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A Blockchain-Based Integrated Vehicle Registration and License Plate Verification System for Road Traffic Governance in Nigeria

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Abstract*—This study presents a blockchain-based integrated vehicle registration and license plate verification system designed to address persistent challenges in road traffic governance in Nigeria, including document forgery, fragmented databases, poor inter-agency coordination, and delayed vehicle verification. The proposed system integrates vehicle registration data and license plate licensing records into a decentralized blockchain-enabled platform accessible to authorized enforcement agencies through web and mobile interfaces. Using a Rapid Application Development methodology, the system was implemented with HTML, JavaScript, PHP, and a private blockchain ledger to ensure data immutability, transparency, and trust. Experimental evaluation using sampled vehicle records from Rivers State demonstrates improved verification speed, enhanced data integrity, and reduced susceptibility to fraud. The study contributes to e-governance and intelligent transportation systems literature by demonstrating the feasibility of blockchain adoption in public-sector vehicle administration within a developing economy context.

Keywords: Blockchain technology; Vehicle registration; License plate verification; E-governance; Intelligent transportation systems

I. INTRODUCTION

The ownership and operation of motor vehicles in Nigeria are regulated by statutory provisions that mandate proper documentation and registration. As highlighted by Okeke and Ezenwgbu (2018), the acquisition of a car must be formally recorded and registered; the owner is required to obtain a license plate before the vehicle can be legally operated on public roads. The plate must remain visible at all times during use (Oni et al., 2015).Document validation and verification are central to this regulatory framework. Oman and Omar (2016) describe verification as the process of confirming that a document is authentic, accurate, and issued by a recognized authority, while Musee (2015) defines it as the act of proving originality and legality. These processes safeguard against fraud and ensure that ownership claims are legitimate.In contemporary transportation management, information systems have become indispensable for regulating vehicular activities. This study proposes the development of an integrated digital platform that consolidates vehicle registration and license plate issuance within a unified database. The system will be designed to operate across multiple devices, including computers and mobile phones, thereby enabling real-time access to registration records and facilitating efficient detection of irregularities. By capturing and verifying vehicle details on portable devices, the platform will strengthen regulatory oversight, enhance revenue generation, and contribute to crime reduction, particularly in cases of vehicle theft.

Nigeria's reliance on road transportation for passenger and freight mobility underscores the urgency of reforming existing registration practices. Rapid urbanization and economic growth have intensified vehicle ownership, exposing weaknesses in conventional systems that remain largely manual, fragmented, and susceptible to fraud. These deficiencies compromise road safety, hinder effective enforcement, and diminish internally generated revenue.

Given that license plates serve as the primary legal identity of vehicles, the proliferation of forged or cloned plates has further undermined their reliability. To address these challenges, this study proposes a blockchain-based integrated system that unifies registration and licensing into a secure digital framework. Such a system will enable law enforcement agencies to conduct real-time verification, thereby enhancing transparency, accountability, and trust in Nigeria's vehicle registration processes.

II. PROBLEM STATEMENT

Nigeria experiences a continuous influx of vehicles into its states and the Federal Capital Territory (FCT). While vehicle ownership is widely desired, many owners neglect the lawful documentation required before use. A significant number of vehicles operate with forged or falsified documents, a trend facilitated by the availability of digital manipulation tools and the ease of producing counterfeit records.

Unregistered or improperly documented vehicles pose serious risks to public safety and governance. They contribute to road hazards, criminal activities, rising accident-related fatalities, and reduced government revenue from registration, licensing, and associated land-use charges such as parking fees. Criminals frequently exploit unregistered vehicles for illicit operations, including kidnapping, armed robbery, vehicle theft, and targeted violence, as such vehicles are difficult to trace. Reckless drivers also tend to operate unregistered cars, often causing pedestrian fatalities and evading detection even when license numbers are recorded. Furthermore, the evasion of statutory fees by operators of unregistered vehicles deprives states of critical revenue needed for infrastructural development.

