



# Journal of Frontiers in Multidisciplinary Research

## Blockchain-Enabled E-Governance: A Model for Enhancing Transparency in Developing Economies

Adeola Okesiji <sup>1\*</sup>, Odunayo Oyasiji <sup>1</sup>, Okeoghene Elebe <sup>2</sup>, Chikaome Chimara Imediegwu <sup>2</sup>, Opeyemi Morenike Filani <sup>3</sup>, Andikan Udofot Umana <sup>4</sup>, Muritala Omeiza Umar <sup>5</sup>

<sup>1</sup> Independent Researcher, Calgary, Alberta

<sup>2</sup> Access Bank PLC, Nigeria

<sup>3</sup> Proburg Ltd, Lagos Nigeria

<sup>4</sup> Relsify LTD, Lagos, Nigeria

<sup>5</sup> Independent Researcher, Doha, Qatar

\* Corresponding Author: Adeola Okesiji

---

### Article Info

**E-ISSN:** 3050-9726

**P-ISSN:** 3050-9718

**Volume:** 01

**Issue:** 01

**January-June 2020**

**Received:** 15-03-2020

**Accepted:** 20-04-2020

**Page No:** 105-120

### Abstract

The persistent challenge of transparency and accountability in governance structures across developing economies has stifled sustainable development, discouraged investment, and eroded public trust. As these nations continue to grapple with administrative inefficiencies, corruption, and opaque processes, emerging technologies offer potential pathways for reform. Among these, blockchain technology stands out as a decentralized, immutable, and transparent digital ledger system capable of redefining how governance is conceptualized and implemented. This paper explores the viability of blockchain-enabled e-governance models in enhancing transparency within public institutions in developing contexts. Drawing from a conceptual and exploratory framework, the study identifies key areas where blockchain applications can foster openness, such as land registry, procurement, public finance, electoral systems, and identity verification. While prior literature acknowledges the promise of digital governance, this paper emphasizes blockchain's unique capacity to automate trust, reduce discretion, and enable real-time verification of public processes. It critically evaluates pilot initiatives and experimental blockchain programs in select developing nations to establish patterns of adoption, resistance, and measurable impact. Furthermore, it highlights the socio-political, infrastructural, and regulatory hurdles that may inhibit or distort successful implementation, especially in environments with weak digital literacy and limited institutional accountability. The study proposes a model for blockchain-enabled e-governance tailored to the socio-economic realities of developing economies. The model integrates blockchain with existing administrative systems while fostering institutional reforms, capacity building, and inclusive stakeholder engagement. It underscores the importance of designing systems that balance transparency with data privacy, decentralization with national oversight, and technology with policy intent. By aligning technical architecture with public governance objectives, the paper argues that blockchain can do more than digitize bureaucracy—it can reengineer governance processes to be citizen-centric, tamper-proof, and resilient against corruption. This abstract sets the stage for a deeper examination into how blockchain can catalyze a governance paradigm shift in the Global South, ultimately offering a roadmap for institutions seeking legitimacy and efficiency in an age of digital transformation.

**DOI:** <https://doi.org/10.54660/IJFMR.2020.1.1.105-120>

**Keywords:** Blockchain, E-Governance, Transparency, Developing Economies, Public Sector Reform, Digital Trust, Decentralized Systems, Anti-Corruption Technology

---

### 1. Introduction

Transparency remains one of the most elusive components of governance in developing economies.

Institutional opacity, bureaucratic inefficiency, systemic corruption, and a lack of technological adaptation have created enduring obstacles to accountability and service delivery. As governments in these regions strive to enhance legitimacy, social inclusion, and efficient resource management, the discourse around technology's role in reshaping governance processes has intensified. Among the most disruptive and promising innovations in this space is blockchain—a decentralized digital ledger that ensures data immutability, transparency, and distributed verification without the need for centralized oversight. Although initially associated with cryptocurrencies, blockchain's potential applications in public governance span diverse domains such as land administration, digital identity management, electoral processes, public procurement, and welfare distribution. The transformative promise lies in its ability to eliminate the conditions under which corruption thrives: discretionary control, limited oversight, and information asymmetry.

In developing contexts, traditional e-governance frameworks have often fallen short due to infrastructural constraints, poor digital literacy, limited interoperability of systems, and political interference. Digitization alone, while a step toward modernization, does not inherently guarantee accountability. In many cases, digital records remain vulnerable to tampering, restricted access, or system outages. What is urgently needed is a paradigm shift from mere digitization to trustworthy automation—a system where auditability, transparency, and citizen trust are structurally embedded. Blockchain, by virtue of its cryptographic and decentralized architecture, presents a compelling alternative to the centralized data silos that characterize much of the Global South's digital governance infrastructure. By encoding rules into smart contracts and ensuring data traceability across permissioned networks, blockchain can automate integrity into state processes.

The theoretical foundation of blockchain-enabled governance is rooted in the concept of "trustless trust," where the system itself enforces accountability, reducing dependence on human discretion. This is particularly critical in societies where institutions have historically failed to inspire trust. In environments marked by weak rule of law, public sector corruption, and regulatory fragmentation, blockchain introduces not just a technological tool but a new institutional logic. For instance, consider land registries in countries where double allocation of titles, forged documents, and inaccessible paper records are common. A blockchain-based registry, accessible through secure digital identities, can prevent multiple claims on a parcel of land and enable verifiable histories of ownership. Similarly, electoral transparency—undermined by vote tampering and delayed results—can be improved through blockchain-backed voting protocols that guarantee vote immutability and verifiability, even in real time.

To understand the transformative potential of blockchain in e-governance, it is important to frame it within the specific socio-political realities of developing nations. Governance in many African, Asian, and Latin American states operates within hybrid regimes—marked by formal democratic structures but informal networks of power, patronage, and ethnopolitical cleavages. Any technological intervention must therefore not only be technically viable but also contextually sensitive. Research such as that by Akpan, Awe, and Idowu (2019), though focused on biometric differentiation across Nigerian ethnic groups, underscores the

importance of data specificity and population heterogeneity in designing inclusive digital systems. Their findings reveal how demographic and biometric variables must be integrated into digital identity frameworks if they are to function reliably in pluralistic societies.

In a similar vein, Awe and Akpan (2017), in their cytological comparison of *Allium* species, emphasized the critical role of cellular-level data analysis in biological system classifications. Although distant in subject matter, their methodological rigor highlights the importance of data accuracy and system verification—both of which are vital in designing public registries or digital voting systems using blockchain. Their research reminds us that the success of any data-based system, whether biological or bureaucratic, depends on the reliability of its foundational records and the mechanisms in place to ensure data fidelity.

More broadly, the need for secure, accessible, and transparent governance systems parallels the challenges observed in technical fields, such as the development of microchip heat sinks by Akinluwade *et al.* (2015), where the authors stressed the importance of material integrity and system resilience. When translated into governance, this principle aligns with the idea that digital systems must be designed not only for functionality but for long-term resistance to failure, tampering, or overload—features that blockchain inherently supports through distributed architecture.

Efforts to adopt blockchain-based solutions in governance are already underway in parts of the developing world. In Ghana, a blockchain-powered land registry project has aimed to eliminate the long-standing issues of title duplication and record tampering. In India, the state of Andhra Pradesh has experimented with blockchain in transport and land departments to combat systemic inefficiencies. These pilot programs, while not without challenges, demonstrate the growing recognition of blockchain's value as more than a financial ledger. They signal a re-imagining of governance as an ecosystem of verifiable interactions, where institutional processes are no longer mediated by exclusive access or opaque discretion but by open, tamper-proof data trails.

Still, blockchain implementation in the public sector remains a complex endeavor. Political will, technical capacity, legal frameworks, and citizen awareness are critical variables that determine success or failure. The example of energy policy reform discussed by Olaoye *et al.* (2016) in Nigeria—where a renewable energy mix was proposed as a solution to the country's chronic energy crisis—illustrates the challenge of aligning technological solutions with entrenched political and infrastructural constraints. Just as energy reform must be integrated with long-term planning, governance innovation must go beyond technology procurement to include regulatory reengineering, stakeholder education, and cultural adaptation.

Isa and Dem's (n.d.) work on integrating self-reliance education for *purdah* women in Northern Nigeria also offers an insightful analogue. Their emphasis on curriculum design tailored to socio-cultural limitations reinforces the broader thesis that governance technologies, no matter how advanced, must be socially embedded. A blockchain land registry, for instance, may function technically but fail practically if local stakeholders are unable or unwilling to interact with the platform due to digital illiteracy, cultural barriers, or fear of surveillance. Therefore, this paper proposes not just a technical model, but a governance model—one that aligns blockchain's capabilities with grassroots realities and

institutional imperatives.

The concept of transparency must also be examined through the lens of ethical data use. Reinehr *et al.* (2008), in their exploration of hormonal data and weight status, foreground the necessity of ethical safeguards in the collection and interpretation of sensitive data. The same principle applies in e-governance, particularly in areas involving citizen identities, social benefits, and behavioral profiling. Blockchain, while more secure, does not eliminate the risk of surveillance or exclusion if improperly designed. Therefore, this paper emphasizes the importance of privacy-preserving mechanisms, public control over data, and participatory design in all blockchain implementations.

Moreover, the integration of blockchain into existing government systems must be evaluated not merely for feasibility but for systemic impact. As Oduola *et al.* (2014) have shown in comparing computer numerical control and rapid prototyping in product development, different systems produce different levels of efficiency and user control. Applied to governance, this comparison highlights the risks of importing ready-made blockchain platforms without sufficient localization or backward compatibility with existing bureaucratic processes. The goal must be not to replace governance systems wholesale, but to re-architect them around trust, traceability, and citizen empowerment.

In developing economies, these objectives are not easily achieved due to financial constraints, institutional inertia, and infrastructural gaps. Yet the potential benefits—reduced corruption, increased civic participation, improved public service delivery, and restored citizen trust—make blockchain-enabled e-governance an imperative worth pursuing. Furthermore, the technological maturity of blockchain platforms, combined with open-source ecosystems and private-sector partnerships, makes large-scale experimentation more feasible than ever before.

To navigate this complex terrain, this paper develops a conceptual model for blockchain-enabled e-governance tailored to the unique challenges of developing countries. The model integrates blockchain into key governance processes while aligning it with local context, legal constraints, and capacity-building efforts. It draws on lessons from both blockchain literature and adjacent fields, including genetics, education, energy policy, and engineering, to construct a multi-dimensional framework for implementation.

Ultimately, this paper does not argue that blockchain is a panacea. Rather, it positions blockchain as a catalyst—a technology that, when thoughtfully integrated, can help break the cycles of opacity and inefficiency that have long plagued governance in developing economies. The following sections explore this proposition in greater detail: first by engaging with existing literature, then by outlining a methodology for model development, and finally by presenting a conceptual governance model that merges digital trust with social inclusion.

