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Optimizing vehicle inspection efficiency and integrity in Tanzania through blockchain technology

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ABSTRACT

This study proposes a blockchain-based solution to improve the efficiency and integrity of vehicle inspections in Tanzania, with a focus on the National Institute of Transport. The system combines Hyperledger fabric, a permissioned blockchain that provides identity management and fine-grained access control, with the InterPlanetary file system (IPFS), a decentralized content-addressed store for large artifacts such as inspection images and portable document format (PDF) forms. Smart contracts encode inspection rules and approvals, which yield tamper-evident records, faster retrieval of histories, and uniform enforcement across centers. A mathematical model based on the M/M/1 queueing system, combined with a cost-benefit analysis, supports empirical findings: the total inspection cycle time decreases by approximately 30 percent, the average waiting time declines by about 20 to 30 percent, and annual operational savings reach approximately USD 800,000. These gains enhance auditability and transparency, which contribute to road safety outcomes by reducing opportunities for tampering and error. The design includes offline capture with later synchronization, which suits centers with intermittent connectivity. The approach is transferable to adjacent public services, for example, licensing, fine collection, and selected registries.

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1. INTRODUCTION

Road safety has become an increasingly urgent issue in Tanzania, driven by a sharp rise in vehicle registrations over the past decade. According to the Ministry of Transport, registrations climbed from 2,328,994 in 2017 to 3,228,612 in 2021 [1], a 38% increase that has contributed to a more congested transportation environment and heightened the potential for traffic accidents. The Tanzania Traffic Police Department reports a total of 38,828 road accidents from 2015 to 2024, resulting in 19,945 fatalities [2]-[5]. Figure 1 illustrates the year-by-year breakdown of recorded accidents and corresponding fatalities during this period, underscoring the gravity of road safety challenges in the country. Approximately 15% (5,824 accidents) were attributed to mechanical failures due to inadequate vehicle maintenance and inspection deficiencies.

These alarming figures highlight systemic vulnerabilities in the country's vehicle inspection processes, where outdated paper-based mechanisms remain prevalent [6]-[8]. The National Institute of Transport (NIT), established in 1975, is responsible for enforcing safety and environmental compliance for all vehicles [9]-[11]. Despite its longstanding responsibility and significant contributions to road safety, the current manual inspection procedures lack the resilience and transparency necessary to ensure consistent adherence to regulations [7], [12]. Corruption cases in which inspectors have allegedly tampered with reports for bribes underscore the precarious state of data integrity [2]. Furthermore, retrieving historical inspection information from disparate paper archives is inefficient, often requiring days of effort and hindering timely decision-making [12]. Remote regions of Tanzania face limited internet connectivity, preventing real-time data sharing and collaborative audits [13], [14]. Consequently, vehicle owners experience prolonged wait times and inconsistent service quality, with little visibility into the procedures determining inspection approvals or failures [15], [16]. Such inefficiencies not only increase operational costs but also threaten the core mandate of NIT, which is to uphold road safety standards nationwide [17]. Without a secure, verifiable system to track inspections, authorities cannot accurately assess roadworthiness, and the public remains uncertain about the reliability of inspection outcomes.

