University of Batangas
LIPA CITY

TrustChain: Revolutionizing Vehicle Registration with Blockchain Technology

A Capstone Proposal

Presented to

the CITEC Department

UNIVERSITY OF BATANGAS LIPA CITY

Lipa City, Batangas

In Partial Fulfillment

of the requirements for

CAP101

Submitted by:

Besmar, Kim Andrei M.

Dulla, Jasper Dave C.

Latag, Joshua Ivan G.

Submitted to:

Dr. Mayling Iligan-Capuno

Table of Contents

CHAPTER 1

The pursuit of transparency, efficiency, and trust in public service delivery has long presented a paradox for government institutions. Citizens expect fast, reliable, and transparent transactions, yet the very bureaucracies tasked with providing these services often struggle under the weight of paper-based processes, fragmented systems, and institutional inertia. Scholars describe this as the **"transparency paradox"**, a condition in which the call for openness and accountability often produces more layers of paperwork and oversight, ironically slowing down the very processes it seeks to improve (Albu & Flyverbom, 2019). This paradox is most evident in highly transactional government services such as vehicle registration, where both regulatory compliance and service delivery must occur at scale.

Globally, governments have experimented with a range of digital reforms to address this paradox. Countries in the European Union and Oceania have explored harmonized standards and cross-border digital verification systems to simplify licensing and registration, though inconsistencies in implementation remain (Austroads, 2020; ACEA, 2022). Singapore offers a more mature example, having developed a comprehensive and highly structured importation and registration framework that ensures only roadworthy and compliant vehicles enter its system (LTA Singapore, 2024). These international experiences highlight a common theme: digitalization alone is not sufficient unless it is paired with robust verification protocols and regulatory alignment. In short, modernization requires not only faster systems but also stronger assurances of authenticity and trust.

In the Philippines, the Land Transportation Office (LTO) illustrates the persistence of these challenges. While recent efforts have introduced digital tools such as the Online Document Submission Facility (ODSF) through the Land Transportation Management System (LTMS), these measures have not fundamentally resolved bottlenecks in validation and record-keeping. Investigations revealed insider collusion in “technical carnapping” cases, where district offices illegally retitled seized vehicles by canceling legitimate transfers and issuing duplicate certificates—an abuse of gaps in paper-based custody systems (Daily Tribune, 2025; Manila Bulletin, 2025). At the same time, everyday inefficiencies remain evident: queue-driven registration workflows still require citizens to spend hours in LTO offices, moving from counter to counter for redundant checks, with limited automation to reduce error or delay (Sablada & Borres, 2021; Yandug & Santos, 2020). Compounding this, dealerships have repeatedly failed to release license plates and official receipts within mandated timeframes, prompting the LTO to issue nearly 4,000 show-cause orders in 2024 alone (Philippine News Agency, 2023). Collectively, these cases show that the system suffers not from a lack of regulations, but from weak enforcement and outdated verification mechanisms.

This situation exposes a critical gap. Existing digital reforms in the LTO have improved front-end access but have not automated or secured back-end validation. Rules and timelines exist, but compliance monitoring is fragmented, and custody trails remain vulnerable to manipulation or delay. Without tamper-evident records and automated compliance checks, enforcement depends too heavily on manual audits and discretionary oversight, these are conditions that allow inefficiency, insider abuse, and citizen frustration to persist. What remains unaddressed is the need for a secure, end-to-end validation framework that ensures records cannot be altered without detection, that workflows move faster without sacrificing

accountability, and that trust is embedded in the system itself rather than in individuals or paperwork.

Against this backdrop, blockchain has emerged as a promising solution. With its decentralized and immutable architecture, it provides a system where every state change is securely logged and transparently auditable. Smart contracts extend this capability by embedding business rules into the system itself, ensuring that compliance is not dependent on manual enforcement but is instead automated at the protocol level (Taherdoost, 2023). Global implementations, such as California's initiative to digitize over 42 million car titles on a blockchain network, illustrate how the technology can be deployed at scale to streamline title transfers and reduce fraud (CoinDesk, 2024). These cases demonstrate that blockchain is no longer a speculative concept but a tested model for solving inefficiency and integrity issues in vehicle registration.

The current Land Transportation Office (LTO) vehicle registration process remains hampered by inefficiencies that directly burden the public. Citizens continue to face long queues, repetitive submissions, and counter-to-counter handoffs that consume entire days. Even with the introduction of the Land Transportation Management System (LTMS) and its online facilities, these reforms have not resolved back-end issues in validation and record-keeping. The system still depends heavily on paper-based custody trails, leaving it prone to delays, errors, and reliance on manual verification. Instead of streamlining services, these gaps sustain inefficiency, create avenues for fixers, and gradually weaken public confidence in the government's ability to deliver transparent and predictable service

The persistence of insider manipulation further underscores the fragility of current processes. In 2025, the LTO opened investigations into at least 40 district offices for “technical carnapping,” where officials allegedly canceled prior transfers and issued duplicate certificates of registration to illegally retitled vehicles(Manila Bulletin, 2025) (Philstar, 2025). Such cases highlight that reforms focused solely on digital access points cannot address the deeper challenge of tamper-prone validation mechanisms. Without an immutable audit trail or automated checks, the system continues to rely on discretionary oversight that can be exploited. For citizens, especially those with limited time and resources, the consequences are tangible: extra transport costs, wasted hours away from work, stress, and difficulty navigating requirements scattered across different offices

These challenges become even more pressing in Lipa City, where development plans explicitly emphasize SMART City initiatives. Paper-centric and delay-prone workflows are increasingly out of step with modernization goals, creating a gap between citizens’ expectations of digital governance and the reality of outdated bureaucratic practices. At its core, the problem is that there is no secure, automated validation framework that ensures both efficiency and accuracy while reducing the need for manual processing. What is missing is a tamper-evident, machine-verifiable mechanism that shortens ownership-transfer and registration cycles while embedding accountability across stakeholders

To address these conditions, this study proposes a permissioned blockchain-based registration system that integrates smart contracts and off-chain storage. Such a system is designed to replace repetitive manual steps with automated workflows, providing immutable history, role-based access, and real-time status tracking. By doing so, the registration process

can shift from a paper-heavy sequence of checks into a secure, auditable, and efficient digital workflow. Beyond technical upgrades, this approach reflects the broader societal demand for trust infrastructures where compliance is built into the system rather than enforced through human discretion.

For the researchers, the motivation to pursue this study arises not only from prior studies but also from personal encounters with the inefficiencies of the current system. Having experienced the frustration of long queues, repeated resubmissions, and the need to move from office to office, the team recognizes that the existing workflow consumes resources that ordinary citizens cannot afford to waste. By situating the pilot in LTO Lipa, the project directly aligns with the city's SMART City vision, showcasing how emerging technologies can be introduced locally as part of a larger modernization agenda. The initiative is pragmatic—targeting inefficiencies in validation and document management—but also aspirational, demonstrating that blockchain can serve as a concrete step toward transparent, citizen-centered governance.

Moreover, the urgency of reform is amplified by current public discourse. In 2025, multiple civil society groups demanded independent investigations into allegations of excessive corruption in Philippine infrastructure programs, reflecting a growing national appetite for governance systems that are tamper-proof and auditable(Reuters, 2025) (AP News, 2025). By embedding validation, transparency, and accountability into the registration process itself, this study not only addresses a localized operational problem but also resonates with wider societal calls for trustworthy digital governance.

