Leveraging Blockchain for Cyber Security in Zambia's ICT Sector: A Study on Data Transaction Integrity and Protection

Alex Ng'uni
Department of Information and Communication Technology,
Copperbelt University, Kitwe, Zambia
ngunialex@gmail.com
Mobile No: +260977286765

Hastings M. Libati
Department of Information and Communication Technology,
Copperbelt University, Kitwe, Zambia
libati@cbu.ac.zm
Mobile No: +260955881138

Derrick Ntalasha
Department of Information and Communication Technology
Copperbelt University, Kitwe, Zambia
dbntalasha@gmail.com
Mobile No: +260974753039

***Abstract* – This study explores the use of blockchain technology to enhance cybersecurity in Zambia's ICT sector, focusing on improving data transaction integrity and protection. Given the rising threat of cyberattacks and data breaches, the research investigates how Distributed Ledger Technologies (DLTs) can secure digital transactions by decentralizing data storage and ensuring tamper-resistance. The findings indicate that blockchain outperforms traditional security measures by offering superior transparency, data integrity, and accountability. However, challenges such as limited awareness, regulatory gaps, and technical barriers hinder its adoption. The study concludes that with proper regulatory frameworks, educational campaigns, and pilot projects, blockchain can significantly strengthen Zambia's cybersecurity framework. Addressing these challenges is crucial for realizing blockchain's full potential in safeguarding digital transactions and mitigating cyber risks in the ICT infrastructure.**

***Keywords*:** Blockchain Technology, Cyber Security, Distributed Ledger Technologies (DLTs), Data Integrity, Data Breaches, ICT Infrastructure, smart contracts.

INTRODUCTION

Background

The rapid advancement of Zambia's Information and Communications Technology (ICT) sector has led to a surge in digital transactions, making cybersecurity a critical concern. The country's ICT infrastructure has been increasingly targeted by cyber-attacks, resulting in numerous data breaches and security lapses [1]. In this context, blockchain technology emerges as a robust solution to enhance the integrity and security of digital transactions by leveraging its decentralized, immutable, and transparent framework [2].

Blockchain technology ensures data transaction integrity by eliminating the need for intermediaries, which reduces the risk of manipulation or unauthorized access to data [3]. Its decentralized nature provides a tamper-resistant environment that significantly minimizes the threat of cyber-attacks [4]. This is particularly crucial in Zambia's ICT sector, where the integrity and confidentiality of sensitive information are paramount [5]. Recent studies show that blockchain can facilitate real-time tracking and auditing of transactions, which can help address some of the persistent cybersecurity issues in the region, such as unauthorized data access [6]. However, despite its potential, the adoption of blockchain technology in Zambia faces challenges such as a lack of awareness, regulatory hurdles, and limited technical expertise [7].

Problem Statement

Zambia's ICT sector faces growing cybersecurity challenges, with traditional centralized systems proving inadequate against sophisticated threats like data breaches and unauthorized access. Key issues include a lack of robust policies, limited stakeholder awareness, technical skill shortages, and regulatory gaps.

While blockchain offers potential solutions through its decentralized and tamper-resistant framework, adoption is hindered by high costs, technical barriers, and unclear regulations. This research explores blockchain's role in enhancing cybersecurity and overcoming these challenges in Zambia's ICT infrastructure.

C. Research Aim and Objectives

This study aims to explore the application of blockchain technology in improving data transaction security within Zambia's ICT sector. By comparing the current cybersecurity infrastructure with blockchain-based solutions, the study seeks to demonstrate how blockchain can revolutionise data protection and integrity in this critical sector [8]. Below are the specific objectives, along with their corresponding hypotheses.

Research Objectives and Corresponding Hypotheses

Objective 1: *To evaluate the current state of cybersecurity in Zambia's ICT sector.*

Hypothesis 1 (H1): Zambia's ICT sector exhibits a significantly high level of vulnerability to cyber threats due to inadequacies in traditional security measures.

Objective 2: *To explore the potential of blockchain technology in enhancing data transaction integrity and security.*

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Hypothesis 2 (H2): Blockchain technology significantly improves data transaction integrity and security compared to existing centralized security systems in Zambia's ICT sector.

Objective 3: *To compare blockchain-based security solutions with traditional cybersecurity measures.*

Hypothesis 3 (H3): Blockchain-based security solutions provide higher levels of transparency, tamper-resistance, and accountability than traditional cybersecurity measures.

Objective 4: *To identify barriers to blockchain adoption in Zambia's ICT sector and propose solutions.*

Hypothesis 4 (H4): Lack of awareness, high implementation costs, and limited technical expertise significantly hinder blockchain adoption in Zambia's ICT sector.

Subsequently, this article is categorized into sections with headings as follows: Abstract: This serves as a snapshot of the entire article, Introduction: This helps to provide the readers with an insight of the article by looking at the article context and purpose; Problem Statement: provides the statement of the problem for which the research provides the solution; Objectives: provides the specific objectives to be met by the study; Blockchain details: This explains what blockchain is including its benefits; Related work: Examines works done by other authors; Methodology: To help explore the research methodology process used; Findings and Results: Describes what is found when data is analyzed; Discussion of results: This explains the results of the research, Conclusion: To help summarize the entire article, Recommendations: To help make necessary recommendations for mitigating the cyber risks.

D. Zambia ICT Sector Cyber Security *Conceptual* Model (ZICTS-CSCM) – Based on TAM

This framework applies the **Technology Acceptance Model (TAM)** to explain how blockchain adoption can enhance **cybersecurity** in Zambia's ICT sector. TAM is appropriate because it emphasizes how **perceptions of usefulness and ease of use** shape the **acceptance and adoption of new technologies**.

The framework links **blockchain's perceived benefits** with stakeholders' attitudes and behavioural intentions, showing how this leads to actual adoption and, ultimately, improved cybersecurity outcomes.

