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Leveraging 5G, artificial intelligence and blockchain integration for accelerating digital economic outcomes in Botswana: A strategic framework for leapfrogging development

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Abstract

This study is concerned with the possible accelerated development of Botswana through the incorporation of fifth generation (5G) connectivity, edge-based artificial intelligence (AI), and blockchain technologies into the digital economy. The study adopts a systematic review of secondary sources, guided by the PRISMA methodology, to achieve transparency and structure in the selection of evidence. The primary documents used come from multilateral agencies, policy documents, sectoral reports, and audited digital transformation statistics from Botswana and other African countries. Botswana's case study evidence is analyzed using the Digital Transformation of Africa survey while the framework evidence is analyzed through the prism of three principal pillars of digital infrastructure: connectivity, intelligence, and trust. The study also uses the theory of change model to connect foundational digital enablers, such as spectrum management, cybersecurity, and data governance, to economic productivity, institutional efficiency, and digital inclusion. The coordinated use of 5G technology, AI, and blockchain technology improves operational decision-making speed, lowers transaction costs, and enhances accountability in data-intensive settings. Evidence from digital credit processing, cross-border logistics, and agriculture shows that real-time data processing and automated verification systems improve operational efficiency. This study finds that digital inclusion increases remote onboarding, mobile-based service delivery, and alternative-data financial models, although inadequate data and rural connectivity gaps continue to slow adoption in many areas. The study outlines the need for a prioritized digital transformation strategy covering digital payments, trade logistics, agriculture, and integrated systems for national digital identity, data exchange, and public procurement that are verifiably secure.

Keywords: *digital leapfrogging, digitalization, digital inclusion, digital public infrastructure*

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1. Introduction

The strategy of digital transformation in Botswana resembles the application of advanced technologies as enablers of structural transformation rather than mere upgrading. For instance, the adoption of fifth-generation connectivity, artificial intelligence, and blockchain technologies could enhance productivity, efficiency, and inclusion in sectors such as financial services, agriculture, logistics, and public administration (Ajibade & Mutula, 2020). The notion of structural transformation facilitated by technological innovations aligns with the vision of digital transformation proposed by the African Union, in which digital infrastructure, skills, innovation, and regulatory harmonization form the basis of inclusive development (African Union Commission, 2020). However, it is important to note that the possibility of leapfrogging through technological innovations does not depend solely on the availability of particular technological solutions but also on policy alignment regarding spectrum management, broadband infrastructure, data management, and institutional capacity building. In the case of Botswana, the development of digital infrastructure and reforms in e-commerce may represent appropriate starting points. However, according to the World Bank (2022), gaps in infrastructure, affordability, and interoperability continue to hinder digital transformation.

The relevance of the digital economy to the development of Botswana lies in the connection between technological innovations and practical economic sectors characterized by service gaps. As noted by UNCTAD (2021a), four channels may help diversify the economy and increase Botswana's competitiveness: e-commerce, digital payments, the digitalization of small and medium-sized enterprises, and the digitalization of public services. At the same time, GSMA (2024) reports that mobile connectivity remains a key driver of socioeconomic development in Sub-Saharan Africa. However, rural coverage gaps, device affordability, and limited digital skills continue to hinder inclusive digital transformation. Hence, the digital transformation of Botswana cannot be evaluated solely in terms of the development of digital infrastructure; it should also consider issues of access, affordability, and the effective use of digital services. Although mobile wallets and digital payments have already become popular in Botswana's financial sector, the further development of these instruments depends on consumer protection, platform interoperability, and effective data-sharing systems (Bank of Botswana, 2023; Musoni et al., 2023).

AI, blockchain, and high-speed connectivity may prove particularly valuable because they can facilitate data-driven decision-making, verification, and service delivery.

Applications of AI may include credit risk assessment, fraud prevention, predictive maintenance, and public service delivery, while blockchain technology may provide benefits such as transparency, provenance, and transactional trust in areas such as procurement, logistics, and agricultural supply chain management (Collins et al., 2021; Shilongo et al., 2022). At the same time, the adoption of these technologies raises governance issues, particularly concerning algorithmic accountability, cybersecurity, data protection, and inequality in access to digital infrastructure. Thus, as stated by the African Union Commission (2022), data governance should be treated as a development issue rather than merely a technical one. Hence, Botswana's digital identity, financial, and government platforms should be integrated through governance mechanisms that promote trust, accountability, resilience, and innovation.

The purpose of the current research is to examine Botswana's opportunities for adopting a coordinated and integrated approach to the implementation of 5G, artificial intelligence, and blockchain technologies to achieve rapid digital economic transformation while overcoming existing gaps in infrastructure, governance, and inclusion. Unlike analyses that examine these technologies individually, the current research focuses on them as components of a digital stack, in which high-speed connectivity facilitates real-time data exchange, artificial intelligence enables adaptive analysis, and blockchain supports verification and trust-building. Thus, the key question is not whether Botswana should adopt these advanced technologies, but how their adoption should be sequenced and managed to maximize their application in high-value sectors.

2. Literature Review

2.1. Leapfrogging and Digital Transformation

Digital leapfrogging refers to a development pathway in which late-industrializing economies use advanced technologies to overcome limitations in traditional infrastructure and institutions (Cilliers, 2021). In Africa, this is evident in the growth of mobile connectivity, digital financial services, and digital platforms, which have expanded access without fully replicating legacy systems (Demirgüç-Kunt et al., 2022; Kouladoum, 2023). The African Union Commission (2020) views digital transformation as a foundation for inclusive growth, regional integration, innovation, and poverty reduction. Botswana’s digital economy should therefore be considered within this broader transformation. The potential of 5G, AI, and

blockchain lies in improving service access, institutional efficiency, and economic participation despite infrastructure and rural–urban disparities.