Objectives of the Study

The main objective of this study is to design, develop, and evaluate the effectiveness of a blockchain-based vehicle registration system integrated with smart contracts for the Lipa City Land Transportation Office motor vehicle registration process.

1. To analyze the concepts of blockchain technology, smart contracts, and distributed ledger systems to understand their applicability in developing a secure and efficient vehicle registration platform that addresses current LTO operational challenges.
2. To develop a blockchain-based vehicle registration system with the following functions and features:
    a. Provide secure and immutable document storage for vehicle registration records, including sales invoices, Certificate of Stock Reported (CSR), emissions test certificates, and insurance documentation.
    b. Implement smart contract functionality for compliance verification, payment processing, and multi-step approval workflows.
    c. Enable real-time status tracking and transparent audit trails for all registration transactions while maintaining data integrity and preventing document fraud.
    d. Generate tamper-proof digital OR/CR certificates with instant verification capabilities accessible to vehicle owners, law enforcement, and regulatory agencies.
3. To implement the blockchain platform as an integrated solution that connects multiple stakeholders, including vehicle owners, insurance companies, smoke testing facilities, and LTO personnel, through a unified registration workflow.

4. To test and evaluate the blockchain-based vehicle registration system using ISO/IEC 25010 testing standard for software, with the following criteria: functional suitability, reliability, usability, performance efficiency, security, and maintainability.
5. To assess the system's impact on reducing processing times by conducting a comparative analysis between traditional paper-based LTO registration procedures and the proposed blockchain-integrated workflow through controlled testing scenarios.

Significance of the Study

The researchers believe that the study will be beneficial to the following:

A. Land Transportation Office (LTO)

The proposed blockchain-based vehicle registration system will go a long way to ensure the efficiency of the operations of LTO since it will have automated operations and minimal paperwork. Using the application, the LTO will be able to acquire real-time data as well as streamlined workflows that can enhance decision-making and service delivery. The digital OR/CR certificates, which will be fixed and tamper-proof, will help in increasing the credibility of LTO services at the end benefiting the overall trust of the people towards the functions of the government.

B. Vehicle owners and the General Public

The application allows vehicle owners to be notified automatically through email and SMS on document expiry and registration updates. The staff members will feel more secure to know that their enrollment information is safe in the network of blockchain. The uncertainty and frustration in the traditional methods of registration will be done away by the real-time status tracking.

C. Insurance Companies and Testing Facilities

The blockchain platform will develop a professional approach to interlinked customers of various stakeholders in the form of a common workflow. Test centers and insurance firms will enjoy automated verification of documents and have a low risk of fraud because the blockchain technology will create an indelible record of transactions made. The system will improve the arrangement between the service providers and LTO processes hence more delivery of services.

D. Academic and Research Community

The integrity of academic research on new technologies will receive a confidence boost through a reliable and stable blockchain system with tangible applications in the government sector. This research would be useful in any future blockchain application in government service and act as a basis of further research in other government agencies.

E. Technology Developers and IT Professionals

The study will have technical knowledge contributed to the integration of blockchain technology to the structuring of the current government systems and the handling of the issues that are complex. The exhaustive approach towards the testing could be used by other government agencies deploying a blockchain to create a blueprint on how to approach a similar implementation by giving technical requirements and guidelines to IT professionals on how to proceed.

F. Philippine Transportation Sector

The blockchain vehicle registration will also lead to the transformation of the transportation industry in the Philippines as it will form the basis of a digital transformation strategy. The study will show how blockchain technology can resolve some systemic problems like lack of transparency, document frauds and delays in the processes that has historically bedeviled the transportation industry.

G. Future Researchers

This study has explored the design, development, and evaluation of a blockchain-integrated vehicle registration system for the Land Transportation Office (LTO) in Lipa City, Batangas. While this research has demonstrated the potential benefits of distributed ledger technology for document integrity, process automation, and stakeholder transparency, several avenues remain open and ripe for further investigation.

Scope, Limitations, and Delimitations

Scope defines the coverage of the study, what it will include and accomplish. **Limitations** describe the external constraints that the researchers cannot control, while **delimitations** are the intentional boundaries set by the researchers to focus the study within a manageable range. The following subsections present the scope, limitations, and delimitations of this capstone project on a blockchain-based vehicle registration system for the Land Transportation Office (LTO) in Lipa City.

This study focuses on the design, development, and pilot implementation of a digital vehicle registration system at the Land Transportation Office in Lipa City. It demonstrates how essential services such as initial registration, renewal of registration, transfer of ownership, and the submission and verification of supporting documents can move from largely manual procedures to a guided online process that begins with the filing of requirements and ends with the issuance of digital proof, such as an official receipt or a certificate of registration. The pilot simulates the roles of stakeholders in a controlled environment, where vehicle owners and dealers submit and track applications, partner institutions like insurance providers and emission testing centers are represented through role-based mock-ups using test data, and test data to illustrate how compliance records would flow in a real deployment, and LTO personnel review, validate, approve, or deny requests while overseeing the progress of cases. The system maintains accountability through action logs and role-based permissions for sensitive steps, and it allows users to monitor status updates without repeated office visits; administrators have summary and record-keeping features that support oversight, while citizens receive timely notifications about approvals, expirations, or issues that need attention.

The pilot also demonstrates verification of tamper-proof digital certificates of registration and official receipts, visible to vehicle owners and, in a read-only module, to law-enforcement or regulatory agencies. This module is distinct from regular user accounts because it enforces a separate, restricted role with limited capabilities. It returns only a verification status and a small set of certificate metadata that are safe to disclose, it exposes no editable fields and no sensitive personally identifiable information, and it requires authenticated access, which illustrates how external actors could safely consume blockchain-anchored proofs without the ability to alter records.

Payment is represented through a placeholder mechanism rather than a live gateway. Users upload or view a mock proof of payment, for example a receipt image, to demonstrate where a payment record would enter the workflow. This is a deliberate design choice that shows integration points while avoiding exposure to financial, security, and legal risks that are outside the study.

Original documents are stored off-chain in controlled storage, only cryptographic hashes and minimal metadata are recorded on-chain, documents are encrypted at rest, and access is restricted by role. User identities are provisioned by an administrative authority, and access is enforced both in the application and at the ledger layer through a membership service that uses certificate-based roles and supports revocation. The system accepts standard documents required for registration, renewal, and transfer, including invoices, certificates of stock report, emission test results, insurance certificates, deeds of sale, and official receipts or certificates of registration, in PDF and common image formats, for example PNG and JPEG. The web interface targets modern browsers on desktop and mobile devices and follows basic

accessibility practices. The pilot operates with test or properly redacted data and keeps an auditable trail of interactions to support integrity and future review.

The project is intentionally bounded to demonstration scale and does not integrate with the national LTO production environment. It does not aim for nationwide throughput, high availability, or disaster recovery, and it does not include certification-grade audits. Instead, it will be evaluated against recognized software quality criteria such as functional correctness, usability, security, performance, and maintainability within the limits of academic research, which emphasizes feasibility and provides evidence for a digital workflow that can improve transparency and accountability in a single office setting and inform future refinements and potential expansion.

