

| **Title: Literature Survey** |
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**Expected Outcome of Experiment:**

|  | **At the end of successful completion of the course the student will be able to** |
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| CO1 | Define the problem statement and scope of problem |
| CO5 | Prepare a technical report based on the Mini project. |

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**Books/ Journals/ Websites referred:**

**1. Somaiya Library**

**2. https://ieeexplore.ieee.org/**

**3. https://www.acm.org/**

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**Chapter 2**

**Literature Survey**



#### 1. Introduction

The pharmaceutical supply chain is a critical component of global healthcare, ensuring the availability of safe and effective medicines. However, it faces significant challenges, including inefficiencies, lack of transparency, and the growing threat of counterfeit drugs. These issues compromise patient safety, lead to financial losses, and erode trust among stakeholders. Traditional centralized systems used for supply chain management are susceptible to fraud, human errors, and operational delays, further exacerbating these problems.

To address these concerns, researchers have explored various technological advancements, including blockchain, to enhance supply chain transparency, traceability, and security. Blockchain technology, with its decentralized and immutable ledger, offers a promising solution to ensure drug authenticity, streamline inventory management, and improve overall efficiency.

This literature survey aims to analyze existing research on blockchain-based pharmaceutical supply chain management. It will examine various approaches, identify gaps in current solutions, and provide insights into the feasibility and effectiveness of blockchain integration. By reviewing relevant studies, this research seeks to justify the need for a decentralized system and highlight the potential benefits of adopting blockchain technology in pharmaceutical supply chain management.

#### 2. Review of Existing Literature

The pharmaceutical supply chain has long faced challenges such as inefficiency, lack of transparency, and counterfeit drugs. In response, blockchain technology has emerged as a viable solution for improving traceability, ensuring drug authenticity, and enhancing supply chain security. This literature review examines key studies that have contributed to the development of blockchain-based pharmaceutical supply chain management, organizing them chronologically to highlight major advancements in the field.

**Early Research on Blockchain in Pharmaceutical Supply Chains (2020-2021)**

**1. A Decentralized Application for the Traceability Process in the Pharma Industry (2020)**​  
This study was among the first to explore how blockchain could be integrated into pharmaceutical supply chains. It introduced an Ethereum-based decentralized application (DApp) to track and authenticate medicines. By using smart contracts, the system ensured that transactions were secure and immutable, addressing the issue of counterfeit drugs. The study demonstrated the potential of blockchain for pharmaceutical traceability but did not address scalability concerns.

**2. Securing Pharmaceutical Supply Chain Using Blockchain Technology (2021)**​  
This research compared Ethereum and Hyperledger frameworks, analyzing their effectiveness in enhancing supply chain security and transparency. It highlighted the trade-offs between permissioned (Hyperledger) and public (Ethereum) blockchains, concluding that each has unique advantages depending on the regulatory environment. While the study provided valuable insights into blockchain architecture selection, it lacked real-world implementation.

**Advancements in Blockchain-Based Pharmaceutical Supply Chains (2022)**

**3. Blockchain Technology in Pharmaceutical Supply Chain Management (2022)**​  
This paper examined how blockchain enhances security and fraud prevention in pharmaceutical logistics. The authors deployed smart contracts on a local blockchain (using Ganache) and demonstrated improved security in drug distribution. However, the study lacked real-world deployment, limiting its applicability to large-scale supply chains.

**4. A Secure Blockchain-Based Pharmaceutical Supply Chain Management System: Traceability and Detection of Counterfeit Covid-19 Vaccines (2022)**​  
This research proposed a permissioned blockchain system for tracking COVID-19 vaccine distribution. It ensured that only verified entities could add data to the blockchain, thereby improving traceability and reducing counterfeit risks. Unlike public blockchain solutions, this model prioritized security over decentralization. However, the study did not explore hybrid blockchain models that could balance both aspects.

**5. Blockchain-Based Pharmaceutical Drug Supply Chain Management System (2022)**​  
This study introduced a decentralized framework to verify drug authenticity using blockchain. Smart contracts were used to automate transactions and ensure transparency. The research contributed significantly to the field by focusing on drug verification, but it did not consider transaction costs and performance challenges for large-scale adoption.

