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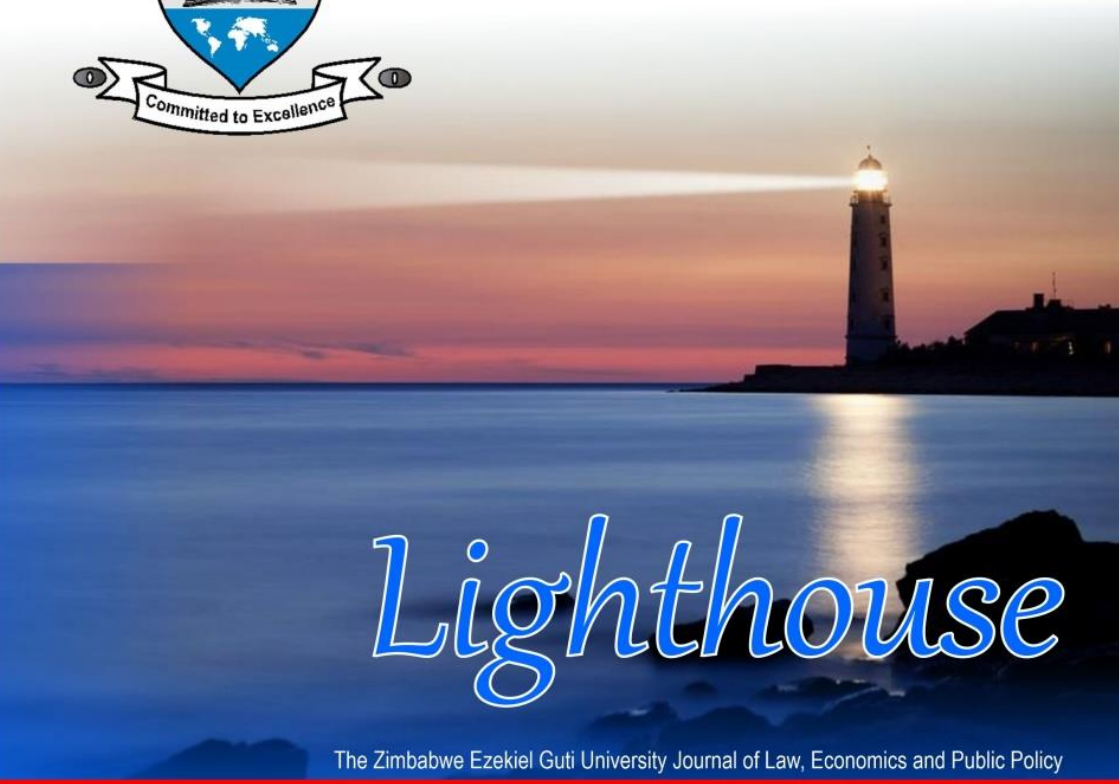

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Disruptive! Unpacking the Role and Place of Digital Frugal Innovation and Sustainable Development in Africa

STANDA SANI[1] AND SIPHIWE PLAXCEDES MANDINA[2]

Abstract

The article explores the role of digital frugal innovation in advancing sustainable development goals (SDGs) across Africa. It examines how affordable and scalable digital solutions address critical challenges such as poverty, healthcare access and educational disparities. A conceptual framework is established to define key concepts and theories related to digital frugal innovation and sustainable development. The methodology includes qualitative case studies and data analysis to highlight successful examples, such as EcoCash and M-KOPA Solar. Findings reveal that digital frugal innovations significantly enhance economic growth, promote social inclusion and contribute to environmental sustainability. The discussion emphasises the importance of addressing challenges, including the digital divide and data privacy concerns, to maximise the potential of these innovations. Recommendations for policy-makers and stakeholders aim to foster an inclusive digital ecosystem that supports sustainable development in Africa.

