

Track and Trace Supply Chain System

Mr. Muthuraju V¹, Mr. Arun Kumar S², Mr. Neelraj S G³, Mrs. Shrushti G S⁴, Ms. Rachana Shetty⁵ and Ms. Vaishnavi A. H⁶

¹⁻²Assistant Professor, School of CSE & IS, Presidency University, Bengaluru, India
Email: muthuraju.v@presidencyuniversity.in, arunkumar.s@presidencyuniversity.in

³⁻⁶School of CSE & IS, Presidency University, Bengaluru, India
Email: {neelrajsg, gsshrusti7, vaishnaviah9483, rachanagshetty70}@gmail.com

Abstract— The rise in consumer product logistics has introduced complexities in supply chain management. Millions of product units must be traced from their origin to the consumer, ensuring quality, transparency, and authenticity. Current barcode-based tracking systems falter beyond the distributor level, often requiring extensive manual intervention. This paper proposes a web-based Track and Trace Supply Chain System that leverages modern technologies such as React.js, Node.js, and MongoDB for seamless tracking, requiring minimal human effort. The system focuses on transparency, efficiency, and scalability, ensuring stakeholders can access real-time updates on product journeys. This research bridges existing gaps in supply chain traceability, offering a scalable, secure, and user-friendly solution.

Index Terms—Track and Trace, Supply Chain Management, RFID.

I. INTRODUCTION

Supply chain management has evolved significantly over the past decades to address growing demands for transparency, efficiency, and quality assurance. In today's globalized markets, ensuring the traceability of products from their point of origin to the end consumer has become critical. A reliable track-and-trace system not only enhances trust but also ensures regulatory compliance and quality control.

Traditional tracking solutions, such as barcode-based systems, often face scalability challenges and require extensive manual intervention. These limitations become more pronounced as products transition beyond the distributor level, leading to inefficiencies and lack of visibility.

This research proposes a modern web-based Track and Trace Supply Chain System designed to overcome these challenges. By leveraging advanced technologies such as React.js, Node.js, and MongoDB, the system enables seamless tracking of products across the supply chain, ensuring minimal human effort, robust scalability, and enhanced transparency.

The purpose of the paper is to bridge existing gaps in supply chain management by providing an innovative, efficient, and user-friendly solution to ensure product traceability on a scale.

II. RESEARCH GAPS OF EXISTING METHODS

Despite the substantial advancements in supply chain management and tracking technologies, several gaps remain that hinder the efficient and transparent management of product traceability. The following are the key research gaps identified in existing methods:

A. Scalability Issues in Traditional Systems

Barcode and RFID-based tracking systems, although widely adopted, struggle to handle large-scale, multi-tiered supply chains.

As products move beyond the first few steps in the supply chain, visibility diminishes, and manual interventions become necessary.

The scalability of these systems is a significant challenge when managing vast amounts of product data across global supply chains.

B. Lack of Real-Time Data Access

Traditional systems often fail to provide real-time updates on product status, location, and movement. The lack of real-time data impedes the ability of businesses to make informed decisions swiftly, especially in time-sensitive industries like food or pharmaceuticals. Current solutions are limited in integrating real-time data from various sources, making it difficult to maintain accurate visibility throughout the supply chain.

C. Limited Integration with Modern Technologies

While blockchain and IoT offer promising solutions, they have not been fully integrated into mainstream supply chain systems. Blockchain, although offering transparent and immutable records, faces adoption challenges in terms of scalability and integration with existing infrastructure. IoT devices, while providing real-time tracking, are often expensive and require high levels of maintenance and monitoring, which limits their adoption.

D. Manual Intervention and Operational Overhead

Most traditional tracking solutions still require significant human intervention for data entry, verification, and troubleshooting. This results in inefficiencies and increased potential for errors. The operational overhead involved in maintaining these systems is high, as companies have to rely on manual processes for updating tracking information and reconciling discrepancies.

E. Data Security and Privacy Concerns

The integration of cloud computing and data sharing across multiple entities in the supply chain raises concerns about data security and privacy. Protecting sensitive product and transaction data remains a critical issue. Current systems often lack robust encryption and security measures to ensure safe transmission and storage of data.

This research aims to address these gaps by proposing a modern, scalable, and automated track-and-trace system that integrates cutting-edge technologies such as React.js, Node.js, and MongoDB, with enhanced security, minimal manual intervention, and real-time data accessibility.

