenced by the flat response line and confidence intervals covering zero. This suggests that population changes alone do not drive significant fluctuations in economic output, implying that other structural factors, such as institutional quality, trade logistics, and investment, play a more critical role in shaping Rwanda's economic development. These findings highlight the need for policies that enhance productivity and economic diversification rather than relying solely on demographic growth for economic progress.

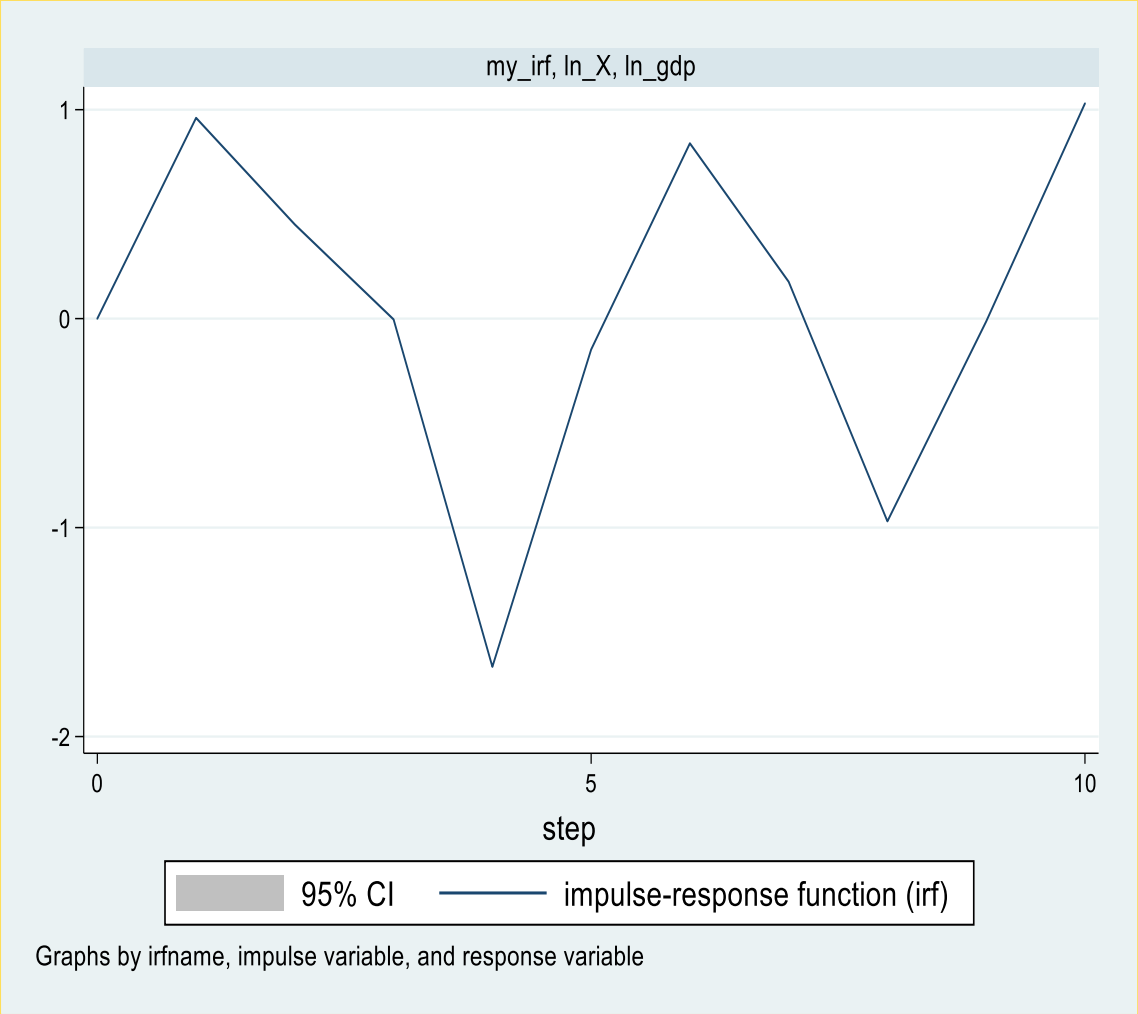

Figure 4: Impulse (ln_X) response(ln_gdp)

The impulse response function (IRF) shows that a shock to exports (EXPORT) initially boosts (GDP), peaking at step 1, but then fluctuates between positive and negative effects over the 10-step period. The oscillatory pattern suggests that export shocks do not have a consistently sustained impact on economic growth, likely due to external market conditions, trade policies, or structural inefficiencies in the economy. This highlights the need for Rwanda to enhance trade logistics, diversify exports, and strengthen institutional frameworks to ensure that export growth translates into long-term economic stability and development.

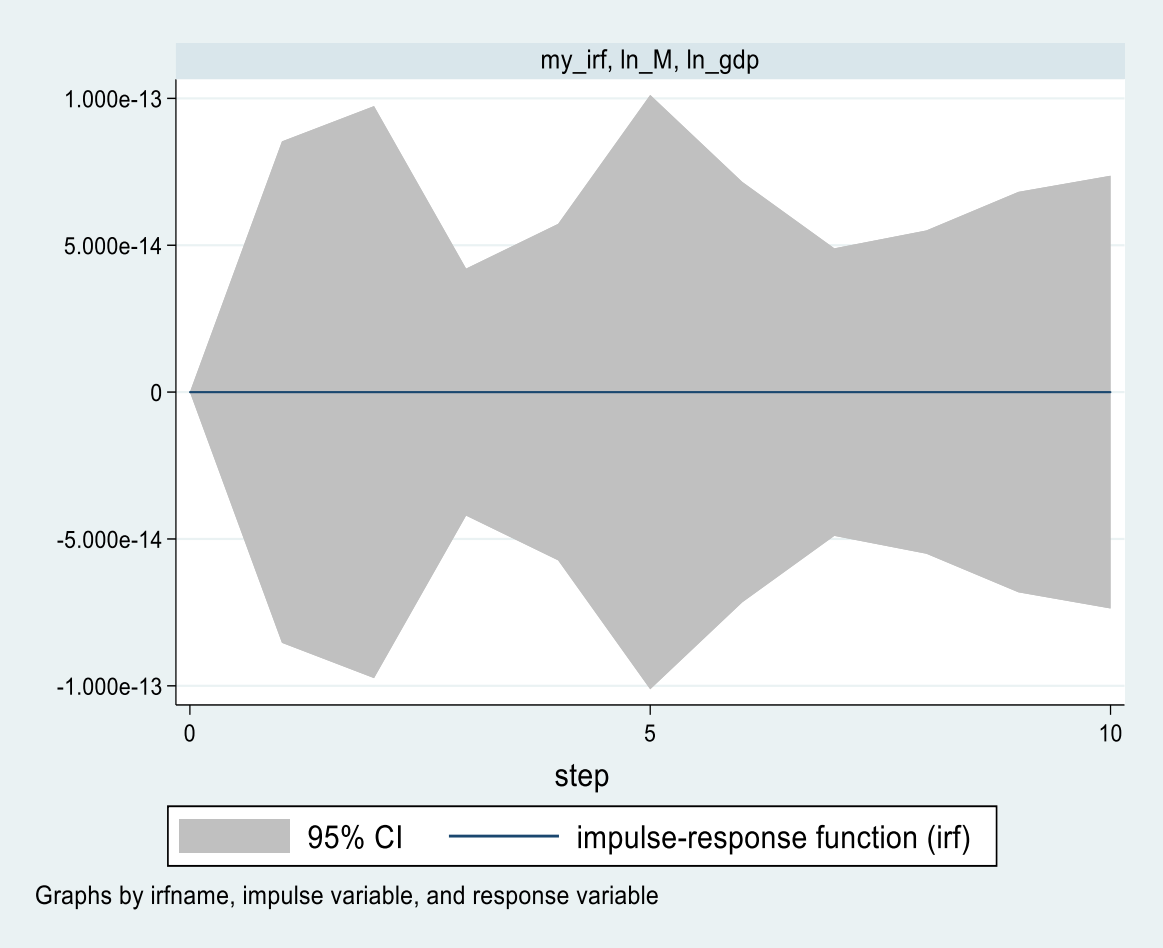

Figure 5: Impulse (ln_M) response (ln_gdp)

The impulse response function (IRF) indicates that a shock to imports has no statistically significant effect on GDP over the 10-step period, as the 95% confidence interval consistently includes zero. This implies that variations in imports do not exert a meaningful influence on economic development within the observed timeframe. Given Rwanda's trade dynamics, this finding underscores the importance of enhancing trade efficiency and balancing imports with productive investments to foster sustainable economic development**.**

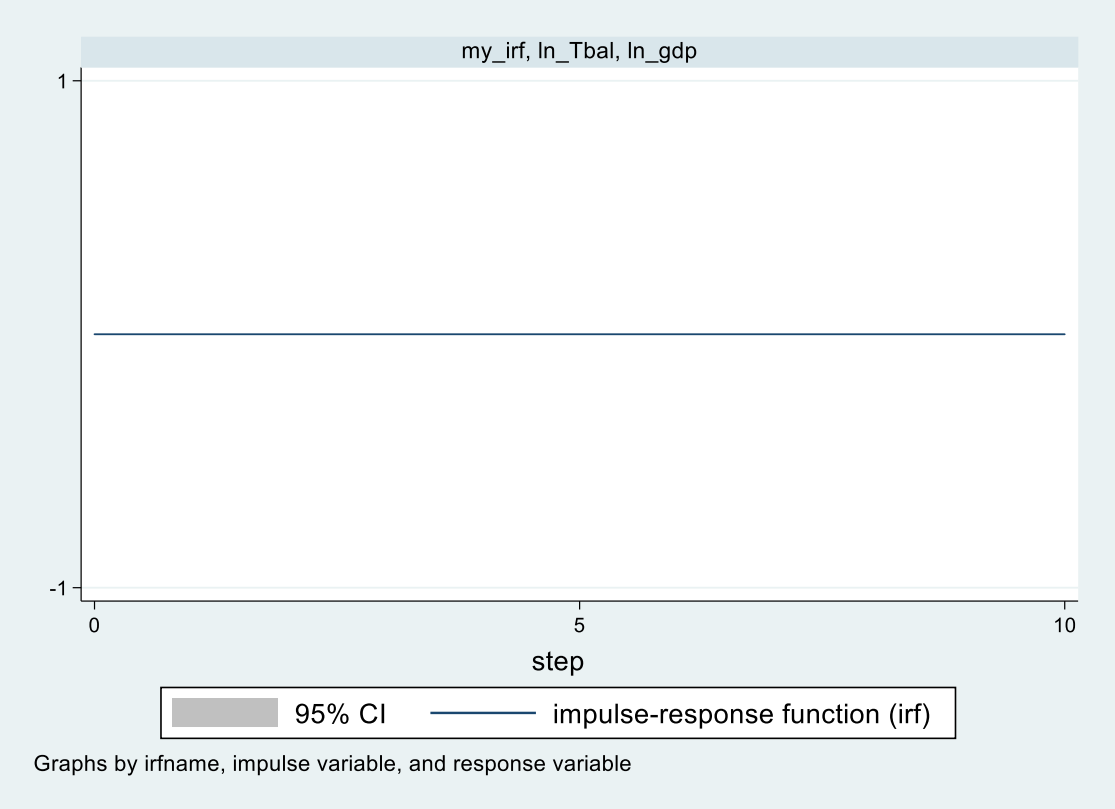

Figure 6: Impulse (ln_Tbal) response(ln_gdp)

The impulse response function (IRF) suggests that a shock to the trade balance has no statistically significant effect on GDP (ln_gdp) over the 10-step period, as the confidence interval consistently includes zero. This indicates that fluctuations in the trade balance do not meaningfully influence economic development within the given timeframe. Given Rwanda's economic structure, this result highlights the need for policies that enhance trade efficiency and export competitiveness to strengthen the link between trade balance dynamics and long-term economic development.

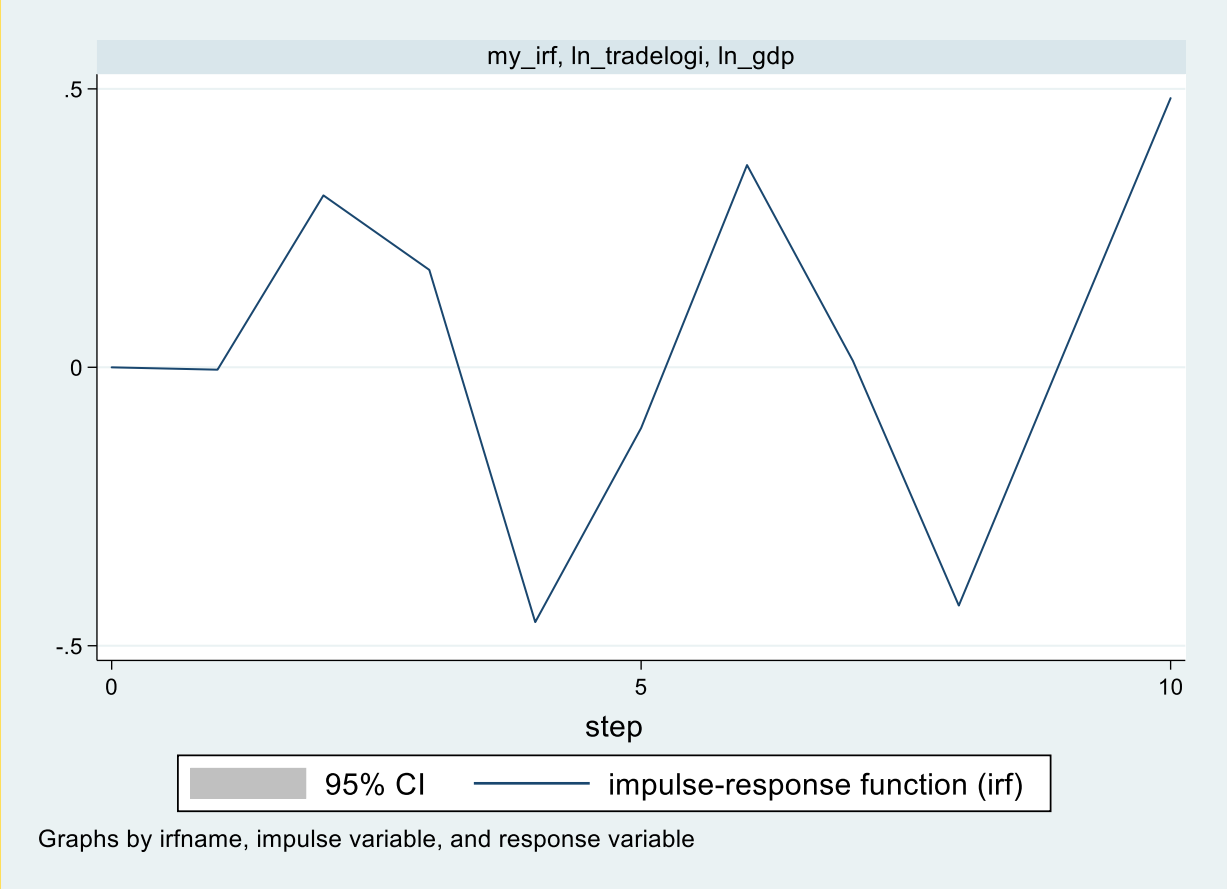

Figure 7: Impulse (ln_tradelogi) response(ln_gdp)

The impulse response function (IRF) suggests that a shock to trade logistics has an oscillating effect on GDP over the 10-step period, initially positive, turning negative around step 5, and becoming positive again towards step 10. The absence of confidence intervals makes it difficult to determine statistical significance, but the cyclical nature indicates that improvements or disruptions in trade logistics have a dynamic impact on economic growth. This highlights the importance of sustained investment in trade infrastructure and efficiency to ensure consistent positive contributions to Rwanda's economic development.