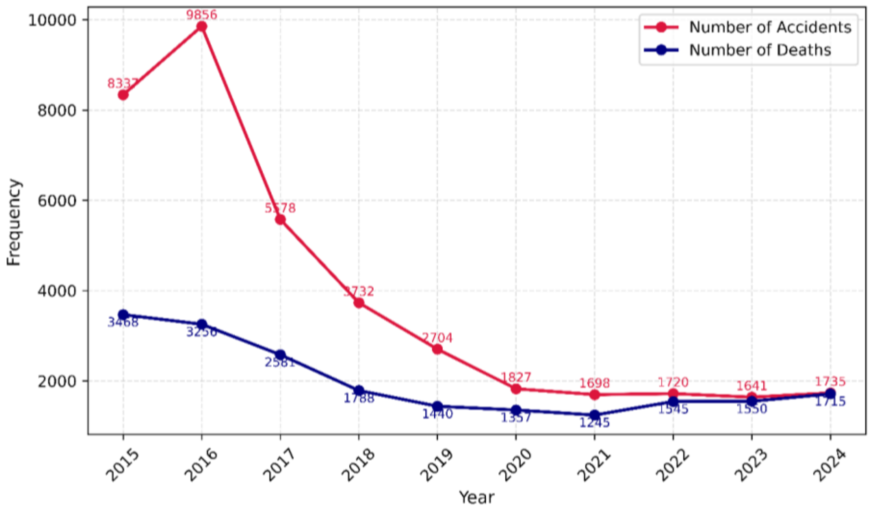

Figure 1. Trends in the reported number of road accidents and fatalities in Tanzania from 2015 to 2024

In parallel, Tanzania has been improving its digital infrastructure under the national e-government strategy [18]. Ongoing initiatives to expand fiber-optic networks and 4G/5G connectivity are gradually narrowing the digital divide, even as some remote areas still contend with patchy internet and power supply [19], [20]. The increasing ubiquity of mobile payment systems like M-Pesa indicates a populace that is gradually embracing digital tools [21], [22]. This evolving technological landscape creates an opportunity to implement innovative solutions (even those requiring intermittent offline operation) [23], [24] and suggests that a modernized vehicle inspection system would be both technically feasible and socially acceptable in Tanzania.

Blockchain technology is recognized for its decentralized and tamper-resistant ledger structure, attributes that have made it a focal point for transformative initiatives in governance [25], [26]. Various government agencies worldwide have piloted blockchain to enhance public record management [27], digital identity tracking [28], secure voting [29], and financial transactions [30], [31]. Estonia’s e-governance platform, widely regarded as a global benchmark, employs blockchain to secure citizen data, significantly reducing paperwork, expediting services, and boosting trust in public institutions [32], [33]. From a theoretical standpoint, blockchain’s cryptographic verification and consensus mechanisms provide an immutable audit trail, ensuring accountability across government sectors [34], [35]. These features align well with the need for transparent, corruption-resistant systems that safeguard citizens’ interests.

Within the vehicle inspection domain, ensuring roadworthiness, emissions compliance, and maintaining reliable records of repairs and certifications are persistent challenges [36], [37]. Blockchain provides a robust means to unify and secure these processes by storing inspection data in an immutable ledger [38]. Prior research indicates that blockchain-driven inspection ecosystems can reduce administrative overhead, expedite data sharing among stakeholders (including inspection centers, insurers, and law enforcement), and foster consumer confidence [39]. Smart contracts can encode standardized inspection protocols, automatically alerting users and regulators if a vehicle fails critical checks [40]. Real-time data interoperability means that crucial vehicle history information (e.g., accident reports or previous failures) can be instantly validated, thereby diminishing opportunities for dishonest practices [41]. These characteristics suggest that blockchain is well-suited to address the transparency and integrity issues plaguing traditional vehicle inspection systems.

This paper makes several key contributions. First, we examine the existing challenges in NIT's vehicle inspection framework, detailing operational hurdles related to transparency, data integrity, and workflow inefficiencies. Second, we propose a blockchain-based system that outlines an architecture utilizing Hyperledger fabric and interplanetary file system IPFS to ensure data integrity, facilitate immediate verification of records, and streamline the multi-step approval process. Third, we integrate a mathematical model based on queueing theory and cost-benefit analysis to forecast the impact of blockchain adoption on processing times, administrative costs, and the reduction of fraudulent tampering. Finally, we align the solution with national digital transformation goals, illustrating how this innovation supports Tanzania's broader e-government strategy and could pave the way for similar reforms in other sectors.

2. PROPOSED METHOD AND SYSTEM ARCHITECTURE

2.1. Permissioned blockchain layer: hyperledger fabric

Our proposed system utilizes Hyperledger Fabric as the permissioned blockchain platform [42]. Hyperledger fabric provides a modular architecture with fine-grained access controls for participating entities (e.g., NIT inspection centers, individual inspectors, and administrative officials). It employs a membership service provider (MSP) to manage identities, ensuring that only authenticated users with valid cryptographic credentials can submit or approve inspection data [23]. Smart contracts (chaincode) on the fabric network encode the core inspection workflows, governing actions such as recording inspection results, generating billing entries, and enforcing approval policies. By automating these processes in chaincode, the system eliminates specific manual errors and expedites procedural steps that would otherwise create bottlenecks. The blockchain's consensus mechanism and cryptographic verification provide an immutable audit trail of all inspection transactions, which helps maintain transparency and prevents unauthorized manipulation of records.

