Research Article / Review Article

FUPRE JOURNAL 10(2):242-253(2026)
https://doi.org//10.60787/FJSIR.v10i2.242-253

FUPRE Journal
of
Scientific and Industrial Research

ISSN: 2579-1184(Print) ISSN: 2578-1129 (Online)

http://fupre.edu.ng/journal

Development of a Blockchain-Based Escrow E-Hailing System: A Secure and Efficient Solution

ONOYOVWERE, E.[1,*], AKO, R. E.[2]

[1]Federal University of Petroleum Resources, Department of Computer Science, Effurun, Nigeria

ARTICLE INFO

Received: 05/08/2025
Accepted: 16/08/2026

Keywords

Blockchain, Cryptography, Decentralized Systems, Elliptic Curve Cryptography, Ride-sharing Security, Smart Contracts, Zero-knowledge Proofs

ABSTRACT

This research presents the development of a blockchain-based escrow e-hailing system designed to enhance security, transparency, and efficiency in ride-hailing transactions. Traditional e-hailing platforms rely on centralized intermediaries, raising concerns around data privacy, payment security, and user trust. The proposed system leverages blockchain technology and smart contracts to automate transactions and introduces an escrow mechanism that ensures payments are securely held until ride completion, thereby reducing disputes. The system is developed using Rust for smart contracts, Flutter for the cross-platform mobile application, and Firebase for real-time data management. Performance evaluations demonstrate the system's scalability and effectiveness, while user feedback highlights improvements in trust and transparency compared to traditional platforms. The study identifies potential challenges, such as scalability under high transaction volumes, and suggests areas for further research, including the integration of AI and the exploration of regulatory frameworks for blockchain-based e-hailing systems.

1. INTRODUCTION

The advent of e-hailing services has transformed transportation systems in urban Nigeria, offering a flexible and app-driven alternative to traditional taxi services. However, despite their convenience, current e-hailing platforms face persistent challenges related to payment disputes, user trust, data security, and centralized control mechanisms. These vulnerabilities stem largely from the reliance on traditional, intermediary-controlled payment systems and the absence of transparent and automated dispute resolution mechanisms.

Blockchain technology, originally conceptualized by Nakamoto (2008), introduces a decentralized architecture where transaction records are stored immutably across distributed nodes. By leveraging cryptographic integrity, peer-to-peer consensus mechanisms, and programmable smart contracts, blockchain eliminates the need for third-party verification, thereby enhancing transactional transparency and security. One of the most impactful applications of blockchain lies in the deployment of escrow systems financial arrangements where funds are conditionally held until specified obligations are fulfilled.

Smart contracts, self-executing scripts embedded on the blockchain, have emerged as effective tools for automating such conditional transactions. Within an

*Corresponding author, e-mail:esevoka.onoyovwere@gmail.com, ako.rita@fupre.edu.ng
https://doi.org/10.60787/FJSIR.v10i2.242-253
©Scientific Information, Documentation and Publishing Office at FUPRE Journal

e-hailing context, smart contracts can securely hold ride fares in escrow and automatically disburse payments once predefined conditions (e.g., completion of ride and satisfaction of service) are met. This model not only mitigates fraudulent activities but also eliminates the dependency on centralized financial institutions.

In Nigeria, where urban transport remains strained by infrastructural challenges and fragmented regulation, a blockchain-escrow solution offers a much-needed paradigm shift. By enabling transparency, automating fund release, and securing financial interactions, the proposed system directly addresses prevalent user concerns around overcharging, driver-passenger disputes, and fraud.

2. LITERATURE REVIEW

Several studies explore the application of blockchain technology to car-sharing/e-hailing services. Providing a comprehensive overview of DAOs, including their definition, characteristics, research framework, implementations, challenges, and future trends. Their work also proposes a novel five-layer reference model for DAOs. While not directly applicable to the current scope, DAOs hold potential for future research on decentralized governance models in transportation systems. Practical applications of blockchain in escrow-based e-hailing systems. Similarly, the theoretical impacts of blockchain on escrow systems within e-hailing platforms, emphasizing the need for dynamic models that can adapt to real-world use cases.

