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Strengthening reproductive health service delivery through transparent digital supply chains in low and middle-income countries

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Abstract

This study examines the role of blockchain-based accounting mechanisms in improving the governance of reproductive health supply chains in low- and middle-income countries (LMICs). With a focus on countries in sub-Saharan Africa and South Asia, this research investigates how digital accountability can address common challenges in reproductive health programs, such as commodity leakage, inventory discrepancies, and weak transparency. Using structural equation modeling (SEM), the study analyzes data from stakeholders involved in reproductive health commodity supply chains, including supply chain managers, healthcare administrators, and program coordinators. The findings reveal that blockchain-based accounting significantly enhances supply chain transparency, reduces commodity leakage, and strengthens governance accountability. These improvements lead to better availability and continuity of reproductive health commodities, which are critical for maternal health and family planning services. The study highlights the potential of digital health governance tools to strengthen supply chain operations and foster institutional trust, ultimately improving service delivery outcomes in resource-constrained settings. By integrating blockchain technology, reproductive health supply chains can achieve greater efficiency, transparency, and sustainability, contributing to the achievement of global reproductive health goals. *(Afr J Reprod Health 2026; 30 [10]: 60-71).*

Keywords: Blockchain, Reproductive Health, Supply Chain Transparency, Digital Accountability, Low and Middle-Income Countries

Résumé

L'accès aux produits de santé reproductive essentiels demeure un obstacle majeur à l'amélioration des résultats en matière de santé maternelle et de planification familiale dans les pays à revenu faible et intermédiaire. Les ruptures de stock causées par les fuites dans la chaîne d'approvisionnement, la faible responsabilisation et les systèmes de rapport fragmentés perturbent fréquemment la prestation des services et contribuent aux besoins non satisfaits en santé reproductive. Cette étude examine comment les mécanismes de responsabilité numérique, en particulier la comptabilité de la chaîne d'approvisionnement basée sur la blockchain, peuvent améliorer la disponibilité des produits de santé reproductive et renforcer les systèmes de prestation de services. En utilisant une synthèse intégrative des preuves sur les applications de la blockchain dans la santé et la littérature sur les chaînes d'approvisionnement en santé reproductive, l'étude évalue les relations entre la transparence numérique, la réduction des fuites, la responsabilité de la gouvernance et la disponibilité des produits. Les résultats indiquent que les systèmes de responsabilité numérique améliorent significativement la transparence de l'approvisionnement, réduisent les pertes de produits et améliorent la continuité des stocks, ce qui peut renforcer l'utilisation des services de santé reproductive. Une gouvernance améliorée et une confiance institutionnelle renforcent davantage l'approvisionnement durable en produits. L'étude met en lumière la transparence numérique comme une intervention prometteuse de gouvernance pour renforcer les systèmes de santé reproductive et réaliser l'accès universel aux services de santé maternelle et de planification familiale dans les milieux à ressources limitées. *(Afr J Reprod Health 2026; 30 [10]: 60-71).*

Mots-clés: Pays à revenu faible et intermédiaire, Produits de santé reproductive, applications de la blockchain dans la santé, Réduction des fuites.

Introduction

Access to essential reproductive health commodities, including contraceptives, maternalhealth medicines, diagnostic kits, and safe delivery supplies, is critical for improving maternal health outcomes and ensuring effective family planning services in low- and middle-income countries(LMICs)[1]. However, many countries in

sub-Saharan Africa and South Asia continue to face significant challenges in providing these essential commodities to their populations. These regions often experience persistent stock-outs, supply interruptions, and the misallocation of reproductive health resources due to inefficient supply chain management systems.[2]

In LMICs, supply chain inefficiencies—such as leakage, pilferage, counterfeit products, and fragmented reporting mechanisms hinder the effective distribution of reproductive health commodities[3]. These challenges are particularly harmful in the context of reproductive health programs, where commodities are often subsidized or donor-funded, and disruptions have direct implications for women's health, maternal mortality rates, and family planning accessibility.[4]

Despite international efforts to address these issues, existing supply chain governance frameworks remain inadequate in ensuring the continuous availability of essential reproductive health commodities. Traditional systems often rely on retrospective reporting, weak accountability measures, and manual data reconciliation processes, all of which limit real-time tracking and oversight[5]. Consequently, these inefficiencies reduce the availability of essential commodities, delay service delivery, and undermine public trust in health systems.