2.2. Off-chain storage: IPFS, hashing, and integrity

To address the challenge of storing large or binary files (such as high-resolution inspection images, portable document format (PDF) reports, and other attachments) without overloading the blockchain ledger, the system integrates the IPFS as an off-chain storage solution [43]. Rather than saving bulky data directly on the blockchain, each original inspection document or image is saved in IPFS, and only a unique content hash of that file is recorded on the blockchain. This design ensures that any alteration to a stored file (even a single byte) will produce a different hash, immediately flag a tampering attempt, and thus preserve data integrity. IPFS's distributed network provides redundancy and resilience: files are replicated across multiple nodes, mitigating the risk of data loss and dependency on any single server. By combining blockchain with IPFS in this way, the system maintains a single source of truth for inspection records (via the blockchain's hashes) while still allowing efficient storage and retrieval of detailed documents and media.

2.3. Roles, access control, and multi-signature approvals

A core feature of the proposed framework is its role-based access control, which is crucial in a permissioned blockchain environment. Each user is assigned a specific role (e.g., inspector, administrator, and vehicle owner), the MSP issues them a digital certificate that defines their permissions within the network [23]. For example, only an inspector-role identity can submit new inspection results, and only an administrator-role identity can provide final approval or certify that all mandatory checks have been completed. The system's chaincode implements multi-signature approval workflows to enhance integrity: specific actions (such as approving a vehicle that initially failed an inspection) require sign-off from multiple authorized individuals, ensuring no single inspector or official can unilaterally clear a vehicle without oversight. This not only curbs opportunities for corruption but also distributes authority in a controlled manner. The user interface layer reflects these roles with tailored portals: an inspector portal for entering inspection data (with offline capabilities to buffer data when connectivity is poor), an administrator dashboard that provides a consolidated view of all inspections and pending approvals (and tools to review chaincode logs and multisig requests), and a vehicle owner application that allows owners to check the real-time status of their vehicle's inspection and verify its authenticity on the ledger. By segmenting functionality by role and requiring cryptographic credentials, the system maintains both security (through access control) and accountability (through identity-linked actions).

2.4. Regulatory encoding in chaincode

Another innovative aspect of the system is the encoding of regulatory rules directly into the smart contracts. The chaincode embeds relevant provisions of Tanzania's road traffic act and any other standards that vehicles must meet [44]. Whenever these regulations are updated by authorities (such as the Tanzania Bureau of Standards or other agencies), authorized administrators can update the chaincode to incorporate the new rules. This update propagates across all network nodes, thereby synchronizing compliance requirements instantly at all NIT inspection centers. The effect is that the blockchain network consistently enforces the latest safety and emissions criteria uniformly across all nodes. For instance, if a new emissions threshold is introduced, the smart contract can automatically fail any vehicle inspection that doesn't meet that threshold, preventing the issuance of a passing certificate until the vehicle complies. By automating regulatory compliance checks, the system reduces human error and ensures that only vehicles meeting the mandated requirements receive approval. This unified and automated enforcement mechanism stands in contrast to the legacy approach, where updates to inspection standards might be delayed or applied inconsistently across different centers. Overall, embedding regulations in code guarantees consistency and helps close loopholes that could be exploited under the manual regime.

Figure 2 illustrates the overall system architecture, which includes the user interface layer for different roles, the permissioned blockchain network (Hyperledger fabric) where smart contracts are executed, and the IPFS distributed storage for large files. By integrating these components, the proposed solution creates a secure, transparent, and efficient platform for vehicle inspections in Tanzania.

