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Blockchain Secured Tracking System

Assisstant Professor Bhavya V, Vinutha B R, Ashmita Chavan, Avni Ivy, Chaithra G
Computer Science and Engineering,
Dayananda Sagar Academy of Technology and Management Karnataka, India

Abstract- Supply chain management plays a crucial role in delivering products efficiently and safely from origin to end-user. However, traditional supply chain systems face challenges such as lack of transparency, data tampering, product counterfeiting, and inefficiencies in traceability. These limitations often result in reduced consumer trust, delayed recalls, and regulatory compliance issues. To address these challenges, this project introduces a blockchain-based supply tracking system designed to enhance transparency, security, and accountability across the entire supply chain. Blockchain's decentralized and immutable ledger ensures that each transaction or event—such as manufacturing, quality testing, packaging, transportation, and delivery—is securely recorded and cannot be altered. By assigning unique QR codes to products, stakeholders can track and verify the product's journey in real time.

Keywords- Blockchain, Supply Chain Management, Product Traceability, Digital Certificate, Smart Contracts

I. INTRODUCTION

Supply chain management is a critical component of global trade, involving the movement of goods from manufacturers to end consumers. Despite its importance, traditional supply chain systems often suffer from key issues such as lack of transparency, poor traceability, data tampering, and the proliferation of counterfeit products. These challenges can lead to inefficiencies, loss of trust among stakeholders, and potential harm to consumers.

Blockchain technology offers a promising solution to these problems. By utilizing a decentralized and immutable ledger, blockchain enables secure, transparent, and verifiable record-keeping across all stages of the supply chain. Each transaction or event—from production and quality testing to distribution and delivery—is permanently recorded and can be accessed by authorized participants in real time.

This project aims to develop a blockchain-based supply tracking system that enhances visibility and trust in the supply chain. The system uses unique QR codes to identify products and track their lifecycle. It supports role-based access for manufacturers, transporters, testing labs, retailers, and consumers, ensuring that each stakeholder can interact with the system securely and appropriately..

1. Related Work and Contributions

Blockchain in Supply Chain

Blockchain technology has been increasingly adopte d to enhance transparency, traceability, and data immutability across supply chains. IBM's Food Trust platform demonstrates how blockchain can ensure end-to-end food provenance and safety [1]. Similarly, the VeChain platform enables decentralized product tracking and authentication, particularly in the fas hion and pharmaceuticals industry [2].

Anti-Counterfeiting Systems

Counterfeit prevention has been a major area of application for blockchain. Everledger uses blockchain to track the provenance of diamonds

and other highv alue items, ensuring authenticity through immutable digital records [3]. Tian et al. proposed a blockchainb ased traceability system for the food supply chain that integrates RFID and IoT data to prevent fraud and enhance food safety [4].

QR/NFC Integration in Blockchain Tracking Research has shown the efficacy of integrating QR codes and NFC with blockchain to provide real-time prod uct authentication. Wang et al. discussed how combining these technologies with decentralized ledgers improves consumer trust in product authenticity [5]. ScanTrust and Prowith decentralized ledgers improves consumer trust in product authenticity [5]. ScanTrust and Provenance.io have built commercial platforms that use unique identifiers to link physical products with blockchain-verified data [6].

Smart Contracts for Automation and Trust Smart contracts automate the verification of conditions like delivery or quality control. Christidis and Devetsikiotis explored how smartcontracts on Ethereum can automate supply chainworkflows and reduce reliance on centralized authorities [7]. They enable a trustless environment where participants can engage without requiring third-party validation.

II. BACKGROUND AND INDUSTRY LANDSCAPE

1. Background

The automotive spare parts industry plays a crucial role in maintaining vehicle performance, safety, and reliability. It includes manufacturers, suppliers, distributors, retailers, mechanics, and end customers. However, traditional supply chains for car spare parts face several critical issues:

- **Counterfeit Products:** The global automotive industry suffers billions in losses annually due to fake or substandard parts. These not only damage brand reputation but also pose safety risks.
- **Lack of Traceability:** Once parts leave themanufacturer, it becomes difficult to track their exact journey through distributors and retailers.
- **Manual and Disconnected Systems:** Most stakeholders use manual systems for inventory, invoicing, and certification, resulting in inefficiencies and errors.
- **Fraudulent Claims and Warranties:** In the absence of verifiable part history, warranty claims may be falsely made or denied.
- **Difficulty in Verifying Authenticity:** Customers and workshops struggle to confirm whether a part is original or compatible, especially when buying online or through intermediaries.