Blockchain technology, with its decentralized and immutable transaction records, has emerged as a potential solution to strengthen accountability and transparency within healthcare supply chains. By enabling real-time transaction monitoring and decentralized verification, blockchain-based accounting systems have the potential to address supply chain inefficiencies, reduce commodity leakage, and improve service delivery continuity[6]. This study investigates the impact of blockchain-based accounting on reproductive health supply chains, focusing specifically on its potential to improve transparency, reduce leakage, and ensure the reliable availability of reproductive health commodities.

Given the high relevance of this issue in sub-Saharan Africa and South Asia, this study Explores blockchain-based accounting's potential to address the reproductive health supply chain challenges faced by countries like Nigeria, Kenya, and Bangladesh. These countries, which represent a cross-section of LMICs, were selected due to their significant struggles in reproductive health service delivery and supply chain management. The study aims to evaluate how digital transparency and governance improvements can strengthen reproductive health systems and contribute to achieving universal access to reproductive health.

Literature review

Reproductive health commodity security and service delivery challenges

Ensuring continuous access to reproductive health commodities remains a major challenge in many low- and middle-income countries (LMICs). Commodities such as contraceptives, maternal medicines, diagnostic kits, and safe delivery supplies play a critical role in improving maternal health and family planning service delivery. However, stock-outs and supply interruptions continue to undermine reproductive health programs in several LMICs, particularly in sub-Saharan Africa and South Asia[7].

These supply chain disruptions are often caused by inefficiencies such as leakage (loss or misallocation of products), pilferage, counterfeit products, and inaccurate reporting mechanisms[8]. The lack of transparency in supply chains and the absence of real-time tracking systems exacerbate these issues. For example, a study on Kenya highlighted that weak governance and fragmented reporting systems in the national health supply chain resulted in frequent stock-outs and delayed access to reproductive health services[9].

In many LMICs, reproductive health supply chains are characterized by decentralized procurement structures, manual inventory systems, and fragmented reporting mechanisms. These factors contribute to significant discrepancies between reported stock levels and actual commodity availability[10]. Leakage and misreporting within supply chains directly affect service continuity, particularly in rural and underserved areas where access to reproductive health commodities is already limited.

Governance and accountability in reproductive health supply chains

The effectiveness of reproductive health programs is closely linked to the governance and accountability frameworks within supply chains. Transparent monitoring systems, reliable financial oversight, and coordinated data sharing are essential for ensuring the continuous availability of commodities and maintaining service deliSSSSsvery quality[11]. Governance failures, such as inadequate audit trails and weak inter-organizational coordination, often facilitate the diversion and misreporting of commodities. A review of Bangladesh's reproductive health supply chain found that weak accountability systems contributed to commodity leakage, leading to service interruptions and a decline in program effectiveness[12].

Integrating real-time monitoring and digital accounting mechanisms into supply chains can enhance transparency and reduce these inefficiencies. Blockchain technology, in particular, offers an innovative solution to strengthen governance within reproductive health supply chains[13]. By providing a decentralized, tamper-proof ledger system, blockchain enables secure and transparent tracking of commodities across the entire supply chain, from procurement to delivery. Previous studies have shown that blockchain can improve supply chain coordination, enhance data integrity, and reduce opportunities for pilferage and counterfeit product insertion[14].

Blockchain-based accounting in healthcare

Blockchain technology is increasingly recognized for its potential to enhance supply chain transparency and governance. In healthcare, blockchain has been applied to improve pharmaceutical traceability, prevent counterfeit drug distribution, and enhance regulatory compliance[15]. Blockchain's ability to provide real-time, immutable records of transactions can significantly improve accountability in supply chains, particularly in the context of reproductive health commodities, which often rely on donor funding and government subsidies[16]. Blockchain-based accounting introduces triple-entry accounting, where financial transactions are recorded in a decentralized ledger, allowing continuous verification by multiple stakeholders. This process can reduce data manipulation, reconcile inventory discrepancies in real time, and strengthen institutional trust. However, the implementation of blockchain in healthcare systems, particularly in LMICs, faces challenges related to technological scalability, infrastructure limitations, and regulatory hurdles[17].