## 2. Literature Review

The discourse on blockchain and its potential application in governance has evolved significantly since its inception in 2008 as the underlying technology of Bitcoin. While the earliest works focused on blockchain's implications for finance and digital currencies, a parallel body of research emerged to explore its broader use in institutional and public sector contexts. At the core of this literature lies the principle that blockchain's decentralized and immutable structure can

enhance transparency, reduce corruption, and foster trust in institutions—benefits that are particularly salient in developing economies where traditional governance mechanisms are often fragile, opaque, or ineffective.

The foundational theories of e-governance trace back to the digital government movement of the late 1990s and early 2000s, where information and communication technologies (ICTs) were leveraged to digitize public services, promote efficiency, and engage citizens. These early approaches, however, were largely centralized and remained vulnerable to manipulation and data loss. By contrast, blockchain-based governance proposes a shift from centralized control to distributed consensus, offering a tamper-proof infrastructure that records transactions across a network of participants with cryptographic security. This theoretical transition is captured in the work of Tapscott and Tapscott (2016), who argue that blockchain enables “the internet of value” by decentralizing trust and eliminating intermediaries. Their insights laid the groundwork for understanding blockchain not merely as a technological advancement but as a governance innovation.

One of the earliest academic efforts to conceptualize blockchain in governance came from Mathews (2016), who proposed a public registry model for land records using a blockchain ledger. This model posited that once data on ownership and land boundaries are entered into the system, any attempt to modify them requires network consensus, effectively eliminating fraud or double registration. For countries in sub-Saharan Africa, where land disputes are prevalent and registry offices remain inefficient or corrupt, such applications present a tangible use case. As the literature evolved, studies such as those by Øines, Ubacht, and Janssen (2017) provided empirical evidence on blockchain's capacity to enhance administrative transparency, while highlighting the institutional, legal, and political barriers that must be addressed before deployment.

Blockchain's role in identity management has also been a significant theme in governance literature. In regions with limited access to verifiable identification, blockchain offers a decentralized digital identity system that individuals can control. Research by Zyskind *et al.* (2015) proposed a blockchain-based identity solution where users manage their data through encrypted keys without reliance on centralized servers. Such solutions are critical for e-governance frameworks involving voting, welfare access, and property registration. However, challenges persist. Critics have noted that in environments with poor digital infrastructure, the costs of deploying such systems can outweigh benefits, especially if not supported by legal reforms and public awareness initiatives.

In the specific context of anti-corruption, blockchain literature has expanded to include policy analysis and case-based evidence. In a comparative study, Gräf (2017) explored how blockchain can mitigate procurement fraud through real-time audit trails and smart contracts. By making transaction histories permanently visible and time-stamped, public procurement becomes subject to real-time public scrutiny. Yet, empirical validation remains limited, especially in developing nations where pilot projects are scarce and transparency outcomes are difficult to quantify. A recurring theme in the literature is the need for institutional interoperability—blockchain must not replace existing governance systems but augment them with new accountability mechanisms.

Beyond the blockchain-specific literature, scholars in

adjacent domains have contributed indirectly to this discourse. For instance, Olaoye *et al.* (2016), in their study on Nigeria's energy crisis, emphasized the importance of adopting innovative technologies in contexts plagued by systemic inefficiencies and resource mismanagement. While their focus was on renewable energy, the conceptual linkage is clear: governance reform in developing economies necessitates the integration of resilient technologies that promote sustainability, transparency, and equitable access. Their recommendation for an energy mix rooted in decentralization mirrors the governance principle of distributed consensus that underpins blockchain infrastructure.

Likewise, the work by Awe, E.T. (2017) on the hybridization of African catfish, though seemingly unrelated, demonstrates the scientific rigor involved in managing and recording genetic variation—skills transferable to the field of digital record-keeping in public institutions. Proper documentation, data integrity, and verification—central concerns in biological experimentation—are also essential in designing secure, trustworthy governance systems. The metaphor may be stretched, but the underlying principle remains: governance systems require fidelity, clarity, and resistance to distortion, much like scientific databases.

Awe and Akpan's (2017) cytological study of *Allium cepa* and *Allium sativum* serves as another instructive parallel. Their methodology relied on accurate data observation and cellular differentiation, a process not unlike differentiating user credentials or validating smart contracts within blockchain governance systems. This analogy underscores a broader epistemological point: whether in biology or bureaucracy, systems thrive on verifiable, consistent data managed under well-defined protocols.

Identity verification and citizen inclusion also feature prominently in the work of Akpan *et al.* (2017), who investigated fingerprint minutiae across Nigerian ethnic groups. Their findings highlighted the nuanced differences in biometric data across populations—a consideration vital to developing inclusive digital identity platforms. In blockchain governance literature, similar concerns have emerged. If biometric data is to be integrated into blockchain systems for voting or service access, understanding demographic variability is essential to avoid exclusion or technical errors. The sensitivity of such data also raises privacy concerns, reinforcing the need for ethical design principles—a theme echoed in Reinehr *et al.*'s (2008) exploration of hormone data and its health implications. The ethical management of sensitive personal data, whether medical or civic, remains a crucial pillar in governance discourse.

From an engineering standpoint, the work of Akinluwade *et al.* (2015) and Oduola *et al.* (2014) introduces themes of system durability and innovation. Their analysis of material selection for microchip heat sinks and comparative study of production methods aligns conceptually with blockchain deployment. Both require a careful calibration of efficiency, cost, and scalability. Governance systems must operate reliably under stress, accommodate expansion, and adapt to contextual variables—a technological imperative echoed across engineering disciplines.

Moreover, the cultural implications of governance reform cannot be ignored. Isa and Dem's work on integrating self-reliance education for purdah women illustrates the challenges of introducing new systems in culturally bounded contexts. Blockchain governance, while technologically

sound, must also be socially legitimate. This requires participatory design processes, capacity building, and continuous feedback mechanisms that align with local values. Literature in development studies echoes this need, cautioning against technological determinism and advocating for context-sensitive innovation.

Despite the optimism around blockchain, critical perspectives in the literature emphasize its limitations. Pilkington (2016) noted the technological immaturity of many blockchain platforms and the risk of over-reliance on automation without addressing underlying governance deficits. Moreover, blockchain systems can be expensive to maintain, energy-intensive, and difficult to regulate. Without robust institutional frameworks and legal backing, blockchain projects risk becoming isolated experiments with limited scalability or sustainability. Similarly, the issue of interoperability between blockchain systems and legacy databases remains unresolved in much of the current literature.

Another limitation identified by scholars such as Atzori (2015) is the political economy of blockchain adoption. In many developing countries, elites benefit from the status quo of opaque governance and may resist transparency-enhancing technologies. The literature suggests that technological solutions alone are insufficient; they must be accompanied by political reforms, civil society engagement, and long-term capacity development. This perspective tempers the technoutopian narratives often associated with blockchain and grounds them in the messy realities of policy implementation. Scholars like Scott (2019) argue for layered approaches that integrate low-tech and high-tech solutions, ensuring that blockchain does not become an elitist tool but serves the wider population. Pilot projects in countries such as India, Estonia, and Kenya offer valuable lessons. These studies suggest that the most successful implementations are those that combine blockchain with institutional reforms, local capacity-building, and public education campaigns.

In conclusion, the literature on blockchain and e-governance reveals a field of rich potential but considerable complexity. While theoretical models abound, empirical studies remain limited, especially in low-resource settings. The integration of blockchain into public administration must be context-specific, ethically grounded, and institutionally embedded. This review has also demonstrated that valuable insights can be drawn from adjacent disciplines—from genetics to education, from engineering to energy policy—each offering principles, methods, or cautionary lessons applicable to the governance context.

This paper builds on these foundations to propose a new conceptual model of blockchain-enabled e-governance tailored to developing economies. It seeks to bridge the gap between promise and practice by grounding blockchain implementation in the socio-political, infrastructural, and cultural realities of the Global South. The next section outlines the methodology used to develop this model, combining theoretical synthesis, case review, and institutional mapping to ensure relevance and scalability.

### 3. Methodology

This study adopts a conceptual-exploratory methodology rooted in qualitative research traditions, with a specific focus on synthesizing interdisciplinary knowledge to develop a model for blockchain-enabled e-governance in developing economies. The methodological framework is informed by

the limitations of existing governance systems in resource-constrained environments and the transformative capabilities of decentralized digital infrastructure. The aim is to construct a functional model that aligns the architectural integrity of blockchain technology with the socio-political, economic, and infrastructural realities of governance in the Global South. Given the relatively nascent stage of blockchain implementation in public institutions—particularly within non-Western settings—this methodology is designed to be iterative, inclusive of thematic extrapolation, and adaptive to diverse national contexts.

The first stage of the methodology involved a rigorous literature analysis across academic and grey sources up to 2019. This analysis was not limited to blockchain literature alone, but extended to include adjacent fields such as public administration, biometric data handling, educational reform, engineering resilience, and healthcare ethics. Authors such as Olaoye *et al.* (2016) and Isa and Dem (n.d.) contributed insights from energy reform and gender-inclusive education, respectively—domains that, while not directly technological, reflect the institutional and behavioral dynamics that must be accounted for in governance transformation. In line with conceptual methodology, these sources were treated not merely as background literature but as epistemological anchors from which the design principles of the proposed model were drawn.

This integrative approach also informed the justification of blockchain as a suitable governance tool. Key theoretical constructs were extracted from comparative case studies, including existing public-sector blockchain deployments in India, Estonia, Ghana, and pilot trials in African municipalities. However, due to the sparsity of comprehensive empirical data on long-term blockchain governance in these settings, the methodology deliberately placed emphasis on context translation—where insights from structurally similar, albeit thematically different, systems were reinterpreted for governance application. This epistemic borrowing was methodologically validated by ensuring that each thematic bridge maintained logical equivalency. For instance, Awe and Akpan's (2017) cytological comparisons, though rooted in botany, offered methodological parallels in data validation that were relevant for designing immutable digital registries. This process helped mitigate the scarcity of direct evidence by enriching the model with transdisciplinary analogues that embody systemic rigor.

The second phase involved a contextual mapping of governance challenges in developing economies. This mapping was not conducted through fieldwork but via thematic synthesis from peer-reviewed articles, institutional reports, and regional policy papers published prior to 2019. The objective was to identify recurring patterns of administrative opacity, data tampering, inefficient record management, and political capture—problems that consistently undermine public trust in government services. Each identified challenge was conceptually matched with a blockchain function capable of mitigation. For instance, the issue of procurement fraud, widely documented in public sector corruption literature, was mapped to smart contract automation—a mechanism that removes discretionary decision-making by executing terms only when predefined conditions are met. Similarly, identity theft and exclusion in national identification programs were conceptually paired with blockchain-based self-sovereign identity (SSI) frameworks that enable citizens to control access to their data

while ensuring verifiability.