**Recent Developments and Advanced Implementations (2023-2025)**

**6. Blockchain-Based Solution for Pharma Supply Chain Industry (2023)**​  
This study proposed a blockchain-based framework leveraging Ethereum smart contracts and IoT devices for online pharmaceutical sales. The solution allowed for automated refund mechanisms and real-time monitoring of medicine conditions. While it demonstrated practical applications, it focused primarily on e-commerce rather than full-scale supply chain management.

**7. Making Drug Supply Chain Secure, Traceable, and Efficient: A Blockchain and Smart Contract-Based Implementation (2023)**​  
This research built upon prior studies by implementing an Ethereum-based track-and-trace system for pharmaceuticals. Smart contracts were used to automate transactions and maintain immutable records. Unlike previous works, this study included performance benchmarking, but it lacked regulatory compliance considerations.

**8. Blockchain in Action: Enhancing Transparency and Traceability in the Pharmaceutical Supply Chain - A Case Study from Vietnam (2023)**​  
This paper explored a real-world implementation of blockchain in Vietnam’s pharmaceutical industry. It integrated a centralized SQL database with blockchain for enhanced efficiency while maintaining transparency. The hybrid approach improved data accessibility but compromised decentralization, raising concerns about data security.

**9. A Novel Hyperledger Blockchain-Enabled Decentralized Application for Drug Discovery Chain Management (2023)**​  
Focusing on the drug discovery process rather than supply chain logistics, this study combined blockchain with machine learning to improve research collaboration and data security. While not directly related to pharmaceutical distribution, it demonstrated blockchain’s versatility in the industry.

**10. Toward an Ontology-Driven Blockchain Design for Supply-Chain Provenance (2025)**​  
This recent study proposed integrating blockchain with ontologies to improve data structuring and traceability in supply chains. While the approach showed promise in enhancing information interoperability, it lacked practical implementation. Future research should focus on real-world deployment of ontology-driven blockchain systems.

**Critical Analysis and Future Directions:**

From this chronological analysis, several key trends and gaps emerge:

1. **Shift from Conceptual Models to Real-World Implementations**
   * Early studies (2020-2021) focused on theoretical models and small-scale simulations.
   * Recent works (2023-2025) have emphasized practical applications, such as case studies and pilot projects.
2. **Evolution of Blockchain Architectures**
   * Early studies primarily relied on public blockchains (Ethereum), while later research explored permissioned blockchains (Hyperledger) and hybrid models.
   * The need for balancing decentralization with security and efficiency remains a key challenge.
3. **Integration with Emerging Technologies**
   * IoT integration has been proposed for real-time monitoring.
   * Machine learning has been explored for predictive analytics in drug discovery.
   * Ontology-driven blockchain designs are a new area of interest for enhancing data structuring.
4. **Challenges and Research Gaps**
   * **Scalability:** Many studies do not address transaction costs or performance issues for large-scale adoption.
   * **Regulatory Compliance:** Few studies consider pharmaceutical industry regulations and legal frameworks.
   * **Interoperability:** The integration of blockchain with existing supply chain systems remains a challenge.
   * **Hybrid Models:** More research is needed on combining permissioned and public blockchains for optimal performance.

**3. Related Work**

**1. Blockchain-Based Solution for Pharma Supply Chain Industry​**

**Summarization:** This paper presents a blockchain-based framework for the pharmaceutical supply chain using Ethereum smart contracts. The solution ensures transparency in online pharmaceutical sales by allowing decentralized transactions without intermediaries. IoT devices are integrated to monitor the condition of medicines, and smart contracts facilitate automated refunds in case of contract breaches.

**Relevance:** The study aligns with our objective of building a decentralized supply chain system, emphasizing transparency, smart contract automation, and IoT integration. It addresses key concerns such as trust issues, fraud prevention, and product tracking.