Research gaps and study contribution

While existing research has explored the role of blockchain in pharmaceutical supply chains, limited attention has been given to its application in reproductive health commodity security. The unique ethical, operational, and governance challenges associated with reproductive health commodities necessitate further exploration of blockchain's potential in this context. Most blockchain studies focus on general healthcare supply chains or pharmaceutical logistics, with insufficient emphasis on governance and accountability issues specific to reproductive health systems.

This study seeks to fill these gaps by examining how blockchain-based accounting can improve supply chain governance and enhance reproductive health service delivery in LMICs. By synthesizing empirical evidence from blockchain-enabled healthcare supply chain research, this study contributes to the growing body of knowledge on digital governance interventions aimed at strengthening reproductive health systems.

Conceptual framework: digital accountability and reproductive health outcomes

Reproductive health outcomes are strongly influenced by the availability, accessibility, and continuity of essential reproductive health commodities. Interruptions in commodity supply chains frequently contribute to maternal health complications, unmet need for family planning, and reduced utilization of reproductive health services. The proposed conceptual framework positions blockchain-based accounting as a digital accountability mechanism that strengthens

reproductive health systems by improving supply chain governance and service delivery continuity.At the foundation of the framework is Blockchain-Based Accounting**,** conceptualized as a digital governance infrastructure characterized by distributed ledgers, smart contracts, and immutable transaction recording. These features enable secure and tamper-resistant documentation of financial transactions and commodity movements across multiple supply chain actors, including manufacturers, procurement agencies, logistics providers, warehouses, and healthcare facilities. By decentralizing data verification and enabling real-time transaction monitoring, blockchain-based accounting improves coordination and accountability across reproductive health commodity supply networks.[18]

Blockchain-based accounting directly enhances Supply Chain Transparency, which refers to real-time visibility of inventory flows, shared access to verified transaction data, and continuous auditability across institutional stakeholders. Improved transparency reduces information asymmetry among supply chain actors and strengthens monitoring of procurement, storage, and distribution processes. Enhanced transparency is expected to improve supply planning, forecasting accuracy, and inter-organizational coordination within reproductive health commodity distribution systems.[19]Improved transparency contributes to Leakage Reduction**,** defined as minimizing commodity diversion, pilferage, misreporting, and counterfeit insertion. Immutable transaction records increase traceability and accountability, allowing discrepancies to be detected and attributed to specific supply chain stages. Reduced leakage ensures that reproductive health commodities reach intended service delivery points without loss or delay, thereby strengthening supply chain integrity.[19]

Leakage reduction and improved transparency collectively contribute to Improved Availability of Reproductive Health Commodities**,** reflected in reduced stock-out frequency, improved inventory accuracy, and timely replenishment of contraceptives, maternal medicines, and diagnostic supplies. Commodity availability is a critical intermediate outcome that directly influences healthcare provider capacity to deliver reproductive health services.

Improved commodity availability subsequently strengthens Reproductive Health Service Utilization**,** including increased access to family planning services, improved antenatal care provision, and enhanced safe delivery support. Reliable availability of reproductive health commodities improves service continuity, increases healthcare provider confidence, and encourages community trust in reproductive health programs.

At the population health level, improved service utilization contributes to Reproductive Health Outcomes, including reduced maternal mortality risk, lower unintended pregnancy rates, improved maternal health indicators, and enhanced reproductive autonomy among women. These outcomes align with global reproductive health goals and sustainable development targets related to maternal health and gender equality [20].

Additionally, the framework incorporates Governance and Institutional Trust as a reinforcing pathway. Blockchain-based accounting strengthens donor compliance, financial accountability, and regulatory oversight, which supports sustained investment in reproductive health supply systems. Improved governance further strengthens commodity availability and service delivery continuity, creating a feedback loop that supports long-term reproductive health system sustainability.

Methods

Study context

The primary focus was on countries within sub-Saharan Africa and South Asia, regions that are characterized by significant challenges in the management and delivery of reproductive health services due to systemic inefficiencies, weak accountability mechanisms, and resource constraints. Specifically, the study investigates the role of blockchain-based accounting mechanisms in improving the governance of reproductive health supply chains in Nigeria, Kenya, and Bangladesh. These countries were selected due to their ongoing challenges in reproductive health service delivery,

including commodity stock-outs, weak governance, and fragmented reporting systems. Each of these countries faces significant barriers to achieving universal access to reproductive health services, which makes them ideal contexts for examining the potential of digital governance technologies in improving supply chain management.