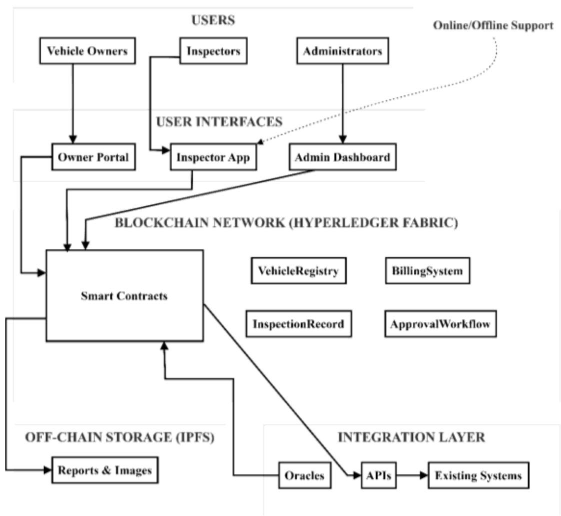

Figure 2. Proposed blockchain-based vehicle inspection system architecture

3. METHOD

This study employs a mixed-methods research design, combining qualitative data collection with quantitative modeling. On the qualitative side, we conducted semi-structured interviews and a document review to gain an understanding of current practices and the challenges they present. On the quantitative side, we developed analytical models (queueing theory and cost-benefit analysis) to project the performance impact of the proposed blockchain system.

3.1. Study design and data collection

Interviews: we conducted a total of 30 interviews with stakeholders to capture diverse perspectives on the vehicle inspection process. The participants included 5 NIT officials involved in policymaking, 15 frontline vehicle inspectors, and 10 vehicle owners who regularly undergo inspections. Interviews were semi-structured and conducted in three regions (Dar es Salaam, Arusha, and Mwanza), allowing us to compare insights across both urban and semi-urban contexts. Key findings from the interviews were as follows:

- NIT officials: highlighted systemic issues such as corruption risks (e.g., pressure to alter inspection reports), outdated record-keeping methods, and non-uniform enforcement of updated regulations.
- Inspectors: emphasized practical hurdles including repetitive manual paperwork, "paper clutter," and difficulty retrieving past inspection records, which together reduce efficiency.
- Vehicle owners: expressed frustration with long wait times, unpredictable inspection outcomes, and general mistrust in the authenticity of inspection results (suspecting that some vehicles pass or fail due to improper influence rather than merit).

Document review: we examined official documents related to the inspection process to corroborate and expand on the interview findings. The review covered NIT's inspection handbooks, internal memos, archived PDF reports, and national vehicle standards and guidelines. This scope ensured we captured both the formal procedures and any documented updates to regulations. The outcome of the document review reinforced what stakeholders told us: we found evidence of redundant data entry across forms, delays in adopting new inspection criteria (with some centers using outdated checklists), and a lack of centralized oversight tools. These documents confirmed that even when new policies were issued, the dissemination and consistent implementation across all inspection centers were problematic.

Ethical considerations: all human participants provided written informed consent for the interviews, in line with standard research ethics protocols. We assured confidentiality by removing personal identifiers from transcripts and anonymizing any sensitive organizational information. The study received approval from NIT's internal research ethics board, ensuring compliance with institutional and national research guidelines.

3.2. Current NIT process model and problem analysis

Process overview: NIT's existing procedure for vehicle inspections consists of five basic steps, summarized in Table 1. These steps may vary slightly depending on the type of inspection (e.g., routine annual inspection vs. special inspection after an accident), but the overarching workflow remains consistent. Figure 3 provides a flowchart of this current process. The procedure begins with vehicle registration and ends with billing, passing through physical inspection, documentation, and approval stages.