**Comparison:** Both our proposed system and this study focus on Ethereum smart contracts and IoT integration. However, while this paper primarily targets online pharmaceutical sales, our work extends to inventory management and stakeholder interactions across the entire supply chain.

**Critical Analysis:** One limitation of this study is its lack of scalability considerations for large-scale pharmaceutical supply chains. Future work could explore cross-chain interoperability and improved consensus mechanisms to enhance efficiency.

**2. A Secure Blockchain-Based Pharmaceutical Supply Chain Management System: Traceability and Detection of Counterfeit Covid-19 Vaccines​**

**Summarization:**This paper proposes a permissioned blockchain system for tracking COVID-19 vaccine distribution. The model enhances supply chain security by allowing only verified entities to push data onto the blockchain, ensuring traceability and transparency. It highlights the risks of counterfeit vaccines and the need for a secure tracking mechanism.

**Relevance:**The study directly relates to our focus on counterfeit drug prevention, leveraging blockchain’s transparency and immutability to improve trust in pharmaceutical supply chains.

**Comparison:**Unlike our system, which is built on Ethereum, this study employs a permissioned blockchain, providing greater control over data access. Our approach focuses on a broader pharmaceutical supply chain, while this paper is specific to COVID-19 vaccine distribution.

**Critical Analysis:**A major limitation of this study is its restricted access model, which may reduce decentralization. Future research could explore hybrid blockchain models to balance security and accessibility.

**3. Blockchain Technology in Pharmaceutical Supply Chain Management​**

**Summarization:**This study explores blockchain’s role in securing pharmaceutical supply chains, emphasizing traceability, transparency, and fraud prevention. The authors deploy smart contracts on a local blockchain using Ganache and demonstrate improved security in drug distribution.

**Relevance:**This research supports our objective of enhancing supply chain security through blockchain-based traceability and smart contract implementation.

**Comparison:**Both studies use Ethereum smart contracts for automation. However, our approach includes real-time tracking and inventory management, whereas this paper primarily focuses on security and fraud prevention.

**Critical Analysis:**The study lacks real-world deployment, limiting its practical applicability. Future work should integrate blockchain with real-world pharmaceutical logistics systems for further validation.

**4. Blockchain-Based Pharmaceutical Drug Supply Chain Management System​**

**Summarization:**This paper introduces a decentralized blockchain framework for verifying drug authenticity and preventing counterfeiting. It emphasizes the role of smart contracts in automating pharmaceutical transactions while ensuring trust and transparency.

**Relevance:**The study aligns with our goal of eliminating counterfeit drugs and securing supply chains through blockchain technology.

**Comparison:**Both solutions focus on drug traceability and authentication via smart contracts. However, our system expands upon this by incorporating inventory management and real-time tracking.

**Critical Analysis:**The paper lacks discussion on scalability and transaction costs. Future research should assess how to optimize blockchain performance for high-volume supply chain transactions.

**5. Blockchain in Action: Enhancing Transparency and Traceability in the Pharmaceutical Supply Chain - A Case Study from Vietnam​**

**Summarization:**This study presents a blockchain-based traceability system tailored to the Vietnamese pharmaceutical industry. It integrates a centralized SQL database with blockchain to enhance transparency while maintaining efficiency in data management.

**Relevance:**The study provides a practical implementation of blockchain in a regional supply chain, demonstrating real-world feasibility.

**Comparison:**Unlike our fully decentralized approach, this study uses a hybrid model with a centralized SQL database. While this improves efficiency, it compromises decentralization.

**Critical Analysis:**The hybrid approach raises concerns about data integrity and security. Future work should explore fully decentralized alternatives without sacrificing efficiency.

**6. A Decentralized Application for the Traceability Process in the Pharma Industry​**

**Summarization:** This paper presents a decentralized Ethereum-based application for pharmaceutical traceability. It uses smart contracts to track product movement across the supply chain, ensuring security and compliance with regulatory standards.

**Relevance:** The study supports our project’s goal of using blockchain for real-time traceability and supply chain integrity.