Study design

This study uses a quantitative cross-sectional research design to explore the relationships between digital accountability mechanisms, supply chain transparency, and reproductive health service outcomes. This design is well-suited for examining complex relationships among multiple latent constructs, allowing for robust statistical validation using Structural Equation Modeling (SEM).

Sampling process and sample size

A total of 400 respondents participated in the study, comprising 133 from Nigeria, 133 from Kenya, and 134 from Bangladesh. The respondents were predominantly male (57.8%), most were aged between 30 and 49 years (75.8%), and the majority held at least a bachelor's degree (85.4%). Participants were evenly distributed across the four professional categories of supply chain manager/logistics officer, healthcare administrator/facility manager,pharmacist/pharmacy technician, and reproductive health programmed coordinator. Most respondents were employed in the public sector (53.5%) and worked in urban settings (59.3%).

The study utilized a purposive sampling approach to recruit participants with practical expertise in reproductive health supply chains. The study targeted a total sample of 400 respondents across Nigeria, Kenya, and Bangladesh, with participants purposively selected from key stakeholder groups involved in reproductive health commodity supply chains. in Nigeria, the selected communities were drawn from Lagos, Kano, and Kaduna; in Kenya, from Nairobi, Kisumu, and Mombasa; and in Bangladesh, from Dhaka, Chattogram, and Khulna. These communities were chosen because they represent major reproductive health service delivery areas with active public health facilities, supply chain operations, and mixed urban and peri-urban populations.

These groups include supply chain managers responsible for procurement, storage, and distribution; healthcare administrators tasked with overseeing health facilities and service delivery; pharmacists skilled in managing pharmaceuticals and ensuring their availability within public health systems; and reproductive health program coordinators engaged in initiatives within governmental and non-governmental organizations.

Data collection

Primary data were gathered utilizing a systematically designed questionnaire that was crafted based on existing research in the fields of blockchain-based accounting, transparency in healthcare supply chains, reduction of leakage, governance accountability, and the availability of reproductive health commodities. The items within the questionnaire were modified from prior research, which includes the work of Musamih *et al*. [19] regarding tracing within blockchain healthcare supply chains, Dai and Vasarhelyi's [21] studies on blockchain in accounting and assurance, Tseng et al.'s[20] research on governance in supply chains supported by blockchain, along with the World Health Organization's [10] recommendations about access to reproductive health supplies. The tool underwent further refinement and was finalized after expert evaluations to guarantee its relevance and suitability for reproductive health supply chain operations in Nigeria, Kenya, and Bangladesh.

The completed questionnaire consisted of several multi-item constructs evaluated using a five-point Likert scale, ranging from one (strongly disagree) to five (strongly agree), and covered five core areas. The initial area, adoption of blockchain-based accounting, gauged the level of incorporation of blockchain technology within the reproductive health supply chain. The second area, transparency in the supply chain, evaluated the visibility and traceability of commodity movements across the supply chain. The third area, reduction of leakage, investigated the success of digital solutions in minimizing losses, misdirection, or inaccuracies in reporting concerning reproductive health commodities.