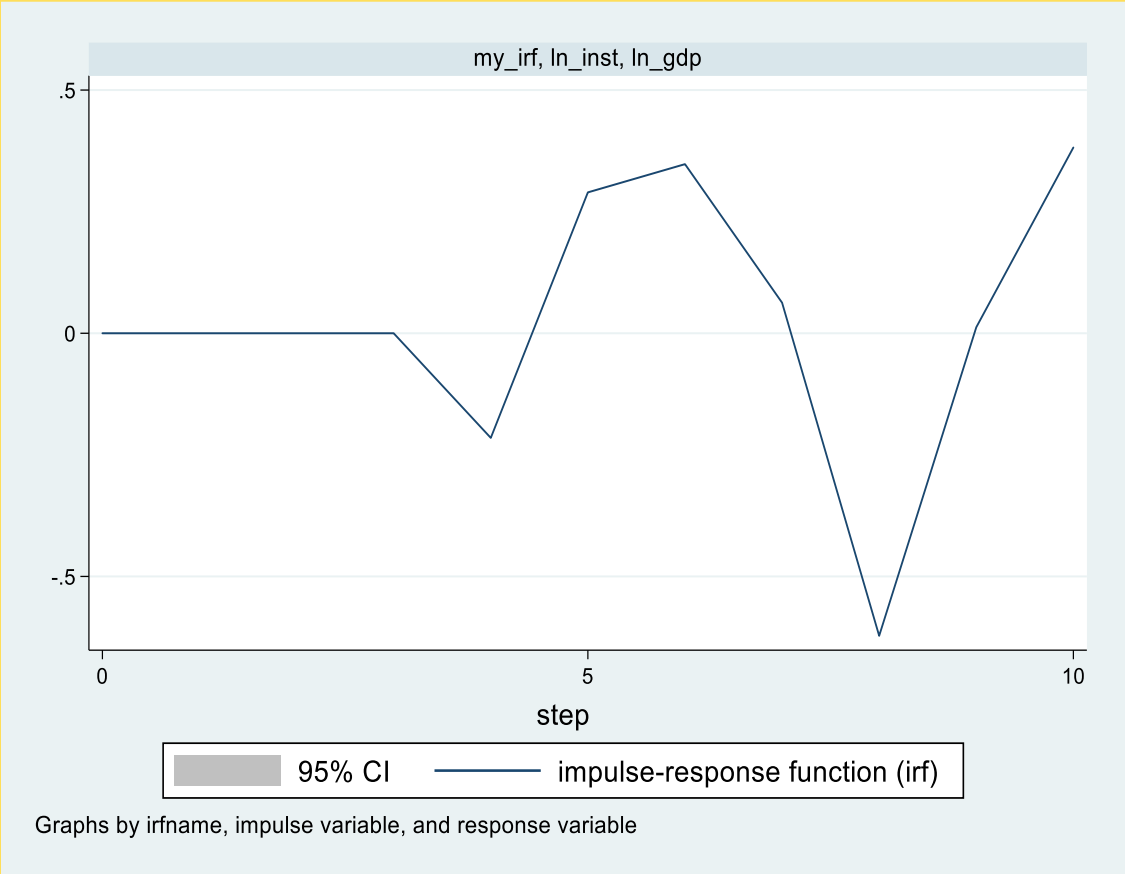

Figure 8: Impulse (ln_inst) response(ln_gdp)

The impulse response function (IRF) suggests that a shock to institutional quality has a delayed and fluctuating effect on GDP, with negligible impact initially, turning positive around step 5, peaking at step 7, and then briefly becoming negative before recovering by step 10. Due to the absence of confidence intervals, the statistical significance of these effects remains uncertain. However, the delayed response implies that improvements in institutional quality take time to influence economic growth, reinforcing the need for long-term policy commitments to strengthen institutions for sustained economic development in Rwanda.

Impulse (ln_fordi) response(ln_JDP)

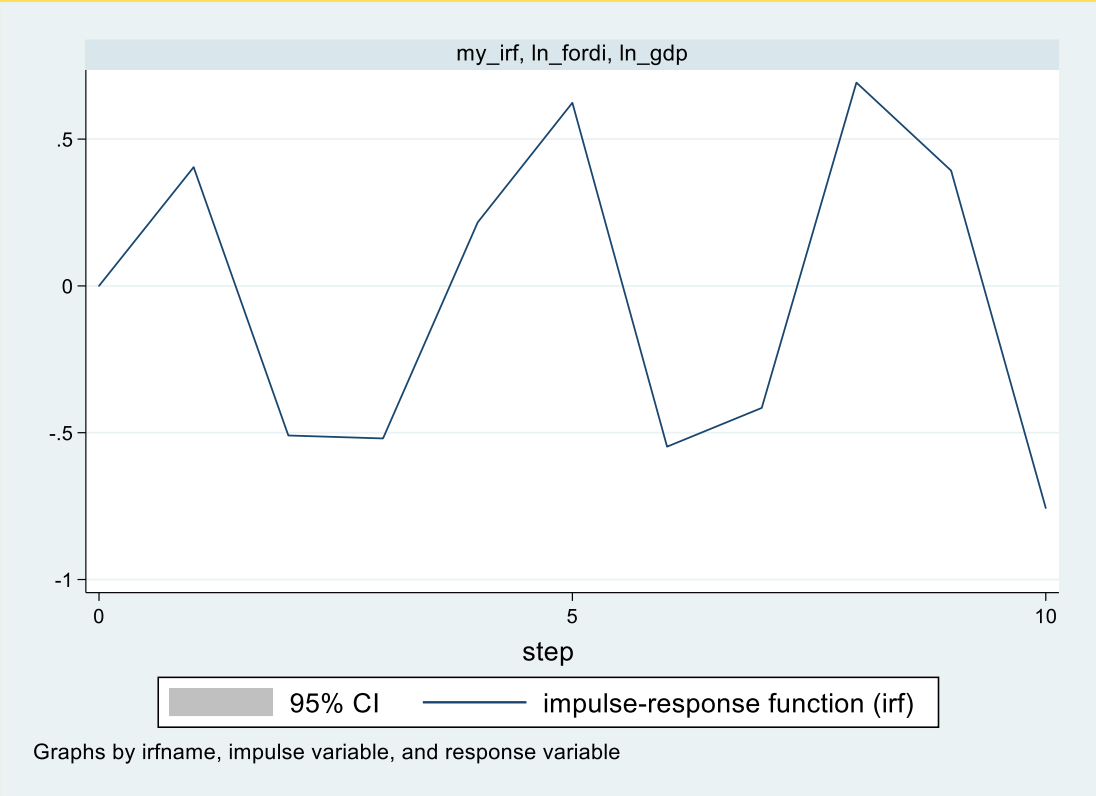

Figure 8: Impulse (ln_fordi) response(ln_JDP)

The impulse response function (IRF) indicates that a shock to foreign direct investment has a fluctuating effect on GDP over the 10-step period, initially positive, turning negative around step 3, peaking positively at step 6, and ending with a negative effect at step 10. Due to the lack of confidence intervals, the statistical significance of these effects remains unclear. The cyclical pattern suggests that foreign direct investment's impact on economic growth is complex, potentially influenced by external economic conditions and requiring complementary policies to maximize its positive effects on Rwanda's development.

The impulse response functions (IRFs) illustrate the dynamic effects of various economic shocks on GDP in Rwanda. A shock to GDP itself shows an initial strong positive impact, followed by cyclical fluctuations, indicating temporary but recurring effects on economic growth. Population shocks have an insignificant impact, suggesting that demographic changes alone do not drive economic growth. Export shocks initially boost GDP but fluctuate, highlighting the need for trade diversification and improved logistics. Import and trade balance shocks have no significant effect, reinforcing the importance of balancing imports with productive investments.

Trade logistics shocks show an oscillating impact, emphasizing the need for sustained investment in infrastructure. Institutional quality shocks have a delayed effect, reinforcing the importance of long-term institutional reforms. Lastly, foreign direct investment shocks exhibit a fluctuating pattern, indicating a complex relationship requiring supportive policies. Overall, the findings suggest that Rwanda’s economic development is sensitive to trade dynamics, institutional quality, and investment efficiency, necessitating policies that enhance economic resilience and sustainable growth.

5. Conclusion

The analysis of Rwanda’s terms of trade impact on economic development shows that variables like GDP, population, trade logistics, and institutional quality are stationary at their levels. In contrast, exports, imports, trade balance, and foreign direct investment are non-stationary at level but achieve stationarity after first differencing. The optimal lag length of 4, determined through AIC, FPE, and LR tests, ensures accurate modeling of dynamic relationships without overfitting. The Johansen co-integration test indicates three long-term stable relationships among the variables, suggesting that Rwanda's economic development is closely tied to its terms of trade in a stable, long-term equilibrium.

Diagnostic tests further confirm the validity of the model, with no significant issues of normality, heteroscedasticity, autocorrelation, or multicollinearity. The model accounts for a substantial share of the variation in the dependent variable, suggesting that fluctuations in the terms of trade have a meaningful influence on Rwanda's economic development. Additionally, the stationarity of the variables ensures that the relationships modeled are consistent and reliable, highlighting the crucial role of stable trade dynamics and sound institutional and logistical frameworks in driving sustainable economic growth in Rwanda.

6. Recommendations

Drawing from the analysis results, it is advised that the Government of Rwanda and relevant policymakers to prioritize on improving trade logistics efficiency to facilitate smoother trade processes, reduce transaction costs, and enhance the competitiveness of exports. Fostering an efficient logistics sector is critical to addressing challenges related to trade facilitation, which could, in turn, boost economic development by enhancing Rwanda's position in regional and global markets. The government should invest in infrastructure development, improve customs processes, and strengthen port efficiency to reduce the costs of trade logistics. Additionally, policies aimed at stabilizing the export price index should be implemented to prevent volatile fluctuations that negatively impact Rwanda's export revenues. The establishment of stabilization funds or hedging mechanisms could help shield exporters from price shocks, ensuring more consistent economic growth.

Furthermore, enhancing Rwanda's trade balance and improving its position in international trade will require focused efforts on diversifying exports, improving market access, and negotiating favorable trade terms. The government should promote sectors with high export potential, such as agriculture, manufacturing, and services, and implement trade agreements that favor Rwanda's economic interests.

Also, as imports and export price indexes play a critical role in shaping trade dynamics, the government should establish policies to monitor and control import prices to prevent inflationary pressures. Additionally, fostering financial policies that encourage foreign direct investment (FDI) and strategic partnerships in sectors that contribute significantly to trade balances can help stabilize the economy. Such initiatives will help foster a more robust trade environment and play a vital role in promoting Rwanda's long-term economic growth.

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Enhancing Small and Medium Enterprises' Performance Through Digital Payments: Roles of Digital Payment Solutions in Ilorin-South Metropolis.

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Abstract

This study examines how digital payment adoption impacts Small and Medium sized Enterprises (SMEs) in Ilorin-South, Nigeria, addressing challenges like cash-related risks and payment delays. Using a quantitative survey of 234 SME owners (sampled via Taro Yamane's formula), the research analyzed mobile banking, Smartcards, and Internet banking effects on SME performance, measured by revenue, customer base, and operational efficiency. Discriminant validity (KMO > 0.7) and reliability (Cronbach's Alpha > 0.7) were confirmed. Regression analysis revealed Smartcards drove 69.4% performance, mobile banking 67%, and Internet banking 38.3%, with ANOVA confirming Smartcards' superior impact ($p < 0.05$). Mobile banking's efficiency and accessibility made it the most influential. The study recommends SME owners prioritize mobile banking and Smartcards, while financial institutions and government collaborate on tailored solutions (e.g., rural-focused subsidies) and financial literacy programs via mobile platforms. Findings underscore digital payments' role in enhancing SME scalability and financial inclusion

Keynote: Digital payment, Smartcard, Mobile banking and SMEs

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7. Introduction

Digital payment refers to an electronic payment system that includes providing clients with both old and innovative goods or services from banks. It is a system that enables online inventory management and payment transactions for both individuals and businesses (Rifat, 2023). Digital payments, Widespread use of digital payments is required to propel the rapidly evolving digital economy, reshaping and challenging traditional ideas to support the expansion of SMEs in Nigeria (Łasak & Gancarczyk, 2021).

Digital payments are significant not just because they allow conventional financial institutions to operate more efficiently but also because they may be used to establish new services and alter existing ones. Nigeria needs to experience a digital revolution that will take numerous shapes and expand its reach to new economic sectors due to the country's increasing number of SMEs. The financial markets, where electronic payments are becoming more significant, should be impacted by the transformation (Chen et al., 2023). In addition to many other sectors, digital payments are becoming more and more crucial for smooth business transactions and for making payments simple when funding SMEs in Nigeria.

SMEs in Nigeria also use electronic payments to enhance customer satisfaction. In July 2018, First Bank, one of Nigeria's largest banks, opened the First Digital Lab in the "Yabacon Valley," Lagos. The bank uses the lab as a platform to work together and progress with the quickly evolving digital payments industry (Adewolo, 2019).However, over the last several decades, the global economy has seen extensive modernisation and digitisation across almost all sectors, resulting in the emergence of whole new industries. This illustrates how the concentration of several creative firms in a single locale promotes the exchange and pollution of ideas across various sectors, resulting in a thriving economic sector and transformative digital payments (Achor et al., 2023).

The aim of the study is to explore the influence of digital payments on the performance of SMEs in Ilorin-South Kwara State. The specific objectives include:

- **i.** Examine the impact of adopting digital payment solutions on the performance of SMEs in Ilorin-South Kwara State
- **ii.** Examine the extent of the relationship between SmartCards and Internet banking adoption on the performance of SMEs in Ilorin-South Kwara State.

1.2 Statement of the Problem

SMEs encounter several challenges in spite of the crucial role they serve. The statistics have shown that only three (3) out of five (5) SMEs survive for five months to a year after being formed, and of those that do, 80% fail by the fifth year (World Bank, 2020). The adoption of electronic payments gives SMEs a way to perform better, which lowers the failure rate. McEvily et al. (2014) made the case that innovation was essential to boosting productivity, competitiveness, and profitability in order to unleash the potential of many SMEs. Therefore, in order to remain viable and continue to operate, SMEs must use electronic payments.

In Kwara State, particularly in the Ilorin South, SMEs often complain about delays in the payment of cheques and a high rate of crime reports due to the mobilisation of cash, which led to the introduction of new digital payments to many business owners in the area. Also, very few studies were conducted on the nexus between digital payment solutions and SMEs in Nigeria. Most previous research was on deposit money banks and not Kwara State in particular. It is imperative to conduct a research on the role of digital payment solutions on the performance of SMEs in Ilorin South metropolis.

2.0 Literature Review

2.1 Concept of Digital Payment

Digital payment is the electronic payment solution for transferring money from one account to another using digital devices or online modes. It refers to an arrangement between a bank and its customer to enable encrypted transactions over the Internet (Rifat, 2023). It is a general word for an electronic banking system that allows a consumer to conduct financial transactions without physically visiting a financial institution (Ombati et al., 2021). Fintech businesses provide business and personal bank accounts built on a comprehensive digital infrastructure. Crucially, businesses like Paystack, Kuda, and Flutterwave are introducing straightforward digital electronic payments with superior client experiences and stylish designs to the Nigerian market. Additional digital payments include bill payments, cash transfers, balance inquiries, and more. Three (3) fundamental categories may be used to group digital payment options. These include mobile, SmartCards, and internet banking (Okeka et al., 2021).

2.2 Growth of SMEs in Nigeria

Small and Medium Enterprises (SMEs) are defined by size in terms of employees and annual turnover. In Nigeria, SMEs are categorized as businesses with fewer than 500 employees, with microenterprises typically employing less than 10, small enterprises fewer than 50, and medium enterprises fewer than 200 (SMEDAN, 2020). Service-based SMEs must have fewer than 49 employees. These businesses are recognized as critical to economic development due to their potential to innovate, create jobs, and stimulate local economies (NBS, 2023).

SMEs form the foundation of Nigeria economy, which accounting for 96% of all businesses, 84% of employment, and contributing approximately 48–52% to the Gross Domestic Product (PwC, 2020; NBS, 2023). Despite their significant role, SMEs face several growth constraints including limited access to finance, high operating costs, inadequate infrastructure, and a shortage of skilled labor. The so-called "missing middle" businesses that are too large for microfinance but too small for commercial lending often struggle to secure the funding they need (PwC, 2020).

