



Drug inventory and supply chain tracking system

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Abstract: A drug inventory and supply chain tracking system utilizes advanced technologies to enhance the efficiency of pharmaceutical logistics, lower operational expenses, and maintain a consistent supply of medications—all while complying with regulatory requirements. These systems incorporate tools such as artificial intelligence (AI), vendor-managed inventory (VMI), RFID technology, and blockchain to automate workflows, improve traceability, and support informed decision-making. Core capabilities include live tracking of inventory, automatic generation of purchase orders, and compliance with standards like the Drug Supply Chain Security Act (DSCSA).

Keywords: Inventory ,Supply Chain Tracking ,Pharmaceutical Logistics ,Regulatory Compliance ,Artificial Intelligence (AI) ,Vendor-Managed Inventory (VMI),RFID Technology ,Blockchain ,Workflow Automation ,Traceability ,Inventory Tracking ,Purchase Order Automation ,Drug Supply Chain Security Act (DSCSA) ,Operational Efficiency ,Medication Supply Management

I. INTRODUCTION

The pharmaceutical supply chain plays a pivotal role in global healthcare, ensuring that essential medications are delivered securely and on time to those who need them. However, this complex network is under mounting pressure from growing threats—ranging from counterfeit drugs to severe shortages of critical treatments—that compromise both patient safety and trust in healthcare systems. In today's interconnected and heavily regulated environment, outdated inventory management and supply chain methods fall short of addressing these pressing issues.

The demand for accuracy, visibility, and responsiveness in drug distribution has never been greater. The COVID-19 pandemic starkly revealed the fragility of current systems: nearly 70% of healthcare facilities reported running low on vital medications, while counterfeit products took advantage of loopholes in monitoring infrastructure. These breakdowns in the supply chain highlight systemic flaws such as inefficient manual workflows, lack of real-time data sharing, overstock or understock scenarios, and delayed responses to recalls or emergencies—all of which translate into significant financial and human costs.

1.1 Motivation

The global pharmaceutical supply chain faces unprecedented challenges, including drug shortages, counterfeit medications, regulatory complexity, and inefficiencies that jeopardize patient safety and healthcare outcomes. These issues underscore the urgent need for robust, technology-driven solutions to modernize drug inventory and supply chain management.

The implementation of a drug inventory and supply chain tracking system is driven by the growing challenges within the pharmaceutical industry, such as counterfeit drugs, supply shortages, and complex regulatory demands. These issues pose serious threats to patient safety, public health, and the efficiency of healthcare operations. A major motivator is the need to protect patients from receiving substandard or expired medications, which can lead to harmful consequences and undermine trust in healthcare services. Additionally, the system supports compliance with stringent regulations like the Drug Supply Chain Security Act (DSCSA), which requires full traceability of prescription drugs. It also ensures secure handling of sensitive data to align with legal frameworks such as HIPAA, reducing the risk of data breaches and associated liabilities. Overall, adopting such systems enhances transparency, ensures timely access to genuine medications, and upholds both legal and ethical standards in pharmaceutical distribution. A drug inventory and supply chain tracking system offers vital benefits that drive its adoption, particularly in improving operational efficiency, combating fraud, and addressing vulnerabilities exposed during global health crises. Traditional manual processes often lead to overstocking or stockouts, costing healthcare systems billions annually, while consuming a significant portion of staff time.

By integrating technologies like AI for demand forecasting, RFID for tracking, and automation, organizations can cut costs substantially and reduce inventory errors.

1.2 Key Features

Modern drug inventory and supply chain tracking systems leverage technologies like blockchain, IoT, AI, and RFID to ensure real-time monitoring, traceability, and predictive management of pharmaceuticals. These systems enhance efficiency by automating inventory tracking and replenishment, support regulatory compliance with standards such as DSCSA and HIPAA, and prevent counterfeit drugs through secure verification methods. Features like cold chain monitoring, mobile access, and automated recalls further ensure drug quality and accessibility. By reducing waste, improving collaboration, and strengthening data security, these systems contribute to safer, more reliable, and sustainable healthcare supply chains.

1.3 Research Objectives

This research focuses on identifying the key biological, environmental, and social factors necessary for controlling and preventing future plague outbreaks caused by *Yersinia pestis*. It investigates genetic resistance in rodents from plague-endemic regions and explores the possible influence of human genetic mutations, like CCR5-Δ32, on disease susceptibility. Additionally, the study examines flea vectors—such as *Pulex irritans* and *Xenopsylla cheopis*—analyzing their distribution to improve control efforts.