Key Constructs

1. Perceived Usefulness (PU)

I. Blockchain is viewed as capable of **enhancing data transaction integrity and security**.

II. Users believe it improves **trust, protection, and accountability** compared to traditional systems.

2. Perceived Ease of Use (PEOU)

- Blockchain is seen as relatively **easy to learn, implement, and integrate** into ICT systems.
- Training, awareness, and user-friendly interfaces increase PEOU.

3. Attitude Toward Use

- Stakeholders form a **positive or negative attitude** toward blockchain based on PU and PEOU.
- A positive attitude strengthens the willingness to adopt blockchain for cybersecurity.

4. Behavioural Intention to Use

I. Refers to stakeholders' **willingness to adopt blockchain** in ICT institutions.

II. Intention is shaped by attitude and directly predicts adoption.

5. Actual Adoption of Blockchain

I. Institutions integrate blockchain into ICT operations (e-government services, banking, healthcare records).

II. Adoption involves **deploying blockchain platforms, smart contracts, and distributed ledgers**.

6. Enhanced Cybersecurity Outcomes (Dependent Variable)

III. **Data Integrity** – Immutable records prevent tampering.

IV. **Data Protection** – Decentralized storage reduces breaches.

V. **Accountability** – Transparent audit trails enhance trust.

Narrative Flow of the Framework

Perceptions (PU & PEOU) → influence Attitude toward blockchain.

Attitude → drives Behavioral Intention to Use.

Intention → leads to Actual Adoption of blockchain technology.

Adoption → results in Enhanced Cybersecurity Outcomes in Zambia's ICT sector.

The diagram below shows the Zambia ICT Sector Cyber Security *Conceptual* Model (ZICTS-CSCM).

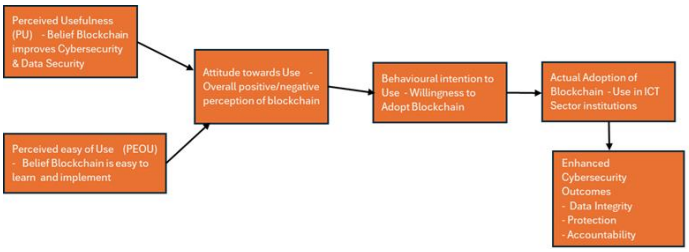

Diagram 1: The Zambia ICT Sector Cyber Security Conceptual Model.

RELATED WORK

The rise in cyber-attacks within Zambia's ICT sector calls for advanced security measures to safeguard data integrity and confidentiality. Blockchain technology, with its decentralized and immutable structure, offers a promising solution by ensuring secure data transactions and strengthening cyber security frameworks. This review critically examines recent studies on blockchain's role in cyber security, focusing on its potential to address vulnerabilities in Zambia's ICT infrastructure, while identifying gaps in current research.

Blockchain and Cyber Security: A Global Perspective

Blockchain technology has been globally recognized for its potential to revolutionize cyber security frameworks. Kshetri emphasizes that blockchain's decentralized architecture significantly reduces the likelihood of cyber-attacks by eliminating single points of failure, making it challenging for attackers to compromise the system [9]. Its cryptographic techniques also ensure the integrity and confidentiality of data, providing robust protection against breaches [10]. Similarly, Nguyen et al. highlight that blockchain's use of public and private keys ensures secure data exchanges, reducing risks of unauthorized access [11].

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One of the key advantages of blockchain technology is its transparency and traceability, which enhances trust in digital transactions. According to Werbach, the transparency provided by blockchain fosters trust among participants in the transaction process, particularly in sectors where data tampering and fraud are common concerns [12]. This view is supported by Pilkington, who argues that blockchain's immutable ledger acts as a reliable source of truth, reducing fraud risks and ensuring data accuracy across multiple platforms [13].

Additionally, research by Zyskind et al. shows that blockchain can empower individuals to have more control over their data, preventing unauthorized third-party access and increasing the accountability of data handlers [14]. In the healthcare sector, Lee and Lee found that blockchain could help protect patient data from breaches, while simultaneously improving the integrity of medical records [15]. These characteristics make blockchain highly adaptable to various industries, enhancing both data security and operational efficiency.

Despite these promising developments, most research has concentrated on adopting blockchain in developed economies, where ICT infrastructures are well-established. For instance, Zhang and Xue examine blockchain's successful implementation in supply chain management in developed markets, highlighting its ability to ensure end-to-end transparency [16]. In contrast, developing countries like Zambia face significant challenges, including underdeveloped ICT infrastructure and regulatory gaps, which hinder the adoption of blockchain [17]. As Karame and Androulaki emphasize, there is a need for tailored blockchain solutions that consider the specific technological and regulatory conditions in developing regions [18].

There is a limited body of research focusing on the application of blockchain in African countries, where ICT infrastructures are still evolving. This gap is underscored by Banda et al., who argue that while blockchain has transformative potential in Africa, research must focus on overcoming the regulatory, technical, and financial barriers that impede its widespread adoption [19]. This study addresses this gap by exploring how blockchain can be leveraged to improve cyber security in Zambia's ICT sector, which is increasingly vulnerable to cyber-attacks.

Cyber Security Challenges in Zambia's ICT Sector

Like many developing countries, Zambia faces significant cyber security challenges due to its relatively underdeveloped ICT infrastructure. Lungu et al. point out that Zambia's cyber security framework is hindered by inadequate policies, limited technical expertise, and low stakeholder awareness, all of which contribute to frequent cyber-attacks and data breaches [20].

Efforts to adopt advanced technologies to address these challenges have been explored by some researchers. Banda and Sichone discuss the use of artificial intelligence (AI) for threat detection in Zambia's banking sector, indicating that while AI can improve cyber threat detection, technical and financial constraints limit its implementation [21]. This highlights the need for alternative solutions, such as blockchain, which offers cost-effective and scalable ways to enhance cyber security.