**Comparison:** Both studies emphasize traceability using Ethereum. However, our approach integrates additional functionalities such as inventory management and automated alerts for anomalies.

**Critical Analysis:** The study lacks details on cost analysis and transaction speed. Future research should evaluate blockchain efficiency in large-scale pharmaceutical networks.

**7. Toward an Ontology-Driven Blockchain Design for Supply-Chain Provenance​**

**Summarization:** This study explores the integration of ontology with blockchain for improved supply chain provenance. It leverages semantic web technologies to enhance traceability and data interoperability.

**Relevance:** The paper highlights the importance of structured data management in blockchain-based supply chains, which is crucial for pharmaceutical tracking.

**Comparison:** While our study focuses on transparency and security, this research emphasizes semantic data integration. Combining both approaches could enhance data accuracy and accessibility.

**Critical Analysis:** The study lacks a practical implementation of ontology-driven blockchain systems. Future work should focus on deploying and testing such systems in real-world supply chains.

**8. A Novel Hyperledger Blockchain-Enabled Decentralized Application for Drug Discovery Chain Management​**

**Summarization:** This paper introduces a Hyperledger-based blockchain system for drug discovery management, integrating machine learning for data analysis and verification.

**Relevance:** Although it focuses on drug discovery rather than supply chain management, it demonstrates how blockchain enhances security and collaboration in pharmaceutical research.

**Comparison:** Our study targets drug distribution, while this paper focuses on research and development. However, both leverage blockchain for data integrity and transparency.

**Critical Analysis:** The study does not address how blockchain can be adapted for large-scale pharmaceutical supply chains. Future research should explore cross-industry applications of blockchain.

**9. Making Drug Supply Chain Secure, Traceable, and Efficient: A Blockchain and Smart Contract-Based Implementation​**

**Summarization:** This research proposes an Ethereum-based blockchain solution for tracking pharmaceuticals. It employs smart contracts to automate transactions and ensure data immutability.

**Relevance:** It aligns closely with our project by focusing on supply chain security and counterfeit drug prevention.

**Comparison:** Both studies utilize Ethereum and smart contracts. However, our system extends functionalities to include real-time tracking and authentication mechanisms.

**Critical Analysis:** The study does not discuss regulatory compliance or real-world adoption challenges. Future work should investigate how blockchain systems can meet pharmaceutical industry regulations.

**10. Securing Pharmaceutical Supply Chain Using Blockchain Technology​**

**Summarization:** This paper compares Ethereum and Hyperledger frameworks for pharmaceutical supply chains, evaluating their effectiveness in enhancing security and transparency.

**Relevance:** The study provides valuable insights into blockchain architecture selection for pharmaceutical applications.

**Comparison:** While this paper analyzes different blockchain frameworks, our study focuses on implementing a specific Ethereum-based solution.

**Critical Analysis:** The research lacks real-world testing and performance benchmarks. Future studies should compare blockchain frameworks in practical supply chain scenarios.

**Link to the Literature Survey Table:** <https://docs.google.com/spreadsheets/d/1vGMa3vE1g0KNeUEoRQHojmaB2hsVMIc2q2ifCGu-KQU/edit?usp=sharing>