2. Industry Landscape

The automotive industry has begun exploring blockchain to bring innovation and trust to spare parts management. Major automakers, part suppliers, and tech companies are piloting or implementing blockchain-based solutions in the following ways:

- OEM (Original Equipment Manufacturer) Verification Manufacturers can register each genuine part on the blockchain at the time of production.
- When sold or transferred, the part's journey is tracked through QR codes or NFC tags scanned at each stage.

Aftermarket Integration

- Authorized dealers and workshops can update the blockchain when a part is installed or replaced, ensuring complete service history.

Customers and insurers can verify this data before making purchases or processing claims.

Counterfeit Prevention

- Blockchain makes it extremely difficult for fake parts to enter the legitimate supply chain, as they lack a valid digital trail.
- Brands such as BMW and Bosch have explored blockchain pilots to fight counterfeit automotive components.

Online Marketplaces and Warranty Validation

- E-commerce platforms can use blockchain to validate that listed parts are genuine.

- When a part fails, warranty claims can be quickly verified by checking its blockchain record.

Regulatory and Compliance Use

- Blockchain can also store compliance certifications and lab test results for safety-critical components, which is crucial for regulatory audits and recalls.

III. BLOCKCHAIN TECHNOLOGY OVERVIEW

Blockchain is a distributed ledger technology (DLT) that allows data to be stored across a network of computers in a secure, transparent, and tamper-proof manner. It eliminates the need for a centralized authority by enabling all participants in a network to access and validate a single, shared version of truth. This section outlines the core concepts of blockchain and how they relate to the tracking and authentication of automotive spare parts.

1. Key Features of Blockchain

- **Decentralization:** Instead of relying on a single server or database, blockchain operates across a network of nodes. This ensures no single point of failure and reduces the risk of data manipulation.
- **Immutability:** Once data is recorded on the blockchain, it cannot be altered without consensus from the entire network. This feature is critical for ensuring the authenticity of spare part records.
- **Transparency and Traceability:** All transactions are recorded in chronological order and can be audited at any time, making it easy to trace a part's origin, ownership, and lifecycle.
- **Security:** Blockchain uses cryptographic hashing and digital signatures to ensure that data is securely stored and only accessible to authorized users.
- **Consensus Mechanisms:** Blockchain networks rely on consensus protocols such as Proof of Work (PoW), Proof of Stake (PoS), or Practical Byzantine Fault Tolerance (PBFT) to agree on the validity of transactions. Private blockchains used in supply chains typically use more efficient mechanisms like PBFT.

IV. LITERATURE REVIEW

In recent years, the integration of blockchain technology into supply chain management has gained significant academic and industrial attention. Researchers and developers have explored its potential to address challenges such as data integrity, counterfeit prevention, and product traceability. This section presents a review of key works that have contributed to understanding and developing blockchain-based solutions, with a focus on applications relevant to car spare parts.

1. General Blockchain Applications in Supply Chain

- Saberi et al. (2019) presented a comprehensive analysis of how blockchain enhances transparency, trust, and traceability across supply chains. Their work emphasized that decentralized ledgers could help monitor complex networks involving multiple stakeholders.
- Kshetri (2018) explored blockchain's role in combating fraud and counterfeit products in global supply chains. He highlighted the importance of blockchain's immutability in verifying product origins and maintaining trusted records.

2. Blockchain for Automotive Supply Chains

- Helo and Hao (2019) proposed a blockchain-based model for managing supply chain transparency in the automotive industry. Their study showed how blockchain can track automotive components from suppliers to end users, increasing operational efficiency.
- BMW's PartChain Project was a real-world initiative aimed at ensuring transparency and traceability of components and raw materials. It used blockchain to enable real-time data sharing between suppliers and the OEM, allowing quick verification of part authenticity.
- Volkswagen and IBM collaborated to track minerals such as cobalt used in electric vehicle

batteries, proving the potential of blockchain to manage compliance and ethical sourcing.