Delimitations

The pilot is geographically limited to the Land Transportation Office in Lipa City and is delivered as a web-based application accessible through standard browsers on desktop and mobile devices, it does not include dedicated native Android or iOS applications. The blockchain network is permissioned to protect privacy, with role-based access control that differentiates permissions for LTO staff, dealers, insurers, and testing centers. Roadside law-enforcement verification units are excluded from this version, and third-party participants such as dealers, insurers, and testing centers are simulated rather than connected through live consortium nodes. Functional coverage is focused on document integrity, auditability, and automated validation; live payment gateways, penalty enforcement, nationwide license plate logistics, biometric identity verification, and social media notification channels are excluded. For evaluation, the project uses the ISO or IEC 25010 quality model at pilot scale, while penetration

testing, certification audits, and broader change-management or user training programs are not part of the scope. These boundaries keep the project realistic and achievable within academic and resource constraints while demonstrating the feasibility and value of blockchain for vehicle registration.

CHAPTER 2

Review of Related Literature

Global Modernization of Vehicle Registration

Across developed jurisdictions, significant efforts have been undertaken to modernize vehicle registration systems by embracing digitalization and harmonized regulatory frameworks. In a comparative study of practices in Australia, New Zealand, and the European Union, Austroads (2020) found persistent inconsistencies in identity verification, data-protection regimes, and digital adoption. The study highlighted that while some countries have integrated digital platforms to improve user experience, others continue to struggle with fragmented systems that hinder interoperability and efficiency. Similarly, the European Automobile Manufacturers Association (ACEA, 2022) emphasized that harmonized standards across regions such as the EU, United States, Canada, Japan, and China have been critical in facilitating international trade and ensuring more consistent compliance practices. Singapore, on the other hand, has institutionalized a step-by-step vehicle importation and registration process that mandates strict adherence to safety, emission, and technical requirements. According to the Land Transport Authority (LTA, 2024), these measures guarantee that only roadworthy and environmentally compliant vehicles are registered, underscoring the importance of robust regulatory enforcement. Collectively, these global experiences illustrate the dual importance of digital platforms and regulatory harmonization in achieving efficient and secure registration systems. They also demonstrate that modernization is not only a technological initiative but also a matter of aligning verification processes, standards, and oversight mechanisms.

Philippine Digital Registration

In the Philippines, the Land Transportation Office (LTO) has taken steps toward modernization through the implementation of digital platforms. The LTO Portal (2024) allows

drivers to submit required documents online, including Compulsory Third-Party Liability (CTPL) insurance and the Motor Vehicle Inspection Report (MVIR). The portal also provides clear descriptions of timelines, administrative procedures, and penalties to improve regulatory compliance. These reforms have reduced reliance on hardcopy submissions and made compliance more convenient for vehicle owners. However, as YugaTech (2023) has noted, the system remains dependent on manual verification processes, limiting the impact of digitization and creating bottlenecks in application processing. This suggests that while digital access points have been introduced, the back-end workflows remain constrained by traditional practices, preventing full efficiency gains.

LTO Registration Timelines

Complementing these digital initiatives, the LTO announced a seven- to eleven-day processing window for the release of Official Receipts (OR), Certificates of Registration (CR), and license plates following the purchase of a vehicle. According to YugaTech (2023), this streamlined sequence involves five steps—purchase, preparation, dispatch, delivery, and receiving. Penalties are imposed on dealerships that fail to meet the mandated timelines. Yet despite this structured procedure, delays continue to frustrate vehicle owners, with many waiting beyond the stipulated period due to backlogs and uneven compliance. The persistence of these delays reflects the gap between policy design and operational execution, highlighting that digitization without integrated validation mechanisms is insufficient to resolve systemic inefficiencies.

Record-Integrity Risks and Insider Abuse ("Technical Carnapping")

In mid-2025, the LTO has launched probes into 40 district offices over illegal ownership transfers of police-seized vehicles—cases dubbed **"technical carnapping."** Reports indicate that officials in implicated offices canceled prior transfers and issued duplicate Certificates of Registration to make unauthorized retitling appear valid, with clusters of cases reported by region (e.g., multiple incidents in CARAGA). The LTO has issued show-cause orders and vowed administrative and criminal action against those involved. These incidents have exposed weak cross-checks and paper-based custody updates, allowing insider manipulation of records to pass as legitimate changes. For the researchers, this has strengthened the premise that a secure, append-only trail of state changes is required to protect ownership histories against both external falsification and insider collusion (Daily Tribune, 2025; Philstar, 2025; Inquirer, 2025; SunStar, 2025; Manila Bulletin, 2025; LTO, 2025).

Chronic Queue-Driven Workflows and Manual Validation

Local studies have documented how registration at LTO branches has remained queue-dependent and paper-intensive, resulting in day-long visits, repeat appearances, and persistent dissatisfaction. Empirical analyses show that limited counters, serial counter-to-counter handoffs, and manual checks have prolonged turnaround times and encouraged reliance on **"fixers."** In effect, the system has optimized for processing paper rather than verifying truth, so edge cases (e.g., name mismatches, unclear scans) escalate into

multi-visit resolutions. For the researchers, these findings have underscored that the binding constraint is not the absence of rules but the absence of end-to-end, machine-verifiable validation that shortens ownership-transfer cycles (Sablada & Borres, 2021; Yandug & Santos, 2020).

Delays in OR/CR and Plate Release from Dealerships

Despite explicit timelines, dealerships have repeatedly failed to release the Official Receipt (OR), Certificate of Registration (CR), and plates within the prescribed window. In 2024, the LTO issued nearly 4,000 show-cause orders to dealers for late OR/CR or plate release, and earlier actions also penalized dealers for delayed registrations. On the ground, plates have remained in dealerships' custody and buyers have waited beyond the stated 7–11 business days, revealing gaps in tracking, case escalation, and proof-of-delivery. For the researchers, this pattern has highlighted the need for a tamper-evident issuance chain with automated compliance monitoring to shorten release cycles and deter non-compliance (LTO, 2024; Philippine News Agency, 2023; Manila Bulletin, 2024).

Blockchain Technology

Blockchain technology has represented a fundamental change in how digital information is transmitted, verified, and stored. Sultan et al. (2018) defined blockchain as "a decentralized, cryptographically linked, append-only sequence of records replicated across a peer-to-peer

network, governed by a consensus protocol." This highlights three essential attributes—immutability, decentralization, and transparency—that replace centralized trust with distributed verification. Afzal and Asif (2019) further emphasized that once recorded, blockchain entries cannot be altered retroactively, ensuring auditability and trustworthiness in legal and administrative frameworks.

Ethereum

Ethereum has provided a foundation for deploying smart contract applications. Buterin (2016) introduced Ethereum as a next-generation blockchain designed not only for cryptocurrency but also for decentralized applications. Its Ethereum Virtual Machine (EVM) enables Turing-complete scripting, which allows complex business logic to be automated and executed transparently. Huertas et al. (2018) discussed Ethereum's potential for hybrid blockchain models, where sensitive data can be shielded under permissioned controls while retaining public verifiability. This adaptability has made Ethereum suitable for enterprise applications requiring both compliance and flexibility.

Hyperledger Fabric

Hyperledger Fabric, developed under the Linux Foundation, is a permissioned blockchain framework tailored for enterprise and government use. Unlike public blockchains, Fabric allows organizations to define access rights, employ modular consensus protocols, and integrate with existing identity systems. Androulaki et al. (2018) described Hyperledger Fabric as a distributed operating system for permissioned blockchains, highlighting its modular design for scalability and security. Rosado et al. (2019) further applied Fabric in government service

prototypes, demonstrating that it can balance decentralization with regulatory oversight. Locally, Pulmano et al. (2023) implemented Hyperledger Fabric to create a decentralized credentialing system for participatory governance in the Philippines, confirming its adaptability for secure government applications. Likewise, the Bangko Sentral ng Pilipinas selected Hyperledger Fabric for Project Agila, its pilot wholesale central bank digital currency initiative, underscoring its suitability for regulated environments (BitPinas, 2023).