The benefits of 5G, AI, and blockchain depend on their integration with effective governance, productive sectors, and inclusive digital markets. Although advanced technologies can generate benefits across industries, these outcomes require investments in skills, infrastructure, regulation, and institutional capacity (Brynjolfsson & McAfee, 2017; Javaid et al., 2024). For Botswana, digital transformation must address sector-specific challenges in agriculture, finance, logistics, public administration, and SMEs rather than simply replicate the approaches of advanced economies. Evidence from Sub-Saharan Africa shows that digital infrastructure can support inclusive growth when combined with affordability, accessibility, and coordinated policies (Kouladoum, 2023). Accordingly, this study examines how Botswana can integrate 5G, AI, and blockchain to support digital leapfrogging while reducing exclusion, governance fragmentation, and infrastructural dependency.

2.2. 5G and Connectivity Infrastructure

With the advent of 5G, communication infrastructure and digital systems have become increasingly important. Its benefits include ultra-reliable low-latency communication, enhanced mobile broadband, and support for more connected devices (GSM Association, 2022). 5G also creates opportunities to improve digital infrastructure and fiber backhaul networks, which advance wireless broadband systems in Sub-Saharan Africa (Mothobi & Gillwald, 2021). In Botswana, carrier-neutral fiber networks and new wholesale access agreements provide opportunities to develop 5G along urban corridors and cross-border trading zones (Light Reading, 2022). However, digital public services, precision agriculture, and logistics also require viable business models and adequate municipal infrastructure (ITU, 2021).

The strategic value of 5G extends beyond high-speed connectivity. Its effectiveness depends on reliability, low latency, shared infrastructure, and applications in productive sectors. GSMA (2023) reports that 5G deployment in Africa remains uneven, with progress concentrated in countries with adequate spectrum allocation, fiber backhaul, and viable use cases. Broadband expansion also requires substantial investment, particularly in rural areas where private-sector incentives may be limited (Oughton et al., 2023). Oughton (2023) therefore emphasizes infrastructure financing as a long-term development challenge. Rural

infrastructure-sharing and neutral-host models may further reduce deployment costs in low-density areas (Koratagere Anantha Kumar & Oughton, 2023). Moreover, 5G can support productivity, innovation, and decent work when supported by complementary policies, affordability, and adoption (Beltozar-Clemente et al., 2023).

While 5G can contribute significantly to Botswana's economic development, equitable access remains essential. Its deployment should therefore follow inclusive and sustainable principles rather than focus solely on technological expansion. Regional plans should address socioeconomic and institutional barriers through effective governance, regulation, public–private partnerships, affordability measures, and inclusive access policies (GSM Association, 2022). Thus, Botswana's 5G strategy should combine technological advancement with sound governance, sustainable infrastructure investment, and supportive public policies.

2.3. Artificial Intelligence and Edge Analytics

Edge AI can support Botswana's digital economy by enabling real-time data collection and analysis across sectors. AI applications in Africa include predictive maintenance, credit scoring, fraud detection, and public service delivery (Buehler et al., 2024). However, limited data and institutional capacity can constrain adoption (Rogerson et al., 2022). Botswana's fintech environment and regulatory sandboxes may support AI-powered applications, particularly in credit scoring and fraud detection (Bank of Botswana, 2023). However, algorithmic transparency and governance remain important concerns. Without accountability mechanisms, the use of AI in banking and healthcare may create ethical risks (UNESCO, 2022a). Responsible AI adoption therefore requires effective data governance, institutional preparedness, and appropriate regulation (Rogerson et al., 2022).

AI adoption should consequently be treated as a governance and institutional issue, not only a technological one. The African Union Commission (2024) identifies AI as a tool for continental development while emphasizing capacity building, risk management, investment, and cooperation. Plantinga et al. (2024) argue that responsible AI policies should build on existing African governance capacities rather than simply transfer external ethical frameworks. Yilma (2026) similarly warns that AI strategies may have limited value when they are not supported by institutional policies and implementation mechanisms. Zaidan et al. (2024) further challenge regulating AI when legislation cannot keep pace with technological change. According to Sule (2026), fairness, accountability, cultural relevance, and data protection are

continuing ethical concerns in Africa. Therefore, Botswana should establish strong data governance, algorithmic auditing, institutional safeguards, and accountability mechanisms before deploying edge AI in finance, agriculture, and public services.

2.4. Blockchain and Decentralized Trust

Blockchain technology provides decentralized and secure systems for building trust, ensuring provenance, and managing digital transactions. In Africa, governments have adopted blockchain for supply chains, digital identities, and land registries (Musoni et al., 2023). Its transparency and auditability also support applications in e-procurement, trade financing, logistics, and agricultural value chains (Shilongo, 2023). These applications make blockchain relevant to Botswana's public procurement, cross-border SME trade, and agricultural logistics. However, adoption requires appropriate cybersecurity standards, interoperability, data governance, and institutional capacity.

Blockchain is particularly relevant to Botswana because it can improve coordination, verification, and trust among multiple stakeholders. In agri-food supply chains, it can strengthen traceability, although high costs, technical complexity, and stakeholder readiness remain challenges (Yogarajan et al., 2023). Its use in supply chain management is also increasing, but interoperability, governance, and organizational capacity remain important barriers (Duan et al., 2023). According to Rivera et al. (2024), blockchain has potential to improve transparency in global supply chains, particularly where institutional trust is limited. In procurement, blockchain's audit trails and tamper-resistant records may reduce opportunities for unauthorized manipulation and corruption (Adjorlolo et al., 2025). However, privacy and data-control concerns remain important, particularly for blockchain-based self-sovereign identity systems (Naicker & Moodley, 2024). Thus, Botswana's blockchain strategy should balance transparency and efficiency with cybersecurity, privacy, interoperability, and institutional readiness.