3. Smart Contracts and Certification Systems

- Christidis and Devetsikiotis (2016) discussed smart contracts and their potential to automate processes like quality checks, payments, and compliance in supply chains. In the spare parts context, smart contracts could verify warranty status, part compatibility, and installation records.
- Zhao et al. (2020) introduced a blockchain-based certification model for critical components in aviation and automotive industries. Their system attached digital certificates to each component, which could be verified at any stage of the supply chain.

4. Gaps and Opportunities

Despite significant progress, several gaps remain:

- **Scalability:** Many blockchain platforms struggle with high transaction volumes typical in large automotive supply chains.
- **Adoption Barriers:** Smaller suppliers may lack the resources or technical knowledge to integrate blockchain systems.
- **Interoperability:** Most systems are built in silos; cross-platform communication between OEMs, dealers, and regulators remains limited.

V. RESEARCH CHALLENGES

1. Scalability

Automotive supply chains involve millions of parts and transactions daily. Blockchain networks must handle these large volumes with low latency to maintain real-time tracking and verification. Current blockchain platforms often face performance bottlenecks, limiting their ability to scale effectively in such demanding environments.

2. Privacy

Supply chain data frequently includes sensitive business information, such as pricing, supplier details, and inventory levels. While blockchain provides transparency, it is essential to implement mechanisms that selectively hide or encrypt confidential data without compromising traceability. Balancing transparency with privacy remains a complex challenge.

3. Regulatory Compliance

Regulations governing data security, product certification, and supply chain transparency differ widely across countries and industries. Ensuring blockchain solutions comply with these varying legal requirements—such as data sovereignty laws and automotive standards—is critical but difficult. This regulatory diversity complicates global adoption.

4. Adoption Barriers

Stakeholders throughout the supply chain may resist adopting blockchain due to fears of excessive transparency or loss of control over proprietary data. Smaller suppliers might lack the technical expertise or resources to participate fully.

Overcoming this resistance requires building trust, demonstrating clear value, and designing user-friendly solutions.

5. Cross-Chain Interoperability

Many organizations already use legacy systems and disparate blockchain networks. Achieving seamless integration and synchronization across different platforms—both blockchain-based and traditional— is necessary to create a cohesive supply chain ecosystem. Research into standardized protocols and middleware is ongoing but still limited.

VI. KEY FINDINGS FROM PREVIOUS RESEARCH

Based on the review of existing literature and case studies on blockchain-enabled supply chain systems, particularly for automotive spare parts, several important findings emerge:

1. Enhanced Traceability and Transparency

- Blockchain effectively creates an immutable and transparent record of every transaction or event related to a spare part, from manufacturing to installation.

- This enables quick verification of part provenance, reducing fraud and counterfeit risks significantly.

2. Improved Counterfeit Prevention

- Real-world pilots, such as BMW's PartChain, have demonstrated that blockchain can reduce the circulation of counterfeit automotive parts by providing verifiable authenticity records linked to physical parts.
- However, the security of physical identifiers (QR codes, RFID) remains a critical point.

3. Automation through Smart Contracts

- Smart contracts have been shown to streamline processes such as warranty validation, payment settlement, and compliance verification without manual intervention.
- This reduces administrative overhead and speeds up dispute resolution between stakeholders.

4. Challenges in Scalability and Adoption

- Most existing blockchain solutions face scalability issues when handling high transaction volumes typical in automotive supply chains.
- Adoption barriers for small suppliers and interoperability issues between legacy systems remain significant hurdles.