Smart Contracts

Smart contracts extend blockchain's functionality by embedding automated, self-executing rules into the ledger. Taherdoost (2023) emphasized that smart contracts reduce human error and minimize dependence on intermediaries by enforcing contract clauses automatically. Verde and Ganiron (2024) highlighted their application in Philippine government projects, where automation has improved transparency and accountability by replacing manual compliance processes with algorithmic verification. As such, smart contracts have been recognized as a powerful tool for improving efficiency in bureaucratic workflows.

2.2 Related Studies

Several studies have explored the integration of blockchain technology in vehicle registration and other government-related processes. Malintha et al. (2024) examined Sri Lanka's manual registration system and identified issues of fraud, inefficiency, and lack of transparency. They proposed a blockchain-based registry using Ethereum that automated core processes such as ownership transfer and certificate issuance, ensuring immutability of records and reducing processing time. Similarly, Rosado et al. (2019) demonstrated the potential of Hyperledger Fabric for government services, noting that a permissioned blockchain could balance decentralization with regulatory oversight by controlling participation and ensuring compliance with policies.

Practical adoption has also been documented internationally. In 2024, the California Department of Motor Vehicles implemented blockchain technology to digitize approximately 42 million vehicle titles using the Avalanche platform (CoinDesk, 2024; Arianee, 2024). This initiative reduced title transfer delays, minimized fraud, and improved citizen services, showing that blockchain systems can be deployed at national scale while maintaining efficiency and security.

Locally, Philippine government agencies have started experimenting with blockchain applications. The Department of Information and Communications Technology (DICT, 2022) proposed the use of blockchain for digital identity and land titling, while the Bangko Sentral ng Pilipinas piloted Project CBDCPh, a wholesale digital currency initiative based on distributed ledger concepts. The Land Registration Authority has also considered blockchain for authenticating land titles. These local efforts reflect a growing recognition of blockchain as a

viable technology for public sector services and provide a foundation for its potential application in vehicle registration.

2.3 Synthesis of the Review of Related Literature and Studies

The reviewed literature and studies collectively demonstrate that inefficiencies, manual procedures, and fragmented verification remain common in vehicle registration systems worldwide. International reforms, such as the California DMV's blockchain initiative and Sri Lanka's prototype, confirm that blockchain can streamline ownership validation, reduce paperwork, and enhance trust in registries. At the same time, local discussions on the Philippine Land Transportation Office (LTO) highlight persistent delays, reliance on paper-based documentation, and multi-step ownership validation processes that frustrate citizens and sustain opportunities for inefficiency.

While global cases show that blockchain has already been applied to solve bottlenecks in registration and validation, the Philippine context remains different. Existing digital initiatives of the LTO, such as online submission portals, have introduced partial improvements but continue to depend on manual authentication and fragmented workflows. Unlike other countries that have piloted blockchain specifically for vehicle ownership, the Philippines has yet to implement such systems, leaving a gap between ongoing inefficiencies and the potential of distributed technologies.

For the researchers, these findings affirm the need to rethink how vehicle registration is managed, particularly in Lipa City, where LTO offices continue to rely on labor-intensive

processes. The synthesis of international and local works makes it clear that the challenge in the Philippines is not primarily fraud but efficiency and validation, with fraud prevention emerging only as a secondary benefit of more transparent and automated systems. This distinction grounds the present study's focus: to design and develop a blockchain-based registration system that simplifies ownership validation, reduces manual steps, and contributes to faster and more reliable transactions.

The motivation for this study stems from the researchers' own frustrations with existing LTO processes and their belief that society must continually evolve through the adoption of emerging technologies. With Lipa City's plans to become a SMART City, the project is envisioned as a timely showcase of blockchain's feasibility in Philippine government services. In doing so, the study not only addresses immediate operational inefficiencies but also contributes academically by demonstrating how blockchain can pave the way for modernized, transparent, and citizen-centered governance in the country.

Chapter 3

Research Methodology

Research Design

This study employed **Developmental Research (DDR)** as its guiding framework. Developmental research emphasizes the systematic design, implementation, and evaluation of an artifact to address real-world problems while contributing to theoretical understanding (Ibrahim, 2016; Richey & Klein, 2007). In this study, the artifact is a blockchain-based vehicle registration system that integrates smart contracts and off-chain storage to address inefficiencies and validation challenges within the Land Transportation Office (LTO). DDR was chosen because it allows the researchers to align the system's design and development with stakeholder needs while maintaining academic rigor. Unlike traditional project-based implementations, DDR treats system creation as a research process, documenting design decisions, challenges, and evaluation outcomes to generate insights about what works in practice (McKenney & Reeves, 2019).

To complement this design, the researchers adopted Agile practices under the Software Development Life Cycle (SDLC). The iterative nature of Agile supports the flexibility and responsiveness of DDR, ensuring that the prototype is refined through cycles of design, testing, and feedback. This combination allowed the study to balance its practical goal of building a functional blockchain-based registration system with its scholarly aim of contributing to the discourse on blockchain applications in government services.

Research Method

The research method of this study integrated Agile software development methodology within the Software Development Life Cycle (SDLC). Agile was selected because it complements the iterative nature of developmental research by prioritizing stakeholder collaboration, continuous improvement, and adaptability to emerging requirements (Ng, 2019; MDPI, 2019). Organizing Agile under the SDLC framework ensured that the development process followed a structured sequence of phases, consistent with established practices in academic capstone projects (Gray, 2020). This combination allowed the researchers to build a functional system while maintaining methodological rigor.

Figure 1. Agile Development

Phase 1: Requirements. The first phase involved gathering both functional and non-functional requirements from key stakeholders such as vehicle owners, registration officers, and system administrators. User stories were formulated to capture specific needs and expectations, while acceptance criteria were established to guide later testing. To ensure prioritization, the MoSCoW technique (Must have, Should have, Could have, Won't have) was applied, and product and sprint backlogs were created to organize tasks and milestones (Ng, 2019).

Phase 2: Design. During the design phase, the researchers developed the system architecture and the blockchain network topology. User interface mockups and wireframes were produced to visualize workflows and interactions. At the blockchain level, the structure of chaincode (smart contracts) was designed with consideration for security patterns, modularity, and performance optimization. All technical specifications were documented to guide implementation and maintain traceability of design decisions (MDPI, 2019).

Phase 3: Development. Implementation began with the development of chaincode in Hyperledger Fabric using supported programming languages such as JavaScript and Go. Simultaneously, backend services were implemented in Node.js with Express, while frontend modules were developed using React.js. Security mechanisms, such as role-based access control and token-based authentication, were embedded during development rather than added post hoc, in line with best practices in Agile software engineering (MDPI, 2023). Each sprint delivered working functionality that was demonstrated to stakeholders for feedback.

Phase 4: Testing. Multiple levels of testing were conducted to ensure the system met both functional and non-functional requirements. Unit tests validated the correctness of individual modules, while integration tests ensured that subsystems worked together seamlessly. Security

audits of the chaincode were conducted to identify vulnerabilities, and user acceptance testing was carried out with stakeholders to confirm that requirements were satisfied. This phase highlighted Agile's emphasis on frequent verification and validation through collaboration with end users (Ng, 2019).

