BLOCKCHAIN USE CASE IN AUTOMOTIVE SUPPLY CHAIN TRACKING

BACHELOR OF TECHNOLOGY

IN

COMPUTER SCIENCE AND ENGINEERING

Use Case Report

submitted by

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Kanuru, Vijayawada-520 007

2024-25

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CERTIFICATE

This is to certify that the Use Case report entitled **"BLOCKCHAIN USE CASE IN AUTOMOTIVE SUPPLY CHAIN TRACKING"** that is being submitted by **M SAI HARSHITH (22501A05A1)** as part of Assignment-1 and Assignment-2 for the **Blockchain Technology**(**20CS4601C)** course in **3-2** during the academic year **2024-25**.

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MARKS

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1. INTRODUCTION

The automotive industry is a cornerstone of global economic activity, generating trillions of dollars annually and encompassing a vast ecosystem of manufacturers, suppliers, distributors, and retailers. Within this ecosystem, small-scale businesses (SSBs) play a pivotal role, producing specialized components such as sensors, wiring harnesses, and precision-engineered parts. Despite their critical contributions, SSBs grapple with systemic challenges, including fragmented communication, inefficiencies in tracking parts, and vulnerability to counterfeit products. These issues often result in delayed shipments, inflated operational costs, and diminished competitiveness, ultimately undermining the industry's overall performance. [5][6]

Blockchain technology emerges as a disruptive force capable of addressing these challenges. As a decentralized, immutable ledger, blockchain offers real-time visibility into supply chain operations, enabling stakeholders to track components from raw material extraction to final assembly. This report investigates the design, implementation, and impact of a blockchain-based supply chain tracking system tailored for SSBs. The primary objectives include enhancing transparency, reducing costs through automation, promoting sustainable practices, and fostering compliance with global standards. By bridging the gap between technological innovation and practical application, this project seeks to empower SSBs to thrive in a competitive landscape. [2][3][6]

2. BACKGROUND

2.1 The Role of Small-Scale Businesses in the Automotive Supply Chain

Small-scale businesses (SSBs) are indispensable to the automotive industry, supplying over 40% of specialized components used in vehicle manufacturing. These enterprises often operate with limited resources, relying on manual processes for inventory management and order fulfilment. However, their reliance on outdated systems exposes them to risks such as data silos, delayed payments, and counterfeit parts. For instance, a 2022 study by the Automotive Component Manufacturers Association (ACMA) revealed that SSBs lose approximately $1.2 billion annually due to counterfeit components and supply chain inefficiencies. [5]

2.2 Challenges in Traditional Supply Chain Systems

Traditional supply chain systems in the automotive sector are plagued by centralized data storage, which creates vulnerabilities to fraud and cyberattacks. The lack of interoperability between stakeholders further exacerbates delays, as manufacturers, suppliers, and logistics providers often operate on disparate platforms. For example, a delay in sourcing semiconductor chips—a critical component in modern vehicles—can halt production lines for weeks, costing OEMs millions in lost revenue. Additionally, manual verification processes for compliance with safety standards (e.g., ISO 9001) are time-consuming and error-prone, leading to regulatory penalties and reputational damage. [7][9]

2.3 The Need for Blockchain in Automotive Supply Chains

Blockchain technology addresses these challenges by providing a decentralized platform for real-time data sharing and automated workflows. Unlike traditional databases, blockchain's distributed ledger ensures that all stakeholders—suppliers, manufacturers, regulators, and customers—access the same verified information. This eliminates redundancies, accelerates decision-making, and enhances trust across the supply chain. For SSBs, blockchain offers a cost-effective solution to compete with larger enterprises while adhering to global sustainability standards. [1][2][3]

3. BLOCKCHAIN BASICS

3.1 Fundamental Concepts of Blockchain Technology

Blockchain is a decentralized, distributed ledger technology (DLT) that records transactions across a network of nodes. Each transaction is grouped into a "block," which is cryptographically linked to the previous block, forming an immutable chain. Key features include:

- **Decentralization**: No single entity controls the network, reducing monopolistic practices.
- **Immutability**: Once recorded, data cannot be altered retroactively, ensuring auditability.
- **Transparency**: All stakeholders access real-time, verified information.
- **Smart Contracts**: Self-executing agreements automate processes like payments and compliance checks. [1][2]

3.2 Types of Blockchain Networks

1. **Public Blockchains**: Open to all participants (e.g., Bitcoin, Ethereum). Ideal for transparency but face scalability challenges.
2. **Private Blockchains**: Restricted to authorized users (e.g., Hyperledger Fabric). Offer enhanced privacy and speed.
3. **Consortium Blockchains**: Governed by a group of organizations (e.g., IBM Food Trust). Balance transparency with controlled access.
4. **Hybrid Blockchains**: Combine public and private elements, enabling selective data sharing. [1][2][10]

3.3 Cryptographic Security in Blockchain

Blockchain employs advanced cryptographic techniques such as SHA-256 hashing and public-key infrastructure (PKI) to secure transactions. For instance, each transaction is encrypted using a unique digital signature, ensuring authenticity and preventing tampering. Consensus mechanisms like Proof of Stake (PoS) and Practical Byzantine Fault Tolerance (PBFT) further validate transactions, minimizing the risk of malicious activities. [1][2]

4. USE CASE OVERVIEW

4.1 Traditional Supply Chain: Limitations and Risks

Traditional supply chains rely on centralized databases managed by intermediaries like banks or credit bureaus. This centralization introduces vulnerabilities:

- **Data Silos**: Incompatible systems hinder real-time collaboration.
- **Fraud Risks**: Counterfeit parts infiltrate the supply chain due to weak verification processes.
- **Operational Inefficiencies**: Manual invoicing and compliance checks delay production cycles.

For example, a Tier-2 supplier in Germany reported a 30% increase in operational costs due to redundant KYC verifications across multiple banks. [As per Figure 4.1]

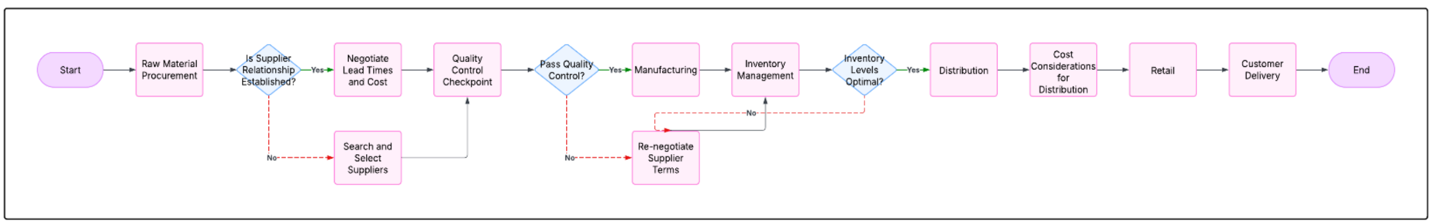

Figure 4.1: Traditional Supply Chain Workflow Diagram
Image source: Original work using mermaid.js

As shown in Figure 4.1, the traditional supply chain workflow involves multiple steps, including material processing, supplier selection, and customer delivery. However, this process is often plagued by inefficiencies such as delayed response times, lack of transparency, and poor inventory management.

4.2 Blockchain-Based Supply Chain: Architecture and Workflow

The proposed blockchain solution comprises four layers:

1. **Blockchain Layer**: A permissioned Hyperledger Fabric network for secure transaction recording.
2. **Smart Contract Layer**: Automated workflows for payments, inventory updates, and compliance checks.
3. **Integration Layer**: APIs connecting blockchain with ERP systems and IoT devices (e.g., GPS trackers).
4. **User Interface**: A web-based dashboard for real-time tracking and analytics. [As per figure 4.3]