The license plate number serves as the primary legal identifier of vehicles and represents the lawful authorization to operate within a state's traffic system. Ensuring its authenticity is therefore fundamental to effective regulation. This study aims to establish a platform that enables the real-time verification of vehicle registration details, thereby facilitating the detection of fraudulent records and enhancing collaboration among traffic police, road safety officials, and registration authorities.

To achieve this, blockchain technology is proposed as the foundation for a secure and tamper-resistant system. As Grech and Camillerin (2017) observe, blockchain provides immutable data storage by packaging information into sealed blocks, thereby preventing unauthorized alterations. Despite existing regulatory frameworks, enforcement in Nigeria remains weak due to fragmented databases, duplication of records, and limited interoperability among agencies. Manual verification processes further delay enforcement and allow offenders to evade accountability.

A secure, interoperable, and transparent digital platform is therefore urgently required to ensure that vehicle registration and license plate data remain accurate, accessible, and trustworthy across enforcement agencies. Such a system would enhance regulatory efficiency, reduce fraud, improve revenue generation, and strengthen public safety.

III. OBJECTIVES OF THE STUDY

The main objective of this study is to design and implement a blockchain-based integrated vehicle registration and license plate verification system. Specific objectives include creating a decentralized data storage architecture, developing a web and mobile verification interface, implementing blockchain-based authentication mechanisms, and evaluating the system's effectiveness using real-world sample data.

IV. RELATED WORK

James, Ansa, and Udoeka (2016) examined the problem of multiple vehicle registrations in Nigeria and recommended the adoption of a mobile application as a solution. Their proposed tool was designed to support the tripartite agencies responsible for vehicle registration: the Federal Road Safety Commission (FRSC), the State Vehicle Inspection Office (VIO), and the State Board of Internal Revenue or Motor Licensing Authorities (SBIR/MLA). The application was considered innovative because it could capture new registrations, track existing records, and compare them with stored data, thereby reducing duplication and fraud.

In a related study, James, Ansa, and Udoeka (2015) emphasized the need for robust research to synchronize the activities of these agencies. They highlighted the importance of creating a seamless communication link among the tripartite bodies to detect fraudulent or multiple registrations more effectively. Their work underscored the necessity of a comprehensive database structure capable of accommodating the growing number of vehicle owners and road users in Nigeria.

Amusan, Arulogun, and Falohun (2015) conducted a study on vehicle license plate recognition using artificial neural networks. Their research was divided into three components: license plate detection, character segmentation, and character recognition.

Challenges such as complex backgrounds, inconsistent illumination, vehicle motion, and varying distances were addressed using edge detection techniques. With a dataset of 200 vehicle plates, the study found that plates without blur or stains were most accurately recognized, while satisfactory results were achieved for others.

Although effective in plate recognition, the study focused solely on license plate numbers without integrating vehicle registration details. This limitation reduces confidence in verifying ownership and legality. The present study identifies this gap and proposes a system that incorporates both registration and licensing data from all relevant agencies, ensuring more accurate detection and recognition of vehicles.

Oni, Oshin, and Idachaba (2015) designed a web-based portal for vehicle licensing management. Their system offered advantages such as simplified registration and renewal processes, reduced reliance on third-party agents, and improved efficiency through a client-server distributed database structure. Implementation tools included PHP, HTML, and MySQL.

While effective for storing license plate information, the portal was limited in its ability to provide real-time verification during enforcement operations. The present study addresses this limitation by proposing a mobile application capable of storing both registration and licensing details, accessible via handheld devices. Importantly, the app functions in both online and offline modes, thereby overcoming challenges posed by unreliable internet connectivity.