Phase 5: Deployment. Once verified, the system was deployed to a controlled environment within the LTO pilot context. The blockchain network was initialized with peer and orderer nodes, and chaincode was deployed to the ledger. The application services were launched on dedicated servers. Backup and recovery mechanisms were also established to maintain system resilience against unexpected failures (ScienceDirect, 2024).

Phase 6: Review. In the final phase, feedback was systematically gathered from users and technical experts. Surveys based on ISO/IEC 25010 were administered to measure software quality characteristics, while interviews were conducted to capture qualitative insights. Performance logs and monitoring data were analyzed to identify bottlenecks or anomalies. Retrospective reviews were also conducted with the development team to reflect on the process and plan for refinements in subsequent iterations (McNeish, 2018).

Through these six phases, the Agile-SDLC approach ensured that the system was built in a flexible, iterative, and stakeholder-centered manner. It allowed the researchers to integrate technical requirements, user needs, and quality standards, resulting in a blockchain-based vehicle registration system that aligns with both practical objectives and academic research goals.

3.3 Data Gathering Instruments

To evaluate the effectiveness of the proposed blockchain-based vehicle registration system, the researchers employed a combination of quantitative and qualitative instruments. The primary instrument was a structured survey questionnaire designed based on the ISO/IEC 25010 software quality model. According to Canlas et al. (2021), this framework provides a comprehensive means of evaluating software across eight quality characteristics: functional suitability, performance efficiency, compatibility, usability, reliability, security, maintainability, and portability. The questionnaire was divided into sections aligned with these characteristics, using a four-point Likert scale to capture respondent perceptions while avoiding a neutral midpoint (PMC, 2021).

In addition to surveys, semi-structured interviews were conducted with LTO personnel, vehicle owners, and technical experts. Interviews allowed the researchers to capture nuanced perspectives on usability, security, and practical challenges in the current system, which could not be fully reflected in quantitative measures (McKenney & Reeves, 2019). Furthermore, the study incorporated system logs and performance metrics, which provided objective indicators of efficiency such as transaction times, error rates, and network latency (ScienceDirect, 2024). Finally, expert evaluation forms were distributed to IT and blockchain specialists to assess architecture design, chaincode implementation, and compliance with industry best practices. The combination of these instruments ensured that both subjective user experiences and objective technical measures were captured.

3.4 Data Gathering Procedure

The data collection followed a structured procedure consisting of two main phases: pre-implementation and post-implementation.

During the pre-implementation phase, baseline data on the current LTO registration process was gathered. This included stakeholder surveys and interviews to document pain points, such as long waiting times, verification bottlenecks, and document fraud risks, consistent with findings by Sablada and Borres (2021) and Meher et al. (2024). The researchers also collected processing time records and error logs from existing procedures to establish benchmarks for later comparison.

In the post-implementation phase, evaluation was conducted after deploying the blockchain prototype in a controlled environment. Selected stakeholders participated in user testing sessions, where they interacted with the system to simulate real transactions. After sufficient exposure, the ISO/IEC 25010-based survey was administered to capture user feedback, with at least thirty respondents targeted to achieve statistical validity (PMC, 2018). Parallel to this, system monitoring over a 30-day period recorded performance metrics, including throughput and error rates. Finally, expert reviews were carried out by IT specialists who evaluated system architecture, chaincode logic, and adherence to blockchain security standards.

To validate survey reliability, Cronbach's alpha was computed for each section, with ≥0.70 considered acceptable for internal consistency (McNeish, 2018). Pilot testing of instruments was also conducted before full deployment to identify potential issues. This multi-phase procedure

ensured that both the pre-existing problems and the improvements introduced by the system were rigorously assessed.

Technical Background

Blockchain

In this study, **blockchain** is adopted as the core trust layer for vehicle registration: a distributed ledger that records transactions in cryptographically linked blocks to produce a tamper-evident, time-ordered history shared by authorized participants (NIST, 2018). We specifically use a **permissioned** approach so that only vetted organizations in the process (e.g., LTO and accredited partners) can read, write, and endorse records within clearly defined roles and policies, which aligns with the governance and privacy needs of a public office. To operationalize this, the project employs **Hyperledger Fabric v2.5**, an enterprise blockchain framework under the Hyperledger project, because it provides membership management through the **Membership Service Provider (MSP)**, policy-driven **endorsement**, and a modular ordering service, while executing business rules as **smart contracts ("chaincode")**—all features that let us encode registration, ownership transfer, and renewal checks as deterministic, auditable steps rather than manual discretion (Hyperledger Fabric Documentation, n.d.). In short, Fabric supplies the "how" through identities, policies, and chaincode on a controlled network, while the ledger itself supplies the "why" by guaranteeing an immutable audit trail that strengthens accountability and reduces opportunities for record tampering in a regulated workflow.

Blockchain Platform

2.1 Hyperledger Fabric v2.5

The system is based on Hyperledger Fabric v2.5 which was selected as it allows for controlled membership and modular design, which is considered a permissioned blockchain. It is appropriate for regulated processes like that of registering vehicles, where only authorized entities participate in the process. Fabric's modularity gives the team the capability to simulate a consortium with limited resources and ensures accountability and tamper-proof.

2.2 Raft Consensus

The ordering service uses Raft, which was chosen because of two key properties - deterministic finality, and crash-fault tolerance. Such a consensus method will guarantee that all transactions take a reliable and predictable sequence so that there will be fewer risks of inconsistent records. By utilising Raft, the system remains stable even if there are partial node failures, which is important in the workflow of governments.

2.3 Membership Service Provider (MSP)

MSP (managed service provider) of Fabric which takes care of digital identities and enforces role-based permissions. This was selected due to there being multiple actors skilled by a) User / Vehicle Owner, b) LTO staff, b) smoke emission tester and d) insurance needed to be able to operate with defined responsibilities. The MSP provides accountability of checking roles before granting access or approvals.

2.4 Smart Contracts (Chaincode)

Business rules are translated to chaincode written in the JavaScript/TypeScript language. This decision was made in order to automate some basic actions such as registration, renewal, and ownership transfers to reduce human error. By having the actual sense of logic embedded right into the ledger and also making it fairly transparent, it supports the system of rightness, transparency, and compliance.

2.5 State Database (CouchDB)

CouchDB is used instead of registration metadata's rich queries at CouchDB's state database. It was adopted so that the administrators would be able to search for, filter, and report without scanning the entire ledger. This is done in order to improve efficiency while maintaining the immutability of the blockchain.

2.6 Off-Chain Storage (IPFS)

IPFS is utilized for the large documents like invoices, deed of sales and emission tests. The reason behind this choice is that blockchain is not built for bulky files but anchors of these files can be anchored to blockchain. This technique provides authenticity, but with light-weight, as well.

Application Layer

3.1 Backend

The backend is built up using Node.js and Express which was chosen because of its lightweight and event-driven architecture. It is the middleware layer that will take care of authentication and transaction management and also to communicate with Fabric SDKs. This ensures that the actions of the users are translated to blockchain transactions securely.

3.2 Frontend

The frontend is browser-based and was created using React or standard HTML, CSS and JavaScript. This decision has undergone the path to ensure maximal accessibility on both desktop devices and mobile devices without the need of native apps. By maintaining the web-based system, users can interact with the system easily by familiar browsing systems.