To monitor growth and performance, SMEs use a blend of financial and non financial indicators such as Return on Assets (ROA), profit margins, customer satisfaction, and market share (Al-Omoush et al., 2023; Osman et al., 2023). As suggested by Adnani et al. (2023), integrating both dimensions is vital for accurate performance evaluation. performance can also be assessed by changes in internal processes, business size, and customer relationships (Dominguez-Escrig & Mallen-Broch, 2023), especially in a dynamic digital economy where innovation is key to survival and competitiveness.

2.2.1 Digital Economy in Nigeria

The digital economy has brought about waves of upheaval. There are now new businesses and new means of communicating. Many businesses and sectors that failed to use the technology to transform their operations have seen a decline in revenue, a loss of market share, or even a total collapse, Deloitte (2020). Utilising emerging technologies like predictive analytics and Internet of things information technology will allow them to enhance their engagement with existing and potential customers, respond faster, and be more productive and efficient.

2.3 Theoretical Framework

2.3.1 Diffusion of Innovation Theory

The Diffusion of Innovation (DOI) Theory, developed by Everett Rogers in 1962, explains how new ideas, technologies, or practices spread within a social system over time. Adoption occurs when individuals perceive an innovation as new and beneficial. This process is gradual, and not everyone adopts innovations at the same pace. Some people are more willing to try new ideas, while others are more resistant. The theory helps explain what drives the acceptance and spread of innovations in society, including in business environments such as SMEs. In the context of digital payments, businesses that adopt financial technologies early often gain better market access, improved customer experiences, and enhanced competitiveness.

The theory also identifies five categories of adopters: innovators, early adopters, early majority, late majority, and laggards. Innovators are risk-takers and the first to try new ideas. Early adopters are open to change and often lead others in embracing innovations. The early and late majority adopt only after seeing proven benefits, while laggards are the most resistant and prefer traditional methods. Understanding these groups is essential when introducing digital payment solutions to SMEs, as it helps tailor strategies for wider adoption based on the readiness and characteristics of the target audience.

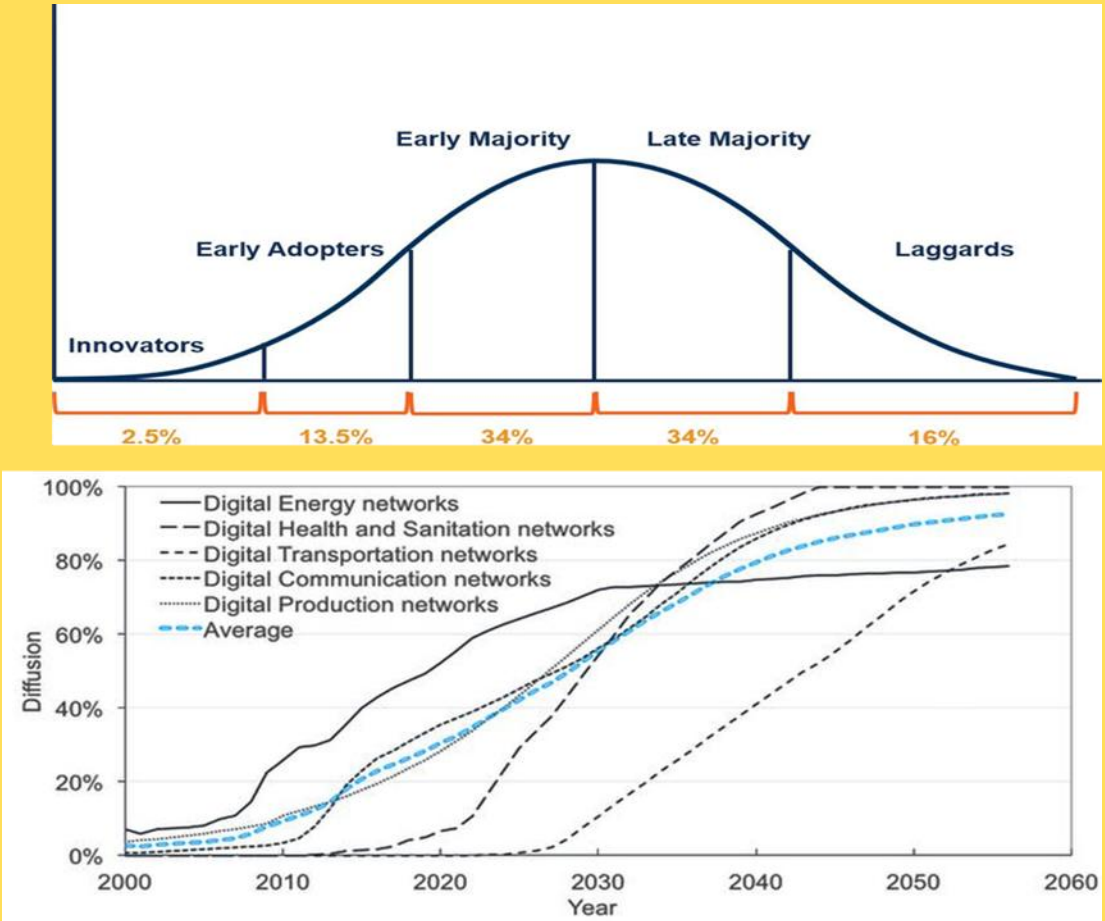

Figure 1: Diffusion of innovation theory and enabling digital technologies.

Source: Ombati et al., 2021

Figure. 1 highlights the dissemination of breakthroughs of DOI theory within the context of enabling digital technologies, with early adopters often driving awareness and adoption. Accelerating their proliferation across sectors and populations, these technologies improve adoption efficiency and scalability by offering venues for experimentation, real-time feedback, and seamless integration into current systems (Ombati et al., 2021).

2.4 Empirical Review

The profitability performance of Nigerian banks after the complete implementation of electronic banking systems was examined by Abaenewe et al. (2019). Increased use of electronic banking, which has revolutionised banking operations in Nigeria and elsewhere, made the research essential.

Adebayo and Yusuf (2022). On journal titled The role of Digital Payment Systems in SME growth According to recent studies, using digital payments can help SMEs develop by increasing transactional efficiency and cutting operating expenses. SMEs who implemented digital payment solutions saw a 20% boost in revenues as a result of quicker transaction processing and lower hazards associated with handling cash.

According to Ahmed and Ali's (2021) study outlined the main obstacles that SMEs face while using digital payment systems. Lack access to technology, ignorance, reluctance to adapt, and worries about transaction security are a few of them. In order to overcome these obstacles and encourage broader adoption, the report suggests specific actions.

Chatterjee A. (2020). Regarding the research Economic growth, the spread of information and communication technology, and financial inclusion Information and communication technology (ICT) is widely used, which makes it possible for ICT-enabled services to spread throughout a variety of industries. Reputable institutions like the United Nations and the World Bank have recommended ICT-enabled services as an economic accelerator for poor countries. Innovative ICT-enabled solutions are necessary for businesses to streamline processes, boost productivity, cut expenses, and shorten development times.

Chen et al. (2023), research on Mobile payments and small business expansion: A study of emerging economies. SMEs can grow their clientele by integrating mobile payments, especially in developing nations where electronic transactions are becoming more common.

According to a study by Jaiswal and Bhatnagar (2023), the financial performance of SMEs in India is impacted by the use of digital payments. According to the study, using digital payment methods enhanced cash flow management, decreased transaction costs, and raised sales because it was more convenient for customers. But issues like the necessity for technological infrastructure and cybersecurity worries were also brought to light.

According to a study by Mensah and Boateng (2021). Barriers to digital payment adoption among SMEs. The study observed that SMEs in rural locations suffer with internet connectivity, limiting their ability to completely integrate digital solutions. Adoption Notwithstanding the benefits, SMEs face a number of obstacles when implementing digital payments, such as resistance to change, technical complexity, and cybersecurity threats.

An extended technology acceptance model by Nambiar and Bolar (2023) on the factors influencing customers' preference for cardless technology over the card for cash withdrawals has highlighted that people wary of electronic payment methods still believe that using cash is safer. This is true even if consumers are aware of how user-friendly and reliable electronic payment systems are. Numerous research have found a number of factors that can affect banking sector customers' decisions to adopt electronic banking services. These elements are accessibility, transaction accleration, banks contributions to improving their clients' electronic literacy, the cost of using electronic services, and the bank's reputation for reliability and simplicity in handling electronic transactions.

Using a case study of Nigerian commercial banks, Taiwo and Agwu (2020) examined the effects of e-banking adoption on organisational performance. Staff members of four banks, Ecobank, UBA, GTB, and First Bank, were given questionnaires to collect primary data. An SPSS was used to analyse the findings using Pearson correlation. It was found that the operational efficiency of Nigerian banks has increased after the introduction of electronic banking as opposed to the days of conventional banking.

3.0 Methodology

The quantitative research follows the objectives of this study, "the digital payment and the performance of SMEs in Ilorin Kwara State," which was guided by the descriptive survey design. This study's research design is best to quantify the cause-effect. The population of 564 is obtained from MBIT as the total number of SMEs operating in Ilorin South as of the third quarter of 2024. This study considers the use of probability and non-probability sampling techniques (i.e. simple stratified random sampling and Purposeful). Thus, probability sampling was embraced to ensure that every target participants had an equal chance of being included in the sample. Sample size determination according to Taro Yamane's formula (1967), obtained n=234 as shown.

Taro Yanane's formula (1967) is presented as below:

$n = N/(1+Ne^2)$ where,

n = sample size

N = population =564

e = level of significance 0.05

1 = constant

Substituting the values

$n = 564/(1+564(0.05)^2)$

$= 564/2.41$

$n = 234.02$

The sample size for this study is 234 SMEs, whereby one top manager, the owner or one active representative that can explain the business operations inside out was chosen for the sake of this work. The primary source of information for this study is primary data.A well-structured questionnaire is used to establish the nexus between digital payment solutions and the performance of SMEs. It is adapted from the work of Taiwo & Awgu (2020).

However, the instrument ratings were based on a five points Likert scale and (15) items in total adapted from Taiwo & Agwu (2020). Descriptive statistics with the use of frequencies means ranking and relative important index (RII) was employed, while inferential statistics used multiple regression and independent t-test using SPSS software.

3.1 Operationalisation of Variables

By determining the definitions of the independent and dependent variables, the researcher may pinpoint the precise idea that influences the study's main variable. An overview of the operationalisation process is provided in Table 1 below. By determining the definitions of the independent and dependent variables, the researcher may pinpoint the precise idea that influences the study's main variable. An outline of the operationalisation procedure is provided in the table below.

Table 1. Operationalisation of variables

S/N	Types of variable	Variables	Indicators	Measurement Scale
1	Independent	Mobile Banking	SMS banking, e-wallets, basic cash transfer	Ordinal &Nomina
2	Independent	SmartCard	POS, ATM, Payment Receipt	Ordinal &Nomina
3	Independent	Internet Banking	Balance Inquiry, Online Purchases, Bulk-cash transfer	Ordinal &Nomina
4	Dependent	Performance of SMEs	Sale volume, Business expansion, increase GDP, Customer Base overtime, rise in income level	Ordinal & Nominal

Source: Author's Computation, (2025).

3.2 Model Specification

The Model of multiple regressions below was used to specify the quantitative relationship between the variables of the study;

Y = B0+ B1X1+ B2X2+ B3X3 **+ e**

Where

Y = dependent Variable= SMEG

$\mathbf{B_0}$ **=** constant

$\mathbf{B_n}$ **=** Coefficient, for n=1, 2, 3,4

X1= mobile banking

X2= SmartCard

X3= Internet banking

e= represents the error term

Table 2. Apriori Expectation

Variables	Expected Sign-on Impact	Apriori
• ***Digital Payments***	+	$\alpha_1>0$
• ***Performnace of SMEs***	+	$\alpha_2>0$

Source: Researcher's Compilation.

3.2 Validity Test

An indication of the validity of the scales was established with a measure of construct validity (i.e., convergent and discriminant validity). Before conducting exploratory factor analysis, Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO-MSA) and Barlett's Test of Sphericity (BTS) was used to test the appropriateness of conducting factor analysis and the correlation matrix of the scales were first examined (Tabachnik and Fidell, 2023). KMO-MSA ranged from 0.763 (Digital Payments) to 0.841 (Performance of SMEs), which were above the recommended 0.60. The table shows the results of the KMO and Bartlett Test.

Table 3. KMO and Bartlett's Test

Construct	No. of Items	KMO	Bartlett's Test	Sig.
Digital Payments	15	0.617	1897.003	0.000
SMEs Performance	15	0.705	1678.234	0.000

Source: SPSS Computation, (2025).

3.3 Reliability Test

The reliability test was equally conducted with item-total correlation and Cronbach's Alpha of the individual scales. Items were resolute to be internally consistent and reliable if they reported a minimum item-total correlation coefficient of 0.40. Howit and Cramer (1997) asserted that reliability coefficients ranging from -0.26 to +0.26 are usually significant at 0.01 level if the sample size is 100 and above and that such scales will provide consistent and reliable scores. Table 4 shows the results of the item-total correlation coefficients and Cronbach's Alpha for the whole scale. Item-total correlation coefficients for all items are above 0.40 and Cronbach's Alpha for the scales is above 0.70 of the recommended threshold in the literature (Hair et al., 2018; Nunnally & Berstein, 2014; Pallant, 2017).Thus, the internal consistency of the measures is not in doubt.

Table 4. Validation exercise showing results of reliability tests

SN	Constructs	Minimum Item-Total coefficients	Cronbach Alpha for Scale	No of the factors identified	No. of items retained
1.	Mobile banking	.625	.793	4	4
2.	SmartCard digital payments	.522	.851	3	3
3.	Internet banking	.614	.775	3	3
6.	Performance of SMEs	.716	.951	5	3

Source:SPS Computation, (2024).

4. Result and Discussion

Table 5 shows the responses of owners and top managers in SMEs in the selected area to the effect of digital payment solutions on the performance of SMEs. The responses of the managers and business owners show that the adoption of digital payment solutions in promoting SMEsis greater than the weighted average mean score of 2.5 on a five-pointLikert scale rating out of an agreed score of 5. Therefore, it is expected that the majority of respondents concede on the use of digital payments to influence business activities in this perception.

Table 5. Perceived responses of business owners on digital payments

Digital Payments	Mean	SD
Mobile banking		
I am able to use mobile payment for bill settlement in my business	4.1500	0.45628
I am able to save business income into e-wallets	3.6600	0.58784
Using mobile banking relieves me the stress of carrying cash	4.5600	0.85372
Mobile banking is convenient and user-friendly	4.9700	0.92301
SmartCards digital payment		
The use of SmartCards enables me to gain enough finance for business expansion	4.3400	0.58784
Access to POS terminal enables my quick response to customers	4.3000	0.45902
I was able to generate Payment Receipt through terminal for customers	4.4300	0.60524
Internet banking		
Access to Internet relieves me of bulk transfer	4.2700	0.67722
I was able to carry online purchases and inventory management	4.6600	0.58784
I was able to to obtain credit saving through online mode	4.1500	0.45628

Mean cut- off point=2.5

Source: Survey 2024

Table 6 displays the relative importance index (RII) and mean ranking of the perceived Prospects for performance in SMEs as a result of the adoption of digital payment solutions in their various business dealings. This is part of the intended strategies to assess how activities of digital payments improved SMEs in the selected case study. The perceived prospects for adopting digital payments are significant, as indicated in the threshold of RIIs>0.5, and ranked on the weighted average mean>2.5 on a decision scale of five-pointLikert ratings. Therefore, it is conceded that the performance prospects of SMEs are likely to be affected by adopting digital payments.