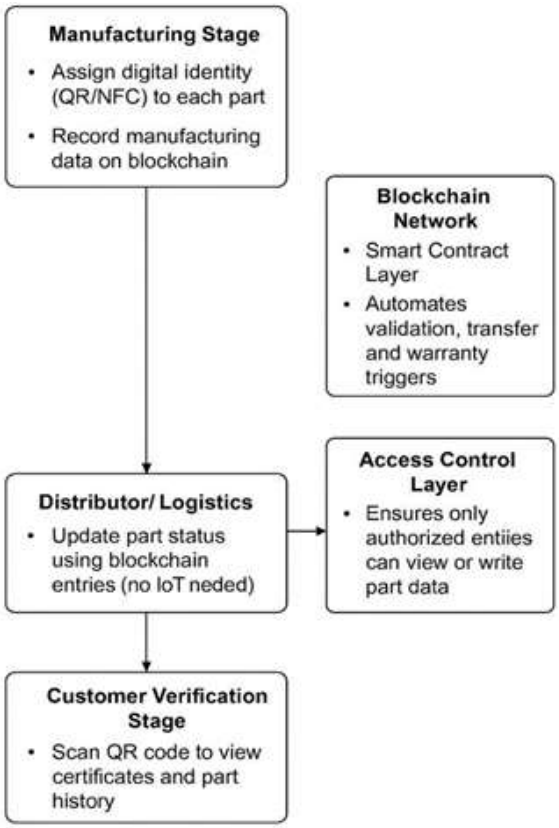
5. Regulatory and Standardization Needs

- Lack of universally accepted standards slows cross-company and cross-border blockchain integration.
- Regulatory frameworks need to evolve alongside technology to ensure legal compliance and data privacy.

VII. PROPOSED METHODOLOGY

1. Manufacturing Stage

At the very beginning of the supply chain, car spare parts are produced by the manufacturer. Each part is assigned a unique digital identity, typically through a QR code or NFC tag physically attached to the part. Essential data such as part specifications, manufacturing details, and quality certifications are securely recorded on the blockchain. This initial registration guarantees the part's authenticity and origin.



2. Supplier and Distributor Stage

Once parts leave the manufacturing facility, they enter the logistics network. Ownership transfer from manufacturer to suppliers and then distributors is logged on the blockchain. Real-time tracking data from IoT devices (like GPS sensors or barcode scanners) updates the status and location of parts during transportation. This ensures transparency and accountability at every handoff.

3. End Customer Stage

Car owners or end customers can verify the authenticity of the spare parts by scanning the QR code using a smartphone app or service portal. They gain access to a transparent service history, warranty status, and certification details, fostering trust in the parts used for their vehicle.

4. Blockchain Network

All these transactions and events are stored in a decentralized ledger maintained by multiple participants in the network. The ledger is immutable, ensuring no data tampering. Smart contracts automate processes such as ownership transfers, warranty claims, and counterfeit alerts, increasing efficiency and reducing manual errors.

5. Data Privacy and Access Control Layer Since some information in the supply chain is sensitive (e.g., pricing, proprietary manufacturing data), this layer encrypts confidential data and restricts access based on user roles. Only authorized participants can view or modify sensitive information, balancing transparency with privacy.

VIII. SYSTEM DESIGN

1. Manufacturer

- Assigns a unique digital identity (e.g., QR code or NFC) to each car part.
- Enters initial metadata such as part ID, frequency value, and manufacturing date.

Output: Data is pushed into the blockchain via smart contracts.

2. Distributor

- Receives the part and logs handling status, seal condition, and transport details.
- Validates the manufacturer's certificate.

Output: Updates are recorded to the blockchain to maintain the audit trail.

3. Customer

- Scans the QR code from the part/package.
- Views final certificate and complete lifecycle via a web/mobile app.

Output: Can verify if the part passed all checks and is genuine.

4. Blockchain System

This is the central architecture layer, shown to the side with two subcomponents:

Smart Contract Layer

Function

- Automates validation logic (e.g., Is the frequency in range? Was the seal tampered?).
- Issues or denies digital certificates based on compliance.
- Handles ownership transfer and warranty tracking.

Access Control Layer

Function

- Manages role-based access (e.g., Manufacturer can write, Customer can only read).
- Encrypts sensitive data (e.g., pricing or proprietary info).