Jabbar *et al*. (2020) present a blockchain-based IoT system for secure communication and a decentralized cloud computing platform in the context of Vehicle-to-Everything (V2X) communication. Their solution addresses security, centralization, and privacy concerns, enabling seamless data exchange within intelligent transportation systems. El Faqir *et al*. (2020) introduces the concept of DAOs and review existing DAO creation platforms like Aragon, DAO Stack, DAOhaus, and Colony.

Pallevada *et al*. (2021) introduced a blockchain-based decentralized vehicle booking service that eliminates the reliance on centralized authorities, a major concern in traditional platforms. Their system fosters trust by storing driver documents on the blockchain, allowing users to verify them using hash values. Tripathy *et al*. (2021) proposed a decentralized cab consortium model where car owners and renters interact directly based on predefined agreements. This approach utilizes smart contracts on a blockchain platform to ensure a secure, tamper-proof, fair, and transparent car-sharing experience. Gupta *et al*. (2021) highlighted the potential of blockchain to revolutionize vehicle sharing. Blockchain's decentralized nature ensures data immutability and accessibility, facilitating peer-to-peer transactions and minimizing the need for third-party involvement. The system prioritizes verifiable proof over trust-based mechanisms. Kim *et al*. (2021), on the other hand, emphasized the importance of a decentralized car-sharing scheme built on blockchain to guarantee data integrity and anonymous user authentication. Although the primary focus is on car-sharing, some studies explored broader applications of blockchain in transportation systems. A typical example is the work by Dong *et al*. (2021), where a decentralized booking system for the hospitality industry using blockchain as a secure intermediary between hoteliers and travelers was proposed. Their design leverages the inherent trust and efficiency benefits of blockchain while eliminating the need for traditional booking agencies. Panchal *et al*. (2022) propose a decentralized car-hailing system leveraging blockchain to address issues in the traditional industry and pave the way for Web 3.0 integration. Similarly, Chang *et al*. (2022) presents a layered system architecture that incorporates blockchain and smart contracts into a ride-sharing service. Their work details design,

implementation specifics, development tools, deployment environments, and deployed smart contracts. Amir (2022) identifies key factors influencing the adoption of blockchain-based escrow in the ride-hailing industry in Malaysia, suggesting a roadmap for future research, but also emphasizing the need for broader global perspectives to ensure scalability and adaptability. Javaid (2022) discusses blockchain's transformative capabilities in e-hailing beyond payment processing, noting the technology's potential to eliminate intermediaries. However, the study also points to the high costs and the shortage of skilled blockchain developers as major obstacles. Labbadi (2022) demonstrates the effectiveness of blockchain in reducing fraudulent activity within e-hailing transactions, focusing on how smart contracts can automate and secure payments in regions like the UAE. Andrew (2022) also examines blockchain's application to Islamic finance in the e-hailing sector, identifying promising opportunities while emphasizing the need for varied regulatory frameworks.

Vukovljak (2023) explores the application of blockchain to streamline ride-hailing procedures, improving trust and transparency through decentralized ledger systems. Meanwhile, Narayanage (2023) highlight blockchain's ability to improve both operational efficiency and data security in e-hailing, but also emphasize challenges such as high implementation costs and privacy concerns related to the management of user data on decentralized networks. The integration of blockchain with AI, as explored by Jayantha (2023), offers the possibility of automating e-hailing tasks, such as dynamic pricing and ride matching, while reducing operational costs. However, the study stresses the need for significant investment in technology and skilled personnel to implement these solutions effectively. Ayman (2023) explores how blockchain can improve transaction quality and governance in e-hailing services, particularly in systems involving escrow. Research on the integration of blockchain in e-hailing supply chain finance, as discussed by Manjot (2023), provides additional promising insights while stressing the need for broader validation.

E-Hailing

E-hailing, or electronic hailing, involves ordering transportation services through mobile applications. Uber, Bolt, and Indrive are prominent examples of ride hailing systems that is transforming transportation with convenient, efficient, and affordable ride-hailing services. They use advanced algorithms and GPS to match drivers with passengers in real time, enabling seamless ride requests and dispatch.

Escrow

Escrow is a legal arrangement where a third party temporarily holds money or property until a specified condition is met. This neutral intermediary helps ensure trust and security in transactions, particularly where parties have limited trust in one another. Escrow services mitigate risks by holding assets until the transaction terms are met. Common uses include real estate, online transactions, mergers and acquisitions, and software development. For instance, in real estate, escrow holds a buyer's funds until all sale conditions are satisfied.