Environmental conditions like altitude, habitat types, and rodent-flea interaction cycles are assessed to pinpoint high-risk areas and propose preventive measures, such as rodent-proof housing. On the public health front, the research emphasizes improving early detection, ensuring timely antibiotic treatments, and developing effective vaccines targeting the F1 antigen. Socioeconomic factors and urbanization trends are also evaluated for their role in influencing exposure and access to healthcare. Lastly, the persistence of plague in wildlife and the impact of climate change on vector behavior are considered in creating long-term, adaptable strategies for global plague management and eradication.

II. LITERATURE SURVEY

Pharmaceutical supply chain management has significantly evolved to tackle challenges such as drug shortages, counterfeit issues, and regulatory demands by leveraging technologies like artificial intelligence (AI), blockchain, the Internet of Things (IoT), and vendor-managed inventory (VMI). These innovations enhance traceability, reduce costs, and increase operational efficiency.

For instance, a study at Fudan University showed that combining AI with VMI led to a 95% reduction in inventory errors and a 42% increase in supply chain efficiency, reducing stockouts and improving patient satisfaction. The COVID-19 pandemic highlighted weaknesses in existing supply chains, prompting the creation of more resilient inventory models to better manage disruptions and perishable goods.

Technologies such as blockchain and 2D barcodes are used for track-and-trace purposes, ensuring drug authenticity and regulatory compliance while enhancing forecasting accuracy. Research in Malaysia identified pharmacies as vulnerable points in the supply chain, suggesting the use of blockchain and big data to address these risks. Blockchain applications, like SAP's Pharma Blockchain, have also been successful in improving traceability and reducing recall times.

In conclusion, while technologies like AI, blockchain, and IoT are transforming pharmaceutical supply chains, additional research is needed to overcome challenges related to scalability, collaboration, and policy to create a more resilient and patient-focused system.

III. PROPOSED SYSTEM

3.1 Problem Statement and Objectives

Proposed systems for drug inventory and supply chain tracking face several significant challenges that limit their effectiveness, scalability, and adoption. A major issue is the continued use of manual or fragmented digital tracking methods, which often result in human errors such as stock imbalances and contribute to approximately 30% operational waste. Additionally, the absence of comprehensive traceability allows counterfeit drugs to infiltrate the supply chain, jeopardizing patient safety and causing global financial losses estimated at \$200 billion annually. Many existing systems also fall short in meeting regulatory requirements like the Drug Supply Chain Security Act (DSCSA) and the EU Falsified Medicines Directive (FMD), exposing stakeholders to legal and operational risks. Temperature-sensitive medications, such as vaccines and biologics, are particularly vulnerable due to inadequate IoT-based cold chain monitoring, which leads to spoilage and an estimated \$35 billion in yearly losses. Moreover, the lack of real-time data sharing between systems like electronic health records (EHR), enterprise resource planning (ERP), and pharmacy platforms hampers timely decision-making, especially during critical situations like drug shortages or pandemics. Finally, the high costs associated with implementing advanced technologies—such as blockchain or AI—prevent smaller and rural healthcare facilities from adopting these solutions, further exacerbating disparities in healthcare delivery.

Lastly, the financial barrier to adopting advanced technologies like blockchain, artificial intelligence, and sophisticated IoT infrastructures cannot be overlooked. These innovations require significant upfront investment, technical expertise, and ongoing maintenance. For smaller healthcare providers, especially those in rural or underfunded regions, the cost is prohibitive. This digital divide not only limits the reach of these systems but also exacerbates disparities in healthcare delivery, where urban institutions benefit from technological advancements while smaller facilities continue to struggle with outdated methods.

3.2 Scope of the Work

The scope of this research involves the conceptualization, development, and testing of a technology-enhanced drug supply chain framework aimed at improving efficiency, transparency, and compliance. Central to this effort is the integration of advanced technologies, including blockchain for secure and decentralized data management, IoT devices for real-time monitoring of environmental conditions, and AI/ML algorithms for forecasting and managing inventory needs. A collaborative approach will be taken, involving key stakeholders such as drug manufacturers, logistics companies, and healthcare providers to identify challenges and create intuitive, user-oriented processes. The system will be designed to align with international regulatory frameworks, incorporating features like automated serial number generation and blockchain-based audit trails to meet standards such as the DSCSA and the EU Falsified Medicines Directive.