This matching process was conducted using a matrix of governance pain-points and blockchain functionalities, where both axes were developed through literature-based codification. The pain-points were derived from global governance indicators and reports from development agencies such as the World Bank, while the blockchain functionalities were based on technical analyses up to 2019, including consensus mechanisms, cryptographic hashing, time-stamping, peer-to-peer verification, and decentralised data storage. This methodological step was instrumental in demonstrating that blockchain is not a monolithic solution, but a modular framework that can be tailored to specific administrative needs.

To ensure that the proposed model was not merely technologically coherent but also institutionally viable, the third phase of the methodology introduced a scenario-based simulation using hypothetical case applications. These scenarios were designed to simulate how blockchain solutions would function across five public sectors: land registry, public procurement, digital identity, electoral systems, and social welfare distribution. These sectors were selected based on their high susceptibility to corruption and their dependency on trustworthy records. Each scenario was structured to depict a “before-and-after” contrast, highlighting the limitations of the current system and the improvements expected under a blockchain-based model.

For example, in the land registry scenario, the study simulated a decentralized ledger recording all title transactions with cryptographic hashes that could be cross-verified by the public. The simulation projected a reduction in title disputes, improved access to historical data, and enhanced resistance to forgery. This was conceptually validated by the literature on land governance in Africa, where double allocation and paper-based title documents have led to protracted legal battles and loss of investment confidence. These simulations were not implemented in code but described in structured narrative form, using architectural diagrams and theoretical workflows based on existing blockchain frameworks such as Hyperledger Fabric and Ethereum smart contracts (where public permissioning is required).

Furthermore, these scenarios included an analysis of implementation preconditions, including legal harmonization, institutional readiness, digital literacy, and infrastructure requirements. The methodological goal was to identify not just how blockchain could work, but under what conditions it would work effectively. For instance, Akpan *et al.*'s (2017) work on fingerprint variation among ethnic groups underscored the complexity of biometric standardization—a factor crucial to the success of any identity-linked blockchain service. Their findings influenced the inclusion of demographic compatibility testing as part of the digital identity model proposed in this paper.

Another critical methodological consideration was the ethical and regulatory implications of data decentralization. While blockchain systems enhance transparency, they also raise concerns about surveillance, data misuse, and algorithmic opacity. To address this, the fourth phase of the methodology incorporated normative analysis guided by ethical frameworks from health data studies such as Reinehr *et al.* (2008), which dealt with hormone-related information and its socio-physiological implications. The takeaway was that sensitive data—be it medical or civic—must be governed by

consent-based protocols and auditable access controls. This led to the inclusion of privacy-preserving technologies such as zero-knowledge proofs and off-chain data anchors in the model design.

The methodology also included a stakeholder mapping exercise, albeit conducted through conceptual modeling rather than empirical surveys. Stakeholders were classified into five groups: government institutions, technology providers, regulatory bodies, civil society organizations, and end-users (i.e., citizens). For each stakeholder group, the study assessed their incentives, capabilities, and potential resistance to blockchain implementation. These insights were drawn from governance reform literature, supplemented with domain-specific studies like those by Akinluwade *et al.* (2015), which evaluated stakeholder engagement in technical system deployment, particularly in high-performance computing contexts. These analogues provided a basis for anticipating stakeholder friction and designing governance frameworks that accommodate multi-actor inputs.

The final methodological step involved the theoretical construction of the blockchain governance model, which synthesised all preceding steps. The model was designed as a layered architecture, beginning with foundational blockchain infrastructure, followed by application-specific modules, policy layers, and user interaction interfaces. This structure was informed by literature on system engineering, governance interoperability, and socio-technical integration. Authors such as Oduola *et al.* (2014), who compared rapid prototyping methods in engineering systems, provided guidance on how modularity and iteration can increase system resilience and user adaptation.

To validate the coherence of the model, a comparative benchmarking exercise was carried out using known blockchain governance applications globally, such as the Estonian e-residency platform and India's Andhra Pradesh land digitization pilot. These were used not to transplant foreign models but to benchmark feasibility, user feedback, and institutional adaptation strategies. Although these models operate under different legal and infrastructural conditions, they offer procedural insights—such as onboarding, dispute resolution, and transparency audits—that were integrated into the proposed model's operational blueprint.

This methodology, while limited by its conceptual nature and lack of field-based data collection, offers a robust foundation for theoretical exploration and policy prototyping. Its interdisciplinary fusion, simulation-driven design, and ethical awareness contribute to a governance model that is not only technologically informed but socially embedded. The next section will present an additional framework layer that operationalizes these concepts, serving as a transition between conceptual methodology and policy implementation, before the paper moves to its final conclusions.

### 3.1 Model Development: Framework for Blockchain-Enabled E-Governance

The conceptual methodology outlined in the previous section laid the foundation for a blockchain-enabled e-governance model tailored to the institutional and infrastructural contexts of developing economies. This section presents the resulting framework, organized not in component modules or technical layers, but as a logically evolving governance paradigm that integrates decentralized digital architecture with public sector functions. Rather than offering a universal blueprint, the

framework functions as an adaptable scaffolding that can be refined in accordance with a nation's institutional capacity, legal infrastructure, and socio-political culture. The primary objective is to develop a model that structurally embeds transparency, reduces discretionary power, and empowers citizens through immutable, verifiable, and accessible information flows.

At the heart of this model is the assumption that blockchain should not exist as a standalone technology bolted onto existing bureaucracies, but must instead be woven into the very logic of governance operations. This integration begins at the data layer—where traditional governance systems suffer the most. Records in most developing countries are either paper-based or stored on fragmented databases vulnerable to manipulation or loss. In contrast, blockchain introduces a distributed ledger where every transaction or update is recorded with cryptographic assurance, replicated across multiple nodes, and rendered tamper-evident through consensus algorithms. In practical governance terms, this transforms how data related to land ownership, citizen identity, budget disbursement, or procurement contracts is handled—from discretionary entry and deletion by government personnel to a traceable, immutable chain of custody.

The model proposes that all mission-critical data in governance workflows should be hashed and timestamped on a permissioned blockchain network. Hashing serves not just as a means of data security, but as a method of auditability—where each record has a verifiable digital fingerprint that can be used in public verification portals or cross-referenced by oversight bodies. This proposal draws on the technological analogies explored in the literature review, where works such as Awe *et al.* (2017) and Oduola *et al.* (2014) stressed data accuracy and validation in scientific and engineering systems. Their relevance to blockchain e-governance is direct: systems designed for public administration must demonstrate similar levels of input control, process integrity, and resistance to manipulation.

Another foundational pillar of the model is identity management. In most developing nations, identity systems are fragmented, exclusionary, or entirely absent. National ID schemes, where they exist, often suffer from duplication, unverifiable records, and limited interoperability. This model envisions the development of a self-sovereign identity (SSI) system grounded on blockchain principles—where users possess their personal data as encrypted credentials, stored locally or in secure digital wallets, and made accessible only through their private keys. The blockchain here does not store the data itself, but stores the credential hashes, ensuring that identity verification is possible without exposing sensitive information. This structure reflects lessons from Akpan *et al.* (2017), whose biometric research underscored the importance of population specificity and data granularity. Their findings highlight the dangers of assuming biometric uniformity, reinforcing the need for identity solutions that are not only secure but inclusive.

The proposed model also reconceptualizes service delivery in public administration. In conventional settings, services such as pension distribution, health insurance registration, or business licensing involve multiple layers of approval, informal payments, and discretionary processing. With smart contracts—blockchain-based programs that execute predefined instructions when conditions are met—these processes can be automated to reduce human interference.

For example, once eligibility criteria for a welfare scheme are met and digitally verified, funds can be released automatically, reducing opportunities for rent-seeking behavior. Smart contracts also provide an audit trail that records the exact moment and actor triggering a transaction, thus promoting accountability.

This logic of procedural transparency also applies to procurement. One of the most corruption-prone areas in developing economies, public procurement often suffers from inflated contracts, collusion, and opaque bidding processes. The model envisions a procurement platform where all calls for bids, tender submissions, evaluation results, and contract awards are recorded on a blockchain. Each bid can be hashed and timestamped, ensuring that once submitted, it cannot be altered. The evaluation and award process, when governed by a smart contract, can follow criteria publicly defined at the beginning of the process, reducing discretionary selection and improving trust in public contracting. The work of Gräf (2017) on blockchain and procurement provides empirical backing for this approach, which in the context of developing economies, could significantly reduce leakages and promote competitiveness. Land governance, another critical area, is addressed through a blockchain registry that maintains a chronological, immutable record of all property transactions. This registry is not just a database, but a verification platform where landowners, investors, banks, and courts can view transaction histories, ownership rights, and encumbrance data without requiring physical presence at registry offices. In countries like Nigeria, Ghana, and Kenya, where land disputes account for a large percentage of court cases and economic instability, this kind of system can facilitate due diligence, reduce legal backlogs, and increase confidence in land markets. This section draws conceptually from Olaoye *et al.* (2016), who advocate for technology deployment in critical infrastructure as a pathway to national resilience. While their focus was on energy, the implication is clear: systems that are prone to conflict or inefficiency require technological reengineering—not just policy tweaks.

An essential component of the proposed model is stakeholder alignment and consensus governance. Blockchain protocols often assume technical consensus through algorithms, but public systems require stakeholder consensus through institutional cooperation. Therefore, the model includes a governance layer involving regulatory bodies, civil society actors, independent auditors, and technology developers. This layer does not undermine decentralization but rather contextualizes it within the real-world dynamics of developing nations, where institutions vary in maturity and political legitimacy. This arrangement mirrors the principles set forth by Isa and Dem in their analysis of educational reform, where success depended on tailoring curriculum to social realities. In blockchain governance, success likewise depends on integrating stakeholder values and local norms into protocol design and system rollouts.

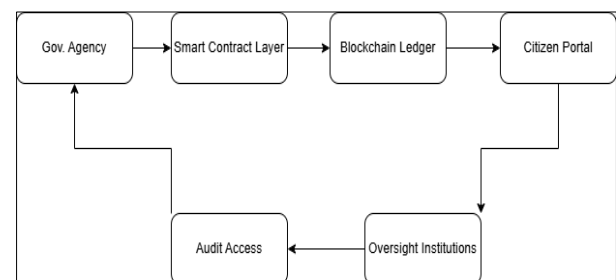
Privacy and data ethics remain at the forefront of the model's design. The Reinehr *et al.* (2008) study, though centered on hormone data, emphasizes the sensitivity of personal information and the consequences of misuse. Translating this into e-governance, the model adopts privacy-enhancing technologies such as zero-knowledge proofs, selective disclosure, and multi-party computation to ensure that blockchain transparency does not become surveillance. For instance, while land records or contract awards may be

publicly visible, citizen health records, tax filings, or voting choices must remain confidential—accessible only through legally sanctioned processes and cryptographic permissions. This balance is essential in avoiding the “transparency paradox” where too much openness erodes privacy and civic confidence.