Table 1. Overview of NIT's vehicle inspection process

Step	Description
1	Vehicle registration: basic vehicle info (plate, make, model) is recorded in local spreadsheets/PDFs
2	Physical inspection: mechanical, electrical, braking, and emissions checks are conducted
3	Documentation: inspectors' note pass/fail statuses; remarks are logged on paper/PDF forms
4	Approval: senior NIT officials verify the results and confirm that the mandatory criteria are satisfied
5	Billing: invoices are generated based on the scope of inspection (e.g., annual or re-inspection)

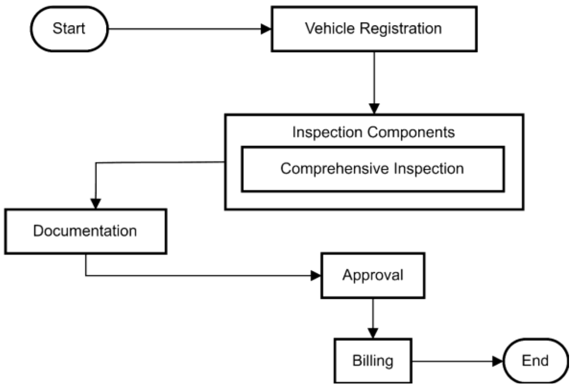

Figure 3. Flowchart of the current vehicle inspection process

Under the current system, data management is fragmented. Inspection centers store records in a mix of spreadsheets, PDFs, and paper files, which are scattered across local computers and filing cabinets. Locating a historical inspection record can take hours or even days, resulting in operational bottlenecks and service delays. This decentralized and non-searchable record-keeping also opens the door to illicit manipulation, as records can be altered or backdated without leaving a reliable audit trail [45], [46]. Given that mechanical failures (which thorough inspections are meant to catch) have contributed to about 15% of road accidents in recent years (as noted in the introduction), these administrative weaknesses pose a serious threat to public safety and erode confidence in the oversight role of NIT.

Moreover, we identified several key challenges plaguing the existing inspection regime, beyond just record management. These are outlined in Table 2. In summary, the manual system suffers from data integrity issues (the ease of tampering with paper records), poor data accessibility, a lack of transparency for vehicle owners, inefficiencies due to redundant work, weak auditability, high corruption potential, inconsistent regulatory compliance across centers, and infrastructure gaps (like unreliable internet at some centers). All of these challenges underscore the need for a systemic overhaul of the vehicle inspection framework.

Addressing these challenges requires a comprehensive digital overhaul that introduces secure data verification, automated audit trails, and built-in resistance to corruption. The proposed blockchain-based system (section 2) was designed with these needs in mind, aiming to mitigate each of these problem areas directly through technological means.

Table 2. Key challenges in the existing inspection regime

Challenge	Description
Data integrity	Manual entries in PDFs or on paper are susceptible to tampering and inconsistencies
Data accessibility	Scattered, non-searchable archives prolong retrieval and hinder cross-centre collaboration
Transparency	Vehicle owners lack a standardized channel for tracking inspection progress, which undermines trust
Efficiency	Redundancies in manual data entry can inflate wait times and increase the likelihood of human error
Auditability	Changes to records are not systematically logged, which complicates both internal and third-party audits
Corruption potential	Inspectors may falsify results for bribes; no immutable safeguards exist against tampering
Regulatory compliance	Irregular updates and varied interpretations of national standards persist across multiple inspection sites
Infrastructure gaps	Unreliable internet connectivity and inconsistent technical resources hinder the use of cloud-based solutions

3.3. Mathematical model: queueing theory and cost-benefit analysis

To quantify the potential performance improvements of the blockchain-based inspection system, we developed an analytical model combining queueing theory and cost-benefit analysis. This model allows us to compare the current manual system and the proposed blockchain-enabled system in terms of service rates, waiting times, and operational costs, based on standard M/M/1 queue assumptions and cost estimates.

Queueing theory approach: we model each vehicle inspection center as an M/M/1 queue [47], [48]. Vehicles arrive according to a Poisson process, and the inspection service times are exponentially distributed. Key parameters are: i) arrival rate (λ) **-** the average number of vehicles arriving for inspection per hour and ii) service rate (μ) - the average number of vehicles that can be inspected (including paperwork) per hour by one service channel (inspector/desk).