Keywords: sustainable development goals (SDGs); Economic growth; social inclusion; digital divide

INTRODUCTION

Africa is experiencing a transformative phase with significant potential for sustainable development through disruptive digital

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frugal innovation (Le Bas, 2023). This innovation, characterised by its affordability and effectiveness, plays a crucial role in addressing socio-economic and environmental challenges (Klemens *et al*., 2023), while aligning with the United Nations' Sustainable Development Goals (SDGs). Understanding the complex relationship between digital frugal innovation and sustainable development requires examing specific barriers that differ across various sectors and regions. In rural areas, inadequate infrastructure limits access to digital technologies, hindering agricultural advancements, while urban regions face a pronounced digital divide which prevents marginalised communities from benefiting from these innovations. Addressing these issues is essential for leveraging opportunities related to gender equality, inclusive growth, poverty alleviation and improved access to healthcare and education (Ritchie, 2023). The article explores the role of digital frugal innovation in advancing sustainable development goals (SDGs) across Africa. It examines how affordable and scalable digital solutions address critical challenges such as poverty, healthcare access and educational disparities.

CONCEPTUAL FRAMEWORK

The conceptual framework explores the relationship between disruptive digital frugal innovation and sustainable development in Africa, highlighting how these innovations address the continent's socio-economic and environmental challenges, while aligning with SDGs. Defined as affordable, scalable and resource-efficient digital solutions tailored for resource-constrained settings, disruptive digital frugal innovations emphasise affordability, user-friendly simplicity, resource efficiency and adaptability through stakeholder engagement. The framework incorporates theoretical perspectives such as the Diffusion of Innovations Theory which details the spread of new technologies within communities (Rogers, 2003) and the Frugal Innovation Theory which focuses on creating value through simplicity and cost-effectiveness in resource-limited environments (Bound and Thornton, 2012). These theories suggest that digital

frugal innovations can penetrate under-served markets, effectively by addressing local needs and aligning with multiple SDGs, including enhancing access to financial services (SDG 1), expanding educational opportunities via mobile platforms (SDG 4) and fostering entrepreneurship and job creation (SDG 8). Despite challenges like infrastructure deficits and the digital divide, growth opportunities persist, particularly through youth engagement in education and entrepreneurship, along with regional integration initiatives such as the African Continental Free Trade Area (AfCFTA), with research by Shahid *et al*. (2023) and Ndwiga *et al*. (2023) highlighting the transformative potential of these innovations in improving healthcare access and enhancing educational and economic participation in Africa.

LITERATURE REVIEW

Disruptive digital frugal innovation focuses on developing affordable and resource-efficient digital solutions that significantly impact resource-constrained settings (Iqbal *et al*., 2021). This innovation combines frugal principles — emphasising simplicity, cost-effectiveness and maximising value — with disruptive technologies such as the Internet of Things (IoT), cloud computing and artificial intelligence. In healthcare, mobile health applications in countries like Kenya, have enabled remote patient monitoring and improved access to medical advice, leading to better health outcomes in rural areas (Ndwiga *et al*., 2023). Agricultural platforms, like mFarm, connect farmers directly with buyers, enhancing market access and reducing costs, while educational initiatives, such as Eneza Education, offer low-cost SMS-based learning resources, significantly increasing educational access for under-served regions (Flamet *et al*., 2024). These applications aim to address pressing social issues sustainably and at scale, making solutions more accessible to a broader range of users, particularly those with limited financial means (Shahid *et al*., 2023).

The impact of disruptive digital frugal innovation extends across various sectors, including healthcare, education, agriculture and banking. In healthcare, mobile health applications, like mHealth, have improved access to services in under-served regions, allowing patients to consult doctors via their mobile devices (Viljoen *et al.*, 2021). Educational platforms, such as M-Shule, utilise SMS technology to deliver personalised learning resources to students, thereby expanding opportunities for marginalised groups (Upadhyaya, 2024). In agriculture, applications, like iCow, provide farmers with essential information on market access and crop management, enhancing productivity and profitability (Marwa *et al.*, 2019). These solutions illustrate a paradigm shift in leveraging technology to tackle social challenges, offering scalable and cost-effective options that foster positive change in resource-constrained environments (Hossain, 2021).