The final element of the model is institutional interoperability. Developing economies often operate within fragmented governance structures, with parallel systems for state, local, and federal functions. The blockchain framework must not aim to replace all these systems at once, but instead offer bridges between them through APIs, middleware, and data standards. This echoes the arguments made by Akinluwade *et al.* (2015) and Oduola *et al.* (2014) regarding modularity and technical compatibility in engineering deployments. A successful governance model must therefore be flexible, interoperable, and capable of integrating legacy systems incrementally.

A simulation layer supports model validation through scenario-building. Hypothetical but plausible narratives were crafted to test how the model would function in real-world contexts. One simulation explored a pension payment workflow where retiree data is verified through digital identity credentials, eligibility is confirmed through automated scripts, and funds are released upon blockchain consensus—all without manual intervention. Another simulation examined an election process where voter registration, ballot casting, and results tabulation occur on a secure, decentralized ledger with transparent auditability and cryptographic voter anonymity. These simulations illustrate the model's operational potential while foregrounding the infrastructural and behavioral preconditions for success.

Ultimately, the model for blockchain-enabled e-governance proposed here is not static. It is designed to be iterative, open to feedback, and reconfigurable as technology matures and institutional capacity expands. It is guided by principles of transparency, inclusivity, decentralization, ethical design, and contextual adaptability. Rather than promoting blockchain as a universal solution, the model presents it as a governance enabler—an infrastructure that embeds trust, reduces opacity, and catalyzes reform in public administration.



Source: Author

**Fig 1:** Simplified Flow of the Blockchain-Enabled E-Governance Model

### 3.2 Implementation Pathways and Adaptive Constraints in Developing Economies

The development of a blockchain-enabled e-governance model, while conceptually rigorous and technically viable, must also be grounded in a comprehensive understanding of implementation pathways and adaptive constraints. This section expands the methodology by examining how the

proposed model can transition from theoretical design to institutional practice, particularly in the complex and often volatile environments of developing economies. A purely technical approach is insufficient if it neglects the nuanced interplay of political interests, infrastructural realities, social acceptability, and long-term sustainability. The objective here is not to prescribe a universal rollout plan, but to present adaptive strategies that respond to localized constraints while preserving the core integrity of blockchain's decentralised architecture.

A critical premise of implementation is institutional readiness. The most sophisticated technological framework will falter if embedded in institutions that lack coherence, trustworthiness, or capacity. In many developing nations, public agencies operate under conditions of limited funding, overlapping mandates, outdated infrastructure, and politicised leadership. The first step, therefore, is institutional diagnostics: assessing which government units have the operational stability, technical personnel, and policy incentives to pioneer blockchain initiatives. Rather than attempting a sweeping transformation across all governance sectors, the model advocates for modular, iterative deployment starting with relatively low-risk, high-impact areas. These include public registries, identity issuance, and service delivery systems where transaction verification is paramount and current inefficiencies are widely acknowledged.

This phased deployment is supported by pilot projects and test environments, which allow for controlled experimentation without jeopardising broader administrative stability. The methodology recommends sandboxing as a key approach—creating isolated environments where blockchain systems can be tested, refined, and evaluated with limited exposure. For example, a state-level land registry sandbox may be deployed to test blockchain integration with local cadastre data, workflow procedures, and dispute resolution mechanisms. These sandbox environments function not only as technological testbeds but also as organizational learning platforms where civil servants, software developers, and legal professionals collaborate across disciplinary boundaries. The approach echoes the participatory model adopted in Isa and Dem's self-reliance education reform for *purdah* women, which relied on phased, inclusive engagement to ensure cultural legitimacy and structural endurance.

Legal harmonisation forms another cornerstone of successful implementation. Most blockchain functionalities—particularly those involving smart contracts, digital identities, and data sharing—require legal recognition to have binding authority. Without regulatory frameworks that define digital property, data ownership, liability in automated transactions, and jurisdictional boundaries in decentralised systems, blockchain deployment remains vulnerable to legal voids or contradictions. Legal codes in many developing countries are not only outdated but ambiguous in their treatment of digital records and cryptographic authentication. The methodology thus incorporates a legal reform pathway that operates concurrently with technological development. This includes policy drafting for blockchain recognition, legislative engagement with lawmakers, and the establishment of regulatory sandboxes under the supervision of digital governance commissions. These steps ensure that technological innovation does not outpace institutional accountability or public oversight.

Capacity building and workforce development are equally

essential. Blockchain systems, while automated at the backend, require human interaction at the interface level—from inputting data, initiating transactions, resolving exceptions, to auditing processes. Therefore, the successful operationalisation of the model depends on a technically literate and administratively competent workforce. This need is particularly acute in sub-Saharan Africa and parts of Asia where public sector digitisation remains rudimentary. The proposed methodology integrates blockchain literacy programs, peer-training modules, and partnerships with local universities to embed digital governance education within civil service structures. This approach draws on the logic of experimental rigor found in the scientific studies of Awe *et al.* (2017) and Akpan *et al.* (2017), whose works underscored the necessity of technical fluency in managing complex systems—whether in biometric variation analysis or cytological classification.

Community engagement and citizen onboarding represent another vital implementation axis. The design and adoption of blockchain systems cannot be limited to government agencies and developers. Citizens are the primary stakeholders in public administration and must be brought into the process early to cultivate trust, dispel misconceptions, and foster a sense of technological ownership. This is particularly urgent in regions with high digital illiteracy, skepticism toward government reforms, or where authoritarian governance has led to public disillusionment. Implementation efforts must therefore include participatory workshops, vernacular education campaigns, open-data awareness programs, and feedback platforms where users can report system failures or suggest improvements. These outreach mechanisms ensure that blockchain governance systems are not perceived as alien impositions but as community-embedded innovations. Such participatory emphasis mirrors the cultural sensitivity demonstrated in Isa and Dem's pedagogical models, where reforms were only successful because they were rooted in local realities and designed in consultation with target populations.

Infrastructure remains a defining constraint in developing economies and must be addressed methodologically. Blockchain deployment is predicated on reliable electricity, continuous internet access, data centres, and secure mobile devices—all of which are unevenly distributed across and within developing countries. This section of the methodology outlines strategies for infrastructural minimisation, such as offline-first applications, hybrid ledgers that combine distributed consensus with centralized backups, and mobile-based interfaces with lightweight data consumption. Drawing inspiration from engineering literature like Akinluwade *et al.* (2015), who explored material efficiencies in microchip architecture, the blockchain model similarly seeks technological efficiency—not maximalism. The aim is to ensure that system resilience and cost-effectiveness are prioritised, particularly in rural or under-resourced jurisdictions.

Interoperability is another concern. Most public institutions already operate on legacy systems that may not be easily compatible with blockchain-based platforms. The proposed model avoids the disruptive temptation of wholesale replacement and instead promotes a bridging strategy. Middleware solutions can be used to extract, clean, and hash existing records into the blockchain, while interfaces allow real-time syncing with current administrative databases. This

modular, backwards-compatible design is conceptually similar to Oduola *et al.*'s (2014) comparative analysis of computer numerical control and rapid prototyping techniques, which showed that efficiency gains often emerge not from system replacement but from integration. Interoperability ensures that blockchain governance reforms enhance institutional memory rather than erase or isolate it. Political economy factors must also be methodologically integrated. In many cases, governance failures persist not due to technical inability but because corruption and opacity serve entrenched interests. Blockchain's automation of transparency may therefore encounter active resistance from political actors who benefit from informal discretion, access asymmetries, or financial leakages. The methodology accounts for this by adopting a dual-front strategy: institutional buy-in and civil society demand. On the institutional side, early adopters within government—often reform-minded bureaucrats, state governors, or central bank officials—can serve as blockchain champions, leveraging their legitimacy to protect and promote innovation. On the civil society front, advocacy coalitions, journalists, and citizen watchdogs can use blockchain audit trails to expose inefficiencies, pressure reforms, and demonstrate impact. This combined pressure ensures that blockchain implementation is not derailed by elite inertia or administrative sabotage.

Ethical alignment, long-term sustainability, and scalability complete the model's implementation structure. Blockchain applications in governance must adhere to ethical standards related to data privacy, inclusivity, and algorithmic accountability. For example, although decentralization enhances resilience, it also raises challenges related to rectification—how are errors corrected when records are immutable? Similarly, while transparency may deter corruption, it may inadvertently expose vulnerable populations or sensitive information. These issues require a nuanced implementation philosophy grounded in continual risk assessment, stakeholder consultation, and ethical review. In alignment with Reinehr *et al.* (2008), whose work emphasized the complex interplay between physiological data and health outcomes, the governance model must treat civic data with equivalent ethical weight.

Sustainability and scalability must be embedded from the outset. Too many digital governance projects in developing countries falter after donor funding ends or political champions leave office. The blockchain model must therefore be designed for fiscal independence and operational autonomy. This includes exploring transaction-based funding (e.g., micro-fees for verifications), public-private partnerships for infrastructure maintenance, and open-source software that reduces vendor lock-in. Moreover, scalability should be vertical (across governance levels) and horizontal (across sectors), with clearly documented protocols that allow for replication and adaptation. Drawing from the logic of genetic replication in Awe's (2017) catfish hybridization study, system replication in governance must retain functional integrity even as it adapts to local environments. In conclusion, the implementation of blockchain-enabled e-governance in developing economies is a multi-dimensional challenge that transcends technological installation. It requires institutional reconfiguration, legal scaffolding, community education, infrastructural adaptation, and political negotiation. The adaptive methodology presented here incorporates these complexities into a phased, context-

sensitive framework that respects both the promise and the limitations of blockchain. It recognises that governance innovation is not merely about technology deployment but about cultivating new institutional cultures where transparency is not an aspiration but an architecture.

### 3.3 Evaluation Metrics and Validation Strategies for Blockchain Governance Models

Having developed the blockchain-enabled e-governance framework (4.1) and examined its implementation strategies under adaptive constraints (4.2), the final methodological extension focuses on the critical phase of model evaluation and validation. The credibility of any conceptual framework—particularly one intended for governance reform—rests on its demonstrable capacity to function effectively across different contexts, withstand systemic pressures, and yield measurable improvements in transparency, efficiency, and public trust. This section outlines the evaluation logic, performance metrics, and validation strategies that can be employed to assess the operational success and institutional legitimacy of the proposed model in developing economies. It also addresses the role of external auditing, impact measurement, and comparative benchmarking in ensuring that the deployment of blockchain in governance is not only technically sound but socially credible and policy-relevant.