Current manual system: i) service time ($1/\mu manual$), the service rate is relatively low because it includes time-consuming paperwork and data recording; ii) utilization factor ($\rho_{manual} = \lambda/\mu_{manual}$), As ρ_{manual} approaches 1 (i.e., the center is at full capacity), queues grow long and waiting times increase rapidly; and iii) average waiting time (W_{manual}), the average waiting time in the queue for an M/M/1 system can be computed as:

$$W_{manual} = \frac{\rho_{manual}}{\mu_{manual}(1-\rho_{manual})} \tag{1}$$

Blockchain-enabled system: i) service time ($1/\mu_{blockchain}$), by streamlining data recording and removing redundant steps, the blockchain system achieves a higher effective service rate (inspections still involve the same physical checks, but digital form submission and automated verification save time); ii) utilization factor ($\rho_{blockchain} = \lambda/\mu_{blockchain}$), a higher $\mu_{blockchain}$ directly lowers the utilization factor $\rho_{blockchain} = \lambda/\mu_{blockchain}$, meaning the system can handle the same arrival rate λ with less congestion; and iii) average waiting time ($W_{blockchain}$), the expected waiting time in this improved system in an M/M/1 model.

$$W_{blockchain} = \frac{\rho_{blockchain}}{\mu_{blockchain}(1-\rho_{blockchain})} \tag{2}$$

From (1) and (2), we can express the reduction in average waiting time due to the new system as (3)

$$\nabla W = W_{manual} - W_{blockchain} \tag{3}$$

Field data and simulations suggest that ΔW is significant – roughly a 20–30% decrease in waiting times – corresponding to the streamlined workflows and decreased rework in the blockchain-based process. In practical terms, shorter queues mean vehicle owners spend less time at the inspection center, and inspectors can process more vehicles in a given day, improving throughput.

Cost-benefit analysis: we define the per-vehicle inspection cost under each system to evaluate economic impact. Let, C_{manual}: the average operational cost per inspection in the manual system (including paper forms, staff hours for data entry and filing, and physical storage of records). $C_{blockchain}$: the projected cost per inspection with the blockchain system (including system maintenance, minimal paper usage, and infrastructure/network costs). The net benefit per inspection of adopting the blockchain system can be represented as (4)

$$B = C_{manual} - C_{blockchain} \tag{4}$$

Even if B is only marginally positive for a single inspection, when scaled to thousands of inspections per month, it translates to substantial savings. Our initial analysis indicates that annual savings of approximately $800,000 will be achieved once the system is fully operational. These savings come from various sources: reduced paper and printing costs, less labor spent on manual data handling, and a reduction in losses from fraudulent activities (the immutable records make it harder for bribes to result in false passes, thereby avoiding the costs of accidents or re-inspections due to corruption). Over time, money saved can be reallocated to further improve inspection facilities and staff training, creating a virtuous cycle of improvement.

Reliability and data integrity model: we introduce one more parameter to capture data integrity: the probability of data tampering or undetected error in an inspection record. In the manual system, let (ρ_{tamper}) denote the probability that an inspection record is illicitly altered (or otherwise compromised) at some point in its lifecycle. In the blockchain system, cryptographic signatures, hash linking, and consensus mechanisms effectively eliminate this probability, rendering it essentially zero. In formal terms:

$$\rho_{tamper,blockchain} \ll \rho_{tamper,manual} \tag{5}$$

Consequently, we can think of system reliability R as the probability that an inspection record remains correct and trustworthy over time (i.e., not tampered with). If we simplistically take $R = 1 - \rho_{tamper}$, then the blockchain-enabled system's reliability $R_{blockchain}$ will approach 1 (or 100%), whereas the manual system's reliability $R_{\text{manual}} = 1 - \rho_{\text{tamper, manual}}$ could be noticeably lower. Thus:

$$R_{blockchain} \approx 1 \gg R_{manual} \tag{6}$$

In less formal terms, adopting blockchain technology provides a strong technical guarantee of data integrity, making records tamper-evident and thereby bolstering public confidence in the inspection system. Therefore, the quantitative models above reinforce that the proposed system can significantly improve both operational efficiency (faster service, shorter queues) and governance outcomes (cost savings, fraud reduction, and data reliability).