IV. SYSTEM FRAMEWORK AND ARCHITECTURE

The drug inventory and supply chain tracking system is structured to deliver complete transparency, adherence to regulatory requirements, and improved efficiency across the pharmaceutical distribution process. It incorporates real-time tracking of drug inventory, including stock quantities, expiration timelines, batch information, and storage conditions such as temperature and humidity. The system issues automated notifications for situations like low inventory levels, approaching expiration dates, or product recalls, facilitating timely and informed responses. Technologies such as RFID, QR codes, and barcodes are employed to track pharmaceuticals throughout the supply chain, ensuring visibility from production to delivery. Blockchain technology is utilized to create an unalterable and secure transaction history, supporting regulatory compliance with standards like DSCSA and GDPR. Additionally, analytics tools help forecast demand, reduce wastage, and generate compliance reports.

The architecture of the system is multi-layered. The front-end consists of user-friendly web and mobile applications accessible by pharmacists, suppliers, and regulatory authorities.

4.1 User Interaction and Data Submission

Data is collected through various channels, combining manual inputs with automated data capture from scanners and IoT devices.

Integration with external platforms like regulatory databases and ERP systems ensures accurate and compliant operations. Blockchain technology is used to log every transaction, creating a tamper-proof, transparent record of the drug's journey. The system ensures data integrity through real-time validation, controlled user access based on roles, and detailed audit logs. Designed for ease of use, the interface emphasizes critical information and provides instant alerts. Mobile access ensures functionality in remote or low-connectivity areas. Overall, this system reduces errors, streamlines operations, enhances safety, and reinforces the integrity of the pharmaceutical supply chain.

4.2 Data Processing and Secure Storage

The Drug Inventory and Supply Chain Tracking System is a secure and efficient platform designed to manage pharmaceutical data while meeting regulatory standards. It gathers and processes information from multiple sources in real time and through scheduled tasks, ensuring timely responses and detailed analysis. The system validates all data, logs supply chain events via blockchain for transparency, and automates workflows using smart contracts.

Data is stored securely using encrypted databases, cloud storage, and immutable blockchain records. Compliance with privacy laws is ensured through anonymization and role-based access controls. Robust security measures—including encryption, multi-factor authentication, and backups—protect data and maintain system reliability. Overall, the system improves traceability, reduces risks of counterfeits, and strengthens pharmaceutical supply chain operations.

V. RESULTS

Loading Test Images: The screenshots show a React and TypeScript-based application built for managing pharmaceutical inventory. It uses modular folder structures like `auth`, `vendor`, and `distributor` to organize code by user roles. The login page handles form states with React hooks and simulates authentication using demo credentials. Routing is managed with `react-router-dom` for navigation and query parameters.

The registration form is clean and user-friendly, collecting information like name, email, password, license number, and user type. It includes icons for better UX and a checkbox to accept terms and policies. Overall, the project is well-structured with clear separation of features, supporting role-based access and inventory tracking.