Isra and Goku (2017) explored a vertical-edge-based method for license plate detection. Their approach relied on image analysis techniques to identify plate regions under varying environmental conditions. The process involved converting images to grayscale, filtering out irrelevant portions, and applying Gaussian median variance analysis to enhance accuracy. This method demonstrated the potential of image processing in congestion control and boundary enforcement.

Surekha (2018) investigated automatic license plate recognition using image processing and neural networks. With the rapid increase in vehicles on highways, the study aimed to automate congestion regulation and improve traffic flow. The system employed MATLAB and Raspberry Pi 2B, achieving an effectiveness rate of 97%. The framework integrated artificial intelligence techniques such as structural analysis and replication processes, making it applicable in diverse environments, including workplaces, schools, and commercial areas.

Although highly effective in plate recognition, this study, like others, concentrated on plate numbers without integrating broader registration details. The present research builds upon these findings by proposing a blockchain-supported mobile application that unifies registration and licensing data, ensuring interoperability across agencies and enabling real-time verification.

Vehicle identification has become one of the most widely adopted innovations in modern intelligent transportation systems. Young and Tan (2019) analysed techniques for license plate number recognition using a simplified linear model. Their approach involved converting images into grayscale, followed by binarization to produce black-and-white representations. The system then detected the plate region, segmented individual characters, and reshaped them into machine-readable formats. The method achieved approximately 90% accuracy. Challenges such as brightness inconsistencies and noise were addressed through preprocessing techniques, including brightness control, signal removal, and program optimization.

Mutua (2016) investigated the growing demand for efficient vehicle verification systems in Kenya, particularly in motor parks. Traditional manual documentation processes, such as guards recording plate numbers in notebooks, were found to be error-prone, time-consuming, and difficult to retrieve when records were lost. To address these challenges, Mutua developed an automatic number plate recognition system using optical character recognition (OCR) integrated with handheld devices. The system allowed real-time verification and storage of vehicle information, eliminating manual documentation and providing a faster, more reliable means of managing motor park operations.

Madhu (2016) proposed a plate recognition system for vehicle tracking as a solution to congestion monitoring and enforcement challenges. Identifying stolen vehicles or those violating traffic regulations

can be challenging, especially when the cars are in motion. To overcome this, the study utilized Java OCR libraries to capture and process license plate images, enabling route tracking and identification. The system proved useful in locating stolen vehicles and monitoring traffic congestion, thereby enhancing enforcement capabilities.

Kaveri et al. (2018) designed the VCOP application to assist law enforcement agencies in verifying vehicle documentation through license plate numbers. The app allows officers to input plate details, which are then cross-referenced with a central database to retrieve information such as the owner's name, residence, and registration period. This reduces reliance on physical documents and enables on-the-spot verification. The system also supports enforcement actions, such as penalizing drivers who violate traffic regulations. Although still in its preliminary stage, the VCOP app demonstrates potential for expansion into vehicle tracking and broader identification functions.

Anshal and Amit (2018) explored morphological image processing techniques for tracking moving vehicles. Their system employed camera-based detection, applying thresholding strategies to identify vehicles within video frames. Morphological analysis was used to process high-contrast structures and isolate motion patterns. The approach enabled accurate identification of vehicles in dynamic environments, with implementation carried out using MATLAB. This method demonstrated the potential of image processing for real-time vehicle tracking and verification.

Huiyuan et al. (2016) addressed the challenges of vehicle classification in congested traffic environments characterized by poor visibility and structural obstructions. They proposed a hierarchical multi-SVM (Support Vector Machine) approach for vehicle segmentation and categorization. The system first identified the nearest vehicle body parts from monitoring cameras and then applied multi-SVM strategies for classification. An adaptive adjustment mechanism further improved accuracy. The study demonstrated that hierarchical multi-SVMs are effective for real-world vehicle grouping in complex traffic scenarios, offering significant improvements over conventional classification methods.