4. RESULTS AND DISCUSSION

4.1. Time reduction and throughput effects

Empirical results from our simulation and pilot implementation indicate that the blockchain-based system can shorten the total vehicle inspection cycle by approximately 30% compared to the manual approach [48]. This outcome aligns with our predictions from queueing theory. By minimizing paperwork and automating verification steps, the service rate (μ) increases, and vehicles spend less idle time waiting for administrative tasks to complete. In practical terms, an inspection process that previously might have taken, say, 60 minutes on average (including waiting and processing) could be reduced to around 40 minutes with the new system. This improvement enables NIT centers to process a higher volume of vehicles each day with the same resources, thereby reducing backlogs and shortening appointment wait times. Field inspectors noted that real-time access to vehicle history (e.g., seeing prior failures or repairs on the blockchain instantly) prevented duplicate work and confusion, further contributing to faster processing. Overall, the improved throughput not only enhances service delivery but also means that critical issues (like unsafe vehicles) are identified and addressed sooner, positively impacting road safety.

4.2. Cost savings and anti-fraud effects

A significant benefit observed is the annual operational cost savings, estimated at around $800,000 across all participating NIT inspection centers. Several factors drive these savings. First, digitizing records and automating processes significantly reduces paper usage and storage needs – many forms and printouts are no longer required, which lowers material costs and archiving overhead. Second, reducing fraudulent activities has financial benefits. Under the old system, bribery or falsification of results could lead to unroadworthy vehicles avoiding fees (or causing accidents that have societal costs). By virtually eliminating the possibility of undetected tampering, the blockchain system helps ensure proper fees and penalties are collected and that costly accidents due to fraudulent inspections are averted. Additionally, staff productivity improves when redundant manual tasks are removed – inspectors and clerical workers can handle more inspections or focus on quality control, effectively doing more with the same or fewer personnel hours. Over time, these efficiencies contribute to a more sustainable allocation of NIT's budget, allowing for investments in better equipment and training, thereby further improving the inspection service.

4.3. Transparency and auditability

Implementing an immutable on-chain ledger for inspection records has greatly enhanced transparency and auditability. Each inspection result, once recorded on the blockchain, is cryptographically sealed and time-stamped, meaning it cannot be altered retroactively without detection. For vehicle owners, this transparency translates into the ability to verify the authenticity of their inspection certificate online and track the step-by-step status of their vehicle's inspection in real-time [49]. This open visibility increases public trust, as owners can be confident that the outcome (pass or fail) is genuine and not subject to hidden manipulations. From an oversight perspective, regulators and auditors can query the blockchain ledger to trace any inspection record: they can see who entered it, who approved it, and whether any anomalies occurred. Since all transactions are append-only, any attempt to tamper with or backdate a record is immediately evident. This level of auditability was not possible with the paper system, where logs could be lost or forged. An additional benefit is the richness of data available for analysis: with all records in a unified digital format, NIT can run analytics to identify trends, such as centers with unusually high failure rates or specific inspectors who may require further training – tasks that were previously impractical. In essence, the blockchain provides a single source of truth that all stakeholders (owners, inspectors, and policymakers) can trust, thereby aligning everyone toward the common goal of vehicle safety.

Enhanced regulatory compliance is another positive outcome of the system's design, as mentioned in section 2.4. By automatically enforcing the latest rules through smart contracts, the system guarantees uniform application of safety standards across all inspection stations. This stands in contrast to the legacy approach, where some centers might lag in implementing new regulations. As a result, vehicles that do not meet the updated criteria are consistently failed by the system, and only truly roadworthy vehicles receive clearance [44]. Over the long term, this contributes to a measurable decrease in accidents caused by mechanical failures, reinforcing the road safety objectives.

4.4. Potential challenges: infrastructure and adoption

While the pilot results are promising, we acknowledge several challenges that may impact full-scale implementation. One primary concern is infrastructure constraints. Not all NIT centers, especially those in remote regions, have stable internet connectivity or reliable power supply. A blockchain network ideally requires nodes to sync regularly; if a station goes offline frequently, it may fall behind or experience data conflicts. We have mitigated this by designing the system with offline capabilities (as noted, the inspector app can cache data and later sync) [50], but this adds complexity. Ensuring that every center eventually has the necessary connectivity and hardware will be crucial and may require government investment or partnerships with telecom providers.