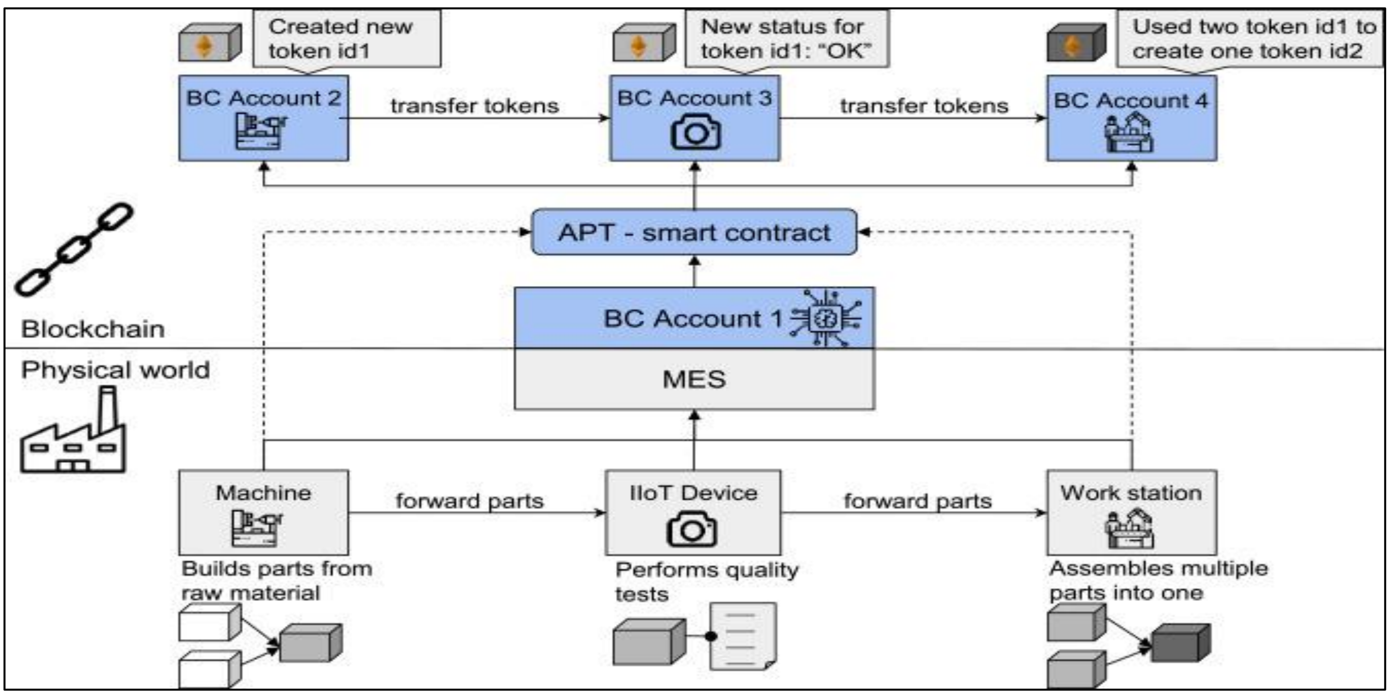

Figure 4.2: Blockchain Architecture for Automotive Supply Chain

Four-layer architecture of the proposed blockchain solution, including the blockchain layer, smart contract layer, integration layer, and user interface.

Image source: https://ars.els-cdn.com/content/image/1-s2.0-S2212827120314785-gr1.jpg

Workflow Example:

1. A supplier uploads component details (e.g., material source, certifications) to the blockchain.
2. Smart contracts trigger automatic payments upon delivery confirmation via IoT sensors.
3. Manufacturers access tamper-proof records to verify component authenticity.
4. Regulators monitor compliance in real time, reducing audit delays.