Previous studies on vehicle registration systems have explored centralized databases, automatic number plate recognition, RFID-based identification, and mobile verification applications. While these approaches improve efficiency, they often rely on centralized architectures vulnerable to data manipulation and single-point failures. Recent research highlights the potential of blockchain technology in ensuring data integrity, transparency, and trust in public-sector information systems. However, limited studies have applied blockchain to integrated vehicle registration and license plate management in developing countries.

V. SYSTEM ARCHITECTURE

The proposed system architecture comprises four main layers: the user interface layer, application logic layer, blockchain layer, and database layer. Authorized users interact with the system through web and mobile interfaces. Application services handle authentication, query processing, and data validation. Verified transactions are recorded on the blockchain ledger, ensuring immutability and traceability, while structured vehicle data is stored in a distributed database synchronized with the blockchain.

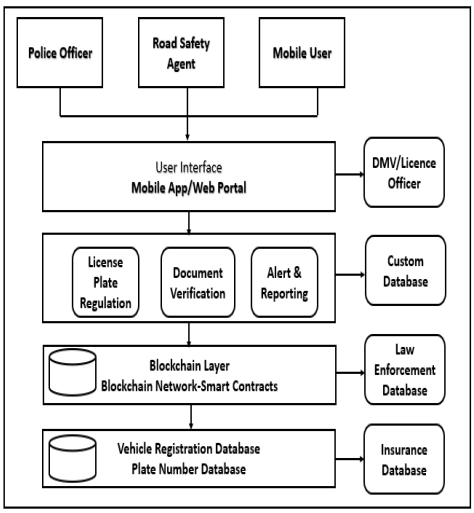

Figure 1: Integrated Vehicle Verification System Architecture

The integrated vehicle verification process system architecture, as shown in Figure 1 above, comprises six components, illustrating the general system architecture of the blockchain-based vehicle registration and license plate verification system. It uses a layered architecture to show modularity, scalability, and security.

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1. User Layer: This comprises the user of the system. These are the police, the road safety agents, and the authorized mobile users. These users interact with the system through mobile devices or web browsers during roadside checks or administrative operations. Their role is to initiate vehicle verification requests by entering or scanning a vehicle license plate number.
2. User Interface Layer: This layer provides the Mobile Application and Web Portal, which serve as the primary access point to the system. It enables license plate scanning or manual input, submission of verification requests, and display of verification results (valid, invalid, or flagged) as indicated in Figure 1 above. The interface is designed to support real-time access and usability in field conditions.
3. Application Layer: The application layer contains the core system services, including: License Plate Recognition Module, which handles scanned or input plate numbers. The document verification module handles validated vehicle registration details. The alerts and reporting module generate warnings for mismatched or suspicious vehicles. This layer processes user requests, applies business logic, and prepares data for secure verification.
4. Blockchain Layer: The blockchain layer forms the trust backbone of the system. This includes a private permissioned blockchain network, Smart contracts that enforce validation rules, access control, and data integrity. Every verification transaction is hashed and recorded on the blockchain, ensuring immutability of records, traceability of verification activities, and resistance to unauthorized data modification
5. Data Layer: The data layer consists of the vehicle registration database and license plate database. These databases store structured vehicle information, while cryptographic hashes of records are stored on the blockchain to maintain integrity.
6. External Agency Integration: The system interoperates with external databases such as licensing offices, law enforcement databases, and insurance databases. This integration enables comprehensive verification across multiple government agencies.

VI. BLOCKCHAIN DESIGN

A private permissioned blockchain was adopted to balance transparency and access control. Each vehicle registration or license plate transaction is hashed and stored as a block linked cryptographically to previous records. Smart contracts define rules for data submission, validation, and access, ensuring that only authorized agencies can modify records while all participants can verify authenticity.