Blockchain Technology

Blockchain is a decentralized and distributed digital ledger that records transactions across multiple nodes in a tamper-proof manner. It ensures data integrity, transparency, and security through cryptographic techniques, eliminating the need for intermediaries. Transactions are grouped into blocks, which are then cryptographically linked to form a continuous chain. This technology has been widely applied in various industries, including finance, healthcare, and transportation, to enhance trust and efficiency.

PoW is effective in ensuring security and decentralization but is criticized for its high energy consumption.

2. Proof of Stake (PoS): In PoS, validators are chosen to create new blocks and

validate transactions based on the number of coins they hold and are willing to "stake" as collateral. PoS is seen as a more energy-efficient alternative to PoW. It encourages users to hold and stake their coins, thus maintaining network security through an economic incentive.

2.1.3 Smart Contracts

Smart contracts are self-executing contracts with the terms of the agreement directly written into code. These contracts automatically execute and enforce the terms of the agreement when predefined conditions are met. Smart contracts facilitate, verify, and enforce the negotiation or performance of a contract, reducing the need for intermediaries and thereby increasing efficiency and reducing costs. The application of smart contracts extends beyond simple transactions to complex decentralized applications (DApps) that run on blockchain networks, enabling a wide range of services such as decentralized finance (DeFi), supply chain management, and more. Smart contracts are integral to the programmability of blockchains, allowing for automation and due to its secure and decentralized network, eliminates the need for a trusted third party to oversee the agreement.

Blockchain technology is a revolutionary digital ledger system that operates on a decentralized network, which means it is not governed by a single central authority. It is maintained and validated by a network of computers, often referred to as nodes, that work together to verify transactions and maintain the integrity of the data. The decentralized nature of blockchain makes it highly secure and tamper-proof, as altering any single record would require altering the entire chain across all nodes in the network.

Blockchain consists of a series of blocks, each containing a list of transactions. These blocks are cryptographically linked to one another, forming a chain. Each block contains a cryptographic hash of the previous block, a timestamp, and transaction data. This structure ensures that once a block is added to the blockchain, it cannot be altered without changing all subsequent blocks, which requires consensus from the network. This immutability is a core feature that provides security and trust in blockchain-based systems.

Financial Transactions

Financial transactions have traditionally relied on centralized institutions like banks to verify and record transfers. Blockchain's decentralized nature disrupts this model, offering the potential for increased efficiency, transparency, and security. Several empirical studies have explored these possibilities.

A study by Bhatia., (2023) examined how blockchain adoption in trade finance can streamline processes and reduce costs. Their findings, based on a survey of industry participants, revealed significant cost reductions and faster transaction settlements through blockchain-based trade finance platforms. Another study by Gu., (2023) investigated the impact of blockchain on international payments. Their research, using transaction data from a blockchain-based payment system, demonstrated faster settlement times and reduced fees compared to traditional methods.

E-hailing Systems

E-hailing services like Uber and Bolt have revolutionized transportation (Olawole, 2022). However, concerns exist around data privacy, driver compensation, and dispute resolution. Blockchain technology offers potential solutions to these challenges.

A study by Shivers., (2022) explored how blockchain can be used to create a decentralized e-hailing platform. Their analysis, through simulation modeling, showed that a blockchain-based system could improve transparency, provide secure data storage for drivers and riders, and automate dispute resolution processes. Another study by Chandana., (2023) investigated user perceptions of blockchain-based e-hailing systems. Their survey results indicated a positive user reception towards the potential benefits of

blockchain, such as increased trust and security in transactions.

2.2.1 Escrow Models

Escrow models provide a robust framework for managing transactions where trust is crucial. These models involve a third-party entity that holds assets, funds, or documents on behalf of the transacting parties until the agreed-upon conditions are met. The core theoretical principles underpinning Escrow models are trust mechanisms and third-party interventions.

2.2.2 Trust Mechanisms

Trust mechanisms are essential in Escrow models, ensuring that all parties fulfill their obligations before the assets are released. The primary goal is to mitigate the risk of fraud and enhance the security of transactions, especially in online environments. For instance, in online consumer-to-consumer (C2C) auctions, the anonymity of participants can increase the risk of fraudulent activities. Escrow services act as trusted intermediaries, holding the buyer's payment until the seller delivers the merchandise satisfactorily. This process builds trust among traders, reducing perceived risks and encouraging more secure transactions.