The 2030 Agenda for Sustainable Development, adopted by all United Nations member states in 2015, emphasises the critical relevance of SDGs in addressing Africa's unique challenges (Carlsen and Bruggemann, 2022). Issues such as widespread poverty, inadequate healthcare systems and limited access to quality education, represent significant obstacles to progress on the continent. Political instability and conflict further complicate these efforts while climate change disproportionately affects vulnerable communities. Targeted actions are necessary to achieve SDGs, particularly focusing on eradicating poverty (SDG 1) and ensuring access to essential services. However, barriers such as inadequate infrastructure, financial constraints and social inequalities, hinder progress, complicating the path toward achieving these goals.

A substantial portion of Africa's population lives in extreme poverty, underscoring the urgency of addressing this pressing issue (Rentschler *et al.*, 2022). SDG 1 aims to eradicate poverty in all its forms, aligning closely with Africa's commitment to providing essential

services like food, clean water and healthcare. Challenges include inadequate infrastructure, especially in rural areas, which restrict access to clean water and healthcare facilities. Financial constraints limit government investment in public services, while political instability and corruption can divert resources away from those in need. Climate change also poses a threat to food security, as unpredictable weather patterns disrupt agricultural production. Furthermore, social inequalities, including gender disparities, further restrict equitable access to these services, placing vulnerable populations at even greater risk.

Quality education remains a cornerstone for sustainable development, as emphasised by SDG 4, which advocates for inclusive and equitable education and lifelong learning opportunities for everyone (Kopnina, 2020). In Africa, guaranteeing equitable access to education, improving literacy rates and enhancing vocational training — especially for women and marginalised communities — are essential steps. As of 2022, literacy rates in sub-Saharan Africa are about 75% for adults, with significant disparities between men (80%) and women (70%) (UNESCO, 2023). Sustainable economic growth, highlighted in SDG 8, focuses on fostering entrepreneurship and creating decent employment opportunities, aligning with Africa's initiatives to improve infrastructure, promote innovation and diversify economies. Successful renewable energy projects across the continent, such as Kenya's Lake Turkana Wind Power Project and Morocco's Noor Ouarzazate Solar Complex, illustrate the potential for integrated efforts to create a prosperous future for African citizens.

Frugal innovation in digital technology emphasises creating impactful, economical and resource-efficient solutions to tackle social issues, particularly in resource-limited settings (Shahid *et al.*, 2023). This approach focuses on developing accessible, scalable and affordable goods, services and business models, with affordability being fundamental to providing low-cost solutions for diverse

consumers, especially those with low incomes, while minimising operating costs without compromising functionality and quality (Hossain, 2021). Simplicity plays a crucial role, as effective design enhances usability and acceptance, allowing users to engage with innovations without unnecessary barriers (Hindocha *et al.*, 2021).

Resource efficiency aims to optimise available resources like infrastructure and energy, maximising utilisation and minimising waste, as exemplified by Tata Motors' Tata Nano, a low-cost vehicle designed with fewer materials and simpler manufacturing methods (Sahdev *et al.*, 2024). Adaptability and collaboration further enhance the effectiveness of frugal digital innovation by tailoring solutions to fit various cultural and socioeconomic contexts, ensuring they meet specific needs (Chakravarty and Knorringa, 2021), with initiatives like m-Pesa in Kenya, transforming financial inclusion through easy money transfers, ultimately addressing critical challenges such as educational disparities and healthcare accessibility, fostering inclusive social progress (Quintero and Quintero, 2023).

STUDY DESIGN AND METHODOLOGY

The study adopts a qualitative approach, focusing on case studies and a desktop survey to explore the impact of disruptive digital frugal innovations in various sectors across Africa. Initially, a comprehensive literature review is conducted to analyse existing research on digital frugal innovation and its connection to SDGs. This is complemented by detailed case studies of successful digital innovations, such as m-Pesa, a mobile payment system that enhances financial inclusion; Eneza Education, an SMS-based platform that increases access to quality learning; m-Trac, a mobile health initiative improving healthcare delivery in Uganda; and M-KOPA Solar, a pay-as-you-go solar energy solution promoting clean energy access. Additionally, a desktop survey is performed to gather quantitative data on the adoption and effectiveness of these digital frugal innovations. This involves analysing existing reports, articles and datasets related to

digital solutions in Africa, as well as collecting statistics on user engagement, impact metrics and barriers to adoption from various online sources, including government and NGO reports, research papers and market analyses. The data collected through these methods are analysed thematically to identify common patterns, challenges and opportunities related to digital frugal innovation in the African context, providing a nuanced understanding of how these innovations can contribute to sustainable development across the continent.