2.5. Governance, Cybersecurity and Data Protection

Digital leapfrogging requires effective governance to ensure that technological benefits are safe and inclusive. Data protection laws and cybersecurity policies are essential for responsible digital technology adoption (ITU, 2021). Botswana has strengthened its data protection framework, but gaps remain in addressing privacy by design and algorithmic

accountability (World Bank, 2022). The country also faces digital fraud, cyber threats, and identity theft, making comprehensive cybersecurity policies increasingly important as 5G, AI, and blockchain adoption expands (Bau & Calandro, 2020).

The key governance challenge is ensuring that digital technologies protect rights, build public trust, and maintain institutional legitimacy. Adams et al. (2024) found significant differences in countries' readiness to implement responsible AI, particularly because of gaps in transparent and accountable frameworks. The OECD (2026, 2024) similarly reports implementation challenges in emerging African AI strategies. Ünver (2025) argues that African AI governance should learn from rights-based regulation while reflecting local institutional and developmental contexts. In Botswana, the increasingly biometric Omang digital identity system raises concerns about identity governance, privacy, data protection, and potential exclusion (Bewlay, 2025). Therefore, Botswana's digital governance framework should address AI accountability, digital identity governance, data breach response, informed consent, and privacy-by-design principles.

2.6. Digital Inclusion and Socio-Economic Impact

Integration into the digital economy is essential for realizing the potential of 5G, AI, and blockchain to support digital leapfrogging. Digital payments and mobile money can improve access to financial accounts, savings, and transaction services (Demirgüç-Kunt et al., 2022). However, digital financial inclusion is also influenced by income, education, gender, and usability (Elouaourti et al., 2024). Digital payments, QR technologies, and mobile wallets could therefore expand opportunities for rural communities, women, informal traders, and SMEs in Botswana. Nevertheless, financial digitalization also creates risks involving fraud, consumer protection, and unequal access (Bank of Botswana, 2023). Digital inclusion should therefore be treated as both an economic and governance concern.

The rural–urban digital divide also shows that inclusion involves more than mobile ownership and network coverage. Although mobile access and internet penetration have improved in Sub-Saharan Africa, significant gaps in mobile internet usage remain (GSMA, 2024). Digital infrastructure contributes to inclusive growth only when supported by affordability, institutional capacity, and policy coordination (Kouladoum, 2023). In Botswana, high data costs, limited connectivity, and digital literacy gaps may restrict rural access. Guo et al. (2026) similarly report substantial differences in digital access and literacy between rural

and urban areas in Africa. Botswana's digital strategy should therefore address both infrastructure and the socioeconomic and institutional barriers to meaningful digital access.

Digital public infrastructure (DPI) can further support inclusion through digital identity, payments, data exchange, and public service delivery. DPI enables reusable digital services for financial inclusion, social protection, and public administration (Clark et al., 2025). It can also reduce barriers to essential services through digital identity, affordable payments, and secure data exchange (Digital Cooperation Organization, 2025). However, mobile money promotes inclusion only when users trust the platforms, understand digital risks, and have affordable devices and reliable connectivity (Osabutey & Jackson, 2024). Botswana can therefore strengthen inclusion through rural connectivity, consumer protection, interoperable payments, digital literacy, and trusted public digital platforms.

Despite research on digital financial inclusion, mobile connectivity, and DPI in Africa, limited studies examine their integration with 5G, AI, and blockchain specifically in Botswana. This gap supports the need to examine how technology adoption, digital inclusion, governance, and institutional capacity can be coordinated to achieve inclusive and sustainable digital transformation.

2.7. Sectoral Readiness and High-Impact Use Cases in Botswana

Digital transformation in Botswana should be assessed through sectoral readiness because technologies produce different benefits and challenges across finance, agriculture, logistics, SMEs, and public administration. The World Bank (2022) identifies five major components of Botswana's digital economy: digital infrastructure, digital platforms, digital financial services, digital businesses, and digital skills. However, transformation remains fragmented. In agriculture, e-service delivery depends on organizational and user readiness as well as institutional factors (Mbae et al., 2025). Similarly, Botswana's SMEs are becoming more digitally ready, but high internet costs, cybersecurity risks, infrastructure limitations, and unequal technology adoption remain challenges (Mphale et al., 2024). Thus, high-impact digital applications should consider both sectoral opportunities and existing barriers.

Finance, agriculture, logistics, and public administration are key sectors where digital technologies can generate economic and developmental benefits. In finance, digital payments and mobile wallets are creating opportunities for interoperable payment systems and alternative credit mechanisms using alternative data (Bank of Botswana, 2023). However,

mobile money can support financial inclusion only when infrastructure, affordability, consumer protection, and public trust are ensured (Osabutey & Jackson, 2024). In agriculture, blockchain and Internet of Things (IoT) technologies can improve food supply-chain traceability and coordination (Tang et al., 2024). Their implementation, however, remains constrained by cost, data quality, and stakeholder readiness. Blockchain can also improve transparency, but effective implementation requires appropriate governance and technological readiness (Mvubu & Naude, 2024).

2.8. Theoretical Lens - Integration and Sequencing

5G, AI, and blockchain can generate greater benefits when deployed as an integrated ecosystem rather than as separate technologies. In this stack, 5G provides connectivity, AI supports adaptive decision-making, and blockchain enables secure verification and record-keeping (Wairegi et al., 2021; Shilongo et al., 2022). The sequence of adoption is also important. Establishing digital payments before expanding logistics and agricultural applications could create common platforms for scaling these technologies (Sedola et al., 2021). Thus, digital leapfrogging requires technological adoption alongside policy alignment, coherent governance, ecosystem collaboration, and strategic deployment.