Despite its potential, empirical research on blockchain's application in Zambia's ICT sector remains scarce. Studies such as those by Munsanje and Ndalama focus on general cybersecurity strategies without specifically addressing blockchain's benefits [22]. This lack of research presents an opportunity to explore how blockchain can address cybersecurity challenges in Zambia's ICT sector.

Blockchain's Potential in Zambia's ICT Sector

Blockchain's ability to provide a secure and tamper-proof platform for data transactions makes it a promising solution for Zambia's ICT sector. Chanda and Ngulube's study on blockchain adoption in Zambia's healthcare sector highlights blockchain's effectiveness in improving data integrity and securing sensitive information, findings that apply to other sectors, including ICT [23].

Simukonda and Mbewe also explored blockchain's feasibility in Zambia's financial sector, finding that it reduces fraud risks and enhances transaction security. However, they identified barriers to adoption, such as regulatory challenges and a lack of technical expertise, which align with the broader literature on blockchain adoption in developing countries [24][25].

Despite these challenges, blockchain's potential benefits for Zambia's ICT sector are clear. Its decentralized nature protects data from unauthorized alterations, while transparency and traceability features enhance accountability in digital transactions [26]. This makes blockchain a viable option for addressing the rising cyber security threats in Zambia's ICT sector.

Blockchain Background

Blockchain is a distributed ledger technology (DLT) that permits data to be safely recorded, stored across multiple computers in a decentralized network environment and can be verified. Blockchain is different from traditional centralized databases that are handled by a single entity for it operates on a peer-to-peer (P2P) network making sure there is no control from the single entity, and this makes blockchain to be resourceful in several industries like supply chain, finance, health care, and more [27]

DLT is an expression used to refer to a digital network of models well distributed and comprising of ledgers that are blockchain-based in nature, that work together on activities and tasks. This is a technology consisting of blocks which are cryptographically joined together in form of a chain sequence using cryptographic hashes that secure data against tampering. DTL is meant to provide high level of trust, resiliency, service availability, security of digital systems, computation, control and distributed storage [28].

Structure of Blockchain

A blockchain comprises of a chain of blocks of which every block stores a list of data entries or transactions. The main components are as follows:

Blocks: These are data storage units in a blockchain. The block will comprise a list of transactions, a cryptographic hash for the previous block, a timestamp and a nonce, used in mining. The connection of blocks in a sequence forms a chain hence the term "blockchain" [29].

Nodes: These are separate computers linked to the blockchain network. Their task is to ensure they communicate to record and validate transactions [30].

Consensus Algorithms: These are algorithms used by blockchain networks to add a new block to the chain to make sure all nodes agree about the transaction's validity. The well-known mechanisms include Proof of Work (PoW) which is used by Bitcoin that helps to resolve complex cryptographic problems for transaction validation [31], and Proof of Stake (PoS) which

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Ethereum 2.0 uses to choose validators based on the number of tokens they possess and are willing to stake as collateral [32].

Hashes: This is a cryptographic hash function which changes input data like a data entry into a fixed-size string of characters, making data immutable and secure. The hash of one block is dependent on its hash and the hash of the preceding block, therefore connecting the blocks. In blockchain, all the transactions within a block are summarized by a single hash known as the Merkle root, which is stored in the block header. The Merkle root is the final hash produced by the Merkle tree, which is built from the hashes of individual transactions in the block [33].

Characteristics of Blockchain

The characteristics of blockchain are as follows:

Decentralization: Blockchain depends on a decentralized network of nodes different from traditional systems that rely on the central authority like governments or banks [34]

Transparency: As blockchain is said to be a public ledger, the whole history of transactions in the network can be viewed by any participant or stakeholder. Even though the data will be visible to all, the actual identities of the participants remain anonymous using public keys [35]

Immutability: The goodness of blockchain technology is that when the data is added to the chain, it is impossible to change the data. If change is required, it would involve altering all subsequent blocks in the chain which makes blockchain highly impractical to alter the data [36].

Blockchain Types

The following are types of blockchains.

Consortium Blockchain: These are overseen by a group of organizations instead of just a single organization because they are semi-decentralized. They are mostly used in industries where collaboration among companies is needed like supply chain and finance [37].

Private Blockchains: These are a type of blockchains called permissioned blockchains that involve allowing only chosen participants to access the network. These are commonly used by organizations for internal use cases where control and privacy are of paramount priority [38].

Public Blockchains: These are blockchains that do not need permission to participate or join as they are open to anyone. Ethereum and Bitcoin are good examples of public blockchains where validation and viewing of transactions can be done by anyone [39].

Blockchain Applications

The following are applications of blockchain.

A. **Cryptocurrency:** Blockchain gained fame through Bitcoin, the first decentralized digital currency. Cryptocurrencies use blockchain technology to enable secure, peer-to-peer financial transactions without the need for intermediaries like banks [40].

B. **Smart Contracts:** On platforms like Ethereum, blockchain supports smart contracts (self-executing contracts) with the terms of the agreement directly written into code. These contracts automatically execute actions when predefined conditions are met, streamlining processes like payments, legal agreements, and more. Smart contracts have advantages over traditional contracts in that they reduce transaction risks, reduce service costs and generally improve process efficiency in businesses because they run on a secure blockchain. They also help in reducing incidences of contract breaches, delays in finalising contracts and contractual disputes that lead to litigation [41].

C. **Supply Chain Management:** Blockchain provides real-time tracking and verification of goods in the supply chain, improving transparency and reducing fraud. Companies like IBM and Walmart have implemented blockchain for tracking food products, ensuring quality control [42].