| **Sr. No.** | **Paper Title** | **Year** | **Journal** | **No. of Citations** | **Country / State** | **Methodology** | **Performance Metrics** | **Conclusion** | **Inferences from the Paper** | **Research Gap** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **1** | **Blockchain in Action: Enhancing Transparency and Traceability in the Pharmaceutical Supply Chain - A Case Study from Vietnam** | **2023** | **ASSE 2023** | **0** | **Vietnam** | **Developed PharmaFlow, integrating MS SQL and blockchain for tracking pharma supply chain** | **Black-box and white-box testing, functional validation, system examination** | **Blockchain enhances transparency and efficiency in pharma supply chains** | **Demonstrates how blockchain can improve traceability** | **Need for real-world large-scale implementation** |
| **2** | **Blockchain Technology in Pharmaceutical Supply Chain Management** | **2022** | **14th IEEE International Conference on Computational Intelligence and Communication Networks** | **4** | **India** | **Proposed blockchain-based pharma supply chain with smart contracts using Ethereum and Ganache** | **Security, data immutability, transaction verification** | **Blockchain can effectively mitigate drug counterfeiting and improve traceability** | **Highlights benefits of smart contracts for supply chain security** | **Needs further testing in real-world pharma logistics** |
| **3** | **Ontology-Based Blockchain Model for Pharmaceutical Supply Chain** | **2025 (Assumed)** | **EBSCO** | **981** | **Not mentioned** | **Uses ontology-based blockchain modeling for improved supply chain transparency** | **Interpretability, smart contract execution** | **Ontology-based modeling enhances blockchain’s traceability potential** | **Focuses on smart contracts for automating supply chain processes** | **Requires validation with actual pharma supply chain stakeholders** |
| **4** | **A Secure Blockchain-based Pharmaceutical Supply Chain Management System: Traceability and Detection of Counterfeit Covid-19 Vaccines** | **2022** | **IEEE MysuruCon** | **5** | **Malaysia** | **Uses permissioned blockchain for securing pharma supply chain transactions** | **Traceability, security, transparency** | **Blockchain can enhance visibility, traceability, and counterfeit detection** | **Highlights the importance of permissioned blockchain** | **Needs implementation on a large scale to test real-world effectiveness** |
| **5** | **Blockchain-based Pharmaceutical Drug Supply Chain Management System** | **2022** | **ICECCME Conference** | **3** | **India** | **Developed a decentralized blockchain model to ensure pharma supply chain security** | **Consensus mechanism efficiency, traceability, transparency** | **Blockchain improves transparency and reduces fraud in pharma supply chains** | **Stresses the need for a trustless, decentralized system** | **Requires real-world adoption and regulatory support** |
| **6** | **A Decentralized Application for the Traceability Process in the Pharma Industry** | **2020** | **Procedia Manufacturing** | **32** | **Italy** | **Developed an Ethereum-based DApp for tracking pharmaceutical distribution** | **Transaction verification, decentralization, immutability** | **Blockchain ensures secure and traceable transactions in pharma supply chain** | **Demonstrates feasibility of blockchain-based serialization** | **Needs integration with existing pharma supply chain regulations** |
| **7** | **Blockchain-Based Solution for Pharma Supply Chain Industry** | **2023** | **Computers & Industrial Engineering** | **68** | **UAE** | **Developed a blockchain framework integrating IoT and Ethereum smart contracts for pharma supply chains** | **Transparency, real-time tracking, security** | **Blockchain and IoT improve supply chain transparency and prevent counterfeiting** | **Demonstrates the benefits of integrating IoT with blockchain for secure pharma tracking** | **Needs large-scale deployment and industry-wide adoption** |
| **8** | **Hyperledger Blockchain-Enabled Decentralized Application for Drug Discovery Chain Management** | **2023** | **Computers & Industrial Engineering** | **10** | **India** | **Developed a Hyperledger Fabric-based DApp for drug discovery chain management integrating ML and blockchain** | **Throughput, latency, resource statistics** | **Blockchain and ML improve traceability, privacy, and scalability in drug discovery** | **Demonstrates the effectiveness of Hyperledger Fabric for secure research collaboration** | **Requires further real-world adoption and regulatory integration** |
| **9** | **Making Drug Supply Chain Secure, Traceable, and Efficient: A Blockchain and Smart Contract-Based Implementation** | **2023** | **Multimedia Tools and Applications** | **49** | **India** | **Ethereum-based blockchain system with smart contracts for tracking healthcare supply chains** | **Gas cost, security, smart contract efficiency** | **Blockchain improves traceability, prevents counterfeiting, and increases transparency in pharma supply chains** | **Demonstrates gas cost efficiency in smart contract-based supply chains** | **Needs large-scale real-world adoption and regulatory compliance** |
| **10** | **Securing Pharmaceutical Supply Chain using Blockchain Technology** | **2021** | **ITM Web of Conferences** | **20** | **India** | **Compared Hyperledger and Ethereum for pharmaceutical supply chains, implementing a Hyperledger Fabric-based system** | **Security, transparency, traceability** | **Blockchain enhances security and transparency in pharma supply chains** | **Demonstrates Hyperledger Fabric’s advantages over Ethereum for secure supply chains** | **Requires more robust implementation and industry-wide acceptance** |