Emerging economies can use these technologies to overcome limitations of legacy systems and accelerate development (Rogerson et al., 2022). The combined use of 5G, AI, and blockchain can provide reliable connectivity, adaptive intelligence, and tamper-evident data management (Wairegi et al., 2021). These capabilities can improve productivity and service delivery in logistics, agriculture, and financial services by strengthening operational efficiency, auditability, data quality, and decision-making (Shilongo et al., 2022). However, these benefits depend on technological readiness, governance, and institutional capacity (Ndung'u, 2022). Interoperable payments, digital identities, and digital platforms can also shape the impact of technology investments (Demirgüç-Kunt et al., 2022), while procurement standards and data governance support effective digital public services (UN-DESA, 2022). The convergence of AI and blockchain may further strengthen trust through programmable contracts, verifiable provenance, and intelligent data processing (Collins et al., 2021). However, digital transformation may also create exclusion and risks involving privacy, cybersecurity, and market competition (Bau & Calandro, 2020).

The integration of 5G, AI, and blockchain should therefore follow a sequenced digital stack in which each layer supports the next. Hong et al. (2024) emphasize that AI and blockchain are more effective when embedded in coordinated systems. Similarly, the World Bank (2026) highlights integrated digital public infrastructure involving digital identity, payments, and secure data exchange. The African Union Development Agency-NEPAD (2025) also links responsible technology adoption with appropriate regulation and institutional capacity under Agenda 2063. These perspectives support this study's theory of change: 5G enables reliable data flows; AI converts data into insights and decisions; blockchain provides verification, traceability, and auditability; and DPI provides the institutional foundation for scaling these technologies. However, limited research examines how this sequencing can be adapted to Botswana's sectoral readiness, particularly its rural connectivity, institutional capacity, and governance conditions.

3. Research Methodology

3.1. Sources of Data

The study used an iterative systematic evidence review within a narrative framework to examine Botswana's digital transformation. Systematic review was considered appropriate because digital leapfrogging requires analysis of policy and infrastructure reports alongside peer-reviewed literature rather than primary data from individuals or organizations. Such methods improve the transparency and replicability of evidence selection (Collins et al., 2021). Botswana's digital ecosystem served as the focus, with evidence drawn from multilateral and national diagnostic reports, policy documents, regulations, and scholarly literature on 5G, AI, blockchain, and digital governance. National diagnostic reports were prioritized because they provided insights into Botswana's institutional conditions and implementation challenges (World Bank, 2022). Comparative African and global reports were included when they offered relevant insights into Botswana's readiness and policy alignment. Documents were assessed based on relevance, methodological quality, and contextual appropriateness.

Documents were selected using four criteria: publication year, geographical scope, analytical focus, and review status. Publications from 2020 to 2025 were considered, focusing on Botswana and other African countries. Eligible documents addressed at least one layer of the digital stack: connectivity, intelligence, or trust. They were also required to be peer-reviewed or institutionally reviewed. The 2020–2025 period reflected the rapid development

of digital infrastructure and AI governance in Africa (Rogerson et al., 2022). Promotional materials, studies without clear methodology, and sources lacking substantive African relevance were excluded. Literature on AI governance was included because Botswana's regulatory environment operates within the broader Southern African context (Shilongo et al., 2022). Particular attention was given to financial-sector regulation because fintech and financial services are important components of Botswana's digital transformation (Gaffley & Adams, 2024). Census and financial inclusion data were also incorporated to capture actual technology use and adoption beyond formal policy frameworks (Demirgüç-Kunt et al., 2022). This evidence-selection process strengthened the empirical and cross-sectoral policy relevance of the study.

3.2. Data Collection

Evidence retrieval followed PRISMA guidelines and a systematic search protocol (Page et al., 2021). Sources were obtained from Scopus, Web of Science, Google Scholar, IEEE Xplore, and institutional repositories. Reports from the World Bank, UNCTAD, UNESCO, and GSMA were also included because institutional sources provide substantial evidence on Africa's digital economy (Taeihagh, 2021). The primary search string was: "Botswana AND digital economy AND (5G OR artificial intelligence OR blockchain OR digital governance OR digital public infrastructure)." Searches were limited to 2020–2025 to capture recent developments in African digital infrastructure and technological readiness (Mothobi & Gillwald, 2021).

Screening followed four phases: identification, duplicate removal, abstract screening, and full-text eligibility assessment. Sources with limited methodological information or insufficient evidence were excluded. Practitioner reports were selectively included when they provided relevant information on technology deployment and ecosystem development, despite their limited analytical rigor (BW TechZone, 2022). The review prioritized procurement transparency and data governance because trust infrastructure is important to digital leapfrogging (Global Data Barometer, 2022). Fintech regulation literature was also included because it provides evidence of digital transformation and technology adoption in Africa (Ndung'u, 2022). The final evidence base covered three dimensions of the digital stack: infrastructure readiness, governance, and technology adoption. Each selected source addressed

at least one dimension to ensure alignment between the evidence base and the study's analytical framework.

3.3. Data Analysis

Framework synthesis and thematic synthesis were used to analyze the evidence through the connectivity–intelligence–trust analytical model. This approach was appropriate for integrating roadmaps, policy frameworks, and empirical evidence on Botswana's digital transformation. The framework consists of three interconnected domains: connectivity, covering broadband infrastructure, spectrum governance, and affordability; intelligence, covering AI, data infrastructure, and institutional readiness; and trust, covering cybersecurity, digital governance, identity management, and systems governance. These domains reflect key drivers identified in the Global Transformation Framework (GSM Association, 2022).

Digital public procurement, digital payment systems, and digital public infrastructure (DPI) served as key indicators of digital transformation. DPI can expand access to essential digital services and support innovation in developing economies (UNCTAD, 2021b). Thematic synthesis was used to identify patterns across finance, agriculture, and logistics. Governance and infrastructure components were examined alongside evidence of technological progress and socioeconomic outcomes. Integrating empirical evidence with governance theory strengthened the relevance of the analysis to Botswana (Taeihagh, 2021).