FINDINGS

Numerous instances of effective digital frugal innovation in Africa have significantly transformed various industries, with M-Pesa, a mobile payment system from Kenya, emerging as a standout example. This platform facilitates money transfers, bill payments and other financial transactions via mobile phones, enhancing access to financial services for the unbanked population (Kitimbo, 2021). M-Pesa's success is attributed to its user-centric design, a robust network of local agents for cash transactions and strong partnerships with financial institutions that bolster its credibility. The supportive regulatory environment in Kenya has fostered innovation, while the platform's cultural relevance has effectively tackled specific economic challenges, setting it apart from other mobile payment systems.

Other innovative solutions, such as BRCK and Eneza Education, further exemplify the potential of digital frugal innovation. BRCK, a solar-powered portable Wi-Fi device, enhances internet access in under-served areas of Kenya, bridging the digital divide and fostering opportunities for communication, entrepreneurship and education (Abecassis *et al*., 2020). The BRCK Kio Kit, which comprises a tablet, projector and internet access, enables teachers to deliver interactive lessons in connectivity-poor regions. Eneza Education enriches the educational landscape by providing interactive learning materials via

SMS and mobile apps, thus improving access to quality education for millions of children (Kizilcec and Chen, 2020). Initiatives like the Cape Town Open Data Portal also contribute to transparency and data-driven solutions in urban planning and community safety (Antenucci and Tomasello, 2023; Sibiya, 2023). Despite these advancements, challenges persist in the adoption of innovations like Hello Tractor and Lifebank, where issues, such as digital literacy and poor internet connectivity, hinder broader acceptance (Abate *et al*., 2023; Chika *et al*., 2024). Addressing these challenges is crucial for maximising the impact of digitally frugal innovations across Africa which aim to create affordable, accessible solutions that enhance the quality of life for marginalised communities (Sun and You, 2023). The effectiveness of these innovations is measured through indicators like accessibility, economic impact and user satisfaction, highlighting their role in bridging the digital divide and promoting sustainable development.

Significant advancements in financial inclusion are increasingly apparent as digital frugal innovations broaden access to financial services for unbanked and underbanked populations (Wachira, 2023). Mobile banking and payment systems offer quick and affordable methods for managing financial transactions, enhancing both security and accessibility. According to the World Bank, approximately 66% of adults in Sub-Saharan Africa had bank accounts in 2021, with the COVID-19 pandemic accelerating mobile money usage by over 30% in various regions. These innovations also democratise access to education and healthcare, as evidenced by mobile learning platforms and healthcare initiatives like mTrac and Kasha that improve educational and health outcomes in underserved areas (Ali, 2023; Mehan, 2023). Furthermore, these technologies promote environmental sustainability through energy-efficient practices and precision farming, addressing critical challenges while fostering sustainable development across the continent (Shahid *et al*., 2023).

Africa presents a unique landscape filled with opportunities and challenges that must be understood to harness its development potential effectively. Investing in quality education is vital for enhancing economic participation among young Africans, facilitating access to various educational levels and promoting vocational training which cultivates critical skills like digital literacy and entrepreneurship. Successful initiatives such as the Nigeria's Youth Entrepreneurship Programme (YEP) and the Humanist Institute for Development Cooperation (HIVOS) Green Entrepreneurship Programme, exemplify support for young entrepreneurs and sustainable ventures in agriculture and renewable energy, while the Anzisha Prize provides mentorship and funding to scale businesses. Achieving economic development requires a collaborative approach among governments, private sector entities, civil society and development partners, focusing on education, skills training, job creation and infrastructure investment. Africa's abundant natural resources offer further opportunities for economic diversification when managed sustainably, as illustrated by initiatives like the Great Green Wall and Ghana's Extractive Industries Transparency Initiative (EITI). The rapid growth of digital technologies also presents transformative prospects that necessitate investments in digital infrastructure and initiatives to improve digital literacy (Zoe Talent Solutions, 2024). Additionally, regional integration efforts, particularly the African Continental Free Trade Area (AfCFTA), enhance economic cooperation and trade, highlighting the need for commitment to reforms and effective policy coordination among African nations to maximise these benefits.