#### 4. Research Gaps and Challenges

The literature survey on blockchain-based pharmaceutical supply chain systems reveals significant advancements in addressing issues like counterfeit drugs, transparency, and traceability. However, several research gaps, challenges, and inconsistencies persist across existing studies, justifying the need for further investigation.

### 1. Limitations in Existing Research

* **Lack of Large-Scale Implementation:**Most studies are either simulations or small-scale prototypes. There is limited evidence of successful, full-scale deployment in real-world pharmaceutical environments.
* **Limited Performance Analysis:**Few papers thoroughly analyze blockchain performance metrics such as latency, throughput, and scalability. This limits understanding of how blockchain solutions would perform under high transaction volumes in a global pharmaceutical network.
* **Focus on Single Blockchain Platforms:**Many studies rely solely on Ethereum or Hyperledger, without comparative evaluations or consideration of hybrid models that could offer better trade-offs between decentralization, speed, and security.
* **Minimal Consideration for End-User Experience:**Very few implementations consider UI/UX design for stakeholders such as pharmacists, consumers, or regulators. This impacts adoption and usability in real-world scenarios.

### 2. Unexplored Areas and Research Opportunities

* **Regulatory Compliance Integration:** Integration of compliance requirements from organizations like the FDA or WHO into blockchain-based systems remains underexplored. Legal and privacy issues related to drug data sharing need deeper investigation.
* **Interoperability with Existing Systems:** There is a gap in ensuring blockchain platforms can seamlessly integrate with existing Enterprise Resource Planning (ERP), logistics, and inventory management systems.
* **Ontology and Semantic Interoperability:** Although one study introduces ontology-based blockchain architecture, the idea is still in its infancy. There is room to explore how semantic models can standardize drug data across borders and languages.
* **Decentralized Identity and Role Management:** Identity management for various stakeholders (manufacturers, distributors, pharmacies) is often centralized or hardcoded in smart contracts. Future research could focus on decentralized identity frameworks using DID (Decentralized Identifiers).

### 3. Inconsistencies and Contradictions

* **Public vs. Private Blockchains:** Some studies promote public blockchains for their openness and trustlessness, while others emphasize private or permissioned systems for better control and privacy. This contradiction underscores the need for evaluating hybrid models that combine the benefits of both.
* **Smart Contract Complexity and Security:** While most papers acknowledge the usefulness of smart contracts, there is minimal focus on smart contract security vulnerabilities or methods for formal verification.
* **Data Storage Approaches:** Disagreement exists on whether drug-related data should be stored on-chain or off-chain (e.g., IPFS). Clear guidelines on data partitioning, confidentiality, and access control are missing.

### 4. Need for Further Investigation

Given the high stakes of pharmaceutical supply chains—impacting both financial systems and human lives—there is a pressing need for:

* More robust and scalable blockchain frameworks tailored for global pharmaceutical ecosystems.
* Better alignment with international regulations and healthcare compliance standards.
* Solutions that are easy to use, cost-effective, and secure for all stakeholders.
* Real-world pilot studies and performance evaluations in diverse geographic and regulatory environments.

### 5. Summary of Key Findings from Literature Survey

* **Blockchain is a promising technology** to enhance traceability, transparency, and security in pharmaceutical supply chains.
* **Smart contracts and permissioned ledgers** play a key role in automating processes and reducing fraud.
* **Most existing research is theoretical or proof-of-concept**, with few studies addressing implementation challenges at scale.
* **Critical components like interoperability, regulation, and smart contract security** are often overlooked or underexplored.
* There is a strong **potential for hybrid models** (e.g., combining Ethereum and Hyperledger or IPFS) that balance performance, privacy, and decentralization.