Table 6. Relative Important Index (RII) of the Perceived Prospects for Performance in SMEs for the adoption of digital payments

Adoption (+)	Frequency of Response					RII	Mean
	5	4	3	2	1		
Needed for increase customer base overtime	97	60	39	21	17	0.77	3.86
Needed for lower operational costs	99	40	33	38	24	0.73	3.66
Needed for business expansion	99	43	26	43	23	0.73	3.65
Needed for an increase in GDP	86	44	36	38	30	0.70	3.50
Needed for increase in sale volume	90	27	37	53	27	0.69	3.44

Source: Field Work Analysis, 2025

4.1 Hypotheses Testing

H_{01}: there is no significant impact of digital payment solutions on the performance of SMEs in Ilorin Kwara State

The R-squared value is displayed in the model summary result, called the Coefficient of determination, is 76.1% (0.761). This implies that 76.1% of the performance of SMEs were explained jointly by the metrics of digital payments (i.e., mobile banking,SmartCard, and internet banking). In comparison, Other variables not included in the model explain the remaining 23.9%. Furthermore, the adjusted R-Square (0.758), When viewed more conservatively, the coefficient of determination is more than 50%. solely in this instance, only 24.2% of the variant of other factors are not captured by the model. This indicates that the other unexplained factors deserve further empirical investigation beyond the scope of the sampled case study. Future studies should be carried out to account for 24.2% of the variation for adjustment. The Durbin Watson (1.858) a statistic with a value ranging from 1 and 2 indicated positive autocorrelation, this indicates that the parameters of digital payments could cause a positive change in the performance of SMEs in this model.

Table 7. Model Summary[b] of Digital Payments and Performance of SMEs

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate	Durbin-Watson
1	.871[a]	.761	.758	3.65870	1.858

a. Predictors: (Constant), Mobile Banking, SmartCard, Internet Banking

b. DV: SMEs

Table 8 displays the results of the ANOVA with the F-statistic = 242.395 at a Significance level of p<0.05 with df (3, 231), which implies that mobile banking, SmartCard and internet banking jointly predicts the performance of SMEs at a 5% level of significant. Thus, the relationship between digital payment solutions and the performance of SMEs SMEs' is at 5%. This is indicated by the p-value<0.05, which is within the Fisher-test rejection range (F0.05(2,465)=731.352>3.84), and by implication, there is a significant relationship between the digital payments and the performance of SMEs at 95% confidence level.

Table 8.

ANOVA[a] test of significance of the relationship between digital payment solutions and the performance of SMEs

Model		Sum Squares	ofDf	Mean Square	F	Sig.
	Regression	19594.705	3	6531.568	242.395	.000[b]
1	Residual	6224.526	231	26.946		
	Total	25819.231	234			

a. Dependent Variable: SMEs

b. Predictors: (Constant), Mobile Banking, SmartCard, Internet Banking

Multiple regression in Table 9, revealed how the metric of digital payments generally regressed over the performance of SMEs. Considering the variables' respective statistical significance as shown by the p-values, all metrics of digital payments passed their test of significance with respect to the performance of SMEs at 5% levels *(p-values<0.05).* Thus, the performance of SMEs is more modest when using mobile banking followed by using SmartCards than when using internet banking in the model. About a 69.4% increase in the performance of SMEs for a unit change in the use of SmartCardsamong the selected cases *(β=0.694, $t_{0.05}$>1.645).* Also, 67% increase in the SMEs' performance for a unit increase in mobile used for the business owners in the area *(β=0.670, $t_{0.05}$>1.645).*

Internet banking propelled a significant increase in the enterprise's performance by 38.3 %*(β=0.383, $t_{0.05}$>1.645)*.This result implies that the metrics of digital payments have a significant impact on the performance of SMEs. Meanwhile, it was observed that mobile banking, with a larger threshold of t-value, contributed most to the performance of enterprises among the selected cases.

H_{02}: there is no statistically significant difference between SmartCards and internet banking adoption on the performance of SMEs in Ilorin Kwara State

Table 9. Regression Estimates of the impact of digital payments on the performance of SMEs

Model	Unstandardised Coefficients		Standardised Coefficients	T	Sig.
	B	Std. Error	B		
(Constant)	-.305	.077		-3.961	.000
Mobile banking	.670	.042	.763	15.958	.003
SmartCard	.694	.112	.703	6.192	.000
Internet banking	.383	.135	.362	2.841	.000

a. Dependent Variable: SMEG

Source: IBM SPSS Computation, 2025

Levene's test for equality of variance result in Table 10 and t-test for equality of means indicates there is a significant difference between the metrics of SmartCards adoption and internet banking adoption for improving the performance of SMEs. Levene's f-test reveals the statistical significanceofanalysing the equality of variance. For testing the null hypothesis, the two groups have unequal variance. The significance value associated with Levene's test indicates that the two groups have unequal variance and the null hypothesis is rejected (p-values<0.05), meaning that all the independent variables (POS, ATM, Payment Receipt, Online purchases, Bulk-cash transfer, and Online credit) were adopted for different purposes among business owners. This indicates that the performance of SMEs is statistically difference between users of SmartCards and Internet banking. Therefore, null hypothesis two is rejected, and the alternative is accepted by positing that there is a statistically significant difference between SmartCards and Internet banking adoption among owners of SMEs in selected areas.

Table 10: Independent t-test of SmartCards and online/internet banking adoption among SMEs in Ilorin South

	Levene's test for		t-test for equality of means	
Test factors	equality of variance			
	F	Sig.	Mean difference	
			Small Enterprises	Medium Enterprises
POS	40.716	.000	-6.050	-1.9924
ATM	50.561	.000	-6.111	-1.9925
Payment Receipt	34.273	.001	-5.233	-1.6906
Online Purchases	63.664	.000	-5.253	-1.5563
Bulk-cash transfer	53.819	.000	-5.288	-1.5563
Online Credit	8.595	.000	-4.351	-1.52171

Source: 2024

DF = degree of freedom, sig=significance

Predictor (constant): POS, ATM, Receipt Payment, Online Purchases, Bulk-cash transfer, Online Credit. DV: Performance of SMEs

4.2 Discussion of Findings

The analysis revealed that moile banking as a positive impact on the performance of SMEs, with a better value of 0.670 and signifance level of < 0.05. this findings aligned with work of Taiwo & Agwu (2020), highlighting the ease of transferring funds and managing accounts as key factors in the increased adoption of mobile banking.

The study also found that the use of SmartCards has a statistically significant impact on the performance of SMEs with a Beta value of 0.694 and a significance level of $p < 0.001$. This result support the preference for SmartCards systems over traditional banking methods, as entrepreneur rely on SmartCards financial transactions, contributing to SMEs development in the area.

5.0 Conclusion

The study has demonstrated that the use of SmartCards and online banking solutions markedly improves the operational efficiency, customer outreach, and financial performance of SMEs. These digital solutions will enhance transaction speed, mitigate cash handling risks, and provide access to wider markets.

The study concluded that the performance of SMEs is statistically difference between SmartCards and Internet banking adoption in Ilorin, particularly with the rise in business development from a single firmsucceeded to more employees and increased sales volume with customer base overtime and income rises demonstration of the performance of SMEs, which further highlights the need for continuousinvesting in digital infrastructure and financial literacy initiatives. This implies that government agencies, financial institutions, and other stakeholders must work to improve access to digital payment technology and provide essential assistance for SMEs to incorporate these tools into their operations.

6. Recommendations

Based on the findings of this study, SMEs in Ilorin-South should prioritize the adoption of digital payment solutions, particularly mobile banking and SmartCards, to enhance their performance. The research demonstrates that mobile banking significantly contributes to business expansion by improving transaction efficiency and reducing security risks associated with cash handling. Therefore, financial institutions and telecommunication providers should collaborate to improve mobile banking services, ensuring wider accessibility, seamless transactions, and better network stability. Additionally, targeted financial literacy programs should be introduced to educate SME owners on the benefits and security measures of digital payments, promoting their confidence and widespread adoption.

Furthermore, the use of SmartCards has been found to be a key driver of SME performance, particularly through improved access to point-of-sale (POS) services and receipt generation for business transparency. Given the high adoption rate of SmartCards among SMEs, financial service providers should expand the availability of POS terminals and other SmartCard-based solutions, especially for small businesses in underserved areas. Policymakers should also explore incentives such as reduced transaction fees and subsidies for digital payment infrastructure to encourage adoption. The government, in partnership with private stakeholders, should create policies that facilitate affordable access.

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Exploring the Role of Green Building Technologies in Smart City Policies in South Africa.

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Abstract

The rapid urbanisation of South African cities has intensified the demand for sustainable, efficient, and innovative urban development strategies. In response, smart city initiatives and green building technologies have increasingly been positioned as central components of national and municipal policy frameworks. This article explores the role of green building technologies within smart city policies in South Africa, with a specific focus on how these technologies are framed, integrated, and prioritised in policy discourse. Adopting a qualitative research design, the study employs a document analysis methodology to examine key national and municipal policy documents, including the National Development Plan (NDP 2030), the Integrated Urban Development Framework (IUDF), selected municipal Integrated Development Plans, and reports from the Green Building Council South Africa. Thematic content analysis is used to identify dominant policy narratives, areas of convergence, and existing gaps in the integration of green building technologies within smart city strategies. The findings reveal that while green building technologies are increasingly acknowledged as critical to sustainable urban development, their incorporation into smart city policies remains uneven and fragmented. Policy emphasis tends to prioritise digital infrastructure and economic competitiveness, often at the expense of comprehensive environmental sustainability and coordinated implementation mechanisms. The article contributes to the growing body of literature on smart cities and sustainable urban governance by providing a policy-focused analysis of the South African context. It further offers recommendations aimed at strengthening policy coherence, enhancing intergovernmental coordination, and mainstreaming green building technologies as integral components of smart city development. This study underscores the importance of aligning innovation-driven urban policies with sustainability objectives to advance resilient and inclusive cities in South Africa.

Keywords: Smart cities, innovation, urban sustainability, green technologies & policy

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1. Introduction

1.1 *Contextualizing Urban Sustainability in the 21st Century*

According to Imafidon et al. (2024) today cities are growing so rapidly, by seeing many people moving into urban areas. However, this growth comes with challenges on environment, housing, energy, and transport. Due to this, government are searching for alternative ways that are new to make sure that the cities are more sustainable, cleaner, and smarter. To ensure effectiveness, it needs to focus on using green building technologies as one of the policies that will be effective. The 21st century came up with many changes in such a way that it can be traced to how people travel, work, and live. The major change is the rapid growth of cities by looking mostly at developing countries where their economies are trying to fit in with the system of developed countries. When cities grow, they require more usage of energy, cause more pollution, and produces more waste. As a result, it is more important to come up with better ways to manage urban areas and to plan (Imafidon, 2024).

Urban sustainability refers to making sure that cities meet the standards and the needs of people without affecting the lives of upcoming generations harder or without causing harm to the environment (Keivani, 2009). The sustainable city should be efficient, healthy, and safe. Furthermore, it should be in a position where it protects natural resources such as green spaces, fresh air, and clean water. This can be done through the use of smart solutions and new ideas that can bring sustainability immensely (Keivani, 2009). This can be important by including the use of renewable energy, improving public transport, and coming up with ways that use less water and energy, and reducing waste. Looking at these steps, it does not only help the environment, but the life of people living in cities will be better due to a healthy conducive environment (Keivani, 2009). Urban sustainability is more about coming up with findings on how to balance environmental care, social needs, and development. In the 21st century it is

about what actions can be taken to make cities become more sustainable where it is not about a choice any longer, but it is about a necessity.

Chauke W.G. & Vilakazi S.

1.1.1 *Smart Cities and Green Building Technologies as Policy Priorities*

Smart cities are cities capable of improving their citizens' life quality, offering a lasting opportunity for cultural, economic, and social growth in a healthy, safe, stimulating and dynamic environment (Casini, 2017). It is concerning cities that operate using data and technology to improve their working process. In smart cities, technologies are used to regulate services (waste collection, transport, and electricity) in smarter and more organized means. The aim is to make sure that people live their lives in an easier, more affordable, and healthier for people living in the city (Casini, 2017). One important aspect of smart city planning is green building technology. These are about building methods and design that reduce things that harm the environment. For instance, green buildings could use systems that use less water and electricity, collect rainwater, and use solar panels. These technologies have positive results in such a way that they help reduce their impact on the environment and lower the cost of running buildings.

According to Razmjoo et al. (2021) now, governments are having inclusiveness in a way that they include green building practices and smart ideas in their policies. This means that they are creating guidelines and laws that will help cities to use these kinds of tools. The creation of policies aims to enhance quality of life, make cities more prepared for any occurrences that might happen in the future, and fight climate change. in places such as South Africa, green building technologies are becoming more popular. They are being used in public buildings, offices, and new housing projects. The government, along with local communities and private companies, are now seeing the value in building in greener ways and smarter. These technologies have a positive impact in bringing local skills development and job creation. For instance, workers need to be trained to install energy-saving systems, smart meters, and install and maintain solar panels. As a result, it shows that smart cities are not only concerned with the environment, but it contributes to supporting the economy (Ramjoo et al, 2021).

1.1.2 *The South African Urban Landscape: Challenges and Opportunities*

1.1.2.1 Challenges

In South Africa, the city scape is influenced by the complicated historical background of apartheid space planning, high population growth, and the inequalities of infrastructures. The inequality in measurable development, which continues in most cities, is one of the major challenges. In the apartheid, the cities were planned in such a manner that they separated the races with the non-whites forced to live in the outskirts of the townships. Some low-income communities continue to reside in informal settlements or on marginalized land with inadequate access to services to this day (Department of Forestry, Fisheries and the Environment, 2024). This division makes the supply of infrastructure, like water, electricity, roads and sanitation more expensive.

Urban spread has been associated with this spatial inequality. Many South African cities can be described as low-density developments and thus, the provision of services to the residents is both inefficient and costly. Low-density places are expensive to offer due to the long distances that the infrastructure must cover, and the inability to utilize public transport effectively (City Energy, 2021). High transport emissions are also another effect of this spread since most of the residents of the sprawl use a personal car to travel long distances.

Furthermore, huge problem within the urban system is the decay of the infrastructure and under-investment. There are numerous cities that are finding it hard to sustain declining water and power systems. The government transparency report states that there was a level of insufficient infrastructure, water delivery systems have leaks and wastage, and most urban systems are exposed to failure because of the under-investment in their maintenance (DFFE, 2024). Even certain cities do not have adequate transport systems and internet connectivity, which hamper smart city plans (DFFE, 2024).

Unreliability and energy poverty are another major issue. Cities in South Africa are taking up a big portion of the national energy, but they experience constant load-shedding (rolling blackouts) and deteriorating electricity distribution systems (City Energy, 2021). Such power outages damage livelihood and economic activity, particularly in the poorer city centers. To illustrate, in Johannesburg, small businesses and households have been destabilized by blackouts, among other things (Mchunu, Onatu & Gumbo, 2023). Township informal houses mostly use unhealthy sources of energy such as paraffin or coal, which pose health hazards (City Energy, 2021; Pathways to Urban, 2021).

The local governments are also weak in governance and financial capacity. Municipalities struggle to put large infrastructure or smart city initiatives into practice and sustain them because corruption, mismanagement, and lack of fiscal resources make it difficult to fund them (Architect Africa, 2025). An example is that in Johannesburg, roads and bridges are falling apart, and most municipal budgets are exhausted through wasteful expenditure, hence it is hard to plan long-term (Architect Africa, 2025).

Housing shortages are a problematic issue on the social front. Informal settlements or crowded houses are habited by millions of people. Although government housing programs are important, they have failed to keep up with demand (City Energy, 2021; Pathways to Urban, 2021). The expansion of backyard shacks (informal houses constructed at the back of the formal houses) increases the pressure on already existing facilities like water and electricity since such houses tend to connect to the supply of the formal house. Most of these new homes at the time outgrow the eligibility conditions of the free basic services (Pathways to Urban, 2021).

Other significant stressors also include urban food insecurity and poverty. The food systems are strained due to increased urban population: many poor households are residing in the areas with

restricted access to fresh food, and there is not much land available to urban agriculture (Sustainable Cities, 2025). This poses social and health problems, particularly on low-income settlements (Multidisciplinary Digital Publishing Institute, 2025).