Africa faces significant infrastructure challenges that impede economic growth, regional integration and social development, with critical areas for improvement, including transportation networks, electricity access, water and sanitation infrastructure and digital connectivity. Enhancing social infrastructure and developing climate-resilient facilities are essential for sustainable progress, as

investments in these sectors can facilitate trade and attract investments. Inadequate transportation networks hinder intra-African trade, while expanded electricity access is vital for industrial power and improved living standards; reliable water infrastructure is necessary for consistent supply and sanitation, ultimately preventing waterborne diseases.

Addressing poverty and income inequality necessitates targeted interventions across various sectors, with policies such as the Social Protection Floors Recommendation aiming to provide basic income security and essential services (Razavi, 2022). Quality education plays a crucial role in breaking the poverty cycle, requiring prioritisation of access and affordability for marginalised communities, alongside the development of healthcare infrastructure to improve service access. Job creation is vital for poverty reduction, supported by inclusive economic growth and entrepreneurship policies. Effective governance enhances these efforts, exemplified by Botswana's Public Procurement Reform which boosts transparency and accountability (Rasetshwane, 2021), Rwanda's National Decentralisation Policy, which empowers local governments (Semina and Bachir, 2024) and Kenya's Access to Information Act, which promotes accountability (Muthomi and Thurmaier, 2024). Such governance reforms, along with investments in education and skills development, are essential for reducing economic disparities and fostering social cohesion that are critical for preventing conflict and ensuring overall stability.

The digital landscape in Africa has experienced remarkable transformation over the past two decades, characterised by increased mobile penetration, expanding internet access and widespread adoption of digital technologies. Mobile phone subscriptions surged from 600 million in 2010 to over 1.3 billion by 2021, reflecting a growth rate exceeding 100% (GSMA, 2021). This digital revolution reshapes various aspects of African societies, providing new opportunities while presenting challenges. For many,

mobile phones serve as the primary means of internet access, especially in rural and under-served areas, bridging the digital divide and facilitating access to essential information and services (Asongu, 2023). Mobile technologies are vital for accessing educational resources, health services and market information, while also enabling digital financial inclusion through platforms like M-Pesa in Kenya. Platforms such as MTN Mobile Money in Ghana and Airtel Money in Uganda have significantly improved financial access for millions and innovations like SnapScan and Zapper in South Africa are transforming payment systems, enhancing the accessibility of cashless transactions (Ntando, 2022). These advancements highlight the ongoing digital transformation across the continent, enhancing economic participation and connectivity for diverse populations.

Infrastructure investments, such as the Africa Coast to Europe (ACE) cable, have been essential in enhancing internet connectivity across Africa (Gabarró *et al.*, 2021). This initiative significantly boosts high-speed internet access in multiple countries, facilitating online shopping, e-learning and connection to international markets (Ravi, 2023). The ACE cable links 20 countries from France to South Africa, greatly increasing bandwidth availability. Additionally, satellite technologies from providers like Starlink and Inmarsat are instrumental in bridging the connectivity gap for remote communities that lack terrestrial infrastructure (Veeranna, 2023). Despite these advancements, challenges such as high data costs and limited coverage in rural areas persist, underscoring the need for ongoing efforts to improve affordability and accessibility.

The digital revolution has fostered a dynamic ecosystem of digital entrepreneurship across the continent (Friederici *et al.*, 2020). Start-up hubs and incubators, such as CcHUB in Nigeria and iHub in Kenya, have emerged to support entrepreneurs in innovating solutions to local challenges (Pangarkar and Vandenberg, 2023). Digital platforms are creating economic opportunities and enhancing financial

inclusion, particularly through mobile money solutions that empower individuals and businesses. However, obstacles related to digital literacy, cybersecurity threats and inconsistent regulatory frameworks, continue to hinder progress. Low digital literacy restricts effective use of online services, particularly in rural regions, while cybersecurity risks pose significant threats to small and medium enterprises (SMEs) lacking robust protection. Addressing these regulatory inconsistencies and inter-operability issues is crucial for the sustained growth of digital financial services (Pazarbasioglu *et al*., 2020), with collaboration among stakeholders being vital for unlocking Africa's digital economy potential (Ediagbonya and Tjoluwani, 2023).