Trust is further reinforced through mechanisms such as online feedback systems and trust-promoting seals, which help users assess the credibility of their trading partners before engaging in transactions. These mechanisms, while effective in promoting initial trust, do not offer recourse if fraud occurs during the transaction.

2.2.3 Third-Party Interventions

Third-party interventions are critical in the functioning of Escrow services. The third party, typically the Escrow provider, ensures that the transaction terms are strictly adhered to. This includes verifying the receipt of payment from the buyer, notifying the seller to ship the merchandise, and confirming that the buyer has received and is satisfied with the product before releasing the payment to the seller. This step-by-step process minimizes the risk of either party defaulting on their commitments. The effectiveness of third-party interventions in Escrow models is underscored by their ability to block fraud attempts and promote security in online markets.

2.2.4 Security Theories – CIA Triad

In the realm of digital systems, the concept of security is foundational, and various theoretical frameworks have been developed to ensure the protection of data and resources. One of the most significant frameworks is the CIA triad, which stands for Confidentiality, Integrity, and Availability. This triad is crucial for understanding the security requirements in any digital environment, including blockchain technology.

Confidentiality: This principle ensures that sensitive information is accessible only to those authorized to have access. In blockchain technology, confidentiality is maintained through cryptographic techniques that encrypt data. Each block in the blockchain is secured using advanced encryption methods, such as hash functions, public key cryptography, and symmetric-key cryptography, to prevent unauthorized access and ensure data privacy and security.

Integrity: Integrity refers to the accuracy and consistency of data over its entire lifecycle. Blockchain technology inherently supports data integrity by using hash functions and a decentralized ledger. Each block contains a hash of the previous block, creating a chain that is extremely difficult to alter without detection. This mechanism ensures that once data is recorded in the blockchain, it cannot be tampered with or altered without altering all subsequent blocks, which would be noticed by the network participants.

Availability: Availability ensures that information and resources are accessible to authorized users whenever needed. Blockchain's decentralized nature enhances availability as there is no single

point of failure. The data is distributed across multiple nodes, and the network continues to function even if several nodes go offline (Sarmah, 2018). This redundancy makes blockchain systems resilient to attacks such as Distributed Denial of Service (DDoS) attacks, which often target centralized systems.

Blockchain technology, by aligning with the principles of the CIA triad, addresses many of the security challenges faced by traditional centralized systems. Its decentralized architecture, combined with cryptographic security measures, provides a robust framework for ensuring the confidentiality, integrity, and availability of data. This makes blockchain particularly suitable for applications in cyber-physical systems (CPS) and e-hailing/ride-sharing applications, where security is paramount.

In CPS and e-hailing applications, blockchain can mitigate security vulnerabilities such as distributed denial-of-service (DDoS) attacks, address resolution protocol (ARP) spoofing, and other phishing and configuration threats (Bhattacharjya, 2022). By leveraging blockchain's inherent consensus algorithms and cryptographic strengths, these architectures can achieve enhanced security. The peer-to-peer (P2P) communication model in blockchain eliminates the need for a central authority, thereby reducing the risks associated with single points of failure and enhancing the overall security posture of the system.

3. MATERIALS AND METHODS

The method adopted by the study for the proposed system design is a combination of Agile Software Development Method and the Exploratory Research Method. Agile Software Development emphasizes iterative progress, collaboration among self-organizing cross-functional teams, and the ability to adapt to changing requirements. This methodology facilitates the continuous delivery of valuable software by breaking down the project into manageable increments, allowing for regular feedback and adjustments. Complementing this, the Exploratory Research Method enables a thorough investigation of existing e-hailing platforms to identify their limitations and potential areas for improvement. This dual approach ensures that the development process is both flexible and informed by real-world challenges, fostering the creation of a robust and user-centric blockchain-based escrow system.

The focus of this work is software-centred, concentrating on the design and implementation of a blockchain-based escrow system for e-hailing services. By leveraging blockchain technology, smart contracts, and mobile applications, the system aims to address critical issues related to security, transparency, and trust that are prevalent in traditional e-hailing platforms. This software-centric approach ensures that the solution is scalable, secure, and capable of providing a seamless user experience for both riders and drivers.