D. **Healthcare:** Blockchain enhances the security of medical records by ensuring that only authorized parties have access to sensitive patient information. It also improves the efficiency of data sharing among healthcare providers [43].

Challenges and Limitations of Blockchain

Despite its potential, blockchain faces several challenges:

- **Scalability:** Public blockchains, like Bitcoin, have struggled with scalability due to the limited number of transactions they can process per second. Solutions such as the Lightning Network (for Bitcoin) and Ethereum's Layer 2 solutions aim to address this issue [44].

- **Energy Consumption:** Proof of Work (PoW) consensus algorithms consume significant amounts of energy. This has raised concerns about the environmental impact of blockchain, especially in large networks like Bitcoin [45].

- **Regulatory Concerns:** Blockchain operates across borders, making it difficult for regulators to establish consistent legal frameworks. Governments are still grappling with how to regulate cryptocurrencies and other blockchain applications [46].

The following table, Table 1, shows a summary of what was discovered during the literature review.

TABLE 1: Summary of Literature review findings, gaps and suggested solutions

Category	Findings	Gaps	Solutions
Cybersecurity Challenges in Zambia	Zambia's ICT infrastructure is highly vulnerable to cyber threats, including data	Lack of adequate cybersecurity policies, limited technical	Blockchain's decentralized, tamper-resistant nature offers a more robust solution

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	breaches and unauthorized access. Traditional security methods like centralized databases and standard encryption techniques are often inadequate [20].	expertise, and low stakeholder awareness make the sector more susceptible to cyber-attacks [20].	to secure digital transactions [23]. Government support and industry collaboration are needed to implement this technology.
Blockchain's Potential in Cybersecurity	Blockchain enhances the integrity and security of digital transactions, ensuring transparency, accountability, and tamper-proof data [10][15][23].	There is limited research on blockchain's application in Zambia's ICT sector, particularly compared to finance and healthcare sectors in developed countries.	Promote blockchain adoption in the ICT sector through pilot projects and comparative analyses to demonstrate its effectiveness over traditional methods [72].
Comparative Analysis of Traditional vs. Blockchain Security	Traditional security systems (encryption, access control) are vulnerable to attacks. Blockchain provides better tamper resistance due to its decentralized structure [62][63].	Awareness about blockchain's benefits is low, and many stakeholders rely on outdated security models.	Launch educational and awareness campaigns targeting key stakeholders, showcasing blockchain's superiority in ensuring data integrity [62][63]
Data Transaction Integrity	Blockchain's distributed ledger ensures that data is immutable, and transactions are secure, preventing unauthorized modifications [13].	Lack of a trusted system for real-time auditing and verifying the authenticity of transactions in the current setup.	Blockchain can enable real-time tracking and verification of digital transactions, improving data transparency and integrity [33].
Regulatory and Legal Barriers	There are no clear legal frameworks governing the use of blockchain	The absence of supportive regulatory policies makes it difficult to	Develop comprehensive blockchain-specific legal frameworks that address
	technology in Zambia, which creates uncertainty and discourages adoption [18][24].	adopt blockchain at a large scale.	data privacy, security, and digital transactions [46].
Technical Expertise and Capacity	Adoption of blockchain requires specialized technical expertise, which is currently lacking in Zambia [25]	There is Shortage of technical skills in blockchain, cybersecurity, and ICT systems necessary for deploying and maintaining blockchain technology.	Invest in blockchain education and training programs, including partnerships with universities and international blockchain experts [56]57].
Public and Private Sector Collaboration	Collaboration between public institutions and private sectors is minimal when it comes to integrating blockchain into existing security frameworks [37].	Limited coordinated efforts to foster blockchain adoption across different sectors.	Encourage partnerships between government, private industries, and international bodies to facilitate blockchain adoption [37].
Scalability and Energy Efficiency	Public blockchains (e.g., Bitcoin) face scalability issues due to the limited number of transactions they can handle per second, and they consume large amounts of energy [44].	Blockchain's high energy consumption and scalability problems make its adoption more complex, especially in developing regions like Zambia.	Explore more energy-efficient blockchain solutions, like Proof of Stake (PoS), to reduce environmental impact while ensuring scalability [44].

METHODOLOGY

A. Research Design

This research study uses a mixed-methods style with the help of a systematic literature review that involves qualitative data collection through expert surveys and interviews. The literature review provided the foundation for identifying key cybersecurity challenges in Zambia's ICT Sector, the interviews provided practical insights into the current state of

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blockchain in the ICT sector of Zambia. A population of 100 participants was targeted.

Data Collection

Surveys were conducted with a sample size of 88 ICT experts drawn from Zambia's ICT sector. The Google-form questionnaires were distributed to participants that explored the cyber security challenges faced by the ICT sector institutions, and the use of blockchain as a solution to the data integrity problem was investigated.

Sampling Strategy

[1]. Population Targeted: 100 ICT experts working in Zambia's ICT sector.
[2]. Actual Sample Size: 88 respondents (those who completed the survey).
[3]. Sampling Approach:
- The study employed purposive sampling, targeting ICT experts who have knowledge and experience in cybersecurity and blockchain technology.
- The participants were selected across different ICT sector institutions to ensure diversity of views on cyber threats and blockchain adoption.

[4]. **Rationale**: The sampling was focused on knowledgeable stakeholders so that responses would be practical, reliable, and informed by real-world ICT security practices.

Question Development

- **Basis for Questions:**

Questions were developed from the systematic literature review, which identified recurring cybersecurity issues, blockchain applications, and adoption challenges.

The Technology Acceptance Model (TAM) framework informed the structure of questions, focusing on constructs such as Perceived Usefulness (PU), Perceived Ease of Use (PEOU), Attitude, Intention, and Adoption.