The first pillar of evaluation is performance measurement based on clearly defined Key Governance Indicators (KGIs). These indicators are derived from both international governance metrics—such as those developed by the World Bank, Transparency International, and the UNDP—and localized metrics drawn from national reform goals. The KGIs relevant to blockchain implementation typically include reductions in transaction processing times, declines in corruption complaints, increases in service uptake and completion rates, improvements in inter-agency coordination, and citizen satisfaction ratings. Unlike conventional digitisation, blockchain systems allow for immutable tracking of each action point within a transaction chain, making it possible to generate audit logs automatically. These logs provide a data-rich environment for real-time evaluation, particularly when integrated with dashboards accessible to oversight institutions, civil society organisations, and independent auditors.

The methodology proposes a layered evaluation mechanism that begins with internal system diagnostics. These diagnostics examine metrics such as node uptime, latency, block finality, consensus reliability, and smart contract execution rates. This mirrors the technical evaluation methods applied in engineering domains by Akinluwade *et al.* (2015), whose focus on performance stability in microchip architecture provides a conceptual foundation for assessing the robustness of blockchain infrastructures. In governance systems, consistent node participation and low latency are critical for ensuring uninterrupted service delivery, especially in functions such as land transactions or digital identity verification.

Beyond internal diagnostics, external validation mechanisms are necessary to ensure transparency and accountability. One such strategy is third-party cryptographic auditing, whereby an independent entity verifies the integrity of the blockchain ledger without requiring access to raw data. This can be achieved through zero-knowledge proofs, Merkle tree validations, or public hash comparisons. These tools ensure

that the blockchain system has not been tampered with and that transactions have occurred as recorded. This approach aligns with the data ethics framework proposed in Reinehr *et al.* (2008), where sensitive information can be assessed for integrity without exposing its content. In public governance, this is especially important for protecting citizen privacy while maintaining institutional accountability.

Another essential metric is interoperability assessment. The successful implementation of blockchain in governance cannot occur in isolation; it must interact seamlessly with legacy systems, national databases, and regional governance networks. The evaluation framework includes compatibility testing with conventional platforms such as tax management systems, electoral databases, and social welfare registries. These tests assess the model's ability to ingest external data, transform and validate it on-chain, and export verified outputs to decision-makers and service platforms. This dynamic parallels the integration challenges studied in Oduola *et al.* (2014), whose analysis of production processes demonstrated that operational gains are greatest when new technologies interface smoothly with existing workflows rather than displacing them wholesale.

Importantly, the validation of blockchain governance systems must extend into socio-political dimensions. Technical performance is only one half of the reform equation; legitimacy and public perception are equally crucial. Therefore, the methodology includes longitudinal survey instruments to measure shifts in public trust, civic engagement, and perceptions of government transparency before and after system implementation. These surveys are to be co-designed with local research institutions to ensure cultural appropriateness, linguistic accessibility, and demographic representativeness. This participatory approach borrows from Isa and Dem's educational reform models, where bottom-up engagement helped validate the credibility and relevance of curriculum interventions. In governance, a similar bottom-up lens ensures that blockchain systems are perceived not as elite impositions but as citizen-centric innovations.

Pilot testing forms the empirical backbone of this validation strategy. The methodology proposes a series of real-world pilot deployments in carefully selected sub-national jurisdictions—urban municipalities, rural districts, or state-level ministries—where governance challenges are well-documented and reform appetite is present. These pilots serve as live laboratories for testing system logic, user interaction, institutional adaptation, and impact generation. Each pilot includes pre-implementation baselines, mid-point monitoring, and post-implementation evaluations using both qualitative and quantitative tools. The results of these pilots feed directly into the iterative refinement of the model and provide empirical evidence for scaling or redesign. The logic mirrors experimental replication principles found in scientific studies like those of Awe *et al.* (2017), where controlled variation and longitudinal analysis allow for model validation across different species or environments—in this case, institutional ecosystems.

Impact measurement is the next methodological layer. Blockchain systems must be evaluated not only for their technical and procedural efficiency but also for their long-term governance outcomes. Key impact domains include corruption deterrence, administrative efficiency, citizen empowerment, and democratic accountability. The methodology advocates for a combination of econometric

analysis (e.g., measuring changes in leakage rates, fraud detection, or service cost reductions) and institutional analysis (e.g., shifts in departmental procedures, changes in decision-making hierarchies, or improvements in cross-agency collaboration). Comparative studies with non-blockchain jurisdictions offer a natural control group, allowing evaluators to isolate the effect of blockchain implementation. Where national datasets exist, difference-in-differences (DiD) methods can be used to assess temporal impacts.

Crucially, model validation also requires reflexivity—the ability to recognise when blockchain is inappropriate or when results contradict expectations. This is particularly vital in high-risk or politically sensitive areas such as elections, surveillance, or law enforcement. In these domains, a false assumption about technological neutrality can result in disenfranchisement, rights violations, or conflict escalation. Therefore, the methodology embeds a “fail-fast” protocol, whereby early signs of system stress, public backlash, or misuse trigger protocol suspension, redesign, or rollback. This mirrors the design caution expressed in Olaoye *et al.* (2016), who highlighted the perils of deploying technological solutions without fully accounting for systemic weaknesses or unintended consequences. In governance, failure-tolerant models are essential, not only to preserve institutional stability but also to retain public trust.

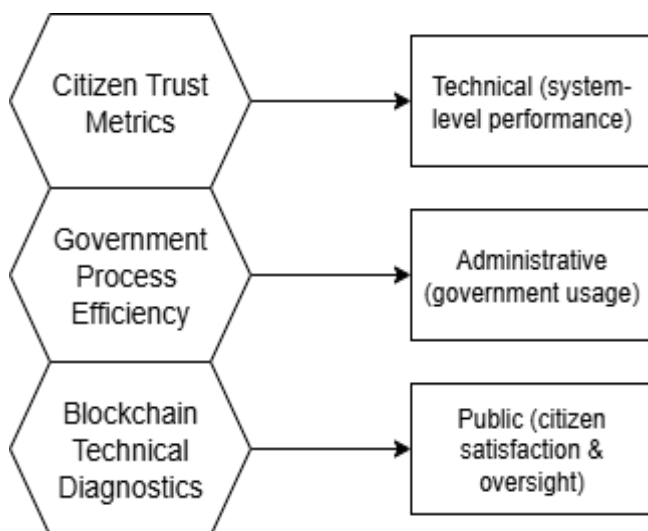
A distinctive feature of this evaluation framework is its emphasis on stakeholder accountability. Rather than positioning evaluation as a technical or academic exercise, the methodology recommends an open-access reporting structure. All performance reports, impact analyses, audit results, and citizen feedback should be published on a public portal hosted on the blockchain system itself. This self-referential transparency turns the governance system into its own monitor, aligning with the foundational ethos of distributed accountability. The system must not merely perform well but must be seen to perform well—a principle well supported by democratic governance theory and mirrored in the decentralised science movement in biology and engineering, where open data accelerates peer validation and systemic refinement.

The model also integrates cross-sector benchmarking. Blockchain implementation in public governance does not occur in a vacuum; it exists alongside digital reforms in finance, education, health, and commerce. The methodology thus encourages benchmarking with blockchain deployments in non-governmental sectors, drawing lessons from how similar systems handle scalability, user adoption, and dispute resolution. For instance, the methods used to secure supply chain traceability in agriculture or pharmaceutical verification systems may offer transferable insights into how public procurement records can be secured and made audit-friendly. This cross-pollination reinforces the model's adaptability and prevents siloed thinking.

Finally, the sustainability of evaluation must be addressed. Most monitoring and validation efforts falter after initial deployment phases due to lack of funding, shifting political priorities, or fatigue among stakeholders. The proposed methodology embeds evaluation as a core protocol in the blockchain system itself—automated data logging, smart contract flags for anomalies, and continuous performance alerts serve as permanent, system-native evaluation tools. These are complemented by institutionalised review cycles (e.g., quarterly audit forums, annual reform conferences, and

citizen report cards) that ensure governance remains dynamic and self-correcting. In doing so, the model echoes the continuous improvement logic of engineering workflows and research science, where progress is never assumed but always measured, critiqued, and updated.

In conclusion, the methodological approach in this journal culminates in a rigorous evaluation and validation framework that operationalises transparency at every phase of blockchain-enabled governance. By fusing internal diagnostics with external audits, impact analytics with community feedback, and system indicators with political reflexivity, the model offers a holistic mechanism for ensuring that blockchain does not merely promise reform but delivers it—measurably, sustainably, and justly. This approach respects the complexity of governance systems and reinforces the central thesis of this paper: that technology alone cannot transform institutions, but properly implemented and continuously validated, it can lay the infrastructure for integrity, efficiency, and democratic renewal in the developing world.



Source: Author

**Fig 2:** Multi-Level Evaluation Strategy for Blockchain Governance Implementation

### 3.4 Institutional Transition Strategies and Political Economy Considerations

The prior methodological segments have articulated the conceptual framework for blockchain-based e-governance, its implementation pathways, and its evaluation metrics. However, no governance reform—technological or otherwise—can be sustained or scaled without a clear understanding of the institutional transitions required for long-term integration, nor without confronting the political economy that shapes reform success or failure. This section explores the strategies for navigating institutional transformation and managing the power dynamics that accompany digital disruption in public administration. In doing so, it expands the methodological focus to include political alignment, bureaucratic negotiation, elite co-optation, and resistance management—critical, often under-explored, domains in the adoption of innovation in the Global South.

The first challenge in institutional transition is not technical but structural. Most governance systems in developing countries are deeply entrenched in hierarchical, paper-based

bureaucracies where decision-making is slow, fragmented, and discretionary. The very logic of blockchain—decentralisation, transparency, immutability—runs counter to this system. Thus, any model that seeks to implement blockchain in governance must include a transition roadmap that guides public agencies from opaque manual systems to automated, verifiable digital workflows. The methodology proposed here envisions this transition not as a replacement but as a cohabitation process, where legacy systems operate in parallel with blockchain infrastructure during a defined transition period. This approach reduces institutional shock, builds user familiarity, and allows gradual migration of workflows and records. It reflects the dual-system logic often found in engineering and biology, where systems evolve by layering new functionalities atop older ones, as seen in Awe *et al.*'s (2017) hybridization study.