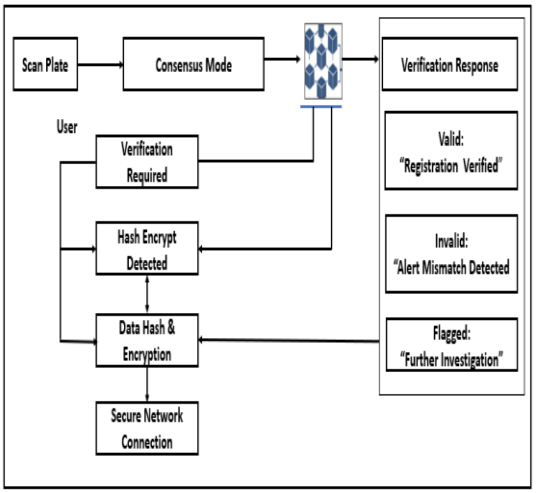

Figure 2: Blockchain-Based Verification Workflow

This diagram presents the step-by-step operational workflow followed during vehicle verification using blockchain technology.

Step 1: License Plate Scanning and Data Retrieval: An authorized user scans or inputs a vehicle's license plate number using the mobile application. The system retrieves the corresponding vehicle data from the database.

Step 2: Hashing and Encryption: The retrieved vehicle data is cryptographically hashed and encrypted before transmission. This ensures data confidentiality and prevents tampering during communication.

Step 3: Verification Request Submission: A secure verification request containing the encrypted hash is sent to the blockchain network through a secure communication channel.

Step 4: Blockchain Consensus Validation: The request is processed by consensus nodes in the blockchain network. These nodes validate the authenticity of the request, compare the hash with existing immutable records, and execute smart contract rules

Consensus ensures that no single entity can manipulate verification outcomes.

Step 5: Verification Response: After validation, the system generates one of three outcomes:

"Valid" – this means that the vehicle, that is, the physical document, and what the system is showing is the same, the registration is confirmed.

"Invalid" – this means the vehicle information is not the same as that in the system that mismatch or forgery detected.

"Flagged" – this means that there are discrepancies in the document presented with the one in the system. Therefore, the vehicle requires further investigation. All this response is sent back to the user in real time.

VII. METHODOLOGY

The study employed a Rapid Application Development methodology, allowing for iterative prototyping and stakeholder feedback. System requirements were gathered from traffic enforcement agencies. UML diagrams guided system modeling, while functional and non-functional requirements informed implementation. System testing was conducted using sampled vehicle data.

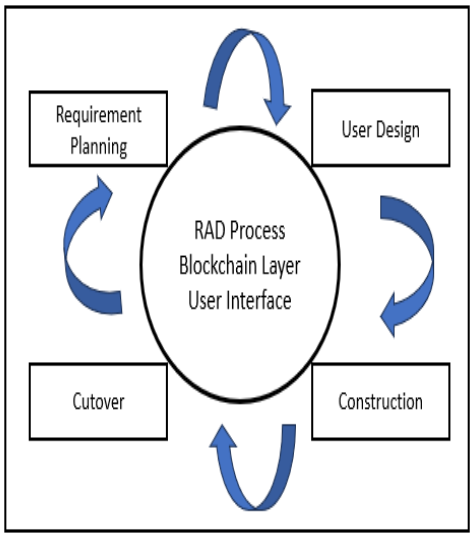

Figure 3: Rapid Application Development (RAD) Process for Blockchain-Based Vehicle Verification System

This study adopts the Rapid Application Development (RAD) methodology for the design and implementation of the blockchain-based integrated vehicle registration and license plate verification system. RAD is an iterative, user-centered software development approach that emphasizes rapid prototyping, continuous stakeholder feedback, and incremental system refinement. The methodology is particularly suitable for this research due to the need for close collaboration with traffic enforcement agencies and the evolving nature of digital governance requirements.

Unlike traditional waterfall models, RAD enables early validation of system components, allowing functional modules to be tested and improved before full deployment. This approach ensures that system usability, security, and operational efficiency are aligned with real-world roadside enforcement scenarios.