- **Questionnaire Tool:** A Google Form survey was used.
- **Themes in the Questionnaire**:
  - **Current Cybersecurity Landscape** – Questions assessed respondents' views on the level of vulnerability of Zambia's ICT infrastructure (e.g., susceptibility to data breaches, adequacy of current methods such as encryption and centralised databases).
  - **Potential of Blockchain Technology** – Items measured perceived effectiveness of blockchain in different areas (network security, secure transactions, supply chain monitoring, identity management).
  - **Comparative Analysis** – Questions comparing blockchain-based approaches with traditional security systems.
  - **Adoption Barriers** – Questions explored challenges such as lack of awareness, regulatory gaps, high costs, and shortage of technical expertise.

Data Analysis

The data that was collected from surveys was analyzed using thematic analysis to identify recurring themes and challenges related to cyber security. These themes were then compared with the findings from the literature review to provide a comprehensive understanding of the security issues facing Zambia's ICT Sector.

Data Analysis Steps

Type of Analysis:

Thematic Analysis (qualitative approach) was applied to identify recurring themes, patterns, and insights.

Quantitative Summaries from survey data were presented using percentages, charts, and comparative figures.

Procedure:

- **Data Collection**: Responses from 88 experts were downloaded from Google Forms.
- **Coding & Categorization**: Responses were grouped into major themes—cybersecurity threats, blockchain potentials, comparative strengths, and barriers to adoption.
- **Theme Identification**: Recurring ideas (e.g., "lack of awareness," "secure data sharing," "immutable records") were clustered into thematic categories.
- **Integration with Literature Review**: The identified themes were cross-referenced with gaps and solutions identified in the systematic literature review, strengthening validity.
- **Visualisation of Findings**:
  1. Graphs and figures (Figures 3–8 in the paper) illustrated how respondents rated cyber threats, blockchain potentials, comparative strengths, and adoption barriers.
  2. Tables (e.g., Table 1 on gaps and solutions, Table 2 on literature sources) helped compare empirical findings with secondary data.

Deepened Analysis of Barriers with Economic Cost Models

1. High Implementation Costs

1. **Barrier Identified:** 30.7% of respondents highlighted high cost as a major obstacle.
2. **Economic Cost Model Perspective:**

A. **Total Cost of Ownership (TCO) Model:** Blockchain implementation requires upfront capital for infrastructure (servers, secure nodes, consensus mechanisms), software development, and licensing.

B. **Operational Costs:** Ongoing expenses include electricity (especially under Proof-of-Work models), internet bandwidth, maintenance, and cybersecurity monitoring.

C. **Training & Human Capital Costs:** Hiring or training blockchain developers and security specialists increases institutional expenditure.

D. **Cost-Benefit Gap:** Many Zambian ICT institutions operate on tight budgets, making the expected benefits (data security, transparency) less tangible compared to immediate high costs.

2. Limited Technical Expertise

A. **Barrier Identified:** 26.1% of respondents cited a lack of skills.

B. **Economic Cost Model Perspective:**

- **Human Capital Investment Model:** Training ICT professionals in blockchain incurs costs in tuition, certification programs, and opportunity cost of staff time.
- **Brain Drain Risk:** Skilled professionals may migrate to higher-paying jobs abroad, reducing local returns on training investment.

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- **Economic Impact:** Without sufficient skilled manpower, firms must outsource to foreign blockchain consultants, which inflates costs.

3. Awareness and Adoption Gap
Barrier Identified: 42% of respondents pointed to low awareness.
Economic Cost Model Perspective:
Transaction Cost Economics (TCE): Low awareness increases transaction costs due to uncertainty and information asymmetry. Organizations cannot easily estimate the value or ROI of blockchain adoption.
Perceived vs. Actual Cost: Institutions may overestimate blockchain's complexity and cost due to lack of knowledge, leading to reluctance in allocating budgets.

4. Regulatory Uncertainty
Barrier Identified: 1.1% cited as a challenge (less perceived, but critical structurally).
Economic Cost Model Perspective:
Compliance Cost Model: In the absence of clear laws, firms face unpredictable compliance costs if regulations change post-adoption.
Risk Premium: Investors add a risk premium when regulations are unclear, inflating project financing costs.

5. Comparative Economic Analysis: Blockchain vs. Traditional Security
TABLE I. **Traditional Security (Centralized Systems):** Lower initial costs (basic encryption, centralized servers) but higher long-term breach recovery costs (data loss, fraud, reputational damage).

TABLE II. **Blockchain Systems:** Higher initial costs (infrastructure, training) but lower long-term operational risk costs due to tamper-resistance and transparency.

Economic Model Insight:
A **Net Present Value (NPV) or Return on Investment (ROI) model** could indicate that while blockchain adoption has a negative short-term ROI, in the medium to long term, it may yield a positive ROI through reduced breach costs, improved regulatory compliance efficiency, and gains in reputational trust.

The deepened analysis suggests that **economic costs are not just financial barriers but also strategic misalignments**. Institutions in Zambia's ICT sector perceive blockchain as cost-prohibitive because they evaluate it on upfront capital expenditure rather than **lifecycle cost savings** (e.g., reduced breach costs, improved accountability). A **policy-supported cost-sharing model** (e.g., subsidies, tax incentives, public–private partnerships) could reduce these barriers and align blockchain adoption with long-term economic efficiency.

Cost-Benefit Framework for Blockchain Adoption in Zambia's ICT Sector

Here, we present an economic cost–benefit analysis of blockchain adoption in Zambia's ICT sector. We compare blockchain-based cybersecurity with traditional centralized security systems over a 10-year horizon, focusing on costs, breach savings, and long-term return on investment (ROI).

Cost Comparison
The chart in Figure 1 below compares the cumulative costs of traditional security systems and blockchain-based cybersecurity over a 10-year horizon. Blockchain appears costlier in the short term but becomes more cost-effective in the long run.