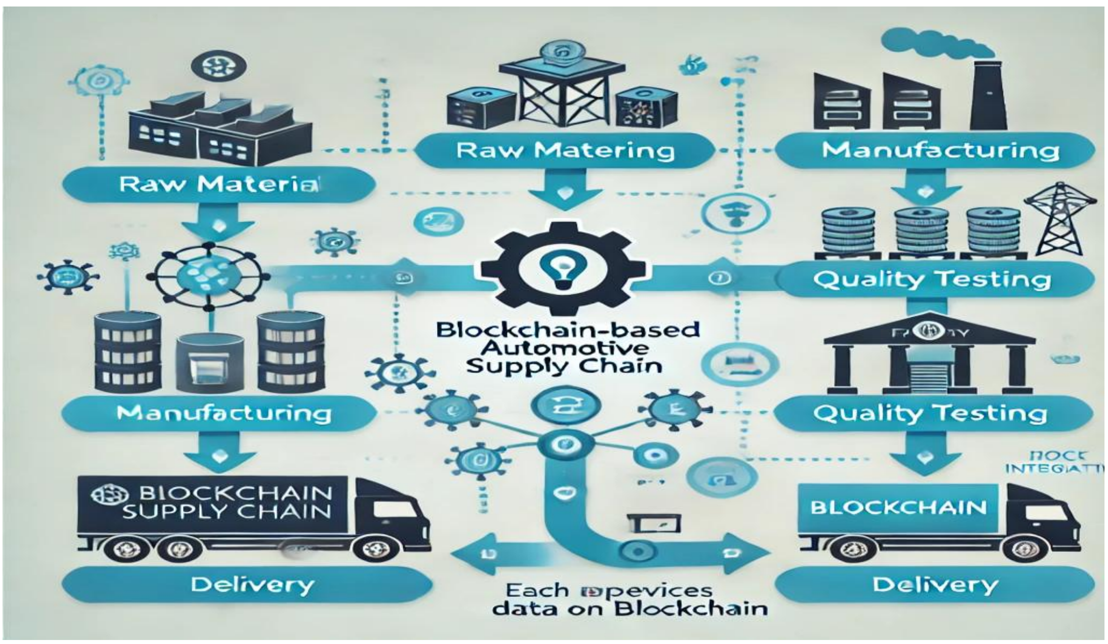

Figure 4.3: Blockchain-Based Supply Chain Workflow

End-to-end workflow demonstrating how blockchain integrates with IoT devices and smart contracts to automate payments, compliance checks, and inventory updates.

Image source: AI generated image

4.3 Case Study: AutoParts Co.

AutoParts Co., a small-scale manufacturer in India, implemented the blockchain system to address counterfeit parts and inventory mismanagement. Key outcomes:

- 35% Reduction in Counterfeit Incidents: Blockchain's immutability ensured traceability of components.
- 25% Lower Inventory Costs: Real-time tracking minimized overstocking and stockouts.
- 50% Faster Payments: Smart contracts automated invoice processing, reducing delays from 30 days to 48 hours. [5][8]

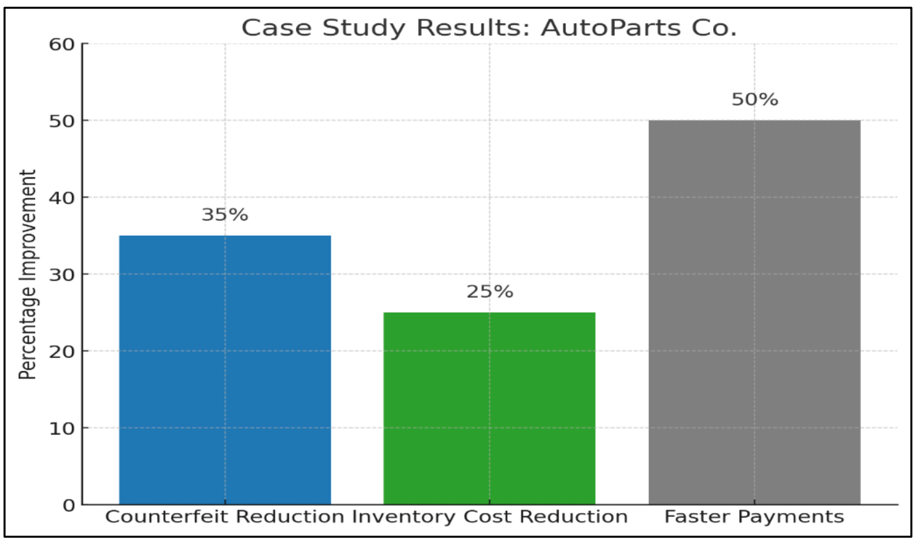

Figure 4.4: Case Study Results (AutoParts Co.)