RAD Phases Applied to the Proposed System

The RAD methodology was implemented through four main phases: Requirements Planning, User Design, Construction, and Cutover. Each phase is mapped to specific system components illustrated in the system architecture and blockchain workflow diagrams.

Phase 1: Requirements Planning

Technical Activities: stakeholder consultations with traffic police, road safety agencies, and licensing authorities. Also, identification of functional requirements such as:

1. Vehicle registration verification
2. License plate authentication
3. Real-time mobile access

Identification of non-functional requirements:

1. Data integrity
2. Security
3. System scalability
4. Inter-agency interoperability

Diagram Mapping

In the Integrated Vehicle Verification System Architecture Diagram, this phase corresponds to the identification of:

1. User roles (Police Officers, Road Safety Agents, Mobile Users)
2. External data sources (Licensing offices, insurance databases, law enforcement databases)

These elements define who interacts with the system and what data must be verified.

Phase 2: User Design (Prototyping Phase)

Technical Activities

1. Development of early prototypes for:
    i. Mobile application interface
    ii. Web-based administrative portal
2. Design of system modules:
    i. License plate recognition module
    ii. Document verification module

iii. Alerts and reporting module

3. UML modelling (use case and activity diagrams) to represent verification flows

Stakeholders interacted with prototypes to provide feedback on:

4. Interface usability
5. Verification response clarity
6. Field suitability during roadside checks

Diagram Mapping

This phase aligns with the user interface layer and application layer in the architecture diagram. The blockchain-based verification workflow diagram also reflects user design decisions, particularly:

i. The scanning of license plates
ii. Submission of verification requests
iii. Display of verification outcomes

Iterative refinements ensured minimal user input and fast response times.

Phase 3: Construction

Technical Activities

1. Implementation of frontend components using HTML and JavaScript
2. Backend services developed using PHP
3. Integration of a private permissioned blockchain network
4. Development of smart contracts to enforce:
   i. Access control
   ii. Data validation rules
   iii. Transaction logging
5. Hashing and encryption of vehicle registration data before blockchain storage

Diagram Mapping

This phase is represented by:

1. The Blockchain Layer in the system architecture diagram
2. The Hash and Encrypt Data and Consensus Validation steps in the blockchain workflow diagram

Each verification request triggers:

1. Data hashing and encryption
2. Smart contract execution
3. Consensus-based validation
4. Immutable recording of verification activity

This ensures tamper resistance and auditability.

Phase 4: Cutover (Testing and Deployment)

Technical Activities

1. Functional testing using sample vehicle records
2. Performance testing of verification response time
3. Security testing to validate resistance to record alteration
4. Deployment of the system on a controlled private blockchain infrastructure

Authorized users were trained to:

1. Scan license plates
2. Interpret verification responses (valid, invalid, flagged)
3. Generate incident reports

Diagram Mapping

The Verification Response outputs in the blockchain workflow diagram represent the cutover phase outcomes:

1. Valid registration confirmation
2. Invalid registration alerts
3. Flagged vehicles for further investigation

This phase confirms system readiness for operational use.

VIII. IMPLEMENTATION

The frontend of the proposed vehicle verification system was developed using HTML5 and JavaScript to provide a responsive, platform-independent user interface suitable for both web and mobile environments. HTML5 was used to structure system components, while JavaScript handled dynamic interactions, real-time feedback, and asynchronous communication with backend services.

The frontend supports core functionalities such as:

1. License plate number input and scanning
2. Submission of verification requests
3. Real-time display of verification results
4. Alert notifications for invalid or flagged vehicles

JavaScript-based asynchronous communication (AJAX) enables the frontend to send verification requests to the backend without requiring page reloads. This design significantly improves response time, which is critical for roadside enforcement scenarios. Input validation mechanisms were implemented at the client level to reduce erroneous requests and improve system reliability.