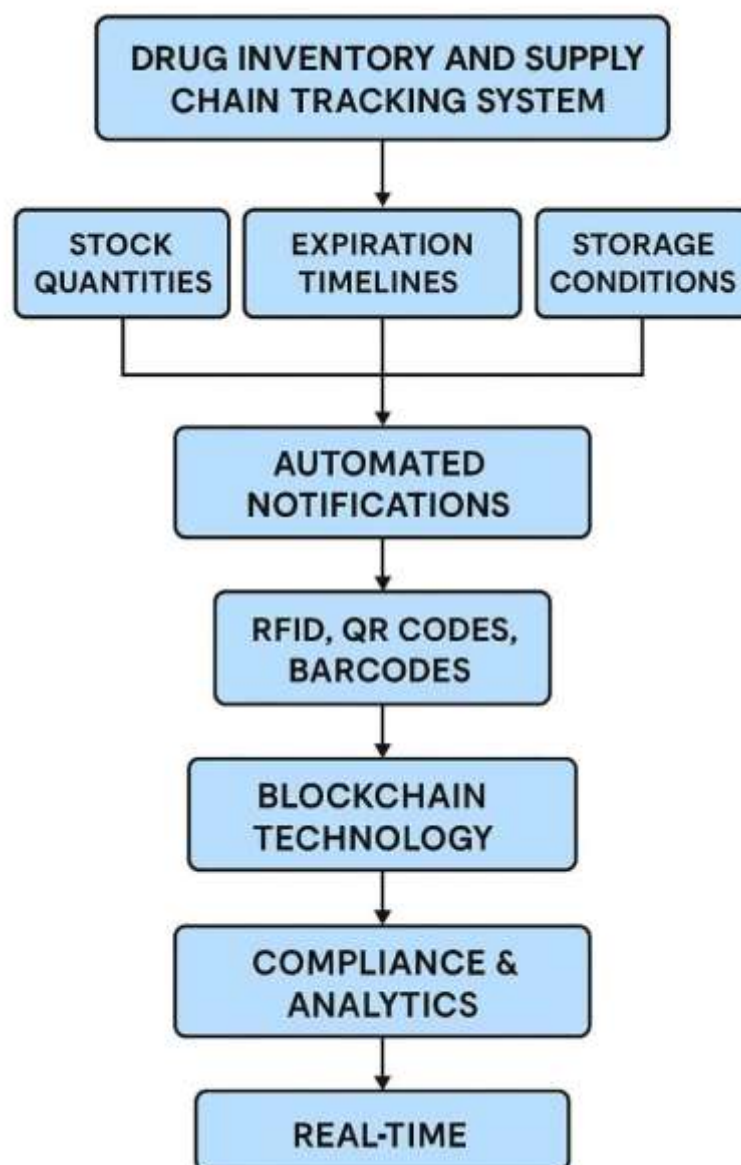


Figure 5.1

Order Tracking : Section of the MedTrack Vendor Portal. It allows vendors to monitor order statuses, with options to filter by status, date, or search by order ID or customer name. The interface displays order details such as order ID, date, product names, quantities, and pricing. In this example, an order containing Aspirin and Lisinopril is marked as “Delivered,” with a total cost of \$74.93. The sidebar includes navigation options like Dashboard, Inventory, Billing, Store, Reports, and AI Features, indicating a comprehensive system for managing pharmaceutical operations.