Bar chart showing a 35% reduction in counterfeit incidents, 25% lower inventory costs, and 50% faster payments after blockchain implementation.

Image source: https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcQyZd4KJUeGDceCzR5myths-qG277wKdkOtWzNerim9agLnKVhTl5oSGxPwsJnyVe4-uOA&usqp=CAU

5. IMPLEMENTATION

5.1 Technical Architecture

The system is built on Hyperledger Fabric, a permissioned blockchain framework, ensuring scalability and privacy. Key components include:

- **Nodes**: Suppliers, manufacturers, logistics providers, and regulators.
- **Channels**: Private communication channels for sensitive data (e.g., pricing agreements).
- **Chain code**: Smart contracts written in GoLang to automate workflows. [10]

5.2 Smart Contract Development

Smart contracts are deployed to handle:

- **Order Fulfilment**: Automatically release payments upon IoT-confirmed delivery.
- **Compliance Checks**: Validate component certifications against regulatory databases.
- **Inventory Management**: Trigger reorders when stock levels fall below thresholds. [2]

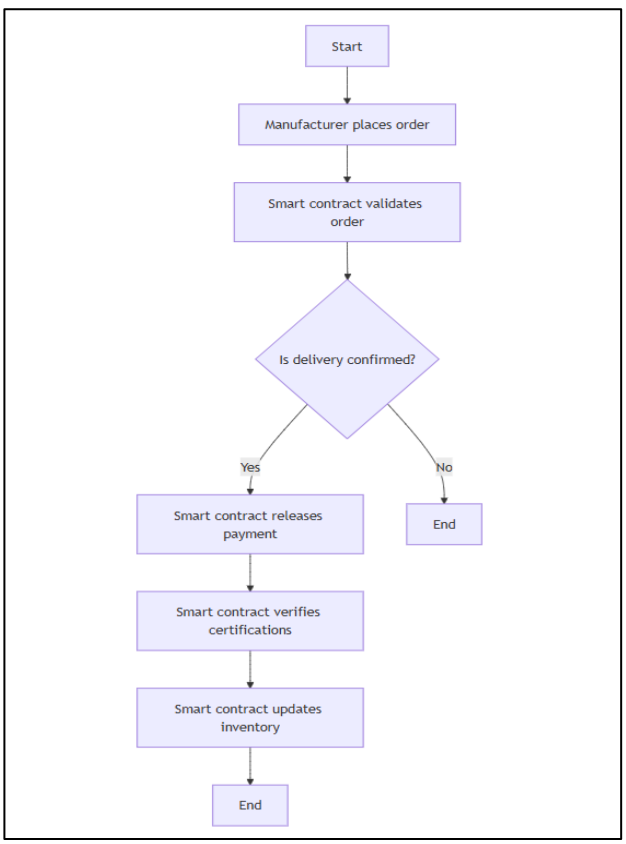

Figure 5.1: Smart Contract Workflow Diagram

Flowchart depicting the automation of order fulfilment, payment release, compliance validation, and inventory management through smart contracts.

Image source: Original work using mermaid.js

Example Code (Solidity): [2]

```
contract PaymentAutomation {
   function releasePayment (address supplier, unit amount) public {
      require(block.timestamp >= deliveryDate, "Delivery not confirmed");
      payable(supplier).transfer(amount);
   }
}
```

5.3 Integration with IoT and ERP Systems

- IoT Sensors: Track location, temperature, and humidity of shipments in real time.
- ERP Integration: SAP and Oracle systems sync with blockchain via REST APIs, enabling seamless data flow. [10]

5.4 Pilot Deployment and Testing

A six-month pilot with AutoParts Co. involved:

- **Stress Testing**: Simulated 10,000 transactions/hour to assess scalability.
- **Security Audits**: Identified and patched vulnerabilities in smart contracts.
- **User Training**: Workshops for suppliers and manufacturers on blockchain navigation. [4][10]