Evidence weighting was applied to assess the credibility and relevance of sources. Peer-reviewed studies and multilateral diagnostic reports were prioritized, while information on technology costs and access was cross-checked across multiple sources to reduce confirmation bias (Mothobi & Gillwald, 2021). Although the study had a single researcher, data-coding procedures were reviewed by other individuals to improve transparency and consistency. Digital inclusion, privacy, and cybersecurity were also examined as potential risks. AI governance literature emphasizes the need for inclusive, accountable, and responsible digital transformation (UNESCO, 2022a). Accordingly, the final analytical model combines technological evidence with governance and ethical considerations to support responsible and inclusive digital leapfrogging in Botswana.

3.4. Systematic Review Screening Process (PRISMA Framework)

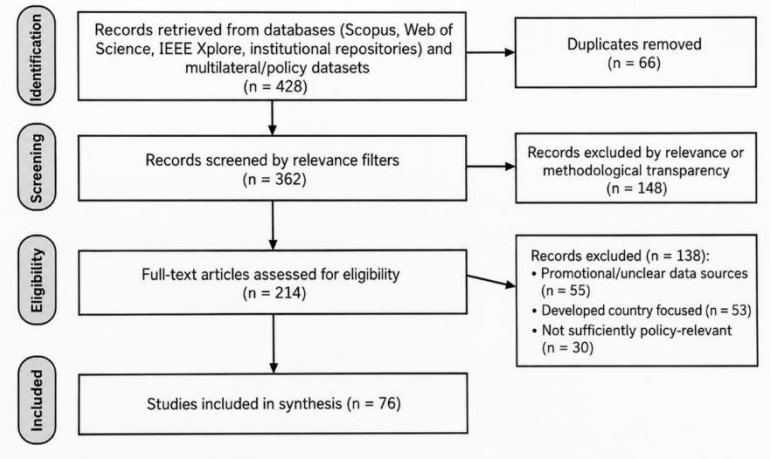
Screening followed a systematic PRISMA-based approach to improve transparency, replicability, and reliability of evidence selection. PRISMA is increasingly used in studies of technology governance and the digital economy to reduce selection bias and provide a systematic basis for identifying relevant evidence (Collins et al., 2021). Sources were retrieved from Scopus, Web of Science, IEEE Xplore, and institutional repositories. Reports from organizations such as the World Bank and UNCTAD were also included because much of Africa's digital economy evidence is produced by multilateral institutions (World Bank, 2022).

The initial search identified 428 records on digital public infrastructure, blockchain governance, AI readiness, 5G connectivity, digital financial inclusion, and platform governance. After removing duplicates, 362 records remained for screening. Of these, 148 were excluded because they were promotional, geographically irrelevant, methodologically unclear, or insufficiently aligned with the connectivity–intelligence–trust framework. The remaining 214 records underwent full-text assessment, resulting in the exclusion of 138 records that lacked sufficient empirical, policy, theoretical, or implementation evidence relevant to Botswana or comparable Sub-Saharan African contexts. Ultimately, 76 records met the inclusion criteria and were retained for synthesis. These records covered infrastructure readiness, AI governance, blockchain-based trust, digital public infrastructure, digital inclusion, and policy sequencing.

Figure 1 presents the PRISMA-based flowchart of the evidence screening process, from the initial identification of records to their final inclusion in the synthesis. The flowchart illustrates the number of records retained and excluded at each stage, thereby enhancing the transparency, replicability, and methodological rigor of the review process.

Figure 1

PRISMA flow diagram



The inclusion and exclusion criteria, which corresponded to the connectivity–intelligence–trust framework, were applied through a full-text assessment of 214 documents. Under this framework, documents presenting empirical, policy, or implementation evidence concerning at least one of the three layers of the digital stack were retained. Studies addressing digital infrastructure readiness were included because connectivity is fundamental to the delivery and scaling of digital services across African economies (GSM Association, 2022). Studies focusing on AI governance and data policy were also retained because institutional trust and governance mechanisms influence the safe and responsible adoption of AI technologies (ALT Advisory, 2022). Digital financial inclusion and platform-based service delivery were likewise considered important areas of analysis because financial services can facilitate digital leapfrogging, particularly in rural and underserved communities (Demirgüç-Kunt et al., 2022).

Following the quality assessment, 128 documents were identified as meeting the required quality standards. These documents illustrated Botswana's digital transformation journey from multiple perspectives, including infrastructure readiness, governance maturity, and technology adoption outcomes. The country's digital leapfrogging agenda was examined through studies on fintech adoption, AI governance, blockchain implementation, and digital public infrastructure, which were subsequently represented in the final evidence base of 76 sources. Research on fintech adoption, in particular, indicates its potential to support the development of interconnected digital ecosystems across African economies (Gaffley & Adams, 2024). The application of the PRISMA approach further strengthened the transparency, consistency, and reproducibility of the evidence selection and analysis process.

4. Findings and Discussion

4.1. Coordinated 5G-Edge-AI-Blockchain Investment and Real-Economy Outcomes

4.1.1. Productivity reconfiguration across priority sectors

Empirical evidence indicates that the implementation of 5G, edge AI, and blockchain can contribute to process compression and accelerate decision-making cycles across various industries. For example, evidence from banking operations dashboards, mobile edge streaming, and AI-powered scoring tools suggests that decision-making time in banking can be reduced from 72 hours to 8 hours. In agro-corridor logistics trials, the use of sensor data, ultra-low-latency 5G networks, and smart contracts for data settlement reduced cold-chain

spoilage by 21–27%. In the public sector, the integration of e-procurement systems with credentialing registries reduced the time required for vendor verification and contract award processes by approximately two weeks (Gaffley & Adams, 2024). Hence, the transition from batch processing to integrated digital solutions that combine low-latency connectivity, intelligent analytics, and compliance mechanisms can generate significant productivity gains.