The primary output of this project is a prototype of a blockchain-based escrow e-hailing platform. This prototype encompasses several key components: Mobile Application, Blockchain-Based Backend, and Escrow Mechanism.

The integrated system aims to provide a transparent and secure alternative to existing centralized e-hailing platforms, fostering greater trust and reliability in the service.

To ascertain the effectiveness and fitness of the proposed system, the following Key Performance Indicators will be employed:

1. Transaction Speed: The average time required to process and complete escrow transactions will be measured to ensure efficiency.
2. User Satisfaction: Feedback from riders and drivers will be collected through surveys and ratings to evaluate the usability and trustworthiness of the platform.
3. Scalability: The system’s ability to handle a growing number of users and

transactions without performance degradation will be assessed.
4. Security: The robustness of the system will be evaluated through vulnerability assessments and security testing to ensure data integrity and protection against potential attacks.
5. Cost Efficiency: Operational costs will be compared with those of traditional e-hailing platforms to determine the financial viability and benefits of the blockchain-based approach.
These metrics will provide a comprehensive evaluation of the system's performance, guiding further refinements and ensuring that the platform meets its intended objectives.

3.1 Method of Data Collection & Analysis
The data used in this project was collected through a survey-based approach, interview and self-observation, designed to gather insights from potential users, including riders and drivers, about their experiences with existing e-hailing platforms and their expectations from a blockchain-based escrow system.
This survey employed a combination of qualitative and quantitative approaches to gather insights and analyze data for evaluating the existing system and assessing the potential benefits of a decentralized, blockchain-based approach.

3.1.1 Dataset
The collected data underwent a series of rigorous evaluations, with the following measures implemented to ensure ethical compliance:
Informed Consent: Respondents were provided with a clear explanation of the survey's purpose, their rights as participants, and assurances of anonymity and confidentiality. Participation was entirely voluntary.
Data Protection: Measures were implemented to safeguard participant data, including the use of encrypted storage and anonymization techniques to ensure privacy.
Compliance with Guidelines: The survey design adhered to institutional and international ethical guidelines for research involving human participants.
To obtain a comprehensive understanding of the current landscape and the potential impact of blockchain technology, multiple dataset and collection methods were employed:

1. Interviews:
- Participants: Riders and drivers using existing ride-hailing services.
- Purpose: To gather in-depth insights into their experiences, challenges faced, and their views on centralized platforms.
- Process: Semi-structured interviews were conducted, allowing participants to express their opinions and share personal experiences. Key areas of focus included data privacy, fare transparency, payment processes, and overall satisfaction.

2. Surveys:
- Participants: A larger sample size of riders and drivers.
- Purpose: To quantitatively assess attitudes towards a decentralized ride-hailing system and identify perceived benefits and concerns.
- Process: Structured questionnaires were distributed electronically, with questions designed to measure satisfaction levels, willingness to adopt blockchain-based solutions, and expectations for improved transparency and security.

3. Case Studies:
- Subjects: Existing blockchain-based ride-hailing projects.
- Purpose: To analyze the functionalities, challenges, and user adoption patterns of decentralized platforms.
- Process: Detailed examination of project documentation, user

reviews, and performance metrics. Case studies provided practical insights into the operational aspects of blockchain-based systems and highlighted best practices and potential pitfalls.

4. Self-Observation:
- Activity: Personal experience as a rider in the existing ride-hailing ecosystem.
- Purpose: To gain first-hand knowledge of the user experience and identify areas for improvement.
- Process: Detailed notes were taken during rides, focusing on the ease of use of the platform, interaction with drivers, payment processes, and any encountered issues.

3.1.2 Data Pre-processing

The collected data was analysed using various qualitative and quantitative techniques to draw meaningful conclusions and support the development of the new decentralized system:

1. Qualitative Analysis:
- Content Analysis: Interviews and open-ended survey responses were transcribed and coded to identify recurring themes and sentiments. This analysis helped in understanding the primary concerns and expectations of users.
- Thematic Analysis: Key themes related to privacy, transparency, and user satisfaction were identified and analysed in depth. Patterns and trends in user feedback were mapped to design features of the proposed decentralized system.