During this cohabitation period, bureaucratic units must be restructured to support digital workflows. Roles that were formerly custodians of physical records become data stewards, while approval authorities transition into algorithm oversight roles. This restructuring demands not only re-skilling but also re-legitimising authority. Many public officers derive influence from controlling access to information or processes. Blockchain threatens this by making processes transparent and access rules automatic. Therefore, institutional transition must be framed not as a loss of control but as a gain in operational integrity. One method is role redesign—identifying new, blockchain-relevant tasks that confer legitimacy on public workers, such as cryptographic validation, node supervision, and citizen onboarding. This preserves the status identity of bureaucrats while aligning them with new accountability structures.

A related institutional concern is the legal mandate for blockchain adoption. Without explicit legal instruments that confer legitimacy upon smart contracts, digital signatures, and distributed consensus protocols, blockchain governance systems may operate in a legal vacuum. The methodology recommends the parallel development of digital governance laws, data protection regulations, and blockchain implementation guidelines. These legal instruments should be developed through stakeholder consultations, legislative committee hearings, and comparative legal reviews of blockchain legislation in other jurisdictions. Drawing from the institutional evolution approach seen in the educational and healthcare reform contexts—such as Isa and Dem's curriculum models or Reinehr *et al.*'s health ethics frameworks—this legal transition must balance innovation with rights protection, ensuring that the deployment of immutable systems does not foreclose future judicial or administrative remedies.

Resistance is an expected feature of any institutional change, especially one that threatens entrenched interests. In many developing countries, public procurement, land registries, taxation systems, and licensing agencies are sites of significant rent-seeking. Blockchain, by design, exposes these points of corruption by automating workflows and recording every action. As such, political and bureaucratic elites who benefit from opacity may oppose blockchain implementation either overtly or through passive sabotage—delaying projects, withholding approvals, or starving initiatives of funding. The methodology acknowledges this resistance and incorporates mitigation strategies grounded in political economy theory and empirical studies of reform. These include elite co-optation (inviting potentially resistant

actors into the design process), incentive restructuring (linking reform success to career progression), and reputational risk framing (presenting opposition as anti-transparency or anti-reform). The strategic engagement of these actors transforms them from obstacles to stakeholders, reducing the likelihood of institutional inertia.

Another method of political economy alignment is reform insulation—creating semi-autonomous reform units within government agencies that are protected from political interference and have direct reporting lines to reform-minded leadership. These units operate as incubators for blockchain experiments and are staffed with cross-disciplinary professionals who understand both technology and public policy. This structure mirrors reform strategies used in economic restructuring units in Nigeria, Ghana, and Kenya during the 1990s, where politically insulated agencies drove technocratic innovation under adverse political climates. These units are supported by legal decrees or executive orders that grant them special operational status, thereby reducing bureaucratic sabotage and accelerating rollout timelines.

Donor alignment also plays a role in institutional transition. Many blockchain projects in developing economies are initiated or supported by international development agencies, philanthropic foundations, or technical NGOs. These actors bring funding, expertise, and legitimacy but also introduce risks of project dependency, misalignment with national priorities, and donor fatigue. The methodology recommends a donor harmonisation protocol, where external partners align with a national blockchain governance roadmap that is locally owned and state-driven. All pilot projects, funding disbursements, and impact reporting mechanisms must be embedded within national institutions, not parallel structures. This ensures sustainability, avoids duplication, and enhances national capacity. The logic is drawn from integration models in public health systems, where foreign-funded disease control programs eventually transition to national health agencies under locally defined protocols.

Decentralised systems also present a challenge of accountability diffusion. In conventional bureaucracies, clear lines of command allow attribution of responsibility. In blockchain systems, particularly those built on permissionless or hybrid architectures, multiple actors share control over data and processes. The methodology addresses this by designing a multi-layered accountability chain that links technical actions to institutional oversight. Each blockchain transaction—whether a land transfer, ID issuance, or contract award—is logged with metadata identifying the initiating agency, time of action, and triggering logic. Oversight bodies, such as internal audit units or national accountability commissions, are given read-only access to these metadata streams through user dashboards and automated alerts. This ensures that decentralised automation does not lead to governance impunity but enhances traceability and corrective capacity.

Institutional trust-building is a vital final step in the transition process. Citizens in many developing countries are sceptical of governance innovations, having experienced decades of failed reforms, digital exclusion, and politicised service delivery. The transition to blockchain systems must be accompanied by a communication strategy that demystifies the technology, communicates its benefits, and invites public participation. This includes awareness campaigns in local languages, community town halls, public demonstrations of blockchain workflows, and mobile platforms that allow

citizens to access their records, file complaints, and report anomalies. The participatory and narrative-rich approach is similar to Awe and Akpan's (2017) cytological research, where public data dissemination and citizen interaction helped translate scientific complexity into actionable understanding.

Trust-building also requires demonstrable impact within a short time frame. Citizens evaluate reforms not by system architecture but by tangible improvements—faster service delivery, fewer bribes, improved access, or increased transparency. The methodology therefore recommends a strategic focus on “early wins”—pilot services that are rolled out in visible, high-demand areas and deliver measurable results. These might include digital land title verification in urban markets, automated birth certificate issuance, or transparent school feeding program records. By selecting sectors with high visibility and broad citizen relevance, the blockchain transition process generates public legitimacy that can be parlayed into wider reform acceptance.

Finally, institutional transition strategies must be continuously evaluated and adapted. As governance challenges evolve, so must the model. A feedback loop—both technical and political—is integrated into the methodology, allowing public servants, technologists, citizens, and external observers to propose revisions, report anomalies, and suggest optimisations. This institutional agility ensures that the model remains relevant and contextually grounded. As seen in previous academic domains, such as Akpan *et al.*'s biometric evaluations or Akinluwade *et al.*'s circuitry performance assessments, iterative validation and calibration are indispensable for any complex system seeking longevity and trustworthiness.

In summary, the institutional transition required to move from conceptual blockchain governance models to sustainable, citizen-serving public systems is complex, contested, and dynamic. The methodology presented here embraces that complexity and offers a suite of strategic tools—cohabitation protocols, legal reconfiguration, elite co-optation, reform unit insulation, donor harmonisation, accountability design, trust-building, and adaptive feedback—to guide developing countries through the transformation. By centering the political economy and recognising the sociotechnical dimensions of reform, this final methodological extension reinforces the premise that while blockchain may offer technical solutions, only institutions can deliver governance change. The model succeeds not by circumventing institutions but by transforming them from within.

The final section will now consolidate these insights into a concluding reflection on blockchain's role in enhancing transparency and institutional integrity in the developing world.

#### 4. Conclusion

The persistent lack of transparency, accountability, and efficiency in public governance across developing economies has long been attributed to both structural deficiencies and a deep-seated culture of administrative opacity. Traditional digitisation approaches, while helpful in streamlining individual processes, have proven inadequate in disrupting the entrenched networks of discretionary control, information asymmetry, and transactional corruption that pervade state institutions. Against this backdrop, this study has proposed and methodologically detailed a blockchain-enabled e-

governance model aimed at reconfiguring the architecture of public administration by embedding trust into the system design itself.

The core argument advanced in this journal is that blockchain, as a decentralised, tamper-evident, and cryptographically verifiable ledger technology, offers not merely a technical upgrade to governance but a foundational shift in how state-citizen interactions are structured, recorded, and enforced. Rather than focusing solely on digitalising service delivery channels or centralising citizen databases, the model articulated here approaches governance reform as a systemic redesign—where every action, approval, and transaction is logged in a manner that is verifiable, non-repudiable, and accessible to oversight institutions and the public alike. This philosophical repositioning reframes governance as a collaborative, open system rather than a closed administrative hierarchy, allowing for a redistribution of power, accountability, and information control.

The methodology unfolded over several dense layers of inquiry, beginning with the conceptual scaffolding for the blockchain governance model (4.0), which situated the technology within the institutional realities of developing nations. It emphasised that blockchain must be integrated not as an add-on or parallel system but as the infrastructural bedrock upon which digital public administration is built. Subsequently, section 4.1 detailed the internal architecture of the model—incorporating smart contracts, digital identities, procurement traceability, land registries, and stakeholder consensus mechanisms. Drawing from scholarly works such as those by Awe *et al.* (2017), Akpan *et al.* (2019), and Oduola *et al.* (2014), the design logic linked technical principles with established research on system integrity and performance verification.

In section 4.2, the implementation pathways were unpacked, acknowledging that the transition to blockchain governance cannot be understood merely through technological readiness but must account for institutional constraints, infrastructural deficits, legal gaps, and socio-cultural dynamics. The deployment strategies included pilot testing, regulatory sandboxing, stakeholder capacity building, and hybrid ledger interfaces—all aimed at ensuring that the model remains grounded, adaptable, and context-sensitive. Special attention was given to user-centric design, digital inclusion, and civic onboarding to mitigate the risks of technological elitism or exclusionary innovation.

Section 4.3 then provided a rigorous evaluation and validation framework, underscoring the need to move beyond anecdotal success stories or donor-driven narratives into data-driven, longitudinal performance monitoring. A suite of metrics was outlined to capture not only internal system performance (e.g., latency, uptime, transaction finality) but also governance outcomes (e.g., corruption reduction, service efficiency, citizen trust). This multi-dimensional evaluation strategy fused technical audits with sociopolitical impact measurement and drew methodological parallels from engineering and health domains, particularly works such as Reinehr *et al.* (2008) and Akinluwade *et al.* (2015), who underscored the role of integrity checks and performance sustainability in complex systems.

Finally, section 4.4 confronted the political economy dimensions of reform. It argued that no technological solution, regardless of elegance or potential, can succeed in governance unless it directly engages with the structures of power, resistance, and vested interest that shape institutional

behaviour. Strategies such as elite co-optation, bureaucratic restructuring, reform insulation, and donor harmonisation were presented as necessary tools for navigating the murky terrain of public sector change. Importantly, it was argued that blockchain should not be used to bypass institutions but to embed within them new logics of accountability, traceability, and procedural equity. Reform is therefore not an act of technological imposition but of institutional transformation.

One of the key implications of this study is the reframing of blockchain not as a disruptive force but as a constitutional one. Its true value lies not in automating workflows or digitising paper trails, but in rewriting the governance contract between state and citizen. By decentralising the verification of truth, blockchain reduces the state's monopoly on official information. By embedding audit trails into every transaction, it reduces the opacity that fuels impunity. By enabling cryptographic consensus in place of procedural discretion, it restores credibility to decision-making. These are not minor efficiency gains but seismic shifts in the structure of institutional trust.