6. BENEFITS

6.1 Enhanced Transparency and Trust

Blockchain's decentralized ledger provides stakeholders with real-time access to verified data, eliminating discrepancies. For instance, a European OEM reduced disputes with suppliers by 45% after adopting blockchain. [7]

6.2 Improved Traceability and Compliance

Immutable records enable end-to-end traceability of components, ensuring adherence to standards like REACH (EU chemical regulation). During a 2023 recall, a Japanese automaker identified faulty batches within hours using blockchain, minimizing reputational damage. [9]

6.3 Cost Reduction and Operational Efficiency

Automation through smart contracts reduces manual labour and errors. A Deloitte study found that blockchain can cut supply chain costs by 20–30% for SSBs. [3]

6.4 Fraud Prevention and Security

Cryptographic encryption and decentralized validation mitigate risks like counterfeit parts and data breaches. Hyundai's blockchain network reported a 40% drop in cybersecurity incidents in 2022. [8]

6.5 Sustainability and Environmental Impact

Blockchain promotes sustainable practices by enabling precise tracking of raw materials, such as conflict-free minerals and recycled components. For instance, automotive manufacturers can use blockchain to verify compliance with environmental regulations (e.g., EU Battery Directive) and reduce carbon footprints through optimized logistics. A 2023 World Economic Forum study highlighted that blockchain-driven supply chains can lower CO2 emissions by 15% by minimizing redundant transportation. [6]

7. CHALLENGES

7.1 Regulatory and Compliance Hurdles

Divergent data privacy laws (e.g., GDPR in the EU vs. CCPA in California) complicate cross-border implementations. Blockchain's immutability conflicts with "right to be forgotten" mandates, requiring innovative solutions like off-chain data storage. [9]

7.2 Technical and Scalability Limitations

Public blockchains like Ethereum face scalability issues, with transaction speeds capped at 15–30 transactions/second. Hyperledger Fabric, while faster, requires significant infrastructure investment. [10]

7.3 Adoption Barriers

A 2023 McKinsey survey revealed that 60% of SSBs view blockchain as "too complex" due to a lack of technical expertise. Collaborative initiatives, such as industry consortia, are essential to drive adoption. [4]

7.4 Integration with Legacy Systems

Retrofitting blockchain with legacy ERP systems demands custom API development, which can cost upwards of $50,000 for small businesses. [3][10]

7.5 Energy Consumption and Environmental Concerns

Public blockchains like Bitcoin rely on energy-intensive consensus mechanisms (e.g., Proof of Work). While private/permissioned blockchains (e.g., Hyperledger Fabric) are more energy-efficient, transitioning to eco-friendly alternatives like Proof of Stake (PoS) remains critical. A 2024 Cambridge study noted that blockchain networks consume 0.5% of global electricity, raising sustainability concerns. [11]

7.6 Standardization and Interoperability

The lack of universal standards for blockchain protocols complicates cross-industry adoption. For example, a supplier using Ethereum may struggle to integrate with a manufacturer's Hyperledger system. [10]

8. CONCLUSION

Blockchain technology holds transformative potential for small-scale businesses in the automotive industry, addressing critical pain points such as transparency, efficiency, and fraud. The case study of AutoParts Co. underscores the tangible benefits of blockchain adoption, including cost savings, faster payments, and enhanced stakeholder trust.

Future advancements, such as AI-driven predictive analytics and decentralized finance (DeFi), will further amplify blockchain's impact. However, widespread adoption hinges on addressing regulatory ambiguities, improving scalability, and fostering collaboration between technology providers and SSBs. By embracing blockchain, small-scale businesses can not only survive but thrive in an increasingly competitive and digitalized automotive landscape.[2][3][6]

➢ Future Outlook

Beyond AI and DeFi, integrating blockchain with IoT devices and 5G networks will enable real-time monitoring of supply chains at unprecedented granularity. For example, sensors embedded in electric vehicle batteries could autonomously update blockchain records with health metrics, streamlining recalls and warranty claims. [10]