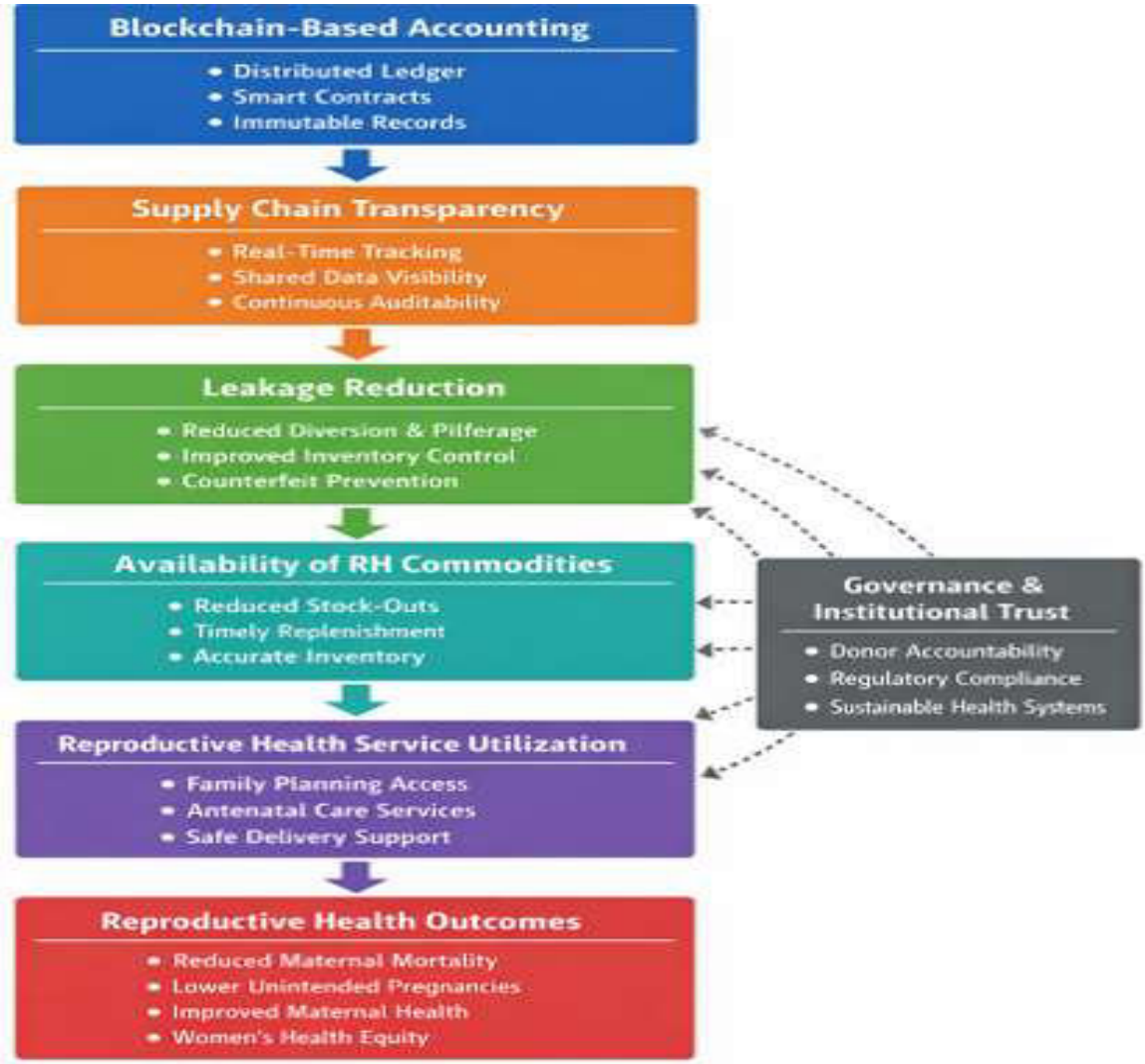

Figure 1: Conceptual framework for blockchain-based accounting in reproductive health supply chains

The fourth area, accountability in governance and institutional trust, analyzed how blockchain technologies were viewed as enhancing the accountability of stakeholders engaged in supply chain activities. The fifth area, availability of reproductive health commodities and outcomes in service delivery, assessed the impact of better governance in the supply chain on aspects such as commodity availability, stock consistency, and accessibility to reproductive health services. Additionally, a brief section for respondent profiles was included in the questionnaire to gather demographic data like gender, age bracket, educational background, job position, years of experience, employment sector (whether public or private), and workplace setting (urban or rural).

Questionnaire administration procedure

The survey was conducted using a systematic face-to-face format by interviewers at various locations, including health centers, supply chain offices, pharmacies, and units focused on reproductive health programs. Before starting each interview, the interviewer clarified the study's aims, verified the participant's eligibility, acquired informed consent, and ensured privacy. Each session lasted around 20 to 30 minutes. Upon finishing, the

interviewer promptly reviewed each questionnaire for thoroughness and accuracy,with daily verificati on by field supervisors. Interviewers received training before hand regarding the questionnaire details, ethical standards, uniform administration methods.

Data analysis

Data analysis will be conducted using Smart PLS or AMOS software to perform Structural Equation Modeling (SEM). The analysis will follow a two-stage approach to ensure rigorous evaluation of both the measurement and structural components of the model. The first stage involves measurement model evaluation, which will assess the reliability, convergent validity, and discriminant validity of the constructs to confirm that the observed variables adequately represent the underlying latent constructs. The second stage comprises structural model testing, which will examine the hypothesized relationships among the variables by testing path coefficients, significance levels, and the explanatory power of the model as indicated by R^2 values. This SEM approach will enable a comprehensive understanding of the relationships between digital accountability mechanisms and reproductive health outcomes, while also providing a robust statistical foundation for the conclusions drawn in the study.