Disruptive digital frugal innovations face challenges related to infrastructure, affordability and digital literacy, yet several solutions have emerged to address these issues effectively. For instance, BRCK, a Kenyan company, developed a rugged, portable internet connectivity device designed for low-resource environments, featuring offline capabilities which allow users to access stored content without constant internet access. This innovation alleviates connectivity issues and reduces costs by enabling multiple users to connect through a single device, thus lowering individual data expenses. Platforms like M-KOPA enhance affordability through pay-as-you-go models for solar energy solutions, making renewable energy more accessible (Baker, 2023). Moreover, simple mobile applications such as Usiku Games deliver educational content in a gamified format, using minimal data and user-friendly interfaces to cater to diverse digital literacy levels (Oberoi, 2024). These applications often incorporate local languages and culturally relevant content, ensuring contextual relevance. Engaging local communities in the design process fosters ownership and involvement, ultimately bridging the digital divide and contributing to sustainable development in Africa.

The rising adoption of mobile phones establishes a solid foundation for digital frugal innovations across various sectors, including finance, healthcare, agriculture and education. As of 2021, mobile phone penetration in sub-Saharan Africa reached approximately 50%, with over 1.2 billion unique subscribers (GSMA, 2021), facilitating access to essential services and information, particularly in remote areas. In finance, innovations like mobile banking and digital payments address the needs of a significant unbanked population, estimated at over 350 million, with platforms such as M-Pesa in Kenya revolutionising financial transactions. In agriculture, mobile applications like iCow and Farmers' Friend boost productivity by providing critical market information and weather forecasts, while telemedicine platforms like mPharma and mobile health apps such as Hello Doctor, enhance access to quality healthcare for under-served communities. Educational initiatives, including e-learning platforms like Khan Academy and local solutions like Tuteria, tackle the challenges of limited education access and teacher shortages, while renewable energy solutions, such as affordable solar power and off-grid systems like d.light, promote sustainability and reliable energy access. Data analytics and artificial intelligence (AI) are also being applied effectively across various sectors to drive insights and inform decision-making, further stimulating entrepreneurship and job creation in Africa.

Sustainable development in Africa is influenced by socio-economic and environmental factors. Effective urbanisation management is necessary for sustainable cities with adequate housing, transportation, sanitation and services. Poverty and income inequality hinder development, requiring efforts to eradicate poverty, promote equitable wealth distribution and foster inclusive economic growth. Africa's natural resources need sustainable management for economic growth, environmental conservation and social well-being. Balancing resource extraction with conservation and promoting sustainable practices is crucial. Climate change and

environmental vulnerability affect agriculture, water resources, health and ecosystems. Climate mitigation, adaptation strategies, sustainable agriculture and renewable energy are essential for resilience and development.

Good governance, strong institutions and political stability are vital. Transparent governance, effective policies and anti-corruption measures are needed to promote sustainable development and attract investments. Quality education and human capital development empower innovation and economic growth. Health challenges and inadequate healthcare infrastructure impact development. Infrastructure development, including transportation, energy, water and connectivity, is crucial for growth and inclusion. Regional integration initiatives like the AfCFTA foster economic cooperation and sustainable development. Cultural factors and community participation are important. A comprehensive approach involving governments, civil society, private sector and international partners, is necessary to achieve sustainable development in Africa and the SDGs.

Digital frugal innovation, characterised by affordable and impactful solutions developed with limited resources, holds significant potential for advancing SDGs by enhancing access to essential services, such as healthcare, education, finance and energy. This innovation approach empowers marginalised communities and small-scale entrepreneurs, optimising resource use, reducing ecological footprints and increasing resilience to climate change. Mobile health applications, e-learning platforms and digital finance solutions can provide vital health information and telemedicine services to remote areas lacking adequate healthcare infrastructure. Additionally, e-commerce platforms enable small businesses to reach broader customer bases and facilitate secure transactions, while digital agriculture technologies enhance resource management and farm

productivity, supporting informed decision-making for environmental conservation.