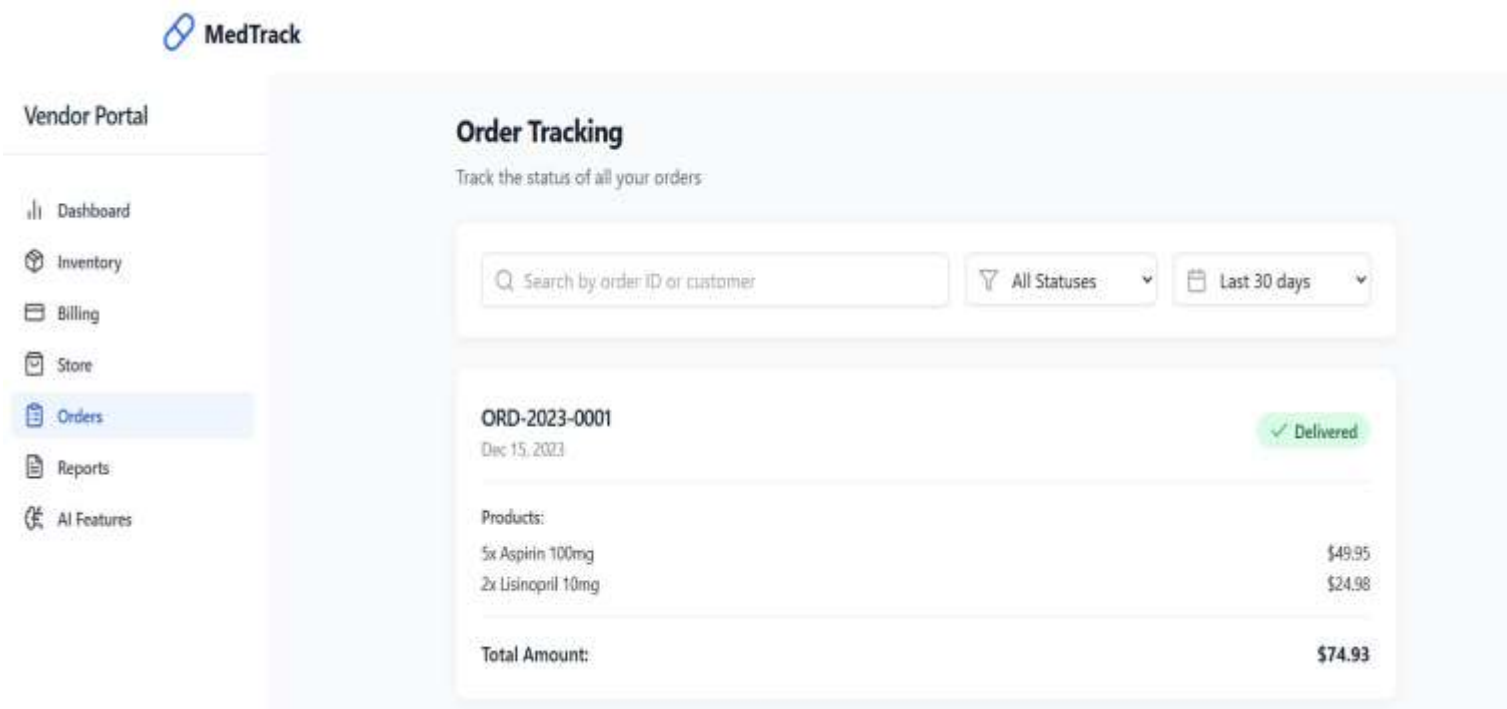


Figure 5.2

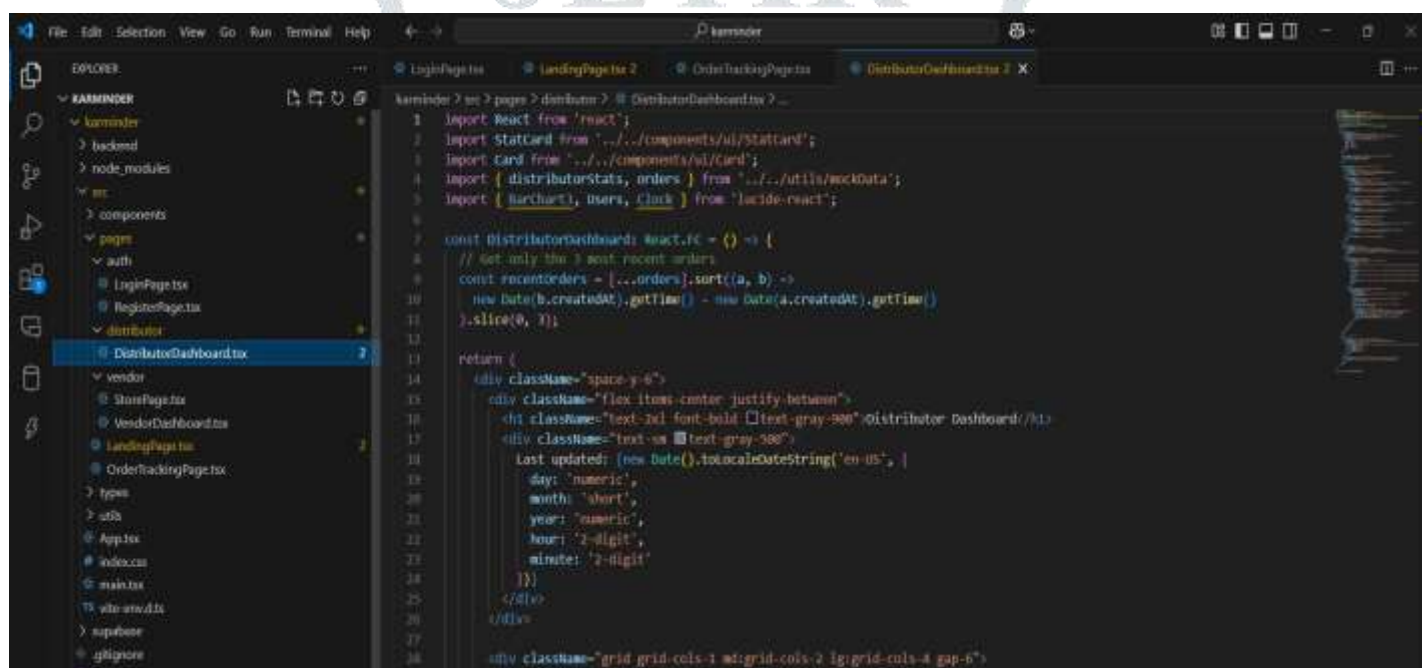


Figure 5.3

The DistributorDashboard.tsx file is a React component written in TypeScript and is part of the "Drug" project. It resides within the pages/distributor directory and is responsible for displaying a visual interface tailored for distributors. This component imports various UI elements such as StatCard and Card to present data in a clean, organized manner. It also uses icon components like BarChart3, Users, and Clock from the lucide-react library to enhance the visual presentation. One of the key functionalities of this dashboard is to retrieve order data and sort it based on the creation time, allowing only the three most recent orders to be displayed. This ensures that the distributor is always presented with the latest and most relevant information. The component features a heading labeled "Distributor Dashboard" and shows the last updated date and time using the toLocaleDateString() function, which formats the timestamp according to the user's locale settings. The layout is constructed using Tailwind CSS utility classes, ensuring a responsive and user-friendly design that adapts well across different devices. Overall, the dashboard offers a functional and aesthetically pleasing interface for distributors to quickly access important updates and insights.