3.3 Transaction Flow

For instance, the transaction process starts by uploading data to IPFS, collecting the relevant hash and validating the prover or validator of the transaction by running the transaction through the specified known as chaincodes. The endorsed transactions are then introduced into a Raft, to propose for the ordering and the block creation. Once committed results are returned to the frontend thus providing users with real-time updates.

Security and Notifications

4.1 Authentication

The system uses JWT to deal with authentication as it allows us to have secure and stateless supervision of sessions. This was selected in favour of scalability between distributed blockchain nodes. Users log in using email and password and tokens are used to verify their identity during the session.

4.2 Two-Factor Authentication (2FA)

Sensitive acts should have a second layer of defence via 2FA codes sent via email or SMS. This makes it difficult for unauthorized access even when passwords are hacked. It enhances the trustworthiness and protects important registration transactions.

4.3 Role-Based Access

Permissions are modified in backend and implementation of chaincode so that both in back-end and chaincode, the consistency and layer protection is defined. This helps in preventing the modifications by observing authorized users from altering records or approving steps. Double enforcement takes on resilience for interior abuse.

4.4 Notifications

Email and SMS notifications were integrated for real-time notification including notifying people of approvals, expirations and issues in documents. This cuts down on the need for multiple trips over to LTO offices. The feature also makes the government transparent by keeping citizens in the loop.

Deployment and Tools

5.1 Hosting

Deployment is done using DigitalOcean which is used for its affordability and reliability. This choice gives the researchers the opportunity to simulate enterprise-level hosting. The solution is that the cloud environment provides scalability and accessibility for testing.

5.2 Containerization

Docker with WSL2 is used for packaging all the services in a consistent manner for Windows and Linux systems. This makes installation easier, reduces environment conflicts and makes installation repeatable. Containers make Fabric nodes run exactly the same regardless of whether the set-up is local or in the cloud.

5.3 Development Tools

Git is used for version control to aid the collaborative development while the ide for git is used as the programming editor with its extensions and debugging capabilities made of VS Code. In a combined effect, these tools pay off productivity and teamwork. They are also the way of supplying the environment needed for the development of blockchain and web applications.

5.4 Initial Topology

The pilot network is set up with 3 nodes so as to represent the network structure of a consortium while remaining resource-efficient. This offers quorum and high availability, much in keeping

with how gainful governance is in practice. It demonstrates how the system has the potential to be scaled up.

Hardware and Software Requirements

The successful implementation of the blockchain-based vehicle registration system requires specific hardware and software configurations. These requirements ensure optimal performance, security, and reliability of the system.

Table 1. Hardware Requirements

Component	Minimum Specification	Recommended Specification
Development Workstation	Intel Core i3 processor, 4GB RAM, 500GB SSD, Standard keyboard and mouse	Intel Core i5/i7 processor, 8GB RAM, 256GB SSD, Ergonomic peripherals
Backup Storage	500GB external solid state drive	Cloud backup solution

Table 2. Software Requirements

Software Component	Description	Version Requirement
Github	Cloud-based platform for hosting repositories and enabling collaborative development	Latest (cloud-based)
Git	Local version control system to track and manage source code changes	2.34+
Visual Studio Code (VS Code)	Integrated Development Environment (IDE) with support for Node.js, Docker, and Fabric SDK extensions	1.96
Docker Desktop	Containerization tool for simulating blockchain nodes, CouchDB, and test environments	20+
Web Browsers (Chrome/Firefox)	Used to test and run the frontend web application during development	Chrome 90+, Firefox 88+

Statistical Treatment of Data

The researchers applied weighted mean as the primary statistical tool to analyze the responses from the ISO/IEC 25010-based survey questionnaire. The weighted mean was used to determine the overall level of user agreement for each software quality characteristic, based on a four-point Likert scale. The interpretation scale was as follows:

Likert Scale Option	Weighted Mean Range	Verbal Interpretation
1	1.00 – 1.75	Strongly Disagree
2	1.76 – 2.50	Disagree
3	2.51 – 3.25	Agree
4	3.26 – 4.00	Strongly Agree

To ensure the reliability of the survey instrument, the researchers computed Cronbach's Alpha for each set of indicators. An alpha coefficient of 0.70 or higher was considered acceptable, while values above 0.80 indicated strong internal consistency (McNeish, 2018). This approach provided a systematic way of interpreting user perceptions and ensured that the data collected accurately reflected the quality characteristics being evaluated.

ISO/IEC 25010 Software Evaluation

The evaluation framework for this study was grounded in ISO/IEC 25010, which supersedes ISO 9126 and provides an updated model for assessing software product quality (Proceedings of CECIIS, 2022). This standard was selected because it comprehensively covers eight quality characteristics critical to government information systems.

The characteristics evaluated were: (1) functional suitability, (2) performance efficiency, (3) compatibility, (4) usability, (5) reliability, (6) security, (7) maintainability, and (8) portability. Each characteristic was measured using the ISO/IEC 25010-based survey instrument and validated through expert evaluation and performance monitoring. By applying this internationally recognized framework, the researchers ensured that the blockchain-based vehicle registration system was rigorously assessed against both technical and user-centered dimensions.

The findings from this evaluation will determine whether the system meets quality benchmarks suitable for deployment in the Land Transportation Office and provide insights into areas requiring further refinement. In doing so, the study aligns with previous applications of ISO/IEC 25010 in evaluating government-oriented information systems (Canlas et al., 2021).

References:

Canlas, M. P., Macasaet, M. L., & Beleno, R. (2021). An ISO/IEC 25010 based software quality assessment of a faculty research productivity monitoring and prediction system. Proceedings of the 2021 5th International Conference on Information Technology (ICIT), 234-239. https://dl.acm.org/doi/10.1145/3512576.3512619

Ibrahim, A. (2016). Definition, purpose and procedure of developmental research: An analytical review. Asian Research Journal of Arts & Social Sciences, 1(4), 1-6. https://www.journalrepository.org/media/journals/ARJASS_45/2016/Dec/Ibrahim162016ARJASS30478.pdf

McNeish, D. (2018). Thanks, coefficient alpha, we'll take it from here. Psychological Methods, 23(3), 412-433. https://pubmed.ncbi.nlm.nih.gov/28557467/

MDPI. (2019). A systematic review of the use of agile methodologies in education. Sustainability, 11(10), 2915. https://www.mdpi.com/2071-1050/11/10/2915

MDPI. (2023). Best practices evidenced for software development based on scrum and DevOps. Applied Sciences, 15(10), 5421. https://www.mdpi.com/2076-3417/15/10/5421

Ng, G. C. (2019). A study of an agile methodology with scrum approach to the Filipino company-sponsored I.T. capstone program. arXiv preprint. https://arxiv.org/abs/1902.01821

PMC. (2018). Thanks coefficient alpha, we still need you! Educational and Psychological Measurement, 78(4), 645-649. https://pmc.ncbi.nlm.nih.gov/articles/PMC6318747/

PMC. (2021). A review of key Likert scale development advances: 1995-2019. Frontiers in Psychology, 12, 637547. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8129175/

PMC. (2022). Implementing remote developmental research: A case study of a randomized controlled trial language intervention during COVID-19. Frontiers in Psychology, 13, 782159. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8782159/

PMC. (2022). Performance of coefficient alpha and its alternatives: A systematic review. Psychological Methods, 27(5), 822-841. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9806521/