Moreover, cities in South Africa are susceptible to climatic hazards. Weak planning has led to many informal settlements being in flood prone areas or hillsides that are vulnerable to landslides or erosion (DFFE, 2024). Climate change makes these risks even worse and harms the infrastructure, and its maintenance is even more expensive (DFFE, 2024).

1.1.2.2 Opportunities

Despite these enormous challenges, the urban environment also presents a great opportunity to the green building technologies and intelligent city policies. One of the opportunities is high density, integrated urban development. Cities do not need to keep spreading out but should discourage more dense and mixed-use communities. Such models as 15-minute neighborhoods (when all necessary items are within a walking distance) could decrease the number of transport emissions, minimize infrastructure expenses, and enhance social cohesion (Circulareconomy, 2025).

The other opportunity is in nature-based solutions (NbS). The scholars have emphasized the role of green infrastructure (such as ecologically designed buildings, urban gardens, green roofs, and bioswales) in controlling stormwater, enhancing biodiversity, and alleviating the heat-island effect (Aliu & Aghimien, 2025). Incorporating green building methods, towns will be more resilient to climate change as well as sustainable in general.

There are also good opportunities in the direction of smart grids and energy-efficient technologies. The planning of a smart city will enable cities to incorporate renewable energy solutions, which may include solar power, battery storage, and microgrids that are decentralized. This would lessen the reliance on the national grid and would help in alleviating the effects of load-shedding. Energy management based on smart metering and data can be used to raise efficiency and minimize losses (PwC via SA J. of Industrial Engineering, 2023).

Another opportunity is provided by the adoption of social housing programs. Formal, safe housing of low-income groups can be offered in properly designed social housing development with green building materials and technologies to prevent excessive energy and water consumption (Sokhetye, 2025). Social housing can be incorporated into bigger sustainable urban nodes when connected to smart city models. The future of urban agriculture and transformation of the food system is also promising. Cities can promote food gardens in informal settlements, rooftops, or in green areas with the help of proper policies. Such urban gardens assist in combating food insecurity, creating jobs at the local level, and increasing the ecological value (MDPI, 2025; Neumann and Ngobese, 2025).

In terms of their finances, more people are showing interest in green infrastructure funding. The infrastructure investment gap can be sealed using international development funds, climate finance, and partnerships among other ways. As an example, novel financing schemes or incentives to sustainable buildings may direct capital to green building and smart city developments. Moreover, technological innovation forms new economic opportunities. It is claimed that the emergence of smart buildings (the use of sensors, automation, and data analytics) will give rise to new software, hardware, and service companies (SA J. of Industrial Engineering, 2023). This would help to generate job opportunities particularly among young people and aid in switching to the green economy.

Lastly there is better governance and institutional capacity which also presents a challenge and an opportunity. The policies of smart cities can enhance the national, provincial and local governments' coordination. Through online platforms, data openness and participatory planning, citizens can be more engaged in city-level decision making. This will result in better accountable, effective, and participatory urban governance.

1.1.3 *Research Aim*

This study will be aimed at investigating the presence of and support of green building technologies in South Africa smart city policies. This paper is aimed at realizing how such technologies have been identified in national and local policy documents and how they have been integrated as a part of broader sustainability objectives. Since the South African cities have a problem of inaccessible energy supply, strains in infrastructure, high urbanization, and environmental hazards, the study seeks to explore whether the current policy systems are defining green building technologies as viable solutions to these problems. One of the objectives of the study is to determine the degree of policy integration among various sectors.

A smart city design is related to numerous aspects of urban living, such as housing, transportation, water supply, and energy infrastructure. These industries tend to work in isolation hence resulting in disjointed planning. The study thus seeks to know whether the green building technologies are being dealt with in a coordinated manner in these sectors or whether the policies are dealing with them as divergent, independent measures. It involves analyzing whether the national and municipal plans promote cross-sector collaboration or whether individual sectors operate within national and city limits without any distinct connections to the vision of smart cities.

The other objective is to assess the difference between policy intentions on one hand and actual implementation on the other. Numerous policy statements provide powerful pledges to the idea of sustainability, innovation, and clever technologies, yet the truth is in the question of whether these concepts are supplemented by actionable measures. The research will focus on assessing whether there exist guidelines, realistic timelines and measurable targets of green building technologies in policies. It also seeks to research on the question of whether the municipalities possess skills, funds and institutional capacity to implement these plans. This entails assessing

the quality of policy language as it converts into practice on the ground as well as the quality of implementation strategies as being strong, weak, or nonexistent.

The study also seeks to analyze the relationship between green building technologies and the national development priorities and the global commitments. Some of the frameworks that South Africa has conformed to include the National Development Plan 2030, the Integrated Urban Development Framework, and the Sustainable Development Goals. Green building technologies are significant in achieving energy efficiency goals, climate resilience goals, sustainable housing, and better service delivery.

This is why the proposed study seeks to examine the question of whether smart city policies embody these commitments or not and whether they view green building technologies as critical to the achievement of these goals. Besides, the study will find the gaps in policies and the area where the guidance is not fully developed or clear. There are policies that might refer to sustainability and fail to provide specific actions or guidelines towards green building technologies. The study aims at pointing out the areas in which the policies lack depth, clarity, or coordination to be used in future policy formulations. This consists of determining whether some sectors are addressed compared to others and whether some of the crucial themes such as financing, development of skills and provision of regulatory support have been well addressed.

Lastly, the study seeks to develop an advanced insight into the positioning of South Africa in the wider global trend of smart and sustainable cities. With the emphasis on the role of green building technologies, the paper is intended to expose whether South Africa is moving towards the direction indicated by the global trends in smart urban development or whether its policy choice indicates a different direction, impacted by the local issues and opportunities.

1.2. Background and Context

1.2.1. *Global Evolution of the Smart City Concept*

The concept of a smart city has been developing over the years with the increasing pressures of population expansion, environmental pressure, and technological revolution on the cities. Initially, the concept of smart cities came into being in the period when urban areas started applying information and communications technologies (ICT) to enhance the management of urban services (Du Toit, 2023). Sensors, data platforms, and connected infrastructure became valuable to governments and companies in most developed nations, as it would improve and make transport, energy, water, and public safety more efficient and effective (Du Toit, 2023). The concept changed as it grew up to no longer be about technology but about governance and sustainability. The IoT (Internet of Things), big data, and artificial intelligence have been applied in cities to oversee the traffic flows, regulate the use of energy, and anticipate the breakdown of services (Lau, Marakkalage, Zhou, Hassan, Yuen, and Zhang, 2019).

The concept of information aggregation, or the synthesis of data generated by many sources, has emerged as an important tool to help in decision-making. To illustrate, urban applications of smart cities can be comprised of sensor data, satellite imagery, and mobile devices to monitor the urban phenomena (Lau et al., 2019). Meanwhile, the goal of smart cities is no longer efficiency. Expectations are rising that smart cities are expected to contribute to resilience, environmental sustainability, and well-being of the citizens. Contemporary smart city models are more focused on governance, social inclusion, participation, and infrastructure, rather than only the infrastructure (Tan & Taeihagh, 2020).

In developing states, researchers purport that building smart city projects does not only need plugging technology, but it should be accompanied by legislative transformation, capacity-building, and participatory governance (Tan & Taeihagh, 2020). The history of smart cities the world over is a process, however: starting with the ideas of a technological metropolitan utopia, to more practical approaches that emphasize data, sustainability, and citizen involvement. The increasing number of cities across the globe implementing smart city policies is becoming more balanced in terms of technological innovation and social and environmental objectives.

1.2.2. *Defining Green Building Technologies in the Policy Context*

Green building technologies are described as design, building and operation practices that reduce the adverse environmental impact of a building and enhance resource efficiency and occupant health. The Green Building Council of South Africa (GBCSA) defines a green building as a building that either minimizes or eradicates environmental degradation throughout its life cycle, i.e. planning and construction, operation and decommissioning (GBCSA, n.d.). Green buildings are designed to be energy efficient, conserve water, use sustainable materials and have healthy indoor environment (GBCSA, n.d.). Green building technologies in policy terms usually imply tangible steps and guidelines that can be encouraged by the governments. It involves energy-saving heating, ventilation, and lighting, passive design, rainwater collection, and low carbon materials (Ecolution Consulting, 2024).

It is also possible to have policies certified to established rating systems, including Green Star or Net Zero, to make sure that buildings have quantifiable environmental performance requirements (Ecolution Consulting, 2024). Certification tools based on green buildings are important. The GBCSA has a Green Star SA rating system that assesses buildings in a range of categories, which include energy, water, materials, emissions, interior environmental quality, and innovation (GBCSA, n.d.; Lourens, 2025).

The tools serve to offer a quantifiable and objective method by which governments, developers and owners measure the level of greenness of a building (GBCSA, n.d.). Green building technologies are not merely technical innovations, as far policy is concerned. They are a policy tool, the governments can incentivize or control sustainable building by use of building codes, tax benefits, grants and mandatory certification (U.S. Trade & Development Agency, 2024). Governments can create connections between environmental objectives (such as greenhouse gas emissions reduction) and economic growth and social welfare by integrating the green building technologies into the city planning and smart city policies.

1.2.3 Smart Cities in Africa: Trends and Policy Directions

Smart city policy is gaining momentum in Africa with the rising urbanization. Cities are becoming expansive, and infrastructure is usually stretched. Smart city approaches in Africa are thus more oriented towards enhancing service provision (water, transport, energy), resilience and economic opportunity (Sterling Access, 2025). Digital technologies are viewed as major solutions to these urban challenges by the African governments and development organizations, which is why the strategy tends to vary with high-income countries. To start with, some African smart city projects are centered on the so-called leapfrogging, which means that the new technologies should be used to switch to the new system instead of improving existing infrastructure (Smart Africa, 2017). It is an adoption of smart grid systems, mobile-based public services, and sensor-driven waste and transport management without developing massive legacy networks in the first place (Smart Africa, 2017).

Second, the discussion of African smart cities is focused on governance and inclusion. In contrast to pure technology-oriented ones, most African smart city models put an emphasis on community engagement, local capacity and community decision making (Tonnarelli, 2024). As noted by scholars, to be successful in Africa, smart cities should be accompanied by investments

but also social reforms, the enhancement of the institutions of the country, and the benefit of the local population (Tonnarelli, 2024; Tan and Taeihagh, 2020).

Third, the African smart city policies are related to overall development objectives. A lot of smart city plans are in line with the national plans to facilitate economic growth, creation of jobs and sustainable development (Sterling Access, 2025). The structures of smart cities can also serve as a transition between digital innovation and social progress, not efficiency or profit (Smart Africa, 2017). Nonetheless, it has some challenges. Smart city technologies face obstacles in their implementation because of financial difficulties, institutional capacity, and informal economy (Tan & Taeihagh, 2020).

Digital divide is also possible: in the case smart infrastructure is implemented only in rich districts, the disparities may become even greater. Scholars emphasize the fact that the frameworks used in Africa should be designed specifically and not copied directly into the world models of smart cities (Tonnarelli, 2024). Generally, there is a shift towards technological, developmental smart city policies in Africa, one that is sustainable, inclusive, and transformational in economic terms.

1.2.4 South African Policy Landscape

1.2.4.1. *National Development Plan (NDP 2030)*

The National Development Plan 2030 of South Africa is a vision statement whose aim is to eradicate poverty and alleviate inequality by 2030. It has one of its major chapters (Chapter 8) dedicated to the transformation of human settlements and the enhancement of spatial economy (National Planning Commission, 2012). According to the NDP, the cities of South Africa need to be more functional, sustainable and efficient. It underlines the importance of constructing cities in which people reside near employment, social services, and transport connections, to decrease the commuting expenses, as well as to diminish spatial disparity (National Planning Commission, 2012).

The NDP also seeks urban development in a green manner. It advocates the adoption of low-carbon technologies in the construction and infrastructure, compact urban form and enhanced resource utilization in settlements (National Planning Commission, 2012). To achieve these objectives, the NDP proposes planning reforms, stronger institutions and collaborations with the private sector (National Planning Commission, 2012). It all depends on green building technologies in the long run as part of an overall approach to making human settlements more sustainable and equitable.

The Integrated Urban Development Framework (IUDF) is the key policy tool of South Africa in terms of managing urbanization. The IUDF was adopted in 2016 and is intended to shape the way the cities and towns develop and become more inclusive, resource-efficient, resilient, and well-connected (COGTA, 2016). It was partly created by implementing the objectives of spatial transformation in the NDP (COGTA, 2016). The IUDF contains nine policy levels, that is, primary areas of action, such as integrated urban planning, infrastructure, transport, and sustainable human settlements (COGTA, 2016). The IUDF facilitates compact urban development that is mixed-use (COGTA, 2016). This is just in line with smart city concepts and green building: small-size design decreases energy needs, whereas the green technologies can become incorporated into the infrastructure planning.

Cooperative governance is also highlighted in the framework. It requests collaboration between national, provincial, and local government, and the involvement of the civil society and the private sector (COGTA, 2016). The IUDF envisages a new city deal, where the city spatial inequality is resolved, and investments are planned to change the current city footprints instead of extending them (COGTA, 2016; IUDF brochure, 2020). Moreover, IUDF expressly facilitates better utilization of resources, environmental resiliency, and sustainability (COGTA, 2016). It cites the necessity of infrastructural choices that lower ecological footprints, and

sustainable building. This renders the IUDF an effective policy framework of integrating green building technologies in the development of smart cities (COGTA, 2016).

1.2.4.2. *Integrated Urban Development Framework (IUDF)*

The Integrated Urban Development Framework (IUDF) serves as South Africa's main policy tool for navigating urbanization. Introduced in 2016, the IUDF is designed to steer the growth of cities and towns towards becoming more inclusive, resource-efficient, resilient, and interconnected (COGTA, 2016).

It was partly created to support the spatial transformation objectives outlined in the National Development Plan (NDP) (COGTA, 2016). The IUDF identifies nine key "policy levers" that highlight essential areas for action, such as integrated urban planning, infrastructure, transport, and sustainable human settlements (COGTA, 2016). By harmonizing these levers, the IUDF encourages compact, mixed-use urban development (COGTA, 2016). This approach aligns well with the concepts of smart cities and green building, as compact designs help lower energy consumption, and thoughtful infrastructure planning can incorporate green technologies.

Additionally, the framework stresses the importance of cooperative governance. It advocates for collaboration among national, provincial, and local governments, as well as the involvement of civil society and the private sector (COGTA, 2016). The IUDF envisions a "new deal" for cities, aiming to tackle spatial inequality and ensure that investments are strategically directed to transform existing urban areas instead of expanding outward (COGTA, 2016; IUDF brochure, 2020). Moreover, the IUDF explicitly champions the efficient use of resources, climate resilience, and environmental sustainability (COGTA, 2016). It highlights the necessity for infrastructure choices that minimize ecological impacts and promote sustainable building practices. This makes the IUDF a robust policy framework for integrating green building technologies into the development of smart cities (COGTA, 2016).

1.2.4.3. *Green Building Council South Africa (GBCSA) Initiatives*

In South Africa, the Green Building Council (GBCSA) is a non-profit, membership-based organization that was established in 2007 to spearhead the industrialization of the built environment to be green (World GBC, n.d.). GBCSA forms tools, training and certification of green buildings within the country (GBCSA, n.d.). The most conspicuous tool offered by it is the Green Star SA rating system that analyses the environmental performance of buildings in various categories, such as energy, water, materials, emissions, indoor quality, innovation, and others (GBCSA, n.d.; GBCSA Rating Tools, n.d.). The Net Zero certification of the buildings that exceed partial development and are aimed at neutralizing or even outweighing the carbon, water, and waste footprint is also provided by GBCSA (Ecolution Consulting, 2024).

These rating tools provide the private sector and the developers with a shared language and a standardized set of measurable performance criteria on a green building (GBCSA, n.d.). In addition to certification, GBCSA is an advocacy organization. It trains industry practitioners, advances practices of green building, and invites the public to collaborate with the businesses in the construction of sustainable buildings (World GBC, n.d.). GBCSA, by its activity, assists in coordinating building practice with national policy goals, such as the NDP and the IUDF. The practical examples are numerous: several commercial and residential buildings in South Africa have already received the high ratings of the Green Star, which demonstrates the real application of green technologies (Solid Green, n.d.). This is in line with the smart city objectives (efficient, data-driven buildings) and policy objectives (sustainability, resource efficiency).