Despite its promise, digital frugal innovation faces challenges, including the digital divide, insufficient infrastructure, limited digital literacy and the need for inclusivity and equity in access to digital solutions. Addressing these issues requires targeted policy measures, such as prioritising investments in digital infrastructure to expand broadband access and improve mobile network coverage in rural areas. Implementing nationwide digital literacy programmes can educate marginalised groups on effectively using digital tools. Furthermore, creating incentives for private sector participation, fostering public-private partnerships and developing inclusive policy frameworks are essential for ensuring equitable access. Supporting capacity-building initiatives for local communities will empower stakeholders to design tailored solutions, while establishing monitoring and evaluation systems will help track the impact of digital frugal innovations on sustainable development goals, ultimately maximising their effectiveness in a cost-effective and inclusive manner.

The relationship between disruptive digital frugal innovation and sustainable development is dynamic and mutually reinforcing, as these concepts intersect significantly. Disruptive digital frugal innovation focuses on creating affordable solutions accessible to larger populations, particularly in low-resource settings. For instance, Grameen Bank has revolutionised microfinance by offering small loans to entrepreneurs in impoverished communities, thereby reducing cost barriers and promoting economic empowerment. In the healthcare sector, mPharma aims to provide affordable medicines in Ghana and other African nations, while educational platforms like Khan Academy enhance access to learning for marginalised groups through free online courses. Additionally, BBOXX delivers solar solutions to off-grid communities in Africa, promoting sustainable

energy access. These innovations reduce barriers to essential services — such as healthcare, education, finance and energy — thereby enhancing social inclusion, economic empowerment and overall human development, all of which are integral to sustainable development.

Designed for scalability, digital frugal innovations can reach vast populations and significantly address development challenges, contributing to sustainable development goals. This scalability is crucial for rapidly tackling societal and environmental issues. Leveraging digital technologies allows for the implementation of solutions across various sectors, thereby improving the quality of life for many. Emphasising resource efficiency, frugal innovation optimises resource use and minimises environmental impact, incorporating sustainability principles into their design to promote energy-efficient practices and renewable energy adoption. This focus aids environmental conservation and supports sustainable resource management for current and future generations. Furthermore, these innovations empower individuals and communities by providing tools that facilitate participation in economic, social and political activities, ensuring inclusivity in the development process. However, to fully harness their potential for sustainable development, challenges such as the digital divide, infrastructure limitations and digital literacy, must be addressed, alongside fostering multi-stakeholder collaborations and enabling policies that integrate digital frugal innovations into broader sustainable development strategies.

Digital frugal innovation in Africa plays a crucial role in advancing various SDGs by leveraging technology to create affordable and accessible solutions. EcoCash, a mobile payment system developed by Econet Wireless in Zimbabwe, significantly contributes to SDG 1 (no poverty) by providing financial services to previously unbanked populations, thereby enhancing financial inclusion through secure transactions (Chitimira and Ncube, 2023). In rural areas, EcoCash has

transformed financial access, allowing users to conduct transactions without relying on traditional banking infrastructure which is often lacking. This innovation empowers individuals to send and receive money, pay for goods and services and access savings accounts, thus enhancing financial management capabilities and fostering community resilience. In urban areas, EcoCash complements existing financial services by streamling transactions and supporting small businesses, thereby promoting economic growth.