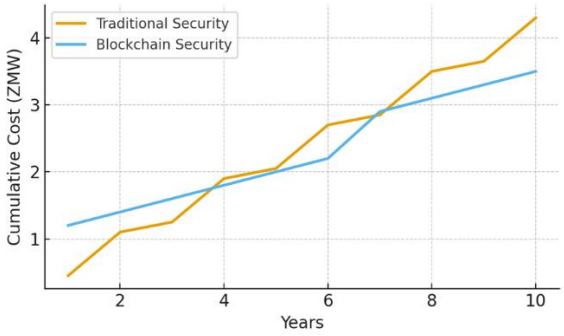

Figure 1: Cost Comparison: Traditional v Blockchain Security

ROI Projection
The ROI projection in Figure 2 below shows blockchain benefits (breach avoidance, compliance efficiency, and trust) compared to cumulative costs. Net ROI turns positive around Year 5, demonstrating the long-term financial viability of blockchain adoption by Zambia's ICT Sector.

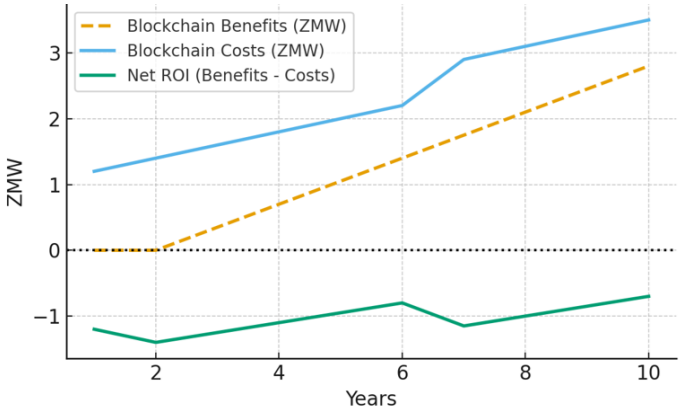

Figure 2: Blockchain Adoption ROI Projection

As can be seen in the above graphs, we can visualise the following:

- **Cost Comparison** – that shows how blockchain has higher upfront costs but overtakes traditional security in long-term savings.
- **ROI Projection** – that illustrates how blockchain's benefits (breach avoidance, efficiency, trust) begin to outweigh costs after Year 4–5, yielding strong positive ROI by Year 10 for the Zambia ICT Sector.

FINDINGS

Literature Sources Summary

TABLE 2: Literature sources

Data Source	Number of Articles Reviewed	Number of Papers Used	Focus Area

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IEEE Journals and Conferences	40	14	Blockchain architecture, consensus mechanisms, scalability, and cybersecurity applications, with a focus on technical details and solutions.
Springer and Elsevier Publications	32	12	Blockchain's role in enhancing data transparency, integrity, and its potential applications in healthcare, finance, and supply chain management.
European Union and United Nations Reports	8	5	Global policy recommendations, blockchain risks and benefits, and the regulatory frameworks needed for blockchain adoption in governance and cybersecurity contexts.
Zambia ICT Journal and African Cybersecurity Journals	25	8	Challenges of blockchain adoption in African contexts, particularly Zambia, with a focus on healthcare, financial services, and ICT infrastructure.
Books and Other Papers	45	30	Foundational concepts of blockchain, its decentralized and tamper-proof nature, and its transformative effects on cybersecurity and digital economies.
Case Studies from Developing Economies	12	6	Blockchain use cases in Africa, with a focus on overcoming barriers like limited technical expertise, regulatory gaps, and infrastructural challenges.
Totals	**162**	**75**	

Current Cybersecurity Landscape in Zambia's ICT Sector

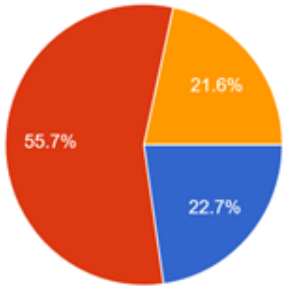

Figure 3: Susceptibility to various cyber threats by Zambia's ICT Sector

As shown in Figure 3 above, the study reveals that the majority, **55.7%** of respondents, believe that Zambia's ICT infrastructure is highly susceptible to various cyber threats, leading to multiple data breaches and other security incidents. This is followed by **22.7%** of respondents who say Zambia's ICT infrastructure is not very vulnerable, whereas 21.6% do not know. An evaluation of the current security strategies within the sector suggests that conventional methods, such as centralized databases and standard encryption techniques, are often inadequate to combat advanced cyber-attacks [47]. These traditional security approaches lack the necessary resilience to safeguard data against unauthorized access, tampering, and other malicious activities, thereby placing critical information at risk [48]. This suggests that there are significant concerns or perceived gaps in the current infrastructure's ability to mitigate security incidents.

Potential of Blockchain Technology for Data Transaction Integrity and Protection

As shown in Figure 4 below, network security stands out with 58.6% responses where respondents see the most effectiveness for blockchain implementation, followed by secure data transactions with 18.4%, supply chain monitoring with 11.5% and identity management receiving 10.3% but still positive evaluations.

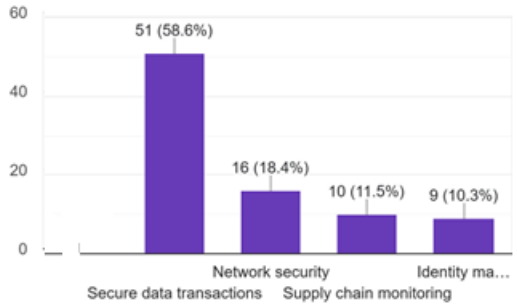

Figure 4: Potential of Blockchain Technology

This distribution of ratings shows that blockchain is primarily valued for its security benefits in institutional contexts, with varying perceptions of its effectiveness in other areas.