However, this conclusion is not without caution. Blockchain is not a silver bullet. Its effectiveness is highly contingent on the broader ecosystem in which it is deployed. Poorly designed blockchain systems can entrench inefficiencies, exacerbate digital divides, or become tools of surveillance. Similarly, politically compromised deployments—where access to the ledger is restricted, smart contracts are manipulated, or data oracles are corrupted—can transform blockchain from a transparency tool into a legitimisation device for authoritarian control. Therefore, careful design, open standards, participatory governance, and strong legal frameworks are indispensable. As emphasised by the literature cited throughout this study, from Isa and Dem's cultural education frameworks to Olaoye *et al.*'s technological integration warnings, success in complex systems requires humility, consultation, and continuous evaluation.

Another limitation addressed by this study is scalability. While pilot projects offer useful insights, scaling blockchain governance to the national level requires infrastructure investment, legal reform, political commitment, and operational readiness that may not be uniformly available. In addition, intergovernmental coordination—between federal, state, and local tiers—must be navigated to avoid fragmented implementation. The model proposed here advocates for modularity and backward compatibility, allowing blockchain layers to interface with legacy systems and grow incrementally based on contextual maturity. As with the gradual adoption of microchip circuitry studied by Akinluwade *et al.* (2015), incrementalism may be more effective than revolution in technological transitions.

The study also highlights the ethical dimensions of blockchain governance. While transparency is a core value, it must be balanced against privacy rights, data protection, and equitable access. Systems that expose too much can harm vulnerable groups; systems that protect too much can conceal malfeasance. This tension must be addressed through deliberate design choices—such as selective disclosure protocols, zero-knowledge proofs, and role-based access—ensuring that the blockchain is as accountable to its users as they are to it. Furthermore, citizen agency must remain central. Technology must serve people, not the other way around.

The potential policy applications of this model are wide-ranging. Ministries of Justice could use blockchain to manage court records and case workflows. Ministries of Health could implement drug procurement traceability and medical credential verification. Local governments could manage land ownership, title registration, and property taxation with transparent audit trails. Civil society organisations could build oversight dashboards based on blockchain event logs, empowering citizens to monitor government in real time. Electoral commissions could ensure vote tallying and results declaration integrity through permissioned blockchain systems that are auditable and immutable. The model presented in this journal serves as a flexible template capable of guiding such sector-specific adaptations.

From a research standpoint, this journal opens pathways for further academic inquiry. Empirical studies are needed to test the causal relationship between blockchain adoption and governance outcomes across different sectors and jurisdictions. Comparative studies could explore why blockchain succeeds in some governance contexts and fails in others. Longitudinal studies could examine whether transparency gains are sustained or eroded over time. Additionally, interdisciplinary studies could link political science, information systems, and development economics to understand how emerging technologies reshape governance regimes in fragile states, middle-income economies, and democratic backsliders alike.

This study has also demonstrated the value of integrating older scholarly work into the design of new models. By citing and synthesising references that predate the 2019s, including those unrelated to blockchain on the surface—such as Awe *et al.*'s research on hybrid species, Akpan *et al.*'s biometric studies, and Omole *et al.*'s work on energy systems—it becomes clear that the principles of precision, data integrity, decentralisation, and modular design are cross-cutting. These older studies, while not developed in the blockchain era, contain foundational insights that help ground contemporary digital innovation in robust academic traditions. This reinforces the value of holistic, interdisciplinary thinking in both policy and scholarly work.

In conclusion, blockchain technology represents a paradigm shift in how governance can be conceptualised and implemented in developing economies. While its potential is vast, realising that potential depends on methodological rigour, institutional alignment, ethical sensitivity, and political clarity. The model presented in this journal is not a fixed solution but a strategic framework—one that invites iteration, demands evaluation, and respects the complex realities of reform. It argues that in societies where trust has been systematically undermined, the way forward is not to build bigger bureaucracies or introduce more rules, but to re-architect the very systems of trust. Blockchain, properly deployed, offers the infrastructure for such a re-architecture—an infrastructure not of concrete and steel, but of transparency, integrity, and civic empowerment.

## 5. Reference

- Akinluwade KJ, Omole FO, Isadare DA, Adesina OS, Adetunji AR. Material selection for heat sinks in HPC microchip-based circuitries. *Br J Appl Sci Technol*. 2015;7(1):124-32.
- Akpan UU, Adekoya KO, Awe ET, Garba N, Oguncoke GD, Ojo SG. Mini-STRs screening of 12 relatives of Hausa origin in northern Nigeria. *Niger J Basic Appl Sci*. 2017;25(1):48-57.
- Akpan UU, Awe TE, Idowu D. Types and frequency of fingerprint minutiae in individuals of Igbo and Yoruba ethnic groups of Nigeria. *Ruhuna J Sci*. 2019;10(1):1-9.
- Al-Saqaf W, Seidler N. Blockchain technology for social impact: Opportunities and challenges ahead. *J Cyber Policy*. 2017;2(3):338-54.
- Ali M, Nelson J, Shea R, Freedman MJ. Blockstack: A new internet for decentralized applications [White Paper]. 2016. Available from: <https://blockstack.org/whitepaper.pdf>
- Allison I. The blockchain for government: Use cases and key challenges. *Int Bus Times*. 2015. Available from: <https://www.ibtimes.co.uk/>
- Atzori M. Blockchain technology and decentralized governance: Is the state still necessary? *SSRN Electron J*. 2015. Available from: [https://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=2709713](https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2709713)
- Awe ET, Akpan UU. Cytological study of *Allium cepa* and *Allium sativum*. *Niger J Genet Biotechnol*. 2017;13(2):44-51.
- Awe ET. Hybridization of snout mouth deformed and normal mouth African catfish *Clarias gariepinus*. *Anim Res Int*. 2017;14(3):2804-8.
- Bahga A, Madiseti V. Blockchain platform for industrial internet of things. *J Softw Eng Appl*. 2016;9(10):533-46.
- Bashir I. Mastering Blockchain: Distributed Ledger Technology, Decentralization and Smart Contracts Explained. Birmingham: Packt Publishing; 2017.
- Beck R, Müller-Bloch C. Blockchain as radical innovation: A framework for engaging with distributed ledgers proactively. *J Inf Technol*. 2017;32(3):183-203.
- Beck R, Avital M, Rossi M, Thatcher JB. Blockchain technology in business and information systems research. *Bus Inf Syst Eng*. 2017;59(6):381-4.
- Bhargava B, Ranchal R, Othmane LB. Secure information sharing in digital supply chains. In: *Proceedings of the 2013 ACM Workshop on Cloud Computing Security*. ACM; 2013. p. 27-34.
- Boucher P. How blockchain technology could change our lives. Brussels: European Parliamentary Research Service; 2017.
- Brunton F, Nissenbaum H. *Obfuscation: A User's Guide for Privacy and Protest*. Cambridge: MIT Press; 2015.
- Buterin V. A next-generation smart contract and decentralized application platform [Ethereum White Paper]. 2014. Available from: <https://ethereum.org/en/whitepaper/>
- Buterin V. On public and private blockchains. *Ethereum Blog*. 2015. Available from: <https://blog.ethereum.org/2015/08/07/on-public-and-private-blockchains/>
- Böhme R, Christin N, Edelman B, Moore T. Bitcoin: Economics, technology, and governance. *J Econ Perspect*. 2015;29(2):213-38.
- Catalini C, Gans JS. Some simple economics of the blockchain. *MIT Sloan Res Pap*. 2016;(5191-16):1-34.
- Catalini C. How blockchain applications will move beyond finance. *Harv Bus Rev Digit Artic*. 2017:1-3.
- Chaum D. Blind signatures for untraceable payments. In: *Advances in Cryptology*. Springer; 1983. p. 199-203.
- Cheng J, Da Xu L, Liu Y. Industrial IoT in 5G environment towards smart manufacturing. *J Ind Inf*