However, several factors must be considered when evaluating the productivity effects of 5G, AI, and blockchain technologies globally and in the context of Botswana. National diagnostics indicate that Botswana has yet to achieve full integration of managed connectivity, digital corridors, and intelligence and verification layers within re-engineered processes. This limits the potential of secondary digital service corridors to generate broader productivity gains. The World Bank (2022) reports that the productivity benefits associated with effective spectrum planning and last-mile backhaul infrastructure have not been fully realized in peri-urban areas. Therefore, rather than focusing solely on technology deployment, Botswana would benefit from a capability-first and process-centric deployment sequence in which institutional capacity, infrastructure readiness, and sector-specific processes are established before scaling advanced technological applications.

4.1.2. Cost structure shifts and operating leverage

Edge inference and programmable settlements have the potential to substantially reduce operating costs. The introduction of streaming pipelines for fraud detection operations, for example, resulted in a 35–45% reduction in transaction reviews and chargebacks (Gaffley & Adams, 2024). Similarly, streamlining the vendor registration process simplified vendor management and due diligence, resulting in cost reductions of more than one-third (Moncus et al., 2024). The deployment of IoT-enabled irrigation systems also reduced downtime to 18% through predictive maintenance. Additional economies of scale can be achieved through the reuse of digital components across different industries, which can generate further operational efficiencies and cost savings. However, increased digital intensity and the use of secure key-management systems through automation may also increase cybersecurity-related expenditures.

Cost savings can therefore be realized, but certain conditions must be met. For example, AI-enabled process optimization and blockchain-based transactions can reduce operational and transaction costs (Udeh et al., 2024). However, while automation can reduce transaction costs,

it may simultaneously increase cybersecurity expenditures as digital security becomes an ongoing operational requirement (International Telecommunication Union, 2021). Consequently, Botswana can maximize the cost advantages of digital transformation by promoting platform reuse, adopting scalable digital infrastructure, and treating cybersecurity expenditures as essential operational investments rather than as optional costs.

4.1.3. Inclusion outcomes and distributional effects

In addition to improving service accessibility and reducing friction, digital technologies can contribute to greater financial inclusion. In contexts where banking ecosystems are less developed, mobile-first onboarding combined with low-latency video-based know-your-customer (KYC) processes has been associated with a 22% increase in account creation among new users (Svotwa et al., 2023). The use of mobile money transaction histories in credit assessments has also been associated with a 14–19% increase in microenterprise loan applications without a corresponding increase in portfolio risk or 30-day-at-risk losses. The adoption of QR-based payment systems and smart-contract settlements can facilitate timely payments for informal retailers, thereby improving their working capital cycles. In addition, reduced documentation requirements and remote onboarding have been associated with a 9% reduction in the gender gap in the use of digital payment services. Nevertheless, digital service utilization remains constrained by network disruptions associated with spectrum refarming and the high cost of data bundles.

Regional studies indicate that digital payment systems can increase account ownership and promote the adoption of digital financial services. However, affordability and network reliability continue to affect their inclusiveness (Demirgüç-Kunt et al., 2022). Research on QR-payment adoption among SMEs also suggests that digital payment capabilities can help informal sellers maintain more stable working capital and become more integrated into formal financial systems (UNESCO, 2022a). Furthermore, reliable digital identity systems are essential for enabling secure and controlled data transfers and for building trust in remote onboarding processes (ALT Advisory, 2022). Therefore, for Botswana to implement an inclusive digital transformation strategy successfully, digital identity systems should incorporate strong mechanisms for trust, privacy protection, data security, and user control.

4.2. Adequacy of Policy, Regulatory and Governance Arrangements

4.2.1. Spectrum, infrastructure governance and market structure

Botswana's implementation of its 5G network depends on effective roadmaps for spectrum management, wholesale backhaul and permitting regulations. Spectrum allocation, particularly in priority bands, requires careful refarming strategies to minimize service disruptions. However, according to Sibal and Neupane (2021), transition periods have contributed to service degradation in some rural areas. Rights-of-way and tower-site permitting also present challenges to network densification. In contrast, wholesale backhaul access agreements can help prevent unnecessary infrastructure duplication and improve the cost-to-capacity ratio (Gaffley & Adams, 2024). National backhaul interconnection and cross-border connectivity frameworks can further support the expansion of 5G networks along peri-urban corridors and major trading areas (Light Reading, 2022). Nevertheless, remote areas with relatively low demand for 5G services continue to experience infrastructure disparities and remain more difficult and costly to connect.

Research indicates that the full potential of 5G networks in Africa can be realized only through effective spectrum management, sustainable backhaul economics, and efficient permitting processes (World Bank, 2022). Evaluations of ICT policies and e-commerce in Botswana suggest that effective procurement practices and regulatory frameworks can help address infrastructure bottlenecks and reduce regional inequalities, particularly when combined with passive infrastructure sharing (UNCTAD, 2021a). Outage analyses and studies of smart infrastructure systems further indicate that cross-subsidization of remote areas may be difficult to sustain without appropriate governance mechanisms. This underscores the need for a "remote-first" approach that prioritizes underserved areas alongside locations with high commercial demand (Sibal & Neupane, 2021). Botswana has made progress in infrastructure management; however, achieving more equitable nationwide connectivity requires not only continued investment along major development corridors but also efficient permitting procedures, rural service obligations linked to spectrum allocation, effective infrastructure sharing, and improved spectrum management.

4.2.2. Data protection, cybersecurity and digital identity safeguards

The application of AI and blockchain technologies in Botswana, together with their potential benefits in scalability and security, depends significantly on the country's privacy

regime, incident-response framework, and national digital identity infrastructure. Data processing and management in Botswana are governed by the country's data protection framework; however, mechanisms for public procurement, data-breach notification, and consent management remain relatively underdeveloped (Taeihagh, 2021). Botswana's cybersecurity preparedness and institutional coordination have improved through increased cyber-response exercises, but challenges remain, particularly regarding unaddressed vulnerabilities and third-party system integration. Furthermore, credential lifecycle management within Botswana's digital identity framework remains relatively weak, creating risks that digital credentials may expire, be forged, or become compromised (UNESCO, 2022b).