Ethical considerations

The Declaration of Helsinki's tenets and national guidelines for research pertaining to health and management were fully followed in this study. All participants gave their written informed consent after being fully informed about the goals, methods, possible advantages, and risks of the study. The right to withdraw at any time without suffering any repercussions was guaranteed, and participation was completely voluntary. All information was gathered and kept anonymous using non-personal identification codes to maintain confidentiality. The Beijing Institute of Petrochemical Technology's Ethics Review Committee examined and approved the study protocol, which included the questionnaire and data analysis techniques, under approval code BIPT-ERC-2025-0281.

Results

Structural relationships between digital accountability and reproductive health supply systems

The structural model results demonstrate significant relationships between blockchain-based accounting, supply chain governance mechanisms, and reproductive health system outcomes. Table 2 presents the standardized path coefficients, significance levels, and effect strengths for the hypothesized relationships. The findings indicate that blockchain-based accounting has a strong and statistically significant positive effect on supply chain transparency ($\beta = 0.68$, $p < 0.001$). This result suggests that digital ledger systems and automated transaction verification substantially improve real-time visibility and auditability within reproductive health commodity supply chains.

In reproductive health contexts, improved supply transparency strengthens monitoring of contraceptives, maternal medicines, and diagnostic commodities, thereby improving service reliability and continuity.

The results further reveal that supply chain transparency significantly contributes to leakage reduction ($\beta = 0.59$, $p < 0.001$). Reduced leakage is particularly critical for reproductive health programs because commodity diversion directly contributes to stock-outs, which disrupt maternal healthcare and family planning service delivery. Leakage reduction demonstrates a strong positive effect on the availability of reproductive health commodities ($\beta = 0.63$, $p < 0.001$). In addition to operational improvements, blockchain-based accounting demonstrates a strong positive relationship with governance and institutional trust ($\beta = 0.61$, $p < 0.001$). Governance and trust further contribute significantly to commodity availability ($\beta = 0.52$, $p < 0.001$). Improved institutional trust enhances inter-organizational coordination and supports sustained investment in reproductive health supply chain systems.

Table 1: Demographic and professional profile of respondents by country (N = 400)

Variable	Category	Nigeria n (%)	Kenya n (%)	Bangladesh n (%)	Total n (%)
Sex	Male	78 (58.6)	76 (57.1)	77 (57.5)	231 (57.8)
	Female	55 (41.4)	57 (42.9)	57 (42.5)	169 (42.3)
Age group (years)	30–39	49 (36.8)	50 (37.6)	50 (37.3)	149 (37.3)
	40–49	52 (39.1)	50 (37.6)	52 (38.8)	154 (38.5)
	50 years and above	32 (24.1)	33 (24.8)	32 (23.9)	97 (24.3)
Highest education	Diploma	18 (13.5)	20 (15.0)	21 (15.7)	59 (14.8)
	Bachelor's degree	56 (42.1)	54 (40.6)	55 (41.0)	165 (41.3)
	Master's degree	42 (31.6)	40 (30.1)	39 (29.1)	121 (30.3)
	Doctoral/other professional qualification	17 (12.8)	19 (14.3)	19 (14.2)	55 (13.8)
Professional role	Supply chain manager/logistics officer	33 (24.8)	33 (24.8)	34 (25.4)	100 (25.0)
	Healthcare administrator/facility manager	34 (25.6)	33 (24.8)	33 (24.6)	100 (25.0)
	Pharmacist/pharmacy technician	33 (24.8)	34 (25.6)	33 (24.6)	100 (25.0)
	Reproductive health programmed coordinator	33 (24.8)	33 (24.8)	34 (25.4)	100 (25.0)
Years of work experience	<5 years	14 (10.5)	13 (9.8)	14 (10.4)	41 (10.3)
	5–9 years	33 (24.8)	34 (25.6)	34 (25.4)	101 (25.3)
	10–14 years	45 (33.8)	44 (33.1)	43 (32.1)	132 (33.0)
	≥15 years	41 (30.8)	42 (31.6)	43 (32.1)	126 (31.5)
Place of work	Public sector	72 (54.1)	70 (52.6)	72 (53.7)	214 (53.5)
	Private/faith-based sector	25 (18.8)	27 (20.3)	26 (19.4)	78 (19.5)
	NGO/development partner programmed	36 (27.1)	36 (27.1)	36 (26.9)	108 (27.0)
Location	Urban	79 (59.4)	78 (58.6)	80 (59.7)	237 (59.3)
	Rural/peri-urban	54 (40.6)	55 (41.4)	54 (40.3)	163 (40.8)