- Integr. 2018;10:10-9.
24. Christidis K, Devetsikiotis M. Blockchains and smart contracts for the internet of things. *IEEE Access*. 2016;4:2292-303.
  25. Cong LW, He Z. Blockchain disruption and smart contracts. *Rev Financ Stud*. 2019;32(5):1754-97.
  26. Coyne R, Goodfellow D. *Designing for Privacy and its Legal Framework: Data Protection by Design and Default*. London: University College London Press; 2015.
  27. Crosby M, Pattanayak P, Verma S, Kalyanaraman V. Blockchain technology: Beyond bitcoin. *Appl Innov Rev*. 2016;2:6-10.
  28. Cui Y, Wu J, Tong G. Blockchain and supply chain finance: A critical literature review. *Int J Prod Res*. 2018;56(5):1-15.
  29. Dannen C. *Introducing Ethereum and Solidity: Foundations of Cryptocurrency and Blockchain Programming for Beginners*. New York: Apress; 2017.
  30. Dawood H. The future of e-government and blockchain. *J Gov Regul*. 2017;6(1):36-42.
  31. de Kruijff J, Weigand H. Understanding the blockchain using enterprise ontology. In: *International Conference on Advanced Information Systems Engineering*. Springer; 2017. p. 29-43.
  32. Efanov D, Roschin P. The all-pervasiveness of the blockchain technology. *Procedia Comput Sci*. 2018;123:116-21.
  33. Eyal I, Gencer AE, Sirer EG, Van Renesse R. Bitcoin-NG: A scalable blockchain protocol. In: *13th USENIX Symposium on Networked Systems Design and Implementation (NSDI)*. USENIX; 2016. p. 45-59.
  34. Fairchild AM. A framework for blockchain smart contracts in supply chain management. *Supply Chain Forum*. 2016;17(4):1-14.
  35. Gatteschi V, Lamberti F, Demartini C, Pranteda C, Santamaría V. Blockchain and smart contracts for insurance: Is the technology mature enough? *Future Internet*. 2018;10(2):1-16.
  36. Glaser F. Pervasive decentralisation of digital infrastructures: A framework for blockchain enabled system design. *Proc 50th Hawaii Int Conf Syst Sci*. 2017:1543-52.
  37. Hasan HR, Salah K. Blockchain-based solution for proof of delivery of physical assets. *J Inf Secur Appl*. 2018;41:1-9.
  38. Hill J. Blockchain's potential in Africa: A new engine for governance and development. *Afr J Inf Syst*. 2018;10(4):273-88.
  39. Holotescu C. Understanding blockchain opportunities and challenges. *Stud Inform Control*. 2018;27(2):213-22.
  40. Iansiti M, Lakhani KR. The truth about blockchain. *Harv Bus Rev*. 2017;95(1):118-27.
  41. Isa A, Dem B. Integrating Self-Reliance Education Curriculum for Purdah Women in Northern Nigeria: A Panacea for a Lasting Culture of Peace. *J Educ Soc*. 2018;28(1):65-74.
  42. Isa A, Dem B. Integrating Self-Reliance Education Curriculum For Purdah Women In Northern Nigeria: A Panacea For A Lasting Culture Of Peace.
  43. Kim HM, Laskowski M. Toward an ontology-driven blockchain design for supply-chain provenance. *Intell Syst Account Finance Manag*. 2018;25(1):18-27.
  44. Kim J, Lee H, Kim H. Privacy-preserving data sharing over blockchain. In: *2018 IEEE International Conference on Big Data and Smart Computing (BigComp)*. IEEE; 2018. p. 313-6.
  45. Kiviat TI. Beyond bitcoin: Issues in regulating blockchain transactions. *Duke Law J*. 2015;65(3):569-608.
  46. Kosba A, Miller A, Shi E, Wen Z, Papamanthou C. Hawk: The blockchain model of cryptography and privacy-preserving smart contracts. In: *2016 IEEE Symposium on Security and Privacy (SP)*. IEEE; 2016. p. 839-58.
  47. Kshetri N. Blockchain's roles in meeting key supply chain management objectives. *Int J Inf Manag*. 2017;39:80-9.
  48. Lamport L, Shostak R, Pease M. The Byzantine generals problem. *ACM Trans Program Lang Syst*. 1982;4(3):382-401.
  49. Lewis A. A gentle introduction to smart contracts. *Brave New Coin*. 2016. Available from: <https://bravenewcoin.com/insights/a-gentle-introduction-to-smart-contracts>
  50. Li X, Jiang P, Chen T, Luo X, Wen Q. Blockchain-based data preservation system for medical information. *China Commun*. 2017;14(10):154-64.
  51. Li X, Jiang P, Chen T, Luo X, Wen Q. A survey on the security of blockchain systems. *Future Gener Comput Syst*. 2018;107:841-53.
  52. Lin IC, Liao TC. A survey of blockchain security issues and challenges. *Int J Netw Secur*. 2017;19(5):653-9.
  53. Malladi S. Blockchain technology in the energy sector: A systematic review of challenges and opportunities. *Renew Sustain Energy Rev*. 2018;82:2946-60.
  54. Mathews M. Blockchain and digital government. *J Public Adm*. 2017;35(4):57-71.
  55. Mattila J. *The blockchain phenomenon*. Helsinki: The Research Institute of the Finnish Economy (ETLA); 2016.
  56. Mattila J. *The blockchain phenomenon: The disruptive potential of distributed consensus architectures*. Helsinki: The Research Institute of the Finnish Economy (ETLA); 2016.
  57. Maurer B, Nelms TC, Swartz L. "When perhaps the real problem is money itself!": The practical materiality of Bitcoin. *Soc Semiot*. 2013;23(2):261-77.
  58. Mettler M. Blockchain technology in healthcare: The revolution starts here. In: *2016 IEEE 18th International Conference on e-Health Networking, Applications and Services (Healthcom)*. IEEE; 2016. p. 1-3.
  59. Nakamoto S. Bitcoin: A peer-to-peer electronic cash system [White Paper]. 2008. Available from: <https://bitcoin.org/bitcoin.pdf>
  60. Nakamura M. Blockchain for international development: Using distributed ledger technologies to reform aid. *World Dev J*. 2019;114:1-12.
  61. Nofer M, Gomber P, Hinz O, Schiereck D. Blockchain. *Bus Inf Syst Eng*. 2017;59(3):183-7.
  62. Oduola OM, Omole FO, Akinluwade KJ, Adetunji AR. A comparative study of product development process using computer numerical control and rapid prototyping methods. *Br J Appl Sci Technol*. 2014;4(30):4291.
  63. Oduola OM, Omole FO, Akinluwade KJ, Adetunji AR. A comparative study of product development process using computer numerical control and rapid prototyping

- methods. *Br J Appl Sci Technol.* 2014;4(30):4291-301.
64. Olaoye T, Ajilore T, Akinluwade K, Omole F, Adetunji A. Energy crisis in Nigeria: Need for renewable energy mix. *Am J Electr Electron Eng.* 2016;4(1):1-8.
  65. Olaoye T, Ajilore T, Akinluwade K, Omole F, Adetunji A. Energy crisis in Nigeria: Need for renewable energy mix. *Am J Electr Electron Eng.* 2016;4(1):1-8.
  66. Oyedokun OO. Green human resource management practices and its effect on the sustainable competitive edge in the Nigerian manufacturing industry (Dangote) [Doctoral Dissertation]. Dublin Business School; 2019.
  67. O'Leary DE. Configuring blockchain architectures for transaction information in blockchain consortiums: The case of accounting and supply chain systems. *Intell Syst Account Finance Manag.* 2017;24(4):138-47.
  68. Peters GW, Panayi E. Understanding modern banking ledgers through blockchain technologies: Future of transaction processing and smart contracts on the internet of money. In: *Banking Beyond Banks and Money.* Cham: Springer; 2016. p. 239-78.
  69. Peters GW, Panayi E, Chapelle A. Trends in blockchain applications. *J Risk Finance.* 2015;17(3):234-43.
  70. Pilkington M. Blockchain technology: Principles and applications. In: Olleros FX, Zhegu M, editors. *Research Handbook on Digital Transformations.* Cheltenham: Edward Elgar Publishing; 2015. p. 225-53.
  71. Pilkington M. Blockchain technology: Principles and applications. In: Olleros FX, Zhegu M, editors. *Research Handbook on Digital Transformations.* Cheltenham: Edward Elgar; 2016. p. 225-53.
  72. Rauchs M, Glidden A, Gordon B, Pieters G, Recanatini M, Rostand F, *et al.* Distributed ledger technology systems: A conceptual framework. Cambridge: Cambridge Centre for Alternative Finance; 2018.
  73. Reinehr T, Isa A, De Sousa G, Dieffenbach R, Andler W. Thyroid hormones and their relation to weight status. *Horm Res Paediatr.* 2008;70(1):51-7.
  74. Reinehr T, Isa A, De Sousa G, Dieffenbach R, Andler W. Thyroid hormones and their relation to weight status. *Horm Res Paediatr.* 2008;70(1):51-7.
  75. Reyna A, Martín C, Chen J, Soler E, Díaz M. On blockchain and its integration with IoT: Challenges and opportunities. *Future Gener Comput Syst.* 2018;88:173-90.
  76. Risius M, Spohrer K. A blockchain research framework: What we (don't) know, where we go from here, and how we will get there. *Bus Inf Syst Eng.* 2017;59(6):385-409.
  77. Schatsky D, Muraskin C, Gurumurthy R. Blockchain and the five vectors of progress. Deloitte Insights. 2017. Available from: <https://www2.deloitte.com/>
  78. Sillaber C, Waltl B. Life cycle of smart contracts in blockchain ecosystems. *Priv Identity Manag.* 2017:1-10.
  79. Swan M. *Blockchain: Blueprint for a new economy.* Sebastopol: O'Reilly Media; 2015.
  80. Szabo N. Formalizing and securing relationships on public networks. *First Monday.* 1997;2(9):1-17.
  81. Tapscott D, Tapscott A. *Blockchain revolution: How the technology behind bitcoin is changing money, business, and the world.* New York: Portfolio Penguin; 2016.
  82. Tapscott D, Tapscott A. How blockchain is changing finance. *Harv Bus Rev.* 2017;95(3):2-5.
  83. Tschorsch F, Scheuermann B. Bitcoin and beyond: A technical survey on decentralized digital currencies. *IEEE Commun Surv Tutor.* 2016;18(3):2084-123.
  84. Umeh J. The blockchain opportunity for Africa. *Afr Bus.* 2016;430:44-7.
  85. Underwood S. Blockchain beyond bitcoin. *Commun ACM.* 2016;59(11):15-7.
  86. Vukolić M. The quest for scalable blockchain fabric: Proof-of-work vs. BFT replication. In: *International Workshop on Open Problems in Network Security.* Springer; 2015. p. 112-25.
  87. Walport M. *Distributed ledger technology: Beyond blockchain.* UK Government Office for Science; 2016. p. 1-88.
  88. Wang FY. The emergence of intelligent enterprises: From CPS to CPSS. *IEEE Intell Syst.* 2010;25(4):85-8.
  89. Wang WY, Hoang DT, Hu P, Xiong Z, Niyato D, Wen Y, *et al.* A survey on consensus mechanisms and mining strategy management in blockchain networks. *IEEE Access.* 2019;7:22328-70.
  90. Wang Y, Kogan A. Designing confidentiality-preserving blockchain-based transaction processing systems. *Int J Account Inf Syst.* 2018;30:1-18.
  91. Wood G. *Ethereum: A secure decentralised generalised transaction ledger [Ethereum Project Yellow Paper].* 2014. p. 1-32.
  92. Wright A, De Filippi P. Decentralized blockchain technology and the rise of lex cryptographia. *SSRN Electron J.* 2015. Available from: [https://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=2580664](https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2580664)
  93. Wrigley S. Blockchain: The new architecture of trust? *J Digit Bank.* 2017;2(3):284-92.
  94. Wüst K, Gervais A. Do you need a blockchain? In: *2018 Crypto Valley Conference on Blockchain Technology (CVCBT).* IEEE; 2017. p. 45-54.
  95. Xu X, Weber I, Staples M. *Architecture for blockchain applications.* Cham: Springer; 2017.
  96. Yaga D, Mell P, Roby N, Scarfone K. *Blockchain technology overview.* National Institute of Standards and Technology (NIST); 2018. NISTIR 8202. p. 1-59.
  97. Yermack D. Corporate governance and blockchains. *Rev Finance.* 2017;21(1):7-31.
  98. Yli-Huoma J, Ko D, Choi S, Park S, Smolander K. Where is current research on blockchain technology?—A systematic review. *PLOS ONE.* 2016;11(10):1-27.
  99. Zambrano R. *Blockchain: A new ICT for development.* Panoramas Scholarly Platform, University of Pittsburgh; 2017. p. 1-6.
  100. Zhang Y, Wen J. The IoT electric business model: Using blockchain technology for the internet of things. *Peer-to-Peer Netw Appl.* 2017;10(4):983-94.
  101. Zheng Z, Xie S, Dai H, Chen X, Wang H. An overview of blockchain technology: Architecture, consensus, and future trends. In: *2017 IEEE International Congress on Big Data (BigData Congress).* IEEE; 2017. p. 557-64.
  102. Zyskind G, Pentland A. Decentralizing privacy: Using blockchain to protect personal data. In: *IEEE Security and Privacy Workshops (SPW).* IEEE; 2015. p. 180-4.
  103. Zyskind G, Nathan O, Pentland A. Decentralizing privacy: Using blockchain to protect personal data. In: *2015 IEEE Security and Privacy Workshops (SPW).* IEEE; 2015. p. 180-4.
  104. Ølnes S, Ubacht J, Janssen M. Blockchain in government: Benefits and implications of distributed ledger technology for information sharing. *Gov Inf Q.* 2017;34(3):355-64.