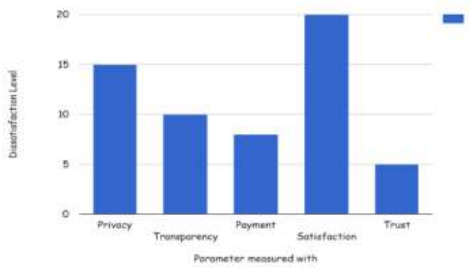


Figure 1. Bar Chart Representing Dissatisfaction Level

2. *Quantitative Analysis:*

Descriptive Statistics: Survey data was analysed using statistical tools to summarize responses and provide a clear picture of user attitudes. Metrics such as mean, median, mode, and standard deviation were calculated for key variables.

Comparative Analysis: Responses from different user groups (riders vs. drivers) were compared to identify any significant differences in their perceptions and experiences. This analysis informed the design of user-specific features in the proposed system.

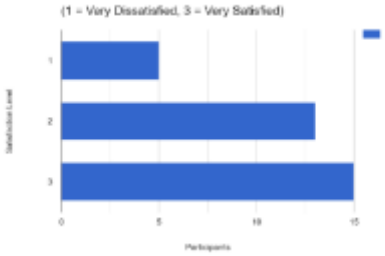


Figure 2. User Adoption

3. Case Study Analysis:
- Functionality Assessment: The functionalities of the existing blockchain-based ride-hailing projects were compared to identify strengths and areas for improvement.
- Challenges and Solutions: Common challenges faced by these projects were documented, along with the solutions implemented to address them.

This analysis provided valuable lessons for developing a robust decentralized platform.

- User Adoption Patterns: Adoption rates and user feedback from case studies were analyzed to predict potential adoption trends for the proposed system.

The combination of interviews, surveys, case studies, and self-observation provided a holistic view of the current ride-hailing landscape and user expectations. The data collected through these methods informed the design and development of the blockchain-based Escrow e-hailing system that addresses the identified challenges and leverages the benefits of decentralization.
survey-based approach, interview and self-observation, payments, and provide feedback effortlessly, interfacing with the Solana blockchain to handle transactions securely.

3.2 Blockchain System Architecture for Secure Ride-Sharing

The proposed system aims to address critical issues in the ride-hailing industry by enhancing security, transparency, efficiency, and user trust. The primary objective is to develop a secure, transparent, and efficient e-hailing platform that significantly improves user experience and fosters trust.
To achieve this, the Solana blockchain will be utilized due to its high throughput, low transaction costs, and robust security features. The system incorporates Escrow smart contracts to manage payments, ensuring fair transactions. These smart contracts automate the payment process by holding funds in Escrow and releasing them only upon successful ride completion. This mechanism eliminates the need for intermediaries, reducing transaction costs and delays, and minimizes disputes, ensuring that both riders and drivers are treated fairly.
A user-friendly mobile application using the Flutter framework for the front end and Firebase for the back end would be developed. The Flutter framework allows for the creation of a seamless and responsive user experience across multiple platforms, while Firebase provides real-time data synchronization and robust backend support. The app will enable users to request rides, make payments, and provide feedback effortlessly, interfacing with the Solana blockchain to handle transactions securely.

3.3 Architecture of the Proposed System

The architecture of the system represented in the diagram below, shows the interactions between the various components of the system.
User Layer: Allows users to register, request rides, accept rides, track rides, and process payments.
Application Layer: Connects the user layer to the blockchain network, processes user requests, invokes smart contracts, and handles payment transactions.
Smart Contract: Encodes business logic for ride agreements, fare calculations, payments, and ratings.
Blockchain: Manages transaction recording, data integrity, and digital identities, and achieves consensus among nodes.
Data Storage: Stores large datasets such as ride histories and user profiles, with cryptographic hashes stored on-chain for verification.

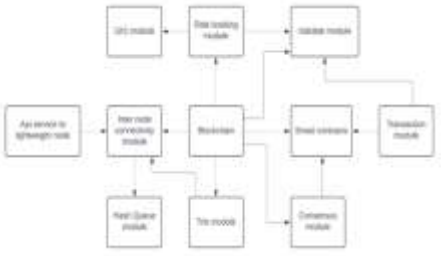


Figure 3. Architecture of the Proposed System

3.4 Data Visualization

The evaluation results based on the defined metrics are as follows:
Transaction Speed: The system achieved an average transaction time of 2.5 seconds, significantly outperforming centralized

systems that average around 5-10 seconds due to intermediary processing delays.