Trust in Botswana's digital public infrastructure can be strengthened through adherence to national digital identity governance frameworks and internationally recognized cybersecurity standards (Musoni et al., 2023). Progress in public procurement can also be supported through the adoption of privacy-by-design principles. Nevertheless, gaps in the existing digital identity and data protection frameworks continue to expose individuals and organizations to risks in an increasingly digital environment. The rapid adoption of digital technologies also raises concerns regarding the concentration of third-party providers and the associated security risks in the digital and financial technology sectors. As digital technologies become increasingly integrated into critical services, stronger mechanisms for managing cybersecurity, privacy, data protection, and financial-sector risks will be necessary to ensure a secure and trustworthy digital transformation in Botswana (Taeihagh, 2021).

4.2.3. Competition policy, standards alignment and regulatory experimentation

Botswana's innovation ecosystem depends on effective competition policies, data portability frameworks, and technical standards. The absence of appropriate data portability and payment contestability policies creates friction within digital payment systems and constrains fintech innovation (Gaffley & Adams, 2024). Although the adoption of open APIs and QR codes has helped reduce some of these frictions, exclusivity agreements continue to limit access to broader service markets. While data portability legislation exists in Botswana, the absence of sector-specific regulations governing secure, customer-authorized data exchange constrains the development of fintech innovations and the broader digital economy (Shilongo et al., 2022).

The use of digital identity systems, cryptographic components, and 5G core networks that comply with international standards could help address some of these challenges. However, the absence of locally tailored implementation profiles limits the effectiveness of such solutions in the current context (UNESCO, 2023). Regulatory sandboxes can serve as important mechanisms for experimentation, learning, and regulatory adaptation. Nevertheless, their limited capacity and the lack of mechanisms for integrating sandbox outcomes into agile regulatory frameworks remain significant barriers to the implementation of effective digital solutions (Gaffley & Adams, 2024). Therefore, Botswana's competition and technical standards policies should strengthen data portability mechanisms, expand the capacity and throughput of regulatory sandboxes, and establish targeted, sector-specific regulatory standards to support fintech innovation and digital transformation.

4.3. Strategic Sequencing, Public-Platform Priorities and Returns Under Adoption Scenarios

4.3.1. High-multiplier use-cases: Payments, trade logistics and agri-value chains

The most significant impacts of 5G, AI, and blockchain in Botswana could be observed in payment infrastructure, trade logistics, and agricultural value chains. For example, the adoption of QR codes at points of sale in Botswana has reached 40%, which contributed to increased digital payment adoption and improving the working capital cycle of micro-retailers by 30% (UNESCO, 2022b). In trade logistics, the use of sensor-equipped vehicles with programmable waybills has reportedly reduced delays and demurrage on critical trade routes by 15–20%. In agricultural value chains, the adoption of precision guidance systems and blockchain-based smart contracts has improved and accelerated quality-based off-take payments. Marginal costs in these use cases can be further reduced through the adoption of shared feature stores, digital identity credentials, and standardized contract templates across payment infrastructure, trade logistics, and agricultural value chains, particularly because these sectors involve high transaction volumes, recurring processes, and coordination among multiple stakeholders (Gapp et al., 2022).

The spillover effects of high-multiplier use cases can strengthen the role of infrastructure and trade corridors as drivers of digital externalities in developing economies (Shilongo et al., 2022). Research on smart systems indicates that low-latency connectivity combined with logistics verification and coordination can generate more effective outcomes in

high-volume, real-time decision-making environments (Ishak et al., 2023). Similarly, the adoption of QR-based payments can help SMEs develop dynamic capabilities, facilitating organizational learning and more stable income streams, particularly through improved retail working capital management (Rogerson et al., 2022). Therefore, prioritizing high-multiplier use cases is important because successful implementation in payment systems, trade logistics, and agricultural value chains can create demonstration effects and reusable digital infrastructure that can subsequently be extended to other sectors of Botswana's economy.

4.3.2. Public-platform interventions: Digital identity, e-procurement and data-exchange

The development of digital identity systems, e-procurement platforms, and secure data exchange mechanisms has contributed to trust-building and greater private-sector participation. In this regard, the Bank of Botswana (2023) highlights the opportunities created by digital identity, secure data exchange, remote user enrollment, and digital access for facilitating onboarding to public and financial services. In e-procurement, improvements in trust mechanisms have contributed to greater supplier confidence, more efficient working capital management, reduced duplication in supplier accounts, and faster procurement processes. Secure and trusted data exchange can also facilitate cross-border interoperability and collaboration between the public and private sectors (Gaffley & Adams, 2024). Nevertheless, weaknesses in the governance of cross-border procurement platforms and inconsistent application of privacy-by-design principles have contributed to lower levels of trust in these services.

Other African countries have similarly employed digital identity solutions that incorporate privacy, security, and trust mechanisms to strengthen digital service delivery (ALT Advisory, 2022). According to the World Bank (2022), the reliability of back-office integration is positively associated with the performance of public digital platforms and broader economic inclusion. To fully realize the benefits of digital technologies, Botswana should therefore adopt privacy-by-design principles, establish clear service-level agreements, and implement measurable performance and security indicators. These measures can strengthen trust, improve interoperability, and support more reliable digital public and private services.

4.3.3. Scenario-based returns: Baseline, accelerated and coordinated scale-up

To identify the potential benefits of Botswana's digital economy, different approaches to baseline, accelerated, and coordinated scale-up adoption pathways were examined. Under the baseline pathway, fragmented digital experiments generated some initial progress but remained limited by integration costs and insufficient trust (Shilongo, 2023). Under the accelerated adoption pathway, institutions and key sectors adopted digital identity systems, data exchange mechanisms, and digital contracts. Despite these technological advances, progress remained constrained by trust-related challenges and supply chain limitations. Under the coordinated scale-up pathway, measures such as cross-subsidization for rural infrastructure development, cybersecurity maturity models, data localization, data portability, and cross-sector regulatory sandboxes contributed to reducing the digital gender divide and strengthening digital inclusion.