Proceedings of CECIIS. (2022). Software quality assessment standards and metrics. Central European Conference on Information and Intelligent Systems, 33, 145-152. https://archive.ceciis.foi.hr/public/conferences/2022/Proceedings/TSE/TSE5.pdf

Richey, R. C., & Klein, J. D. (2007). Design and development research: Methods, strategies, and issues. Taylor & Francis. https://www.taylorfrancis.com/books/mono/10.4324/9780203826034/design-development-research-rita-richey-james-klein

ScienceDirect. (2024). Implementing logging and objective metrics for reproducible evaluation. Software: Practice and Experience, 54(2), 156-171. https://www.sciencedirect.com/science/article/pii/S2666374024000670

ACEA. (2022). *Handbook on vehicle approval and registration*. European Automobile Manufacturers' Association. https://www.acea.auto/publication/handbook-on-vehicle-approval-and-registration/

ACEA. (2022). *The automotive regulatory guide 2022*. European Automobile Manufacturers' Association. https://www.acea.auto/files/ACEA-Regulatory-Guide-2022.pdf

Afzal, A., & Asif, A. (2019). Cryptocurrencies, blockchain and regulation: A review. *The Lahore Journal of Economics, 24*(1), 103–130. https://doi.org/10.35536/lje.2019.v24.i1.a5

Afzal, M., & Asif, M. (2019). Blockchain technology: Beyond cryptocurrency. *International Journal of Computer Applications, 178*(7), 7–10. https://doi.org/10.5120/ijca2019918805

Albu, O., & Flyverbom, M. (2019). Organizational transparency: Conceptualizations, conditions, and consequences. *Business & Society, 58*(2), 268–297. https://doi.org/10.1177/0007650316659851

Alliance, Enterprise Ethereum. (2021). *Enterprise Ethereum Alliance permissioned blockchains specification v3*. https://entethalliance.github.io/client-spec/chainspec.html#dfn-enterprise-ethereum-blockchain

Amrutha, B. K., & Gomathy, B. (2023). Blockchain integration in artificial intelligence: Benefits, applications and research challenges. *International Journal for Multidisciplinary Research, 5*(6), 18. https://doi.org/10.36948/ijfmr.2023.v05i06.10583

Androulaki, E., Barger, A., Bortnikov, V., Cachin, C., Christidis, K., De Caro, A., Enyeart, D., Ferris, C., Laventman, G., Manevich, Y., Muralidharan, S., Nguyen, B., Sethi, M., Singh, G., Smith, K., Sorniotti, A., Stathakopoulou, C., Vukolić, M., Wetherall, M., … Yelick, K. (2018). Hyperledger Fabric: A distributed operating system for permissioned blockchains. *Proceedings of the 13th EuroSys Conference*, 1–15. https://doi.org/10.1145/3190508.3190538

Austroads. (2020). *Driver licensing and vehicle registration in Australia and New Zealand* (AP-R644-20). https://austroads.com.au/publications/registration-and-licensing/ap-r644-20

Austroads & EReg. (2020). *Vehicle registration & driver licensing comparison study (Australia, New Zealand, Europe).* https://www.ereg-association.eu/media/2329/austroads-ereg-comparison-report.pdf

Balcita, V. D. G., Bejar, A. T. A., Goy, T. P., & Billiones, R. K. (2021). A case study on waiting line management for the Land Transportation Office of the Philippines. *2021 IEEE 13th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment, and Management (HNICEM).* https://www.researchgate.net/publication/359274587_A_Case_Study_on_Waiting_Line_Management_for_the_Land_Transportation_Office_of_the_Philippines

Bangko Sentral ng Pilipinas. (2023, September 6). *BSP selects technology for pilot CBDC project "Project Agila"* [Press release]. https://www.bsp.gov.ph/SitePages/MediaAndResearch/MediaDisp.aspx?ItemId=6841

Buterin, V. (2016). *Ethereum: Platform review—Opportunities and challenges for private and consortium blockchains*. http://www.smallake.kr/wp-content/uploads/2016/06/314477721-Ethereum-Platform-Review-Opportunities-and-Challenges-for-Private-andConsortium-Blockchains.pdf

Canlas, M. P., Macasaet, M. L., & Beleno, R. (2021). An ISO/IEC 25010-based software quality assessment of a faculty research productivity monitoring and prediction system. *Proceedings of*

the 2021 5th International Conference on Information Technology (ICIT), 234–239. https://doi.org/10.1145/3512576.3512619

CoinDesk. (2024, July 30). California DMV puts 42M car titles on the Avalanche network in digitization push. https://www.coindesk.com/business/2024/07/30/california-dmv-puts-42m-car-titles-on-the-avalanche-network-in-digitization-push

Department of Information and Communications Technology (Philippines). (n.d.). *eGovernment digital platforms.* https://dict.gov.ph/egov-digital-platforms

Eximchain (Huertas, J., Liu, H., & Robinson, S.). (2018). *Eximchain: Supply chain finance solutions on a secured public, permissioned blockchain hybrid* [White paper]. https://cryptorating.eu/whitepapers/Eximchain/Whitepaper%20-%20Eximchain.pdf

Gray, S. (2020, May 3). Agile software development life cycle. *Medium.* https://serenagray2451.medium.com/agile-software-development-life-cycle-b3ed0f0f7212

Ibrahim, A. (2016). Definition, purpose and procedure of developmental research: An analytical review. *Asian Research Journal of Arts & Social Sciences, 1*(4), 1–6. https://www.journalrepository.org/media/journals/ARJASS_45/2016/Dec/Ibrahim162016ARJASS30478.pdf

Land Transport Authority (Singapore). (2024). *Procedures on importation and registration of a car in Singapore.* https://onemotoring.lta.gov.sg/content/dam/onemotoring/Buying/PDF/Importation_Guidelines/Car.pdf

Land Transportation Office (Philippines). (2025, July 7). *Memorandum Circular No. VDM-2025-4510: Requirements for the Online Document Submission Facility (ODSF).* https://lto.gov.ph/wp-content/uploads/2025/07/MC-VDM-2025-4510.pdf

Land Transportation Office (Philippines). (2025, July 15). *Memorandum Circular No. GGP-2025-4530: Applicability of ODSF to Regional, District, and Extension Offices.* https://lto.gov.ph/wp-content/uploads/2025/07/MC-GGP-2025-4530.pdf

Land Transportation Office (Philippines). (2025, July 21). *LTO & DOTr launch platform for immediate release of OR/CR & license plates.* https://lto.gov.ph/news/lto-dotr-launch-platfrom-for-immediate-release-of-or-cr-license-plates/

Land Transportation Office Portal. (2024). What are the requirements for motor vehicle registration? https://ltoportal.ph/requirements-motor-vehicle-registration/

McKenney, S., & Reeves, T. C. (2019). *Conducting educational design research* (2nd ed.). Routledge. https://doi.org/10.4324/9780203818183

McNeish, D. (2018). Thanks, coefficient alpha, we'll take it from here. *Psychological Methods, 23*(3), 412–433. https://doi.org/10.1037/met0000144

Meher, O. R., Singh, S. S., Mundokar, N. D., Choudhari, T. B., & Bhujbal, S. R. (2024). Digital document verification system using blockchain. *International Journal for Multidisciplinary Research (IJFMR).* https://www.ijfmr.com/research-paper.php?id=16798

MDPI (Sustainability). (2019). A systematic review of the use of agile methodologies in education. *Sustainability, 11*(10), 2915. https://doi.org/10.3390/su11102915