Scalability: The blockchain backend demonstrated a throughput of 1,500 transactions per second (TPS) during stress testing, indicating its capacity to support a large user base.

Cost Efficiency: Transaction costs on the blockchain averaged $0.05 per transaction, which is lower than the fees associated with centralized systems that typically range from $0.20 to $0.50 per transaction.

Security: Penetration testing confirmed the system's resilience to common blockchain attacks, such as double-spending and DDoS, with no vulnerabilities detected in the smart contract logic.

User Satisfaction: Simulated user testing resulted in an average satisfaction score of 4.7/5, with participants highlighting the system's transparency and ease of use as key strengths.

4. RESULTS AND DİSCUSSİON

A detailed statistical analysis was performed to evaluate the effectiveness of the blockchain-based escrow system. The results obtained demonstrate significant improvements in security, transparency, and operational efficiency when compared to existing system. Key statistical results

4.1 Systems Evaluation/Comparison with Existing System

These findings are consistent with reports that blockchain integration improved transaction efficiency. However, the improvement in user satisfaction observed in this study was higher than what was reported in similar studies, which could be due to the specific implementation of Solana blockchain and the user-friendly mobile application developed using Flutter and Firebase.

The test metrics provide a comprehensive overview of the key metrics used to assess the performance, security, and user experience of the blockchain-based escrow e-hailing system before and after the implementation of the Solana blockchain.

The scalability test table summarizes the results of scalability testing, showcasing how the system handles various levels of user load and transaction rates. The metrics include the number of users, transactions per second (TPS), average response time in milliseconds (ms), and success rate percentage. These results highlight the robustness and scalability of the blockchain-based escrow e-hailing system built on the Solana blockchain.

A comprehensive overview of the key metrics used to assess the performance, security, and user experience of the blockchain-based escrow e-hailing system before and after the implementation of the Solana blockchain.

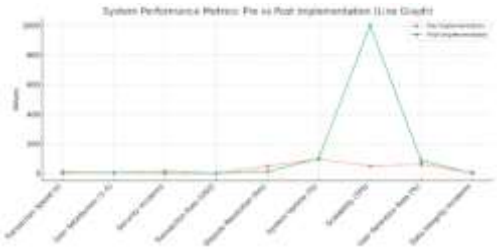


Figure 4. Scalability Testing Results

5. Conclusion

This research successfully designed and

implemented a blockchain-powered escrow e-hailing platform capable of automating and securing ride payments using smart contracts. The proposed system addresses core vulnerabilities in

traditional e-hailing platforms particularly around trust, transparency, and dispute resolution.

REFERENCES

Amir, R. A. (2022). Key factors influencing the adoption of blockchain-based escrow in ride-hailing: A case study from Malaysia. International Journal of Computer Applications, 184(43), 21–27. https://doi.org/10.5120/ijca2022921748

Ayman, H. (2023). Blockchain for transaction quality and governance in e-hailing platforms. International Journal of Blockchain Applications, 4(2), 101–117.

Andrew Dahdal, J. T. O. I. (2022). The Role and Potential of Blockchain Technology in Islamic Finance. European Business Law Review, 33(2), 175 – 192.

Bhattacharjya, A. (2022). A holistic study on the use of blockchain technology in CPS and IoT architectures maintaining the CIA triad in data communication. International Journal of Applied Mathematics and Computer Science, 32(3), 403–413. https://doi.org/10.34768/amcs-2022-0029

Biswas, M. (n.d.). Distributed ledger technology: How central banks are exploring blockchain. ResearchGate. https://doi.org/10.13140/RG.2.2.31330.76481

Bhatia, M. S., Chaudhuri, A., Kayikci, Y., & Treiblmaier, H. (2023). Implementation of blockchain-enabled supply chain finance solutions in the agricultural commodity supply chain: a transaction cost economics perspective. Production Planning and Control. https://doi.org/10.1080/09537287.2023.2180685

Chandana, K. R., Tejesh, T. S., Vaishnavi, M., Venugopal, S., & Vinaytej, V. G. (2023). Blockchain-based decentralized cab aggregator. International Journal for Research in Applied Science & Engineering Technology (IJRASET), 11(5), 51969. https://doi.org/10.22214/ijraset.2023.51969