➢ Policy and Education

Governments and academic institutions must collaborate to create blockchain-friendly policies and upskill workforces. For instance, India's National Blockchain Strategy 2025 emphasizes public-private partnerships to drive adoption among small-scale automotive businesses. [12]

9. SDG ADDRESSED

SDG-9: Industry, Innovation, Technology, and Infrastructure

Blockchain fosters innovation by enabling SSBs to adopt cutting-edge technologies, reducing operational costs and promoting sustainable industrialization. For example, real-time data sharing minimizes resource wastage in production. [6][10]

SDG 12: Responsible Consumption and Production

By tracking the lifecycle of components, blockchain ensures ethical sourcing of raw materials (e.g., conflict-free minerals) and reduces e-waste through efficient recycling programs. [6][9]

SDG 8: Decent Work and Economic Growth

Automation through blockchain creates high-skilled jobs in tech and data management, driving economic growth in regions reliant on automotive manufacturing. [3][6]

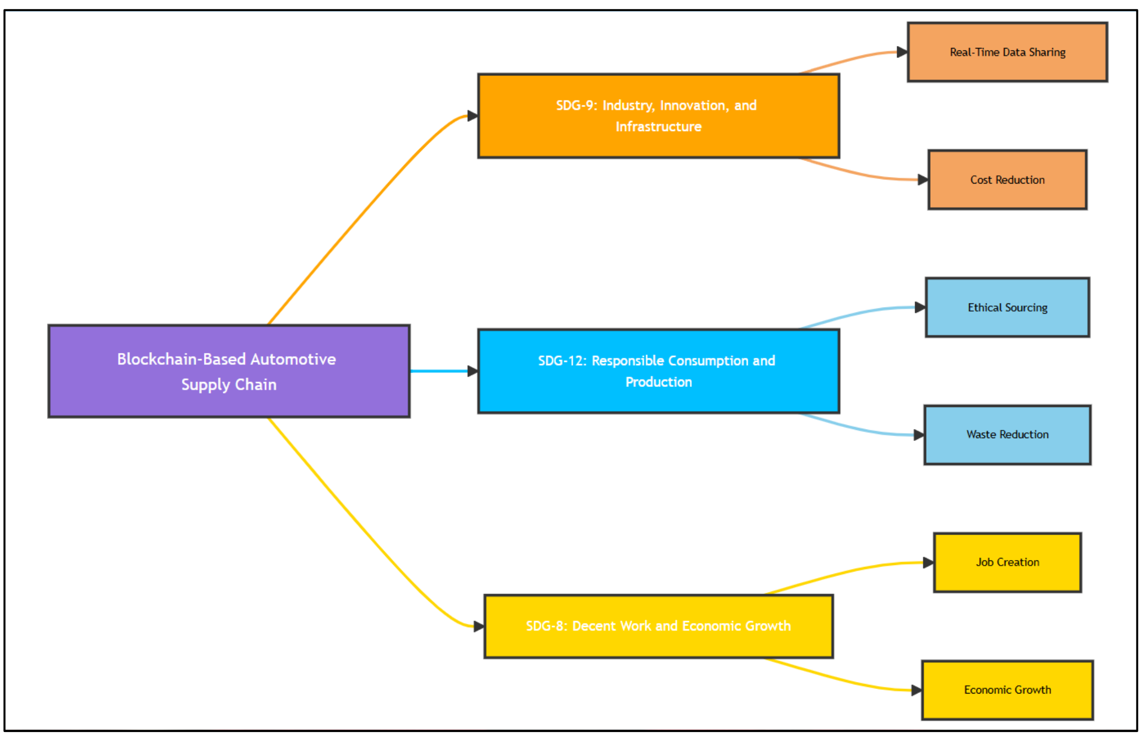

Figure 9.1: Contribution to UN Sustainable Development Goals (SDGs)

Image source: Original work using mermaid.js

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11. APPENDIX A

https://drive.google.com/drive/folders/1MnZY7IpTSg6i3wB9IowgIIHKvZLEwzoS?usp=drive_link