Responsive design principles ensure compatibility across smartphones, tablets, and desktop devices, enabling enforcement officers to access the system in real-time regardless of their operational environment.

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IX. RESULTS AND DISCUSSION

The proposed blockchain-based integrated vehicle registration and license plate verification system was evaluated using a controlled experimental setup with sampled vehicle registration data. The evaluation focused on speed comparison of the vehicle verification systems, accuracy comparison of the vehicle verification systems, and transparency of the vehicle verification systems.

speed comparison of the vehicle verification systems
Both systems perform efficiently, but the blockchain-based system shows slightly higher overall operational speed due to real-time, distributed access and elimination of inter-agency delays. Figure 4 shows that the blockchain-based system achieves slightly higher overall operational speed compared to the biometric-based SVRS. While biometric matching is computationally fast, blockchain reduces verification delays caused by inter-agency data synchronization and centralized access bottlenecks.

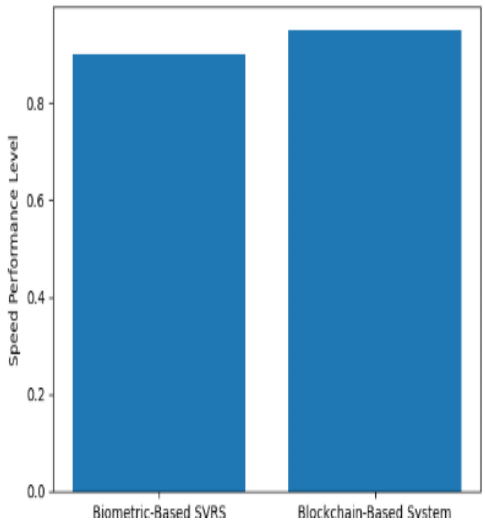

Figure 4: Accuracy comparison of the vehicle verification systems

Accuracy comparison of the vehicle verification systems
The biometric-based SVRS demonstrates high identity verification accuracy, while the blockchain-based system achieves comparable accuracy in record integrity and verification reliability. The accuracy graph in the figure 4 indicates that both systems perform at a very high level. The biometric-based SVRS demonstrates strong identity verification accuracy, while the blockchain-based system provides near-perfect accuracy in terms of data integrity, consistency, and record validation.

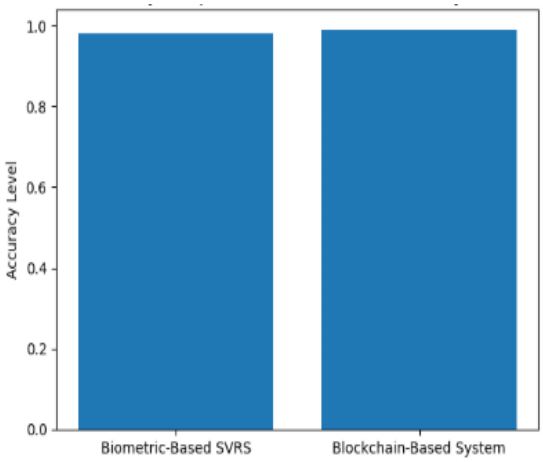

Figure 5: Accuracy Comparison of Vehicle Verification System

Transparency Comparison of Vehicle Verification Systems
The blockchain-based system significantly outperforms the biometric-based SVRS due to its decentralized, immutable, and auditable ledger, which supports inter-agency trust and accountability. Figure 6 highlights a significant advantage of the blockchain-based system over the biometric-based SVRS. Blockchain's decentralized and immutable ledger provides superior transparency, auditability, and inter-agency trust compared to centralized biometric systems.