III. PROPOSED METHODOLOGY

To address the research gaps identified in existing methods, this paper proposes a modern Track and Trace Supply Chain System that integrates cutting-edge technologies to provide a scalable, secure, and efficient solution for real-time product tracking. The methodology consists of the following steps:

A. Technology Stack Selection

- Frontend: React.js is chosen for the front end due to its ability to create dynamic and interactive user interfaces, making it ideal for displaying real-time product tracking data. Tailwind CSS is used to ensure the UI is responsive and visually appealing across different devices.
- Backend: Node.js with Express.js is selected for handling server-side logic and API management. The system utilizes RESTful or GraphQL APIs to ensure smooth communication between the front end and back end.
- Database: MongoDB is selected to store product tracking information. It offers flexibility in managing large datasets, essential for supply chain management.

B. System Architecture

The system employs a client-server framework where the client interface connects with the server to access real-time data related to product tracking. The server is tasked with executing traceability functions, responding to API requests, and managing the database for data storage and retrieval. This design emphasizes scalability, enabling the system to accommodate increasing data loads and user traffic while maintaining high performance as it evolves.

C. Integration of Real-Time Tracking

IoT devices and sensors will be integrated into the supply chain to track the movement of products. These IoT devices will relay live data to the system, enabling continuous updates on the product's location, status, and condition. The integration of IoT with the system will enhance visibility and reduce the need for manual updates.

D. Data Security

To protect the integrity and privacy of product information, the system will implement secure communication protocols such as HTTPS and employ encryption techniques to secure sensitive data. Additionally, cloud-based storage platforms (AWS or GCP) will be used for deployment, ensuring high security and reliability.

E. Minimal Human Intervention

The system is designed to automate most aspects of the tracking process, from data entry to status updates. By integrating real-time sensors and IoT technology, human intervention will be minimized, and manual entry will be limited to exceptional cases only.

F. Deployment and Scalability

The system will be deployed on cloud platforms (such as AWS or Azure) to ensure scalability, high availability, and ease of maintenance. This architecture also ensures that the system can handle increasing data loads as the supply chain grows. This proposed approach offers a secure, scalable, and efficient solution for achieving comprehensive supply chain traceability. It overcomes the shortcomings of conventional methods and establishes a strong framework for future innovations in supply chain management.

IV. SYSTEM DESIGN & IMPLEMENTATION

The Track and Trace Supply Chain System is designed with a modern, scalable architecture that integrates several key components to address the challenges of product traceability. This section outlines the design and implementation details of the system, including its architecture, data flow, and key components.

A. System Architecture

The system adopts a client-server model, consisting of the following components:

- **Client (Frontend):** The user interface, built with React.js and Tailwind CSS, is designed to display realtime product tracking information. It communicates with the backend through APIs, utilizing either RESTful or GraphQL protocols.
- **Server (Backend):** Developed using Node.js and Express.js, the backend processes requests from the frontend, handles product tracking data, and manages interactions with the database for data retrieval and storage.
- **Database:** The system leverages MongoDB to store tracking information. This includes product identifiers, locations, timestamps, and status updates, with MongoDB's scalability and flexibility enabling efficient handling of extensive datasets.
- **IoT Integration:** IoT devices such as RFID sensors and GPS trackers are incorporated to collect real-time data on product location, condition, and movement throughout the supply chain.

B. Data Flow

- **Product Tracking:** Each product in the supply chain is given a unique ID. IoT sensors and GPS devices collect real-time data, such as location and condition, and transmit it to the backend.
- **Backend Processing:** The backend processes the incoming data and updates the product's status in the database. The backend also triggers notifications for significant events, such as delays or issues with the product.
- **Frontend Display:** The frontend fetches real-time data from the backend and presents it in an interactive, userfriendly interface, allowing users to view a product's complete journey from origin to delivery.

C. User Roles and Access Control

The system implements different user roles to control access to specific functionalities:

- **Admin:** Can view and manage all product data, including tracking details, user roles, and system settings.
- **Supplier/Manufacturer:** Can add new products, update their status, and track the products they are responsible for.

- Distributor/Retailer: Can view the products in their inventory and track the location and status of items in transit.
- Consumer: Can view basic product tracking information, such as location and estimated delivery time.

D. Real-Time Tracking and Alerts

- Real-Time Updates: The system provides real-time updates on product status, which is achieved through continuous data exchange between IoT devices and the backend.
- Alert System: The system sends alerts to users (via email or SMS) when there are delays, quality issues, or other deviations from the expected tracking path.

E. Security Features

The system implements robust security features to ensure the integrity and privacy of data:

- Secure APIs: All communication between the frontend and backend is encrypted using HTTPS.
- Authentication and Authorization: User authentication is handled using secure methods, and role-based access control is enforced to restrict unauthorized access.

F. Deployment

The system is deployed on cloud platforms (such as AWS, GCP, or Azure) to ensure scalability, availability, and reliability. Docker containers are used for deployment to simplify the management of the environment and dependencies.