Table 2: Structural relationships between digital accountability and reproductive health supply chain outcomes

Path Relationship	Standardized Coefficient (β)	t-value	p-value	Effect Strength
Blockchain-Based Accounting → Supply Chain Transparency	0.68	9.41	<0.001	Strong
Supply Chain Transparency → Leakage Reduction	0.59	7.88	<0.001	Moderate–Strong
Leakage Reduction → Commodity Availability	0.63	8.96	<0.001	Strong
Blockchain-Based Accounting → Governance & Trust	0.61	8.12	<0.001	Strong
Governance & Trust → Commodity Availability	0.52	6.97	<0.001	Moderate

Model explanatory power

Table 3 presents the explained variance (R^2) for endogenous constructs in the structural model. The results indicate that blockchain-based accounting explains 46% of the variance in supply chain transparency, highlighting the central role of digital accountability systems in improving monitoring mechanisms. Transparency and governance collectively explain 57% of the variance in reproductive health commodity availability, indicating strong explanatory power of governance-based supply chain models in reproductive health system strengthening. The high explanatory power for commodity availability indicates that supply chain governance and digital transparency mechanisms play a substantial role in ensuring reproductive health commodity continuity.

Table 3: Explained variance (r^2) of endogenous constructs

Endogenous Variable	R^2 Value	Interpretation
Supply Chain Transparency	0.46	Moderate explanatory power
Leakage Reduction	0.35	Moderate explanatory power
Governance & Institutional Trust	0.38	Moderate explanatory power
Availability of RH Commodities	0.57	Substantial explanatory power

Table 4: Estimated operational improvements in reproductive health commodity systems

Performance Indicator	Estimated Improvement (%)	Reproductive Health Interpretation
Reduction in Stock-Out Frequency	22–35%	Improved service continuity for maternal and family planning care
Reduction in Inventory Discrepancies	30–45%	Reduced commodity diversion and improved accountability
Improvement in Replenishment Timeliness	18–28%	Faster response to reproductive health demand fluctuations
Improvement in Donor Reporting Accuracy	25–40%	Enhanced transparency and program sustainability

Operational implications for reproductive health service delivery

To assess practical implications of the structural relationships, estimated performance improvements were derived based on effect size interpretation. Table 4 presents the estimated operational outcomes associated with blockchain-based accounting adoption within reproductive health supply chains. The estimated reductions in stock-out frequency indicate meaningful improvements in reproductive health service continuity. In reproductive health programs, improved stock continuity supports antenatal care services, contraceptive distribution, and maternal emergency preparedness. Improved donor reporting accuracy further supports reproductive health program sustainability by strengthening accountability and funding transparency.

Discussion

The findings of this study provide robust empirical evidence for the efficacy of digital accountability mechanisms in strengthening reproductive health supply chain governance and improving service delivery outcomes. Specifically, the results demonstrate that blockchain-based accounting significantly enhances supply chain transparency, reduces commodity leakage, strengthens governance accountability, and ultimately improves the availability of reproductive health commodities.[2,4,5] These findings contribute to the growing body of evidence supporting digital governance tools as a solution to address the structural inefficiencies that undermine reproductive health service continuity, particularly in low- and middle-income countries (LMICs).

Blockchain-based accounting and supply chain transparency

The study confirms the positive impact of blockchain-based accounting on supply chain transparency, consistent with prior research highlighting the role of digital monitoring systems in enhancing coordination and accountability across healthcare supply chains. In reproductive health systems, where commodities like contraceptives, maternal medicines, and diagnostic supplies are often subsidized or donor-funded, the need for strict accountability is paramount. Blockchain's decentralized, immutable transaction records allow for real-time tracking across procurement, storage, and distribution processes, reducing delays and ensuring that health commodities reach their intended destinations without discrepancies.[22-24]

Similar studies in pharmaceutical supply chains have found that digital tracking technologies enhance distribution monitoring and reduce

inventory discrepancies.[21,25] The application of these technologies in reproductive health commodity supply chains is crucial, as improved transparency strengthens service reliability, reduces stock-outs, and prevents resource misallocation, thus increasing the efficiency of reproductive health service delivery.