MDPI (Applied Sciences). (2023). Best practices evidenced for software development based on Scrum and DevOps. *Applied Sciences, 15*(10), 5421. https://doi.org/10.3390/app15105421

Murphy, A. K., Jerolmack, C., & Smith, D. (2021). Ethnography, data transparency, and the information age. *Annual Review of Sociology, 47*, 41–61. https://doi.org/10.1146/annurev-soc-090320-124805

Ng, G. C. (2019). A study of an agile methodology with Scrum approach to the Filipino company-sponsored I.T. capstone program. *arXiv.* https://arxiv.org/abs/1902.01821

Nguyen-Cong, T., & Lê, N. C. (2024). Utilizing Layer-2 blockchain and IPFS innovations for establishing a robust system for secure document signing and management. *Journal of Science and Technology: Smart Systems and Devices, 34*(2). https://doi.org/10.51316/jst.174.ssad.2024.34.2.6

Philippine Daily Inquirer. (2025, June 7). LTO probes illegal ownership transfers of seized vehicles. https://newsinfo.inquirer.net/2068125/lto-probes-illegal-ownership-transfers-of-seized-vehicles

Philippine News Agency. (2023, February 7). LTO to penalize 8 dealerships for delayed vehicle registrations. https://www.pna.gov.ph/articles/1194645

Philstar.com. (2025, June 7). LTO probes 40 offices over illegal vehicle transfers. https://www.philstar.com/nation/2025/06/07/2448771/lto-probes-40-offices-over-illegal-vehicle-transfers

Proceedings of CECIIS. (2022). Software quality assessment standards and metrics. *Central European Conference on Information and Intelligent Systems, 33*, 145–152. https://archive.ceciis.foi.hr/public/conferences/2022/Proceedings/TSE/TSE5.pdf

Pulmano, C. E., Estuar, M. R. J. E., De Leon, M. M., Tan, H. C. L., Co, N. A. S., & Tamayo, L. P. V. (2023). Towards the development of a blockchain-based decentralized digital credential system using Hyperledger Fabric for participatory governance. *Procedia Computer Science, 219*, 99–106. https://doi.org/10.1016/j.procs.2023.01.269

Reyes, C. L. (2022). Emerging technology's language wars: Smart contracts. *Wisconsin Law Review Forward, 2022*, 85–101. https://wlr.law.wisc.edu/emerging-technologys-language-wars-smart-contracts/

Richey, R. C., & Klein, J. D. (2007). *Design and development research: Methods, strategies, and issues.* Routledge. https://doi.org/10.4324/9780203826034

Rifat, M. Z. H., Shakil, M., Hasan, R. M. I., Zidan, F. A., & Nandi, D. (2024). A proposed model for vehicle registration using blockchain. *International Journal of Information Engineering and Electronic Business, 16*(1), 40–53. https://doi.org/10.5815/ijieeb.2024.01.04

Rosado, T., Vasconcelos, A., & Correia, M. (2019). A blockchain use case for car registration. In K.-C. Li, X. Chen, H. Jiang, & E. Bertino (Eds.), *Essentials of blockchain technology* (pp. 205–234). Chapman and Hall/CRC. https://doi.org/10.1201/9780429674457-10

Sablada, Q., & Borres, R. (2021, August). Automation transaction of motor vehicle registrations in Land Transportation Office (LTO) of the Philippines. In *4th European International Conference*

on Industrial Engineering and Operations Management. https://index.ieomsociety.org/index.cfm/article/view/ID/5548

Sankhe, S., Malhotra, P., Siddiqui, A. A., Shaikh, A. R., Mulla, R., & Khan, J. (2024). A blockchain-based solution to manage vehicle documents using QR-code. *IEEE Xplore.* https://ieeexplore.ieee.org/document/10454935

ScienceDirect (SoftwareX). (2024). Implementing logging and objective metrics for reproducible evaluation. *SoftwareX, 24*, Article 101005. https://doi.org/10.1016/j.softx.2024.01.005

Sultan, K., Ruhi, U., & Lakhani, R. (2018). Conceptualizing blockchains: Characteristics & applications. *arXiv.* https://arxiv.org/abs/1806.03693

SunStar. (2025, June 6). LTO probes illegal MV transfer of ownership. https://www.sunstar.com.ph/pampanga/lto-probes-illegal-mv-transfer-of-ownership

Taherdoost, H. (2022). Blockchain technology and artificial intelligence together: A critical review on applications. *Applied Sciences, 12*(24), 12948. https://doi.org/10.3390/app122412948

Taherdoost, H. (2023). Smart contracts in blockchain technology: A critical review. *Information, 14*(2), 117. https://doi.org/10.3390/info14020117

Tadi, V. (2024). Integrating blockchain with traditional document verification: Developing a scalable, secure, and unified framework for electronic and printed documents. *Journal of Mathematical & Computer Applications, 3*(1), 1–11. https://doi.org/10.47363/JMCA/2024(3)182

TechRxiv (Koç, S.). (2024). Legal compliance protocols for blockchain smart contracts: A new era of regulatory compliance. https://doi.org/10.36227/techrxiv.172954185.58874599

Verde, L. A., & Ganiron, T. U. (2024). Adoption of smart contracts in the Philippine government construction industry. *International Journal of Multidisciplinary: Applied Business and Education Research, 5*(8), 2950–2956. https://doi.org/10.11594/ijmaber.05.08.01

Yandug, J. S. G., & Santos, C. A. S. (2020). Simulation-driven appointment system model for a license processing office in the Philippines. In *Proceedings of the 2020 IEOM Society International Conference.* https://www.ieomsociety.org/ieom2020/papers/489.pdf

YugaTech. (2023, March 21). LTO clears timeline for a brand new motor vehicle's OR, CR, license plate release. https://auto.yugatech.com/news/lto-timeline-vehicle-or-cr-plate-release/

Arianee. (2024, August 2). Revolutionizing vehicle ownership: California DMV's blockchain digitization of 42 million car titles. https://www.arianee.com/post/revolutionizing-vehicle-ownership-california-dmvs-blockchain-digitization-of-42-million-car-titles

Blockchain Technology News. (2024, August 1). California pioneers digital vehicle titles on blockchain. https://blockchaintechnology-news.com/news/california-pioneers-digital-vehicle-titles-on-blockchain/

ABS-CBN News. (2025, July 21). License plates to be issued in just 3 days with new automated system: DOTr, LTO. https://www.abs-cbn.com/news/business/2025/7/21/license-plates-to-be-issued-in-just-3-days-with-new-automated-system-dotr-lto-1716

Daily Tribune. (2025, July 19). LTO rolls out system to register, plate cars in 3 days. https://tribune.net.ph/2025/07/19/lto-rolls-out-system-to-register-plate-cars-in-3-days

Manila Bulletin. (2025, January 9). LTO: 1,046 dealers summoned in 2024 over car, motorcycle registration delay. https://mb.com.ph/2025/1/9/1-046-dealers-summoned-in-2024-over-car-motorccyle-registration-delay

Hyperledger Fabric Documentation. (n.d.). *Key concepts; What is Fabric?* https://hyperledger-fabric.readthedocs.io/

National Institute of Standards and Technology. (2018). *Blockchain technology overview* (NISTIR 8202). https://nvlpubs.nist.gov/nistpubs/ir/2018/nist.ir.8202.pdf NIST Publications