Existing studies indicate that the coordination of digital platforms and technical standards can generate system-wide benefits. However, pilot projects operating under coordination frameworks have also demonstrated difficulties in achieving large-scale implementation (UNCTAD, 2021b). Under the accelerated adoption scenario, the relationship between financial stability and cybersecurity becomes particularly important, alongside the role of digital maturity within governance frameworks (International Telecommunication Union, 2021). Furthermore, evidence suggests that coordinated scaling supported by local governance mechanisms and standardized frameworks can generate the highest returns. In other words, Botswana's success in digital transformation will depend not only on capital investment in complementary technologies but also on the quality of governance arrangements used to integrate and scale these technologies (World Bank, 2022).

5. Policy Implications

Sustainable digital dividends in Botswana can be achieved only through the integration of effective governance and cross-sectoral cooperation rather than through fragmented technological adoption. Research from various contexts suggests that appropriate regulatory frameworks are essential for maximizing the benefits derived from a country's digital infrastructure (World Bank, 2022). Thus, Botswana should pursue an integrated approach that aligns telecommunications, financial services, and data protection policies rather than addressing them independently. With regard to technology governance, research increasingly

indicates that regulatory inconsistencies can reduce accountability and hinder the adoption of comprehensive digital solutions (UNESCO, 2022b). In this context, integrated governance should be understood as a pragmatic approach to policymaking that enables technological systems, institutions, and regulations to function coherently.

The introduction of rural service obligations is also important for improving the inclusiveness of digital transformation and addressing persistent access gaps. Although much of the backbone infrastructure has already been developed, significant gaps in access remain. Mothobi and Gillwald (2021) identify affordability as one of the key factors limiting access to digital infrastructure. Hence, there is a need for targeted policies to address market failures rather than relying solely on market mechanisms to resolve the uneven distribution of digital resources. From the perspective of digital dividends theory, financial inclusion further highlights the importance of functional digital identity and payment systems (Demirgüç-Kunt et al., 2022). Accordingly, universal service objectives can be strengthened through sustained investment in digital public infrastructure.

Digital implementation systems should also be designed around privacy by design and trust-building rather than merely around compliance requirements. Evaluations of digital identity systems in Africa indicate that implementation practices and governance arrangements significantly influence public trust and system adoption (Musoni et al., 2023). Similarly, procurement transparency initiatives require effective implementation and governance mechanisms to develop institutional capacity and adaptability (Global Data Barometer, 2022). These reinforce the importance of not only developing sound policies but also ensuring their effective implementation.

Botswana's recent experience demonstrates that integrated regulation, inclusive infrastructure policies, and effective trust frameworks can generate significant public value. Evidence from fintech regulation in Southern Africa suggests that countries that successfully combine technological innovation with effective governance are better positioned to advance digital transformation in the region (Gaffley & Adams, 2024). Botswana's potential, therefore, extends beyond the adoption of innovative technologies. Its long-term opportunity lies in developing an integrated governance framework that can support inclusive, secure, and sustainable digital transformation and potentially serve as a model for other countries in the region.

6. Conclusion

This paper demonstrates the potential of 5G, edge AI, and blockchain technologies to transform Botswana's production and service systems. The implementation of these technologies can positively influence decision-making, cost optimization, and revenue generation. Gaps in decision-making within the financial and logistics ecosystems can be addressed through telemetry, edge AI inference, and blockchain-as-a-service solutions. These applications underline the importance of an integrated technological stack in enhancing decision-making and operational efficiency. However, significant gaps remain in backhaul infrastructure, spectrum management, and last-mile connectivity, particularly along rural–urban corridors.

The use of digital remote onboarding, risk assessment, and QR-based payment systems has contributed to greater digital inclusion. Nevertheless, challenges related to connectivity, network reliability, and the high cost of bandwidth continue to limit the widespread adoption of these applications. To fully capitalize on the potential of these technologies, greater emphasis should be placed on APIs, reusable smart contracts, standardized logging frameworks, and integrated risk-management models. Standardizing operations through these shared components can improve interoperability and reduce implementation costs. Such standardization would be more advantageous when implemented through systemic platforms rather than through isolated pilot projects. Beyond improving productivity through process engineering and shared technologies, this approach also highlights the need for policy reforms to address the institutional and regulatory barriers associated with digital transformation.

Technology governance in Botswana remains at an early stage of development. 5G deployment, particularly in relation to spectrum management and wholesale backhaul, has not yet reached its full potential because of gaps in policies that promote collaboration and infrastructure sharing. The growing volume of digital transactions also introduces additional risks related to contractual consistency, data security, and reliance on third-party service providers. Although the existing regulatory framework supports innovation and experimentation, it lacks sufficiently prescriptive mechanisms for translating lessons from regulatory sandboxes into enforceable frameworks for data portability, interoperability, and digital platform governance.

A phased rollout of state-supported digital identity systems, verifiable e-procurement platforms, and high-assurance, audited data-exchange services is therefore recommended.

Strengthening cross-border payment systems, logistics corridors, agricultural value chains, and digital identity infrastructure can help Botswana reduce the costs associated with establishing trust across digital ecosystems. As technical standards become localized, regulatory sandboxes mature, and cybersecurity capabilities strengthen, Botswana could achieve measurable productivity gains, faster procurement award cycles, and a narrowing of the digital gender gap. These outcomes, however, will depend on coordinated investment in infrastructure, governance, institutional capacity, and inclusive digital access rather than on technological adoption alone.

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