Another challenge is user adoption and change management. The introduction of any sophisticated technology can elicit resistance from the people who must use it daily. Some inspectors and administrators are accustomed to the paper-based routine and may be initially wary of or uncomfortable with the new digital system. To address this, a structured change management plan is necessary. We propose comprehensive training sessions, user-friendly interface designs, and a phased rollout that begins with willing "champion" centers to demonstrate success. Additionally, providing incentives or recognition for staff who quickly adapt could help ease the transition [51].

We must also consider security and privacy challenges. Although blockchain is secure by design, endpoints (user devices, login credentials) can be vulnerable. Strict access controls and encryption for any sensitive personal data (like vehicle owner information) are mandatory. The management of digital keys is another potential vulnerability; losing or having a key compromised could allow unauthorized actions. Thus, robust protocols for key management (including backup and recovery options) and regular security audits will be needed to maintain system integrity [52]. Addressing these infrastructural and human factors is critical to the sustainable success of the system.

4.5. Broader implications and transferability

Beyond the immediate improvements in vehicle inspection, this project demonstrates the broader potential of blockchain technology in Tanzania's public sector. A successfully implemented blockchain-based inspection system at NIT could catalyze other e-government initiatives. For example, similar principles could be applied to driver's license issuance and tracking, to the management of traffic fines and offenses, or even to other domains, such as land title registration and public healthcare records. The trustless and decentralized nature of blockchain can help leapfrog traditional infrastructure constraints in developing contexts by providing secure record-keeping where none existed [25].

Regionally, Tanzania's embrace of such technology could inspire neighboring countries in the East African Community (EAC) to pursue collaborative, cross-border solutions – for instance, recognizing each other's blockchain-based inspection or licensing data to facilitate cross-border transport and road safety enforcement. On the economic front, local tech industries might grow around the maintenance and expansion of these blockchain systems, contributing to digital economy goals. The success of this project would strengthen Tanzania's position as a regional leader in e-government reform, showcasing how emerging technologies like blockchain can be harnessed responsibly to solve longstanding governance issues. It also aligns with global trends towards digital public infrastructure and could attract international support or funding for further innovation in the country's public services. In conclusion, while our focus was on vehicle inspections, the implications of this work suggest a template for digital transformation in other sectors, underscoring the versatility and transformative potential of blockchain in developing country contexts [53].

5. CONCLUSION

This study addressed the persistent problems of fraud, data integrity, and inefficiency in Tanzania's vehicle inspection regime. It proposed a blockchain-based solution (augmented by IPFS for file storage) as an optimal framework for secure and transparent record-keeping. Our evaluation indicates substantial benefits, including a 20–30% reduction in processing time and approximately $800,000 in annual operational cost savings. These gains demonstrate a compelling return on investment for the new system, considering both improved service delivery and resource efficiency. By embedding regulatory standards in smart contracts, the system ensures uniform compliance across all inspection stations, directly mitigating mechanical issues that previously accounted for roughly 15% of road accidents in Tanzania. In short, the combination of enhanced throughput and unassailable data integrity promises a new era of safer and more accountable transportation. The framework described is not limited to vehicle inspections; it can be adapted to other public service domains (such as healthcare records management, tax collection, or licensing systems), supporting Tanzania's broader digital transformation goals. Implementing this blockchain-based inspection system thus positions Tanzania at the forefront of embracing innovative technologies for public good, illustrating a path that other sectors and countries might follow in pursuit of efficiency, transparency, and trust.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
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So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest. They have no known competing financial, personal, or professional relationships that could have influenced the work reported in this paper.

INFORMED CONSENT

Written informed consent was obtained from all interview participants.

ETHICAL APPROVAL

The study did not involve experiments on humans or animals. Stakeholder interviews were conducted in line with institutional guidelines, written informed consent was obtained from all participants, and no identifiable personal data were retained.

DATA AVAILABILITY

The data that supports the findings of this study are available on reasonable request from the corresponding author, CK, and from the second author, RS. The data are not publicly available because they contain information that could compromise participant privacy.

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