1.1.3 Linking Smart Cities, Green Technologies, and the Sustainable Development Goals (SDGs)

The smart city strategies and green building technologies in South Africa relate to the Sustainable Development Goals (SDGs) of the United Nations. Specifically, SDG 11 Sustainable Cities and Communities is very relevant. SDG 11 advocates to have inclusive, safe, resilient, and sustainable cities (United Nations, n.d.). Policy makers can directly support most of the SDG 11 goals, such as decreasing the per capita environmental impact, enhancing housing, and facilitating integrated urban planning, by encouraging the use of green buildings and smart infrastructure (United Nations, n.d.). Other SDGs can also be supported with smart city policies. An illustration is smart energy systems and green buildings minimize greenhouse emissions, which is part of SDG 13 -Climate Action. Green buildings promote SDG 6- Clean Water and Sanitation through efficient use of water and sustainable building material. Another aspect of the smart city design that can be used to meet SDG 9 Industry, Innovation and Infrastructure and SDG 12 Responsible Consumption and Production is smart transport systems. Smart city strategies are being used in South Africa to complement green building technology projects to boost the development agenda of the country. Sustainable and integrated human settlements in line with the SDG principles are already advocated by the NDP and IUDF (National Planning Commission, 2012; COGTA, 2016).

Once the green building practices are mainstreamed in planning smart cities, these international goals become tangible: e.g. with Green Star certification, local governments can monitor the number of buildings that meet sustainable performance standards, which will be part of national reporting on SDGs achievement. Besides, the certification of green buildings and investments in smart cities can open the gates to international sources of climate financing. Numerous financing systems in the world are giving preference to SDG-related initiatives particularly emphasizing resilience, low-carbon infrastructure, and sustainable urban development

initiatives. Therefore, the inclusion of green building technologies into the smart city policies may help South Africa to be a destination of climate finance and public-private initiatives that will support SDGs.

1.2. Problem Statement

1.2.1. *Policy Ambitions vs. Practical Realities, Fragmented Governance and Institutional Silos, Limited Mainstreaming of Green Building Practices in Policy*

South African smart city policy is all about sustainability, but it does not match what happens on the ground. National documents like the *South African Smart Cities Framework* talk about clean energy systems, efficient buildings and digital innovation but local government cannot implement this because of lack of budget, staff and long-term planning capacity (Naidoo & CSIR/DCoG, 2021). Many municipalities do not have the technical skills to integrate green building technologies into their daily planning processes, so policies remain theoretical not practical. The gap between ambition and reality widens when municipalities are under pressure to focus on urgent issues like service delivery, informal settlement growth and aging infrastructure. These pressures push green building projects to the backburner (Das & Emuze, 2020).

Fragmented governance and institutional silos make these challenges worse. Departments of housing, energy, water, transport and environmental planning work in isolation from each other which prevents coordinated action on green building (Rana et al., 2023). Smart city planning requires inter sectoral cooperation, but South Africa's urban governance system is often described as disjointed with limited integration between national and municipal policies (South African Cities Network, 2020). When institutions work in silos, planning frameworks do not align and this results in duplication of work, slow approvals and difficulty in integrating new technologies into existing systems. Silos also limit communication between departments and reduce the ability of cities to adopt shared solutions like energy efficient building codes or green materials.

Due to this fragmentation, green building practices have not been mainstreamed carefully into everyday policy. Despite the legislative tools afforded South Africa such as SANS 10400-XA energy efficiency standard and Green Star certification system, less than ten percent of buildings in South Africa can be regarded as incorporating advanced sustainability standards (Sithole et al. 2024). Green buildings are becoming more known, but still on the top end of the spectrum mostly with commercial developments around this development rather than public building or affordable housing (Green Building Council South Africa 2025).

Most municipalities and major urban areas have only recently begun to update their building codes that must pass through due to careful city planning, so this governance falls behind has made it optional rather than standard practice. But this piecemeal mainstreaming does little to advance our national sustainability aspirations and, in fact, likely widens the chasm between policy intention and practice consequence. South African cities have long faced coordination challenges that stand in the way of implementing these kinds of integrated green building and smart city policies, urban researchers say system thinking is required (Brandt & Siebert , 2022).

The disconnection of smart city planning from environmental and building governance misses so many opportunities to integrate systems such as renewable energy in new housing projects or nature-based infrastructure for climate resilience (van der Merwe et al., 2019). However, in the absence of common modes and forms of governance for city-building that integrates these green building aspirations into mainstream urban development. Rather they are standalone pilot projects that never scale out into the urban system. Most are linked to the 3 big problems such as divide between policy ambition and practical reality, governance in silos, underwhelming levels of mainstreaming smart city policy.

As a result, green building technologies continue to sit on the "periphery" of planning rather than at its "core," energy performance contracting. This means cities are unable to make the best use of green design for energy efficiency, climate adaptation and urban facilities. The underlying problem appears to not be a lack of ambition, but rather the absence of systemic coordination and implementable measures that would translate those ambitions into broad-level green building implementation.

1.3 Justification for the Study

South Africa's up against some tough challenges right now, environmental, economic, and governance issues that really cannot wait. When scholars look at the water shortages, heat waves, and unreliable energy in so many cities, it is obvious that sustainable building design is not just a nice-to-have. It is essential.

Green building technologies cut energy use, make indoor spaces more comfortable, and help cities bounce back from climate shocks. They are a key piece of the puzzle for any smart city that wants to cut emissions and deliver on sustainable living (van der Merwe et al., 2019). If society wants smart cities that work, they need to figure out how to weave these technologies into policy, and fast. There is another problem such as governance. Right now, fragmented institutions and a lack of coordination make it hard for cities to scale up green building solutions (Rana et al., 2023). No one is sure who is responsible for what, and that slows everything down. Digging into these institutional roadblocks, this research can point out where policy frameworks fall short and how to fix them. Smart cities cannot exist without everyone working together, across sectors. If that does not happen, sustainability goals just are not going to be met. Then there is the economy.

South Africa's construction sector has been struggling with slow growth, little investment, and jobs disappearing. Green buildings offer a way out. They can spark demand for new tech, create green jobs, and give the whole sector a much-needed boost (Green Building Council South Africa, 2025). Looking at how green building fits into smart city policy is not just about saving the environment; it is about finding real strategies for economic recovery and future growth. Plus, energy-efficient buildings save money in the long run and add value, which means adopting these practices supports the financial health of both public and private projects (Grant et al., 2020).

This research matters because it adds to what we know about a place that, honestly, does not get enough attention, South Africa, and really, most of Africa. Most of what we hear about smart cities comes from richer countries. Their infrastructure, government systems, and tech just don't match what you find in the Global South (Brandt & Siebert, 2022). South African cities have their own mix of problems: uneven growth, inequality everywhere you look, not enough funding, and lots of informal settlements. These realities call for green building solutions that fit the local context.

In South Africa, this study fills a big gap and shows how green building could work when cities are dealing with all this complexity. There is also a social reason for digging into this topic. When there is a bringing of green buildings into affordable homes or public spaces, people save money on energy, live healthier lives, and end up in better, more comfortable communities (van der Merwe et al., 2019). Smart city plans that include green building tech can push back against inequality, making sustainable living possible for everyone, not just those who already have plenty. That is right in line with South Africa's own goals around fairness, resilience, and making life better for everyone. One last thing, smart city policies need to be real. Right now,

a lot of strategies talk about a big game about sustainability but do not actually say how to put green building tech in place, pay for it, or keep track of progress (Naidoo & CSIR/DCoG, 2021).

This study looks at the gap between what is promised and what is happening. The goal is to come up with solid, practical advice for policymakers, developers, and planners—stuff they can use. With the right guidance, future investments can really move the needle of making cities greener and more sustainable.

2. Literature Review

2.1. *Conceptualizing Smart Cities: Theories and Frameworks*

People talk about smart cities as places where digital tools and data shape how we live, work, and move around. The idea is simple: use technology to make cities more sustainable, efficient, and livable. But behind that buzz, there's a lot of debate about what makes a city "smart." One big theory that can be heard about is technological determinism. This one explains that as cities get more sensors, data networks, and automation, those technologies start to steer how the city works. Think of smoother traffic, better water management, and safer streets because of smarter systems (Kitchin, 2014). Supporters of this idea usually zero in on how new tech gets rolled out and how it can tighten up control and coordination across a city. But there's another way to look at it. The socio-technical systems approach pushes back against the idea that tech alone calls the shots. It says real-world things like culture, politics, money, and community values shape how digital tools get used (Hollands, 2015). They cannot just drop a new gadget into a city and expect magic.

Communities, governments, and even local policies decide whether a piece of tech succeeds or fails. Plus, this approach keeps reminding us that unless smart city systems tackle inequality and include everyone, they don't really work. Connected to that is the governance angle. Here, it's all about who makes the decisions, who sets the rules, and how different groups, especially residents, get a say in what happens next. Researchers like Meijer and Bolívar (2016) say smart

city projects work best when people get involved, not just experts or officials. Residents should help plan, monitor, and judge these projects so they solve real problems. Sustainability is another big piece of the puzzle.

This approach says technology should help cities protect the environment, build up the economy, and include everyone at the same time. It's not just about speed or shiny new apps, it's about long-term resilience, tackling climate change, saving energy, and managing resources better (Ahvenniemi et al., 2017).

Tech should cut waste and emissions, and make cities healthier, not just faster. Then there's the triple-bottom-line idea. This one measure smart cities by how well they do on three fronts: environment, society, and economy. It's a way to see if things like green buildings or renewable energy aren't just good for business, but also for people and the planet (Elkington, 1997). The goal here is balance don't trade off the environment for a quick profit. The human-centered model is all about people. It says smart cities need to boost quality of life, bring everyone in, and treat people fairly. This model focuses on well-being, social bonds, and empowering marginalized groups by making sure digital tools and services reach everyone (Komninos, 2015). This really matters in places where gaps between rich and poor are still huge.

Another important framework is the integrative model. Instead of looking at tech in isolation, it connects the dots between systems like transport, energy, waste, housing, and water. The idea is to get everything working together through digital coordination less waste, more resilience, stronger cities (Angelidou, 2015). Of course, not everyone's convinced smart cities are all upsides. Critics point to risks like privacy issues, surveillance, unequal access, and the clout of big tech companies controlling city data. Without strong rules and real safeguards, smart cities can end up making old inequalities even worse (Sadowski, 2019). That's why a lot of scholars keep pushing for ethical guidelines and tighter oversight.

2.2. Global Perspectives on Green Building Technologies

Green building technologies cover everything from advanced construction methods to smart systems that cut down on resource use, save energy, and make healthier spaces for people. They've become a big part of the push for global sustainability and climate-friendly city planning. All over the world, people see green buildings as a major way to shrink a city's carbon footprint since buildings use up so much energy (International Energy Agency, 2021).

A lot of cities and countries rely on certification systems like LEED, BREEAM, and Green Star. These rating systems set the bar for how to design, build, and run buildings with the environment in mind. They help track things like energy efficiency, water savings, waste reduction, and indoor air quality (U.S. Green Building Council, 2020). Plus, these standards push developers and cities to build responsibly and stick to green policies. In places with more resources, green buildings often come packed with renewable energy tech. They will see solar panels, geothermal heating and cooling, wind turbines, and energy storage systems all working together to cut out fossil fuels. Germany and Sweden, for example, have strong policies that support "energy-positive" buildings places that make more energy than they use (European Commission, 2020). There's a clear link here between green buildings and bigger climate action plans. Water-saving tech is another big piece of the puzzle.

Think greywater reuse, low-flow toilets, rainwater collection, and smart sprinklers all tools that fight water waste. In regions facing water shortages, like Australia, Singapore, and parts of the Middle East, these systems have caught on fast in both homes and offices (Chong et al., 2018). Smart tech is everywhere in green buildings now. Things like smart meters, automated building controls, and sensor-driven lighting or ventilation help cut energy waste and give real-time data

on how things are running. These systems fit right in with the digital tools cities use for smart urban planning, making green buildings a key part of the bigger smart city picture (Zhao et al., 2019). But it's not just about saving energy or water.

Green buildings also put people's health in front and center. Increasingly, you'll find buildings using non-toxic materials, better ventilation, and designs that let in natural light. Research shows these features can cut down on breathing problems, sharpen thinking, and even make people more productive (Allen et al., 2016). That's why health-focused green design is really taking off worldwide. Money talks, too. Governments like those in the US, Singapore, and the UK are offering tax breaks, subsidies, and grants to get more builders and owners on board with green upgrades and new builds. Studies prove these incentives work, they boost adoption rates, especially in the private sector (Zuo & Zhao, 2014). With these financial nudges, cities can hit their climate goals faster and bring emissions down in the building sector.

Another big shift is that more countries are tying green building standards to their national climate policies. Lots of governments now include energy-efficient buildings in their targets under big deals like the Paris Agreement. Green buildings help countries hit emission reduction targets and build resilience against climate risks (United Nations Environment Programme, 2020). Research from around the world keeps pointing out just how important green building technologies are for sustainable, smart cities. Experts say they work best when plugged into bigger city systems such as smart power grids, better public transport, and creative ways to handle waste. This whole-system approach connects green buildings to the heart of smart city development by improving energy use, cutting emissions, and using digital tools to guide decisions.

2.3. Policy Integration of Sustainability and Innovation

When governments try to blend sustainability with innovation in policy, it gets real, they must build rules, incentives, and systems that push for eco-friendly tech but don't forget about people or the economy. A lot of countries are setting up national and city-level policies to get everyone

on board with green building tech. It all ties into those bigger smart city plans you keep hearing about. The idea is to protect the planet, use resources wisely, and keep cities moving forward with new digital tools.

Most of the time, this starts with a big picture framework. Think about climate action plans, energy efficiency roadmaps, and green infrastructure guidelines, all those government blueprints that steer how cities grow.

The United Nations' Sustainable Development Goals (SDGs), for example, give countries a set of targets for sustainable cities, clean energy, and smarter consumption (United Nations, 2015). These guides push cities to use things like efficient lighting, renewable energy gear, and water-saving tech in their building codes. Zoom in a bit, and you'll see cities getting creative with their own policies. They roll out smart city plans aiming to cut emissions, sort out waste, improve buses and trains, and build greener buildings. It's not just government, either these plans pull in developers and researchers, too (Batty et al., 2012). Working together, they try out new tech, swap ideas, and figure out what works. Rules matter, too. Building codes now often demand better energy performance, and planning laws nudge designers to use less stuff. These regulations shape what materials and tech developers use. And it works, research shows that tougher rules really do boost green building and shrink environmental footprints (Janda, 2011). Money always comes into play.

Innovative building tech isn't always cheap at the start, so governments throw in rebates, tax breaks, grants, or low-interest loans to help cover the cost. They also team up with private investors through public-private partnerships to get more green projects off the ground (Wang et al., 2018). Tech is a big piece of the puzzle. Governments back smart systems like building automation, smart meters, and energy trackers. These tools collect data that helps cities save energy and manage resources more efficiently. By plugging digital tech into building policies, cities can build better energy grids and even let people share energy across networks (Gómez et al., 2019).

There's a social side, too. If policy doesn't include everyone, it misses the point. More governments now mix social housing with green building standards, making sure even low-income folks get the benefits of sustainable homes (Turcu, 2012). So, innovation isn't just about shiny new tech, it helps cut inequality and protect the environment at the same time. The countries that really make this work usually have strong leadership and coordination. Ministries, city agencies, businesses, and community groups all need to be in sync. That's how smart city policies and green building efforts line up with national climate goals, local plans, and what people need on the ground.

2.4 South African Scholarship on Smart Cities and Green Development

In South Africa, research on smart cities and green development has picked up speed lately. The country's dealing with fast-growing cities, limited resources, and deep-rooted social gaps. Researchers keep coming back to how South Africa's approach to smart cities really mirrors its national goals, things like better public services, job creation, cutting emissions, and building resilience (South African Government, 2020). One big topic is how smart tech fits in with the country's ongoing service delivery problems.