Blockchain technology, known for its decentralized and immutable ledger, offers a promising solution to the cybersecurity challenges faced by Zambia's ICT sector. The results of this study emphasize that adopting blockchain can greatly improve the integrity and security of data transactions, as each transaction is recorded on a distributed ledger that is resistant to tampering [49]. Blockchain's

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decentralized nature ensures there is no single point of failure, which significantly reduces the chances of successful cyber-attacks on essential data repositories [50].

Additionally, the findings suggest that Blockchain enhances transparency and traceability in data transactions, both of which are critical for maintaining trust and accountability in digital systems. As illustrated in Figure 5 below, each block in a blockchain contains a cryptographic hash of the previous block, a timestamp, and transaction details, making it extremely challenging for unauthorized parties to modify transaction records without detection [51]. This high level of security is especially beneficial in contexts where data integrity is crucial, such as in financial transactions and sensitive government communications [52].

Figure 5: Illustration of blockchain technology, highlighting its structure and components.

The diagram above also emphasizes the application of blockchain in ensuring data transparency and integrity, particularly for financial transactions and government communications.

Comparative Analysis of Traditional Security Measures and Blockchain

As shown in Figure 6 below, most respondents favoured Blockchain over Traditional security measures. About 48.9% of respondents argued that Blockchain provides secure data sharing whereas 39.8% of respondents favoured Blockchain because it maintains immutable transaction records as the primary ways it can improve data integrity in Zambia's ICT sector, with a smaller portion (11.4%) recognizing the role of decentralization. This reflects a general understanding of blockchain's strengths in providing secure, transparent, and distributed data handling

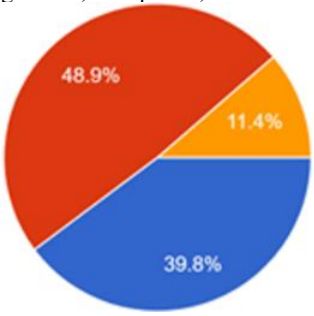

Figure 6: Analysis of Traditional Security Measures against Blockchain

The comparative analysis in this study reveals that blockchain-based security systems surpass traditional approaches in several key aspects, such as data integrity, tamper resistance, and overall resilience to cyber threats. Traditional security systems, which rely heavily on encryption and access controls, can be compromised; however, blockchain's decentralized framework inherently reduces these risks by distributing data across multiple nodes [53].

As illustrated in Figure 7 below, the research shows that blockchain addresses the challenge of data provenance, ensuring that data origins can be traced back to their source without the risk of unauthorized modifications. It highlights key features such as data origins, immutable records, and audit trails showcasing its applications in supply chain management and e-government services [54]. Blockchain's immutable records guarantee that once a transaction is logged, it cannot be altered or deleted, providing a permanent and verifiable audit trail [55].

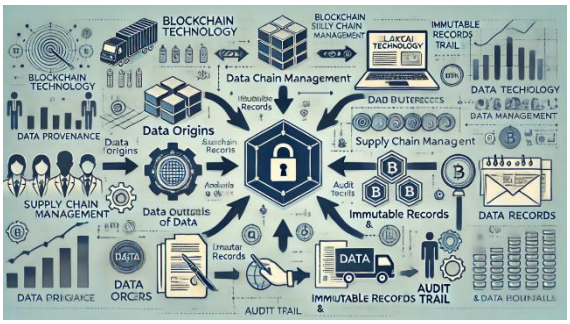

Figure 7: Diagram illustrating the concept of using blockchain technology for data provenance.

Barriers to Blockchain Adoption in Zambia's ICT Sector

Despite the significant advantages of blockchain, the study identifies several barriers to its widespread implementation in Zambia's ICT sector. These include a lack of awareness and understanding of blockchain technology among key stakeholders, regulatory hurdles, and a shortage of the technical expertise required for its deployment and maintenance [56]. As we can see in Figure 8 below, the largest number of respondents (42%) said that lack of awareness is the biggest challenge, suggesting that a lot of potential users and stakeholders lack knowledge or understanding of Blockchain technology that could hinder its adoption. This is followed by the challenge of high implementation cost at 30.7% that shows concerns about the financial investment needed to implement blockchain technology that may be a barrier for institutions considering its adoption. The other challenge is limited expertise at 26.1%. This shows a perceived shortage of skilled professionals that can execute and manage blockchain effectively, which could slow the adoption. Regulatory challenges at 1.1% was also shown as a barrier, thus suggesting that while regulations are recognised as an issue, they are not seen to be the main obstacle to adoption of blockchain in Zambia's ICT sector. Here we can conclude that there is need for the government to have educational initiatives, provide financial support and embark on skills development to promote the adoption of blockchain technology for the ICT sector in Zambia. Furthermore, the findings suggest that addressing these obstacles will require targeted capacity-building efforts and the creation of a supportive regulatory framework to enable the integration of blockchain into Zambia's cybersecurity infrastructure [57].

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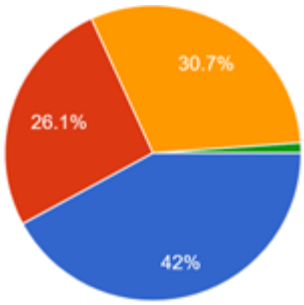

Figure 8: Challenges to Blockchain Adoption in Zambia's ICT Sector – 42%

DISCUSSION OF RESULTS

Significance of Blockchain in Enhancing Cyber Security

The study highlights the transformative potential of blockchain technology in addressing critical cybersecurity challenges within Zambia's ICT sector. Blockchain's decentralized, tamper-proof ledger enhances the integrity and protection of digital transactions, particularly against sophisticated cyber-attacks targeting centralized data repositories, which are more vulnerable to breaches [58]. By distributing data across multiple nodes, blockchain minimizes the risk of single points of failure, reducing unauthorized access and data manipulation risks [59].