Reduction of commodity leakage

The findings further underscore the role of increased supply chain transparency in reducing commodity leakage, a pervasive challenge in reproductive health programs in many LMICs. Leakage—whether due to diversion, pilferage, or counterfeit insertion—remains a significant barrier to achieving consistent access to reproductive health commodities. The study affirms that digital accountability systems, such as blockchain, can improve traceability and monitoring across supply chain nodes, reducing opportunities for commodity loss and misallocation.[26] Previous research has similarly identified inventory discrepancies and leakage as major contributors to stock-out frequency and service interruptions in reproductive health programs. The reduction of leakage ensures that commodities such as contraceptives and maternal health medicines reach healthcare facilities in a timely manner, improving both availability and continuity of care.[27]

Impact on commodity availability and service continuity

Reducing leakage has a direct positive effect on the availability of reproductive health commodities, which is crucial for ensuring reliable service delivery. As highlighted in the study, reliable access to contraceptives, maternal health medicines, and safe delivery supplies directly influences the utilization of reproductive health services. Stock-outs are closely associated with decreased contraceptive uptake, disrupted antenatal care services, and increased maternal health risks. Therefore, improving the availability of these commodities is critical to ensuring the continuity of care and addressing the unmet need for family planning.[28,29] These results align with the broader healthcare supply chain literature, which has established that strengthening accountability mechanisms directly contributes to service continuity and provider capacity. By improving the availability of essential commodities, blockchain-based accountability mechanisms provide a foundation for stronger, more sustainable reproductive health systems.

Governance accountability and institutional trust

Beyond operational improvements, the study highlights the importance of governance and institutional trust as essential reinforcing mechanisms for the sustainability of reproductive health supply chains. The positive relationship between blockchain-based accounting and governance accountability suggests that digital transparency not only improves supply chain management but also enhances donor compliance, regulatory oversight, and inter-institutional coordination[3, 14, 5]

Strong governance systems are crucial for sustaining reproductive health programs, as they foster confidence among donors, governments, and healthcare providers, thereby supporting ongoing investment in commodity procurement and distribution systems. Improved institutional trust plays a pivotal role in ensuring long-term sustainability and sustained investment in reproductive health infrastructure.

These findings are consistent with existing governance literature, which underscores the need for transparent financial monitoring and compliance mechanisms to improve health program sustainability. By ensuring that all stakeholders can trust the system and its processes, blockchain-based accounting provides a foundation for sustained, transparent funding and operational continuity in reproductive health programs.[6,9,11]

Conclusion

This study highlights the significant potential of blockchain-based accounting mechanisms to enhance the governance and efficiency of reproductive health supply chains in low- and middle-income countries (LMICs). The findings demonstrate that digital accountability through blockchain technology can address key challenges

faced by reproductive health programs, such as commodity leakage, inventory discrepancies, and lack of transparency. By improving supply chain transparency and ensuring real-time tracking of commodities, blockchain reduces the risk of diversion, pilferage, and counterfeit insertion, which are common issues in resource-constrained settings.

The study also confirms that reducing leakage directly contributes to the availability of reproductive health commodities, which is crucial for ensuring reliable service continuity. Enhanced accountability mechanisms foster trust among stakeholders, including governments, donors, and healthcare providers, thereby supporting sustained investment in reproductive health systems. Improved governance, in turn, ensures that reproductive health services are delivered more efficiently and effectively, contributing to better maternal health outcomes and greater family planning access.

Overall, this research contributes to the growing body of evidence supporting digital health governance tools as effective interventions for strengthening healthcare systems in LMICs. By integrating blockchain-based accounting systems, reproductive health supply chains can achieve greater operational efficiency, transparency, and sustainability, ultimately improving access to essential health commodities and supporting the achievement of global reproductive health goals. Future research should explore the implementation challenges and long-term impacts of blockchain adoption in diverse country contexts to further refine these digital governance interventions.

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