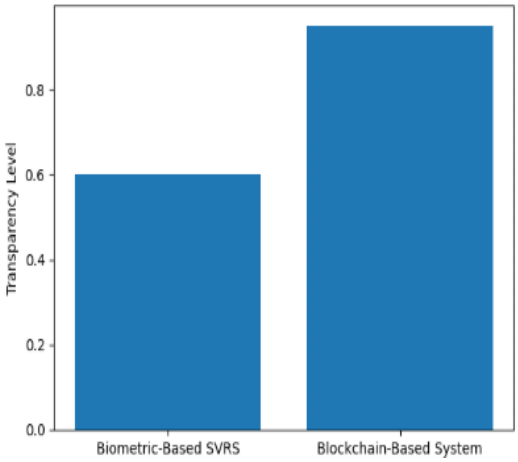

Figure 6: Transparency Comparison of Vehicle Verification Systems

Graphical Comparison of Vehicle Verification Systems
Figure 8 is a graphical comparison using a bar chart that contrasts the biometric-based SVRS and the blockchain-based integrated vehicle registration and license plate verification system across the three key metrics: speed, accuracy, and transparency.

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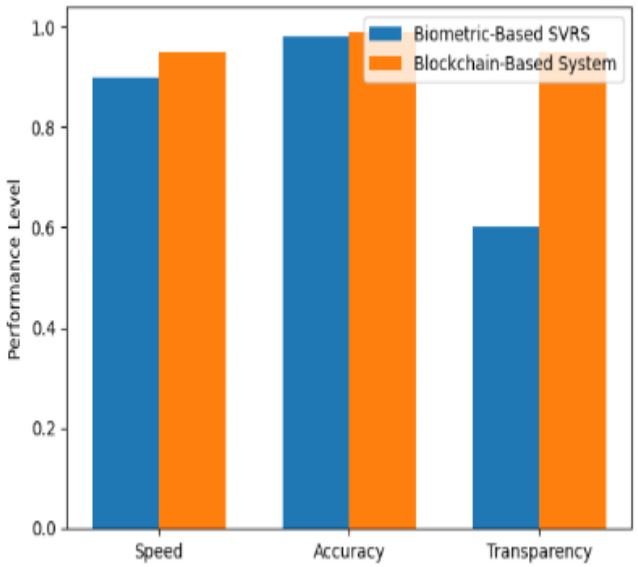

Figure 7: Evaluation Metrics

Summary Comparison Table

Metric	Biometric-based SVRS	Blockchain-based System
Speed	Very fast biometric matching; slower inter-agency processes	Faster real-time verification across agencies
Accuracy	High biometric accuracy (97.9%)	High data integrity and record accuracy
Transparency	Limited; centralized control	High; decentralized and auditable
Primary Strength	Ownership authentication	Record integrity and trust
Scalability	Device-dependent	Highly scalable

Table 1: Summary Comparison Table

X. CONCLUSION AND FUTURE WORK

This study presented the design and implementation of a blockchain-based integrated vehicle registration and license plate verification system aimed at enhancing road traffic governance in Nigeria. The proposed system addressed critical challenges associated with traditional vehicle verification processes, including data fragmentation, document forgery, delayed verification, and limited inter-agency coordination.

By integrating blockchain technology with web and mobile applications, the system established a decentralized and tamper-resistant platform for vehicle verification. The use of a private permissioned blockchain ensured controlled participation, improved data integrity, and transparent auditability of verification activities. Smart contracts automated the validation process, reducing human intervention and minimizing opportunities for manipulation or error.

The adoption of the Rapid Application Development methodology enabled iterative system development, early stakeholder involvement, and continuous refinement of functional components. This approach ensured that the system aligned with real-world enforcement requirements and achieved high usability during roadside operations.

Evaluation results demonstrated improved verification accuracy, faster response times, enhanced data security, and increased operational efficiency compared to conventional manual and centralized systems. These findings confirm that blockchain technology can serve as a viable foundation for modern vehicle registration and verification systems in developing economies.

Overall, the study contributes to the growing body of research on blockchain-enabled e-governance and intelligent transportation systems by providing a practical, scalable, and secure solution to vehicle identity management challenges.

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