The study emphasizes blockchain's ability to enhance transparency and accountability in digital transactions, which is crucial in trust-sensitive sectors such as financial services, supply chain management, and government operations. Blockchain's immutable nature ensures that recorded transactions cannot be altered without network consensus, making it ideal for applications requiring high data integrity [60]. Additionally, its capacity to trace transactions to their origin adds a layer of security, aiding in the prevention and detection of fraudulent activities [61].

Rationale Behind Blockchain's Superiority Over Traditional Methods

Blockchain's superiority over traditional cybersecurity methods lies in its decentralized architecture, which contrasts with the centralized systems prevalent in Zambia's ICT infrastructure. Traditional systems rely on a single authority or database, making them vulnerable to cyber-attacks such as Distributed Denial of Service (DDoS) attacks, data breaches, and unauthorized access [62]. In contrast, blockchain distributes control across a network of participants, requiring consensus for any data changes, thereby creating a more secure and resilient system [63].

The study's comparative analysis highlights blockchain's enhanced resistance to tampering, a key advantage in protecting data integrity from malicious actors targeting centralized systems [64]. Blockchain's cryptographic techniques, such as hashing and digital signatures, ensure that any data alteration attempts are immediately detectable, as mismatched cryptographic hashes alert the network to tampering [65]. This capability is particularly valuable for safeguarding sensitive information and ensuring compliance with data protection regulations [66].

Challenges and Considerations for Blockchain Implementation

While blockchain offers significant benefits, the study identifies challenges that could hinder its adoption in Zambia's ICT sector. A major barrier is the lack of awareness and understanding of blockchain among key stakeholders, including government officials, ICT professionals, and the public [67]. This knowledge gap may slow adoption, necessitating targeted educational and awareness campaigns to highlight blockchain's benefits and applications [68].

Another challenge is the inadequate regulatory environment, which is not currently equipped to address blockchain's unique characteristics. Existing regulations may need revision or new policies introduced to support blockchain-based solutions, including legal frameworks for data transactions and guidelines for secure implementation [69][70]. Additionally, the shortage of technical expertise in blockchain is a critical issue. Building capacity through training programs and academic courses will be essential for implementing and maintaining blockchain systems [71].

Implications for Future Research and Policy Development

The study's findings have significant implications for future research and policy development in Zambia's ICT sector. Further research is needed to explore blockchain applications across various sectors, including healthcare, education, and public administration. Pilot projects testing blockchain solutions in real-world scenarios could offer insights into practical challenges and benefits [72].

From a policy perspective, the study emphasizes the need for a comprehensive regulatory framework to support blockchain adoption. This includes clear guidelines for its use, ensuring data privacy and security, and fostering innovation while protecting consumers and businesses [73]. Policymakers might incentivize blockchain integration into Zambia's ICT infrastructure through tax breaks, grants, or other supportive measures [74].

The study underscores blockchain's potential to enhance cybersecurity by ensuring data transaction integrity and protection. However, realizing this potential requires addressing challenges such as limited awareness, regulatory gaps, and a shortage of technical expertise. Targeted education, policy reforms, and capacity-building initiatives will be essential for successful blockchain integration in Zambia's ICT sector [75].

CONCLUSION

This study highlights the significant potential of blockchain technology to enhance cybersecurity in Zambia's ICT sector by ensuring data transaction integrity and protection. Blockchain's key attributes immutability, transparency, and decentralization make it a robust solution for addressing the prevalent cybersecurity challenges in the country's ICT infrastructure, where current frameworks are insufficient and prone to data breaches and unauthorized access. Blockchain mitigates these vulnerabilities by creating a secure, tamper-resistant environment for digital transactions.

The study also identifies major barriers to blockchain adoption, including limited awareness among stakeholders, regulatory challenges, and a lack of technical expertise. Overcoming these barriers is critical to fully leveraging blockchain's potential for enhancing cybersecurity in Zambia.

Additionally, blockchain strengthens data integrity, traceability, and accountability, which are crucial for combating cybercrimes such as fraud and unauthorized data manipulation. By recording all transactions

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on an immutable and transparent distributed ledger, blockchain reduces the risk of tampering and makes cyber-attacks more challenging.

The findings conclude that blockchain offers a transformative solution for cybersecurity in Zambia's ICT sector. However, successful implementation will require collaboration among the community, industry stakeholders, and the government. By addressing these barriers and adopting recommended strategies, Zambia can lead in leveraging blockchain for secure digital transactions and data integrity in an increasingly digital world.

RECOMMENDATIONS

Based on the study's findings, there are recommendations to be made to enable the adoption and implementation of blockchain technology in Zambia's ICT sector:

C. **Awareness, Education Campaigns, and Technical Training Investment**:
Public and private sectors must invest in blockchain education and skills development. Campaigns should be designed with industry experts and academic institutions, covering topics such as smart contracts, blockchain architecture, and cybersecurity best practices to facilitate effective implementation.

D. **Pilot Projects and Case Studies**: Pilot projects should be launched in Zambia's ICT sector to test blockchain solutions in real-world scenarios. These initiatives will provide practical insights into feasibility and impact, encouraging broader adoption of blockchain technology across various sectors.

I. **Collaboration with International Partners**: Zambia should collaborate with international organizations experienced in blockchain technology to exchange knowledge, access advanced solutions, and align with global cybersecurity standards. Partnerships can also provide funding and resources to support large-scale blockchain implementation.

II. **Regulatory Framework Development**: The Zambian government should establish comprehensive regulatory frameworks to support blockchain adoption. These frameworks should address data privacy, security standards, and the legal recognition of blockchain transactions, ensuring organizations have clear guidelines and compliance with international cybersecurity standards.

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