Cities in South Africa juggle power cuts, water shortages, old infrastructure, and neighborhoods still divided by the past. Researchers say smart grids, water sensors, and digital tools can help cities run better and keep officials accountable (Naidoo, 2021). These systems cut down on waste and let cities manage what little they have more wisely. Green building tech gets a lot of attention, too, especially since the government's signed onto some serious climate commitments. Green buildings tick several boxes for the National Development Plan and the National Climate Change Response White Paper, energy efficiency, renewables, and better city design (Department of Environmental Affairs, 2011).

More companies are adopting green building standards, thanks in part to the Green Building Council South Africa, which sets benchmarks like Green Star SA (GBCSA, 2020). But it is not all smooth sailing. High upfront costs, a shortage of technical know-how, and not enough awareness among developers and policymakers' slow things down (Darko & Chan, 2018).

Researchers keep saying: South Africa needs stronger policies and incentives to speed up the use of energy-efficient materials, smart systems, and renewable energy in buildings. Governance comes up a lot in literature. Studies make it clear that smart city projects don't work without solid teamwork across national and local governments, clear direction, and real partnerships with businesses and universities (Mouton & Islam, 2021). When these groups pull together, cities can test new ideas and build the skills needed for smarter, greener growth.

Social inequality is another theme that researchers refuse to ignore. They argue that smart city plans must speak to the needs of poorer communities and not just leave them further behind. Tech like green building and smart systems should make housing more affordable, boost access to energy, and cut household bills (Maphoto & Singh, 2020). The goal is to be the first city that improves life for everyone, not just a lucky few. Finally, there's a lot of focus on urban resilience. Researchers dig into how cities can use green tech, smart water systems, and energy-wise buildings to face climate threats—droughts, heatwaves, flooding (Ziervogel, 2019). The message is simple: climate adaptation must be baked into any smart city strategy.

2.5 Identified Gaps in Literature

While the writings about smart cities and green building technologies are growing both internationally and in South Africa, certain gaps do still exist. One of the significant gaps is the scant investigation of the extent to which green building technologies are incorporated into

smart cities policy. There are numerous studies on smart cities or green buildings, but they fail to demonstrate the adequate integration of these concepts in South African policy. There is a need to investigate the nexus between environmental objectives, technological advancement and urban governance in more detail.

Another gap concerns the little information on how lower tier municipalities enforce adaptive smart city and sustainability policies at the South African national level. Much of the literature tends to center on national policy frameworks and does not focus on how policies are captured at the city level. There is a dearth of studies on the municipal level preparedness, proficiency, and institutional frameworks to promote the integration of green building technologies in the smart city model.

Another missing piece is research on low income or informal settlements. Much of the smart city literature is about fancy homes or commercial towers. but south Africa's city landscape includes big informal neighborhoods with no running water or electricity. Little research exists on how green technology and digital systems could be adapted to support affordable housing and help people save resources. More research is needed to understand how sustainability and tech can solve inequality. There also is a lack of study on how green buildings and smart cities affect people. Many reports talk about the environment and the tech benefits, but not many look at how these things change lives, including communities, and give people a voice. There is little information on how users feel, how communities get involved, and how the public trusts the use of digital and green tech.

Another key missing part is looking at how green building works overtime in South Africa. Many checks on work still to be done or buildings not yet built, but not many follow how these new systems hold up over time when used in different weather and life settings. They need to learn more about what gets broken, how much people save, and what effect it has on nature over time. Finally, there is not enough African views in the world smart city ideas. Most of the work is from Europe, Asia and North America where the money and tech are different. South African cities have their own problems like unfair wealth; past city designs and lack of tech.

We need more work that shows what Africans go through in their cities and what will work best for them. These missing pieces show that we need more real, open, and in the field work to know how to get South African smart city plans to use these tech ideas in a way that makes sense to their lives and places.

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3. Methodology

3.1. Research Design: Qualitative, Exploratory

This study takes a close, open-ended look at how green building stuff fits into smart city plans in South Africa. Going with a qualitative approach lets us really dig into the meanings, aims, and vibes of these policies. It is a good route since policy papers are full of tricky concepts you cannot just measure.

The exploratory setup is handy since the whole link between green buildings and smart city policy is new in South Africa. Not much research exists on it yet (Creswell & Poth, 2018). This lets the researcher find fresh angles and see patterns that might be missed with more rigid methods. Having a flexible, qualitative setup matters because it lets the researcher roll with the punches when looking at policy papers, which can jump around in focus and how they're laid out. The setup allows for reading and comparing policies from national, city, and industry levels. By checking these papers, the study figures out how green building concepts are worded in smart city talk. It also checks how these concepts match South Africa's goals for getting better as a country. So, using this kind of approach helps expose the heart of what policies care about, where the holes are, and how green building is thought about when looking at the bigger picture of cities growing in a way that lasts.

3.2 Method: Document Analysis

This research mainly looks at documents. It is a popular way to do qualitative research because it gives you a way to look at and understand written info in a step-by-step way (Bowen, 2009). It works well if you're studying policies because policies are official documents that show what the government wants to do, its plans, and how it plans to do it. Looking at these documents helps me see how they describe green building tech, what goals they are trying to reach, and

how they fit into plans for smart cities. In reading the policies, the information picked a bunch of times and jotted down notes about the big ideas. Then, looked at the notes to see if there were any themes, things that kept popping up, or what they meant relating to green building and smart cities.

Doing it this way is nice because they can see what the policies say plainly but also kind of read between the lines. Plus, they do not have to worry about stuff like getting a hold of policymakers for interviews or if people remember things right, since the policies are written down and do not change. Looking at documents also lets you see how different levels of government think. Like, national policies might talk about big goals, but city plans might get into detail. Combining these together, good results in terms of better idea of how green building tech is being used in South Africa's planning.

3.3 Selection of Policy Documents

3.3.1. National (White Papers, NDP, IUDF)

At the national level, South Africa has White Papers, the National Development Plan (NDP), and the Integrated Urban Development Framework (IUDF). These are key documents because they lay out the long-term goals for development and keeping things sustainable. The NDP shows where South Africa wants to be by 2030, like having good environmental practices and energy-saving infrastructure (National Planning Commission, 2012). The IUDF helps shape urban areas and focuses on making cities smart and sustainable (Department of Cooperative Governance, 2016). White Papers on things like energy, housing, and the environment give government departments extra guidance on dealing with climate change and encouraging good building practices. Because these national policies create a base for what cities and specific industries do, they are super important to this study.

3.3.2. Municipal (city strategies, integrated development plans)

City hall papers, things like city plans and development roadmaps, lay out how places like Johannesburg, Tshwane, and Cape Town are tackling city growth, climate change, and energy. These papers are more into the nitty-gritty than national rules do. For example, some cities have

plans for green building rules, solar power, and better transport (City of Cape Town, 2020). Developing road maps are really important because they show how cities plan to meet national targets locally. They also reflect what resources cities have and what problems they face. Looking at these city papers helps us see how green building ideas are being used in cities.

3.3.3. Sectoral (housing, energy, transport)

When talking about sector policies, it is about stuff related to homes, energy, and getting around. They picked these areas because they really have an impact on how green building stuff gets used in South African cities. Like, the National Housing Code has rules about saving energy and using sustainable materials (Department of Human Settlements, 2009). Energy plans, like the Integrated Resource Plan, talk about renewable power and cutting down on electricity waste (Department of Energy, 2019). Transportation plans cover low-emission travel and planning infrastructure.

These policies show how different parts of the government either help or hold back the use of green building tech. Plus; they tell us if these areas are on the same page as smart city ideas at the national and city levels. By looking at papers from different fields and levels of government, we can get a better handle on how green building tech fits into smart city plans. This way, we make sure to grab both the big ideas and the real-world plans.

3.4 Analytical Approach: Thematic Content Analysis

3.4.1. Coding Strategy

The initial step of coding is referred to as open coding. During the open coding stage, the researcher reads each document and underlines statements that relate to sustainability, technology, urban planning, energy use, housing development, or environmental management. The researcher labels these statements with short descriptors. After open coding, the researcher moves to the axial coding stage. At this stage, the researcher compares and organizes the initial codes into categories based on any relationship between them. For example, codes that relate to "energy efficiency," "solar technology," and "building standards" may be grouped together in a higher order category related to types of green building technologies. The final stage of

coding is called selective coding in which the researcher identifies core themes in the data that best explains how policies link green building technologies to smart city approaches.

This systematic coding strategy provides a useful framework to support the process of ensuring that the major themes are grounded in the actual text of the documents. It also reduces the potential for researcher bias, as the researcher must justify how initial codes ultimately were combined into themes.

3.4.2. Key Themes of Analysis

The analysis is guided by several major themes. Promotion of building energy efficiency is one of them. Numerous policies emphasize the necessity to decrease the consumption of energy and advance renewable energy technologies. The other theme is sustainable urban development where policymakers aim at minimizing environmental effects by means of improved planning and infrastructural development.

The third theme is innovation and technology that encompasses the application of digital, smart meter, and new building materials. Fourth theme can be as policy and governance. This theme discusses the theme of policy-supporting and policy-contradicting policies, as a way of promoting green building technologies. Other themes are climate resiliency, quality of housing, and funding mechanisms. The concept of climate resilience is reflected in the policy that talks about adaptation to extreme weather, and the concept of housing quality is reflected in sectoral policies that focus on safe and efficient living conditions. One can fund it through incentives, grants or partnerships to fund green buildings. These themes are useful because they enable the study to know the strong points and the weaknesses of the South African policies.

3.5 Research Limitations

The research has several shortcomings. The availability of policy documents and their quality is one of the constraints because document analysis will require such documents. Certain

policies are old obsolete or incomplete, and this restricts the precision of the analysis. The second weakness is that the documents will capture official directives and not practicality. There may be policies that talk about the high support of green building technologies, but this does not necessarily imply that the same objectives are implemented in practice.

These policies can only be confirmed through interviews or field studies, which cannot be done without. Another weakness is that there is the risk of interpretation bias. Despite thematic content analysis giving a systematic approach, the researcher still gives out interpretations according to what he/she understands. This can affect the codes and themes development. Also, the specific national, municipal and sectoral documents are the subject of the study. Although these documents are pertinent, they might not reflect everything which influences green building technologies. Also, policies in certain cities can be in greater detail than in others, which will provide an uneven analysis. The other constraint is that the policy contexts vary with time. New policies can be introduced, and old policies can be updated. Due to this, the study presents a picture and not an ultimate decision. Irrespective of these shortcomings, the study is also informative on the way green building technologies are appreciated in the policy of smart cities in South Africa.

4. Results

4.1. Policy Recognition of Green Technologies in Smart City Strategies

The policies of a smart city in South Africa consider green building technologies as important increasingly. National plans like the National Development Plan (NDP), the Integrated Urban Development Framework (IUDF) emphasize the inclusion of clean energy systems, environmentally conscious buildings, and efficient urban infrastructure in supporting the sustainable cities (National Planning Commission, 2012; Department of Cooperative Governance, 2016).

These policies indicate that government bodies accept green building as a major component of the long-term city change. They also perceive technology as something that is needed in enhancing the quality of life and reducing the environmental effects. At the local level, green

technologies are referred to in Cape Town, Johannesburg and eThekwini smart cities or climate action plans. The Climate Change Strategy of Cape Town involves residential and commercial buildings being committed to the use of energy-efficient buildings, solar photovoltaic (PV) facilities, and water saving methods (City of Cape Town, 2021).

The Smart City Strategy of Johannesburg also acknowledges the necessity of environment-friendly building systems that will decrease the amount of electricity consumed and enhance the comfort inside of a building (City of Johannesburg, 2020). These reports indicate that green building technologies are presented as the ones that facilitate digital innovation, environmental aspiration and climate resilience. Although the recognition is evident, the policies differ in the extent of detail that they offer. There are policies that provide measures that should be taken, like energy-efficient building codes and lighting, and those where the general statements are made, and their instructions are not precise.

Voluntary rating instruments like the Green Star SA and Net Zero certifications have been presented by the Green Building Council South Africa (GBCSA) and have affected the language of municipal policies and allowed cities to implement quantifiable sustainability principles (GBCSA, 2022). Nevertheless, these tools have not come to be uniformly incorporated in local government strategic plans. Most cities talk about green buildings and are not necessarily involved in firm implementation strategies. While the support of renewable energy can also be found in national energy policies (including the Integrated Resource Plan or IRP), the latter has an indirect connection to green buildings by promoting energy-efficient technologies (Department of Mineral Resources and Energy, 2019).

Although the IRP does not target buildings directly, it establishes an enabling environment through the promotion of distributed renewable generation, e.g. rooftop solar systems. This assists the smart city initiatives in taking up the greener energy models and lower strain on the electricity grid. The other recognition is through international commitments of South Africa. Being one of the signatories to the Paris Agreement, the country is under pressure to lower carbon emissions, and green building technologies are used to achieve these requirements

(South African Government, 2022). These larger promises are usually used to explain their environmental ambitions in smart cities.

Since cities are the major source of carbon emissions, the implementation of environmentally friendly building technologies has become a significant element of national climate response. Although this has been acknowledged, policy to action gaps in translation exist. Green technologies have been recognized in many policies but have little funding support or technical advice. The local governments usually have the problem of capacity, limited budgets and slow processes of approval. Consequently, the magnitude of implementation varies across various municipalities. The identification of green building technologies is at the policy level, but the implementation is still poor.

4.2 Weak Integration Across Sectors

4.2.1. Housing and Urban Infrastructure

Housing backlog is a problem in South Africa that determines the integration of green technologies into the built environment. Major housing developments are regularly oriented on price and speed of delivery over the long-term environmental effectiveness (Turok and Scheba, 2018). Consequently, green building technologies have employed disparity in the state-sponsored housing projects. Although the policies favor sustainable building, some real projects are not based on a sustainable building approach since most of them use the traditional materials and modes of construction since they are inexpensive and readily available. In the Breaking New Ground (BNG) policy, sustainable human settlements are already mentioned, yet green building technologies including insulation, greywater reuse, and passive solar design are not enforced (Department of Human Settlement, 2004).

Technology is thus seen as optional but not mandatory elements of smart cities by many municipalities. This vague connection between the dwelling and environmental objectives minimizes the possible effects of green technologies. There have been some pilot developments

utilizing energy-saving solutions, but these are small-scale. As an illustration, some of these social housing in Cape Town and Johannesburg have solar water heaters or efficient lighting.

Nevertheless, such interventions are usually done by way of donor-funded or research-based interventions instead of practice. Unless there is greater integration of policies, the green building technologies will be restricted to local neighborhoods instead of influencing the overall housing sector. There is also poor integration in urban infrastructure. Green technologies are rarely applied in the use of roads, public facilities, and community amenities. As an example, smart lights, sustainable drainage systems or climate-resilient materials are not commonly installed. The urban budgets are more biased towards repair rather than innovation in the case of under-resourced regions. The penetration of green building technologies will not be much until the infrastructure planning process embraces the sustainability standards in totality.

4.2.2. Transport and Energy Efficiency

A significant contributor to the emission in South African cities is transport. Nevertheless, transport planning does not necessarily include the introduction of green building technologies, although these two areas have a high level of interrelation. Through renewable energy systems, it is possible to directly connect smart transport infrastructure like electric vehicle (EV) charging stations to green buildings. However, the focus of most municipal transport schemes remains on road widening and not low-carbon mobility (South African Cities Network, 2021). This minimizes chances of matching building technologies with greater urban energy efficiency objectives.

There are energy efficiency policies, but the application differs. The National Energy Efficiency Strategy encourages efficient lighting and solar water heaters as well as better building envelopes (Department of Mineral Resources and Energy, 2016). These interventions are in direct relation to smart city objectives. Most of the municipalities, however, do not have the enforcement capacity to enforce the building efficiency standards. Consequently, energy

efficient designs are being utilized more in the high-income developments than the low-income or government aided developments. Green technologies are also not well integrated in the public transport systems.