G. Outcomes

The Track and Trace Supply Chain System is expected to provide several key outcomes that will improve the efficiency and transparency of supply chain management. The outcomes of the project include:

- Real-Time Traceability: The system will offer real-time tracking of products as they progress through the supply chain. Users will be able to view the current status, location, and condition of each product, from its point of origin to its final destination.
- Increased Transparency: The solution will enhance transparency by providing stakeholders with access to the entire journey of a product, ensuring accountability at every step of the supply chain. This can help in verifying the authenticity and origin of products.
- Reduced Operational Costs: The system will decrease operational costs by automating product tracking and removing manual processes, leading to reduced overhead and fewer human errors. This will result in savings related to labor, time, and resources.
- Improved Decision-Making: With access to real-time data, stakeholders will be able to make more informed decisions quickly. For example, suppliers and retailers can address delays or issues as they arise, improving customer satisfaction and operational efficiency.
- Scalability and Flexibility: The system is designed to be scalable and flexible, able to handle increasing data loads and integrate with other systems in the future. This ensures that it can grow as the supply chain expands.
- Enhanced Security: Data integrity and security will be ensured through encryption, secure communication protocols, and role-based access control. Sensitive supply chain data will be protected, reducing the risk of fraud and data breaches.
- IoT Integration: By integrating IoT sensors and devices, the system will capture real-time data from products, reducing the need for manual updates and improving the accuracy of tracking.
- User-Friendly Interface: The interface will be userfriendly, intuitive, and easy to navigate, ensuring a seamless experience for all users, including suppliers, distributors, and consumers.

These outcomes will streamline supply chain operations, enhance product traceability, and improve overall supply chain management, leading to greater efficiency, security, and transparency.

V. RESULTS AND DISCUSSION

- System Performance: The system successfully tracked products in real-time, providing continuous updates to stakeholders. The performance was analyzed based on metrics such as data accuracy, response time, and scalability. Overall, the system demonstrated excellent performance in maintaining real-time data synchronization across all stages of the supply chain.
- User Interaction and Feedback: User feedback was collected from various stakeholders, including suppliers, retailers, and consumers. The results showed a high level of satisfaction, particularly in the ease of use and

accessibility of the system. Users reported that the interface was intuitive, and the information provided was valuable for making better decisions.

- **Real-Time Tracking Accuracy:** The integration of IoT devices such as RFID tags and GPS sensors significantly improved tracking accuracy. Products were successfully tracked with minimal error, and the system demonstrated excellent accuracy in identifying the location and status of products in real time.
- **Cost Savings and Operational Efficiency:** Implementing the system led to a reduction in operational costs. Automation of the tracking process minimized human errors, and real-time updates reduced the need for manual interventions. Additionally, the system improved supply chain efficiency, leading to faster decision-making and improved customer service.
- **Security and Data Integrity:** The system's security measures, including encrypted communications and role-based access control, successfully ensured the integrity and privacy of data. The system passed all security tests, and no significant data breaches were encountered during testing.
- **Challenges and Future Improvements:** Although the system performed well overall, some challenges were encountered, such as IoT device calibration and network latency issues. Future improvements could include further scaling of the IoT network, integration with AI for predictive analytics, and enhanced user interface features to cater to a wider range of devices and platforms.

VI. CONCLUSION

The proposed system also offers scalability, enabling it to grow alongside the expansion of the supply chain and adapt to future technological advancements. While the system addresses existing gaps in traceability, future work could explore additional integrations, such as machine learning for predictive analytics or blockchain for further enhancing data security and transparency.

In conclusion, the Track and Trace Supply Chain System offers a robust, efficient, and scalable solution for modern supply chain management, providing valuable insights into how technology can optimize supply chain operations and ensure higher levels of efficiency, transparency, and trust.

REFERENCES

- [1] D. R. Bell, S. Gallino, and A. Moreno, "How to trace the supply chain in the digital age," *Harvard Business Review*, 2018. [Online]. Available: <https://hbr.org/2018/12/how-to-trace-the-supply-chain-in-the-digital-age>.
- [2] M. Golkowski, "Blockchain in supply chain: A gamechanger for transparency," *Supply Chain Management Journal*, vol. 15, no. 3, pp. 150-164, 2021. [Online]. Available: <https://doi.org/10.1016/j.scm.2021.08.002>.
- [3] K. Reimers, R. Johnston, and S. Klein, "The role of real-time updates in modern supply chain management," *Journal of Business Logistics*, vol. 40, no. 2, pp. 124-138, 2019. [Online]. Available: <https://doi.org/10.1111/jbl.12195>.
- [4] P. Wills, "Implementing web-based supply chain software: A technical approach," *Web Technology Journal*, 2020. [Online]. Available: <https://webtechjournal.com/articles/supply-chain-software>.