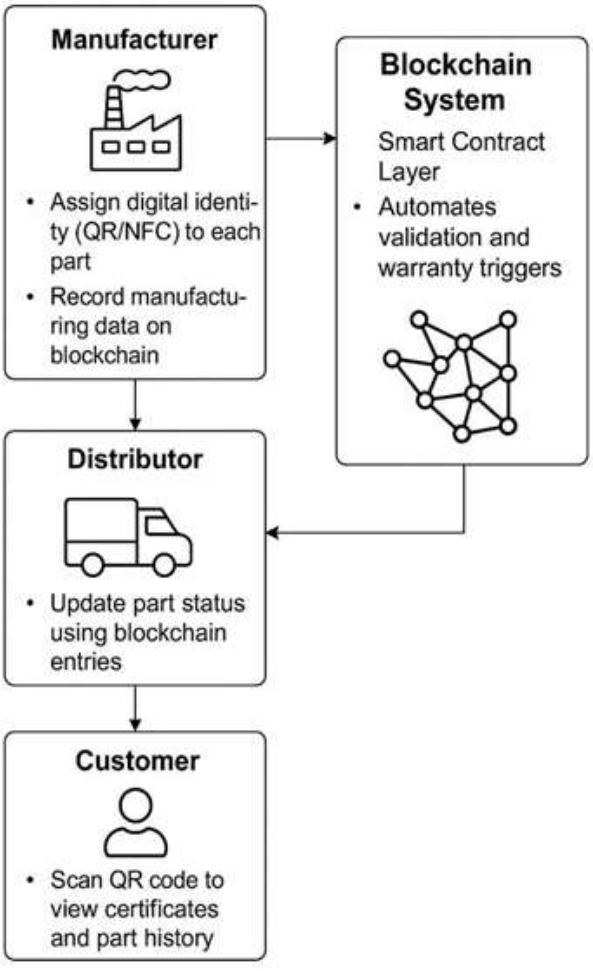


Fig 8.1

Impact and Benefits

Impact

- **Enhanced Transparency:** Every transaction is recorded on a tamper-proof ledger, increasing visibility for all stakeholders.
- **Improved Traceability:** Unique IDs on parts allow tracking throughout the supply chain, reducing counterfeit risks.
- **Increased Security:** Decentralized data storage protects against hacking and fraud.
- **Greater Accountability:** Immutable records promote responsibility among manufacturers, suppliers, and dealers.
- **Faster Recalls:** Faulty parts can be quickly identified and removed, improving vehicle safety.

Benefits

- **Reduced Counterfeiting:** Blockchain's verification minimizes fake spare parts entering the supply chain.
- **Operational Efficiency:** Automated smart contracts reduce manual checks, lowering delays and errors.
- **Cost Savings:** Fewer fraud cases and process automations cut operational costs.
- **Enhanced Customer Trust:** Transparent and reliable tracking builds consumer confidence in product authenticity.
- **Regulatory Compliance:** Automated, auditable recordssimplify meeting industry standards and regulations.

Summary

- Blockchain can transform tracking and management of car spare parts in automotive supply chains.
- Traditional supply chains suffer from counterfeit parts, low transparency, poor traceability, and inefficiency.
- Blockchain offers decentralization, immutability, and transparency for secure record- keeping.
- Unique digital identities and shared ledgers enable end-to-end traceability of spare parts.
- Smart contracts automate warranty validation, service logs, and compliance without manual work.
- Main challenges include scalability, privacy, regulatory compliance, stakeholder resistance, and interoperability.
- Research shows blockchain improves supply chain integrity, reduces fraud, and increases customer trust.
- Proposed methodology covers the entire supply chain from manufacturing to end-user verification.
- Benefits include enhanced security, efficiency, cost reduction, and trust.
- Blockchain is a promising technology to modernize automotive spare parts tracking and management.

V. CONCLUSION

A Blockchain Secured Tracking System provides a reliable, transparent, and tamper-proof method for tracking goods, data, or assets across various industries. By combining blockchain's decentralized nature with real-time data input from IoT and smart contracts, the system ensures high levels of security, accountability, and efficiency. Whether it's tracking pharmaceuticals, food, or logistics, this technology reduces fraud, improves compliance, and builds trust among stakeholders. As industries continue to demand greater traceability and automation, blockchain-secured tracking stands out as a transformative solution.

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