As an example, Bus Rapid Transit (BRT) models in Johannesburg and Cape Town incorporate certain energy-saving options, yet they are not entirely aligned with the carbon-cutting objectives since they continue to be based on the use of diesel buses (Walters, 2021). The combination of green buildings and transport hubs, such as solar canopies, shade buildings or regenerative braking systems, is not extensive. Moreover, the electricity crisis in the country has compelled the adoption of emergency energy systems by the municipalities instead of long-term green designs. Intensive load-shedding has driven cities to install diesel generators, rather than investing in renewable building systems. These short-term decisions influence the way smart cities strategies are developed and lower the level of energy-efficient technologies implementation in social buildings.

4.2.3 Waste and Water Management

The issue of water scarcity and waste management offers a good chance of green building technologies, and there is a very low level of integration. The municipal water departments are frequently independent of urban planning teams, and in this way, it is not easy to implement water-effective designs on a large scale (Enqvist & Ziervogel, 2019). Greywater recycling, water-saving fixtures, and rainwater harvesting among others are listed in the policies but are not standardized in all housing, commercial, and public projects. Repeat droughts experienced in South Africa indicate the necessity of water-saving structures. The drought crisis in Cape Town in 2018 showed that technologies at the household level can decrease demand, although these technologies have not become an integral part of building codes or smart city policies yet (Ziervogel, 2019).

Rather, they are promoted but not compulsory and this results in inequitable adoption. Gaps are also indicated in waste management policies. Green buildings may also encourage the reduction

of waste by providing recycling facilities on the site, composting, and construction techniques that lead to minimal waste of materials. Nevertheless, building policies are hardly related to the municipal waste strategies.

The waste systems in most cities are still based on landfills, and this restricts the ability of green buildings to support the practices of the circular economy (Godfrey and Oelofse, 2017). Smart waste technologies are not prevalent in South African municipalities, e.g. sensor-enabled bins or waste-to-energy. In the instances that they exist they tend to be pilot projects, as opposed to integrated programs. The role played by buildings in the reduction of waste will not be high without better coordination between the environmental departments and urban planning.

4.3 Innovative Practices in Selected Municipalities

Nevertheless, not all municipalities show unpleasant trends, others prove to be promising in terms of innovation. Cape Town has been regarded as a green building technology leader. The city facilitates the use of solar PVs, water-saving technology, and the green building standards of both community and private projects (City of Cape Town, 2021).

The smart design that is employed by MyCiTi public transport system also helps decrease the level of emissions and promotes integrated mobility. Johannesburg has also launched several pilot eco-districts and energy efficient governmental buildings. Attempts to promote renewable energy, enhanced urban green areas, and the use of low-carbon transport can be seen in the Joubert Park Solar Project and in the Corridors of Freedom urban development framework (City of Johannesburg, 2020).

Through these projects, it is reflected how the use of integrated design can help to enhance the environment, as well as to support social development. Climate adaptation efforts in eThekwini (Durban) have also been successful. The municipality applies the use of green roofs, water-sensitive city form, and natural infrastructure developments to enhance climate resilience (eThekwini Municipality, 2020).

The Green and Sustainable Building Guidelines in the city give an incentive to the developers to adopt resource efficient construction methods. Durban demonstrates that natural systems can be used together with building technologies in smart cities as the city is dedicated to ecosystem-based adaptation. Solar-powered public facilities, energy saving lights, and eco-friendly municipal buildings were also tried by other municipalities like Tshwane and Nelson Mandela Bay.

Though the projects are not very large, they prove the increased attention to sustainability. The innovations are also largely supported through public-private partnerships, donor funding, and civil society organizations. The GBCSA is also certifying commercial buildings in large cities, which aids in the increase of standards even in the situations when the government is not enforcing it (GBCSA, 2022).

Despite these accomplishments, the innovations are still lopsided. Cities that are well-equipped have more green technologies, and small cities are limited in financial and technical resources. This paves way to unequal development of the country and restricts development of smart cities on the national level. Even in major cities, innovations frequently remain concentrated in the business central areas rather than diffusing them to the low-income neighborhoods.

4.4 Policy Tensions: Economic Growth vs. Environmental Sustainability

One of the biggest problems of South Africa has been the conflict between the economy and environmental sustainability. Policymakers tend to have more focus on job creation and housing provision and economic growth rather than green technologies, particularly in places facing poverty and unemployment (Turok, 2016). Although green buildings have the potential of saving costs in the long run, certain areas of short-term politics do not concur with the long-

term costs incurred in building the green building. Budgets of municipal entities are low, and green technologies are believed to be costly.

The result of this is that some policymakers prefer traditional construction approaches that are relatively cheap in the short run. This leads to the fact that sustainability standards are even considered as being lower than fast service delivery (Cirolia, 2020). The tension influences the implementation of smart city policies and delays the implementation of green building technologies. These policy tensions are also determined by the influence of the private developers.

Green designs can be applied in high-income neighborhoods due to the increase in property value, but low-income residential projects cannot afford to pay extra expenses. In the absence of subsidies or incentives, green technologies can increase inequality as it will be available to more affluent people. A second conflict is due to the dependence of South Africa on fossil fuels. Mining and manufacturing are among energy intensive industries in the national economy. The technologies used in green building have decreased energy requirements, yet larger economies are still dependent on electricity generated by coal. This leads to contradictions in policies, with cities promoting renewable power as national energy policy ensures production of coal (Eberhard & Naude, 2016).

Other policy makers fear that tough sustainability policies will drive away investment. Other people claim that green building technologies have the potential to generate new economic activities, including renewable energy, retrofitting, and eco-construction employment (UNEP, 2021). These discussions indicate that the economy and environmental objectives tend to fight each other politically.

5. Discussion

5.1. Interpreting Findings Against Global Best Practices

Results in South Africa reveal that green building technologies are gradually being integrated in smart city planning, albeit the extent of integration is not in tandem with the international benchmark. Green buildings are a component of a broader digital ecosystem in most of the major smart cities like Singapore, Copenhagen, and Barcelona. Cities also tend to implement Internet of Things (IoT), real-time monitoring, smart meters, and high-level automation in buildings to minimize the consumption of energy and water wastage (International Energy Agency, 2021).

There is a global trend in terms of data-driven efficiencies, integration of renewable energy, and full-life-cycle sustainability. Policies in South Africa to improve energy efficiency include policies like the Green Building Council South Africa (GBCSA) rating systems and national policies like SANS 10400-XA guide. Those frameworks are associated with the international standards that encourage the minimization of carbon emissions, passive design, and improved management of resources (GBCSA, 2023). Solar power, efficient insulation, low-energy lighting, and water-saving systems are now provided in many of the buildings in cities like Johannesburg and Cape Town. These characteristics are like international green building practices particularly those ones in emerging economies which have similar resource limitations.

Nevertheless, South Africa continues to use low-technology solutions more as compared to the best practices across the globe. Although the world is shifting towards sensor-based management and predictive energy analytics, and building-level digital twins, the South African cities tend to focus on simple efficiency measures and minimum performance requirements

(UN-Habitat, 2020). This is an indication of a disconnect between policy intentions and technological uptake.

Meanwhile, these less complex interventions are context-specifically applicable, as newer technologies are sometimes costly and demand a set of skills that most of the municipalities are not ready to possess yet. South Africa is also in line with international values of sustainability and requires further incorporation of superior technologies to equal the most developed smart cities. Provided that these gaps are tackled, in particular, in the area of digital innovation, the creation of automation, and data management, the country would be on a path to the standards adopted at the international level.

5.2. Implications for Urban Governance in South Africa

The green building technologies and their combination with the smart city policy should have significant implications on the governance of cities in South Africa. To begin with, city management requires more technical skills. The officials in the municipalities must be aware of energy modelling, passive design, building auditing and green certification. This involves long-term institutional support and continuous training. The National Development Plan (NDP) emphasizes that sustainable development requires the establishment of local government capacity (National Planning Commission, 2012).

In the absence of effective internal capabilities, municipalities will be unable to achieve compliance, performance monitoring, or performance appraisal of building plans. Second, implementation of green building propels the cities to embrace a more collaborative approach of governance. Smart cities rely on systems of government departments, and both private developers, utilities, research centers, and community organizations. The country of South Africa also collaborates with other organizations, including the Council for Scientific and Industrial Research (CSIR) and universities to conduct research on energy efficiency, climate adaptation, and cost-effective green technologies (CSIR, 2022). The partnerships assist the

cities to overcome the challenges related to resource scarcity and technical disjuncture's. Urban governance is thus made more collaborative and knowledgeable.

Third, the systems of governance should respond to financial challenges. Green building technologies have the ability of saving operational expenses; however, their initial investment is normally expensive. Cities must have financial systems that can allow developers to embrace sustainable technologies. As observed in other countries, incentives, including green bonds, tax rebates, and public- private partnerships can be used to boost adoption (World Bank, 2020). South Africa is also starting to use green bonds to finance infrastructure in certain cities, as the case of the water infrastructure bond in Cape Town. Nevertheless, there are still few similar practices on green buildings.

There is a necessity for stronger financial governance with incentives and mechanisms of risk-sharing. Fourth, governance should deal with inequality. The spatial inequality and disproportional municipal capacities in South Africa imply that green building technologies could be in richer regions. Devoid of strategic plans, the development of smart cities can increase the existing gaps. UN-Habitat (2020) notes that fair development of smart cities demands a policy that would promote equity in sharing the benefits of such developments among all communities. Cities should thus have a system of governance that is both innovative and affordable and socially inclusive.

5.3. Policy Rhetoric vs. Implementation Gaps

The results reveal that there is an obvious disconnect between the robust language applied in policy documents and the actual magnitude of implementation in South Africa. Most policies on a national and municipal level outline bold visions, including the net-zero carbon buildings and a smart, sustainable city. The Department of Environment, Forestry and Fisheries and the GBCSA emphasize the significance of climate-resilient development and massive implementation of green building concepts (GBCSA, 2023). The government of South Africa

has also undertaken the goal of cutting down on the emissions as per international laws that are part of the Paris Agreement (Department of Environmental Affairs, 2018).

Notwithstanding these commitments, a lot of cities fail to deliver on the targets of implementation. One of the biggest reasons for this gap is lack of technical capacity. The municipalities may be short of energy professionals and building assessors who can evaluate the proposals of smart technologies, as well as employees.

The findings of research of South Africa Local Government Association (SALGA, 2021) indicate that there are a high number of municipalities with critical shortages of skills, particularly in the fields of engineering and planning. There is also a financial gap. Green technologies do help save money in the long run, but the initial expenses remain a hindrance, particularly in lower-income regions. Developers do not always want to participate in voluntary green certification, and municipalities have no money to renovate old state buildings. Implementation is slow without financial incentives or subsidies. According to the World Bank (2020), developing nations require the availability of funding to help them transition to green cities, and South Africa is not an exception.

Fragmented policy coordination at levels of governments is another factor. Smart city plans, climate policies, municipal by-laws, and energy rules do not necessarily coincide. As an illustration, the national building standards might not be entirely adequate to support municipal climate plans, and the municipalities might understand national regulations differently. This incompatibility undermines execution and delays.

Lastly, the discourse of smart cities tends to focus on hi-tech innovation, but numerous cities implement simple green solutions. The lack of integrated data systems, smart grids and advanced building automation is evidence of the lack of correspondence between policy

language and operational capacity. This gap depicts that there is a necessity of more realistic policy formulation, better coordination, and an enhanced support mechanism.

5.4. Positioning South Africa in the Global Smart Cities Discourse

The place of South Africa in the global discussion of smart cities is determined by its advantages as well as its weaknesses. Sustainable urban development is evident in the country, and it has embraced the idea of green buildings, an indication that the emergent economies can actively contribute in the transition of the world towards low-carbon cities. Engaging in projects like C40 Cities and world climate deals, South African cities put themselves in the global networks promoting environmental innovation (C40 Cities, 2021). The ability to emphasize on cost-effective, context-appropriate technologies is one of the strengths of South Africa. Although the rich nations can opt to use costly automation systems, passive design, solar energy, and effective water systems are favored by South Africa. Such solutions apply to most developing nations that have comparable limitations.

A study conducted by UN-Habitat (2020) postulates that emerging city economies need to concentrate on the low-cost innovations that enhance fundamental services when it comes to smart cities instead of the costly ones. The South African approach represents such an attitude and provides an example to be followed by the other nations in which cost-effectiveness and rudimentary infrastructure are the central concerns. Nevertheless, another significant problem concerns South Africa as well that can affect its global standings.

Red tape in implementation, non-existent municipal capacities and constraints in infrastructures slow down the pace of improvement. South African cities cannot implement sophisticated technologies on a large scale as compared to other cities in the world like Singapore or Amsterdam. The instability in power supply, the old infrastructure, and the lack of funds are also significant obstacles. Nevertheless, South Africa can also teach valuable lessons to the

world. It shows how intelligent cities can reconcile environmental objectives with socio-economic facts and that sustainability should be associated with equity. Experience has shown that it requires flexible approaches, effective collaboration, and advanced policies. Through the outlined advantages, South Africa can go on to influence discourses about smart and sustainable development in the emerging economies.

6. Conclusion and Recommendations

6.1. Summary of Key Findings

The results indicate that South Africa is enjoying significant gains in applying green building technologies into the smart city policy, but the progress is also uneven. GBCSA certifications and national frameworks assist in the alignment of the local practices with world sustainability objectives. South African cities have generally started to include energy-efficient design, renewable power systems and water saving technologies. They are in line with the best practices in the world that emphasize fewer emissions and resource efficiency. Meanwhile, there exist apparent boundaries. The practice usually lags behind the policy objectives due to technical incompetence, lack of funds, and effective coordination mechanisms of the municipalities.

Although international smart cities apply high-performance technologies, including automation and IoT, in South Africa, the primary concern is the efficiency of low costs. This is a suitable strategy in domestic settings but not in full accord with international standards of intelligent innovation. All in all, South Africa demonstrates the interest, development, and opportunities, yet the country requires enhanced institutional resources, improved financing processes, and policy coordination to achieve the full potential of smart city and green building agenda.

6.2 Policy Recommendations

6.*2.1. Stronger Policy Alignment and Integration*

To ensure there are no duplications or confusion, policies at the national, provincial and municipal levels should be synchronized. Municipal climate targets should be supported by national standards of building and the national sustainability goals should be evident in the municipal by-laws. Accountability is enhanced and implementation is enhanced through clear

alignment. Inter-governmental joint planning platforms ought to be established to promote similarity in the way regulations are interpreted.

6.2.2. Capacity Building for Municipalities

Natural green building evaluation, energy modelling, and smart-technology evaluation should be trained in the long run-in municipalities. Municipalities can come up with technical support units to undertake the related evaluations pertaining to sustainability. Professional development can be supported by collaborating with CSIR, universities, and GBCSA. The local authorities are to be trained in how to plan their buildings and monitor systems financially to be green as well.

6.2.3. Financing Mechanisms for Green Technologies

The barrier of finances should be overcome to make it more widespread. Tax deductions, low-interest loans, retrofit subsidies, and grants on energy-efficient government buildings are some of the incentives that governments can also introduce. Green bonds must be increased to finance projects in building. Such collaboration as a partnership between the government and businesses can be useful in distributing risks and making municipalities less overburdened. With the affordable financing models, green technologies become affordable to the developers and public institutions.

6.2.4. Strengthened Intergovernmental Coordination

Better communication and coordination at government level is needed. It should establish a national platform of smart city and green building coordination. This platform may lead to alignment of policy, sharing of best practices and tracking progress across the municipalities. Enhanced coordination will contribute to uniform implementation, less duplication and resource utilization.

6.3 Future Research Directions

Long-term performance of green buildings in South Africa needs to be studied in future. Research must monitor utility consumption, water conservation, comfort of occupants, and expenditure. Knowledge of these outcomes can be used to help in designing better policies. It is also possible to conduct comparative analysis of various cities and reveal the reasons why certain municipalities are doing better than others.

To have equitable development of smart cities, research on affordable smart technologies that can be used in low-income regions should be carried out. Lastly, the research should be expanded in the future by looking at the community attitudes on smart city projects in order to know how the community feels about the changes as well as how the benefits can be distributed more broadly.

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