Beyond financial services, digital frugal innovations tackle public health challenges, as exemplified by mPedigree in Ghana which combats counterfeit pharmaceuticals and supports SDG 3 (good health and well-being) (Owusu, 2020). This platform utilises mobile technology to enable consumers to verify the authenticity of medications, ensuring access to safe products and improving health outcomes. In the education sector, Eneza Education in Kenya demonstrates the impact of digital solutions on SDG 4 (quality education) by providing educational content via basic mobile phones, significantly increasing access for over three million students and enhancing learning outcomes in under-served areas (Owusu *et al.*, 2024). M-KOPA Solar in Kenya further illustrates contributions to SDG 7 (affordable and clean energy) through its pay-as-you-go solar home systems, enabling off-grid households to access clean energy and promoting sustainable practices (Wandera and Olonde, 2024). While these innovations address specific SDGs by leveraging affordability and scalability, challenges such as the risk of exacerbating the digital divide, data privacy concerns and the sustainability of technology without ongoing support must be carefully managed to ensure equitable and effective outcomes.

Digital frugal innovation has significantly influenced economic growth in Africa by leveraging digital technologies to create new business opportunities, enhance entrepreneurship and boost productivity (Nguimkeu and Okou, 2021). Platforms like Jumia and M-Pesa have

expanded market access for small-scale entrepreneurs, connecting them to broader customer bases and stimulating economic activity while generating employment. Innovations in agriculture, such as Farmerline, provide farmers with real-time information that enhances productivity and market access, contributing to inclusive and sustainable economic growth across the continent. Furthermore, these innovations have fostered social inclusion by overcoming traditional barriers to access through mobile technology and low-cost solutions (Lorini *et al.*, 2020). Educational platforms like Eneza Education extend access to quality learning materials for marginalised communities, while mobile money systems empower the unbanked with secure financial services. This not only promotes citizen engagement, but also amplifies marginalised voices, contributing to social justice.

Challenges and risks associated with these solutions must also be acknowledged. The digital divide remains a significant barrier, particularly for populations in rural areas who may lack access to these innovations. Over-reliance on technology can lead to vulnerabilities if systems fail or if users lack digital literacy, while concerns regarding data privacy and security highlight the risks of personal information breaches. Additionally, while promoting clean energy, the production and disposal of digital devices can create environmental challenges. The potential for market monopolies in the tech industry could also limit competition and hinder the availability of diverse solutions.

In conclusion, digital frugal innovation in Africa has positively impacted economic growth, social inclusion and environmental sustainability by creating opportunities and promoting sustainable practices. Addressing challenges related to digital infrastructure access, digital literacy and inclusivity will be essential for maximising these benefits and fully harnessing the potential of digital frugal innovation for sustainable development.

CONCLUSION AND RECOMMENDATIONS

The exploration of disruptive digital frugal innovation in Africa reveals its transformative potential in addressing critical challenges related to sustainable development. Frugal innovations enhance access to essential services such as healthcare, education and financial services, particularly for marginalised populations through creating affordable, scalable and resource-efficient solutions. Successful case studies, such as M-Pesa and EcoCash, among others, illustrate how digital frugal innovation can significantly improve economic growth, promote social inclusion and contribute to environmental sustainability across the continent. However, the findings also highlight persistent challenges, including the digital divide, inadequate infrastructure and insufficient digital literacy that hinder the widespread adoption of these innovations. Addressing these barriers is crucial for maximising the impact of digital frugal innovation on Africa's sustainable development goals (SDGs).

To maximise the impact of disruptive digital frugal innovation for sustainable development in Africa, it is essential to prioritise investments in digital infrastructure, particularly in rural areas, to enhance connectivity and accessibility. This includes expanding broadband access and improving mobile network coverage which will facilitate the adoption of digital solutions. Additionally, nationwide digital literacy programmes should be implemented to empower marginalised communities, equipping them with the skills needed to effectively utilise digital tools. Collaboration among government, private sector entities and civil society is vital. Fostering public-private partnerships can stimulate innovation and investment in digital solutions. It is also crucial to develop inclusive policies that ensure equitable access to digital innovations while addressing data privacy concerns and ensuring that solutions are contextually relevant. Furthermore, supporting solar energy and other renewable power sources in rural and remote areas will provide essential energy access, enabling communities to utilise digital technologies effectively. Capacity-building initiatives should focus on empowering

local communities to design and implement tailored solutions, enhancing ownership and engagement. Finally, establishing robust monitoring and evaluation systems will help track the effectiveness of these innovations in achieving sustainable development goals, providing data to inform future policies and initiatives for continuous improvement.

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