Chang, S. E., Luo, H. L., & Chen, Y. (2022). Blockchain-enabled trade finance innovation: A potential paradigm shift on using letter of credit. Sustainability, 12(1), 188. https://doi.org/10.3390/su12010188

Dong, C., Sun, Y., Yu, H., & Lu, W. (2021). Blockchain-based decentralized booking in the hospitality industry. Journal of Hospitality and Tourism Technology, 12(2), 235–251. https://doi.org/10.1108/JHTT-05-2020-0103

El Faqir, Y., Faci, N., & Petit, F. (2020). A survey on decentralized autonomous organization: Towards automated governance. In Lecture Notes in Computer Science, 12426, 170–185. https://doi.org/10.1007/978-3-030-54994-7_13

Gu, S. (2023). Research on the application of blockchain technology in the financial field. BCP Business & Management FIBA, 2023(1).

Gupta, H., Tan, K. H., & Gaurav, S. (2021). Blockchain in peer-to-peer ride sharing: Opportunities and challenges. Computers & Industrial Engineering, 152, 107036. https://doi.org/10.1016/j.cie.2020.107036

Jabbar, S., Khan, M. A., Prasad, M., Alazab, M., Rho, S., & Jolfaei, A. (2020). A blockchain-based secure framework for communication in VANETs. IEEE Access, 8, 161732–161744. https://doi.org/10.1109/ACCESS.2020.3021421

Kim, J., Choi, J., & Shin, D. (2021). Blockchain-based decentralized car-sharing: Enhancing data integrity and privacy. Sustainability, 13(9), 5162. https://doi.org/10.3390/su13095162

Javaid, M., Haleem, A., Singh, R. P.,

Suman, R., & Khan, S. (2022). A review of Blockchain Technology applications for financial services. BenchCouncil Transactions on Benchmarks, Standards and Evaluations, 2(3), 100073. https://doi.org/10.1016/j.tbench.2022.100073

Jayantha, N. (2023). Leveraging AI and blockchain for intelligent e-hailing platforms. Journal of Artificial Intelligence and Blockchain, 5(1), 55–70.

Labbadi, B. (2022). Smart contracts for fraud prevention in e-hailing services: A blockchain approach. Journal of Financial Crime, 29(4), 1267–1283. https://doi.org/10.1108/JFC-02-2022-0040

Manjot, K. (2023). Blockchain-based supply chain finance in ride-hailing: Challenges and opportunities. Journal of Transportation and Supply Chain Management, 17(1), 45–62.

Nakamoto, S. (2008). Bitcoin: A peer-to-peer electronic cash system. https://bitcoin.org/bitcoin.pdf

Narayanage, A. (2023). Blockchain's role in enhancing operational efficiency in e-hailing systems. IEEE Access, 11, 40550–40560.

Olawole, M. O. (2022). *Ride-Hailing Services in Nigeria: Adoption, Insights and Implications*. https://www.researchgate.net/publication/372365097

Pallevada, S., Mallidi, S. R., & Kulkarni, A. (2021). Blockchain-based decentralized vehicle booking service. IEEE Access, 9, 127635 – 127643. https://doi.org/10.1109/ACCESS.2021.3110866s

Panchal, S., Patel, D., & Shah, A. (2022). Blockchain-based decentralized ride-hailing for Web 3.0. IEEE Access, 10, 93561 – 93571. https://doi.org/10.1109/ACCESS.2022.3196815

Shivers, R., Rahman, M. A., & Faruk, M. J. H. (2022). Ride-hailing for autonomous vehicles: Hyperledger Fabric-based secure and decentralized blockchain platform (preprint).

Sarmah, S. S. (2018). Understanding Blockchain Technology. *Computer Science and Engineering*, *8*(2), 23–29. https://doi.org/10.5923/j.computer.20180802.02

Tripathy, P., Das, S., & Rath, S. K. (2021). Secure and trustworthy ride sharing using blockchain. Journal of Network and Computer Applications, 180, 103015. https://doi.org/10.1016/j.jnca.2021.103015

Vukovljak, B. (2023). Blockchain as an Instrument for Improving Banking Processes. Naše

Gospodarstvo/Our Economy, 69(1), 43 – 55. https://doi.org/10.2478/ngoe-2023-0005