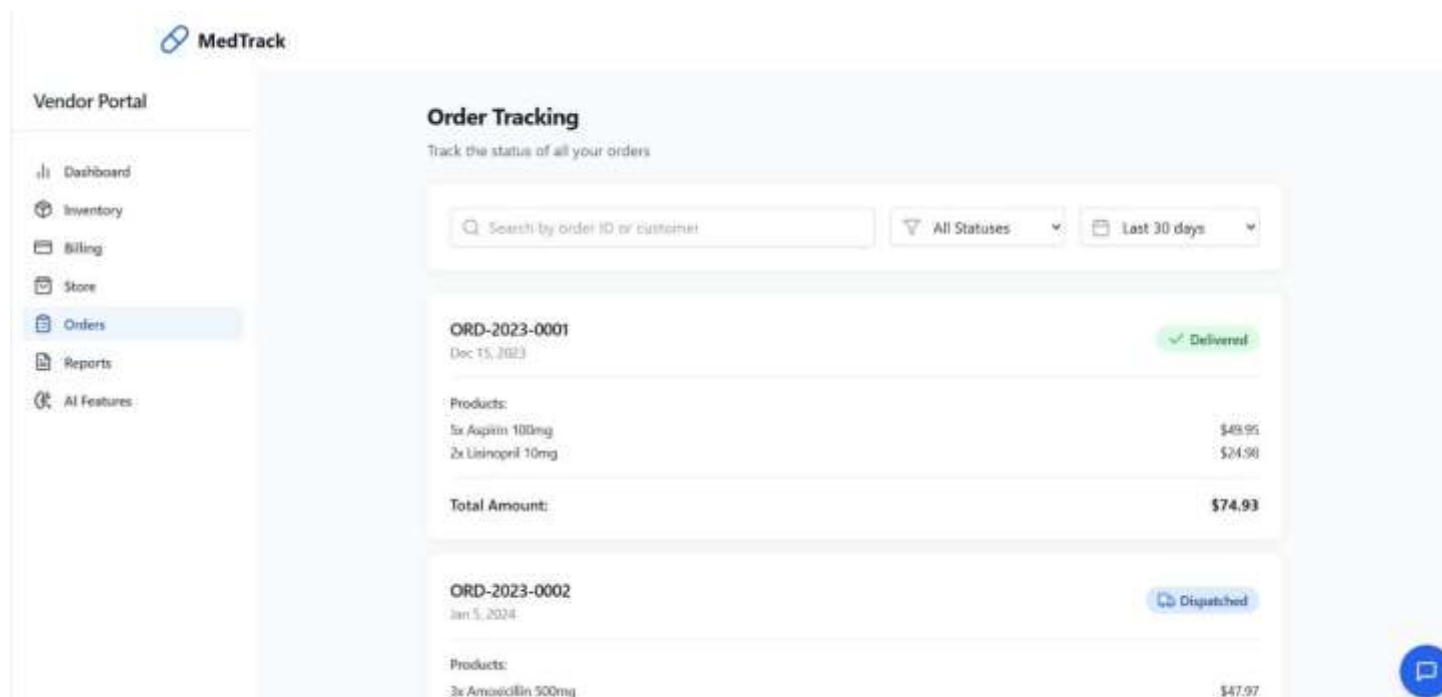


Figure 5.4

The figure illustrates the login and dashboard interfaces for both retailers and pharmacists. After successfully logging in, the retailer is directed to their dashboard, where they can manage drug-related data. Upon receiving drugs from a manufacturer or wholesaler, the retailer has the ability to verify the authenticity of the drugs and update specific attributes. These include the drug ID, the name of the current holder, the certificate number associated with the holder, and the geographic coordinates (latitude and longitude) of the drug's location. Similarly, the pharmacist logs into the network upon receiving the required drugs and can also update relevant drug details through their respective dashboard interface. This system ensures traceability and transparency across the drug distribution chain.

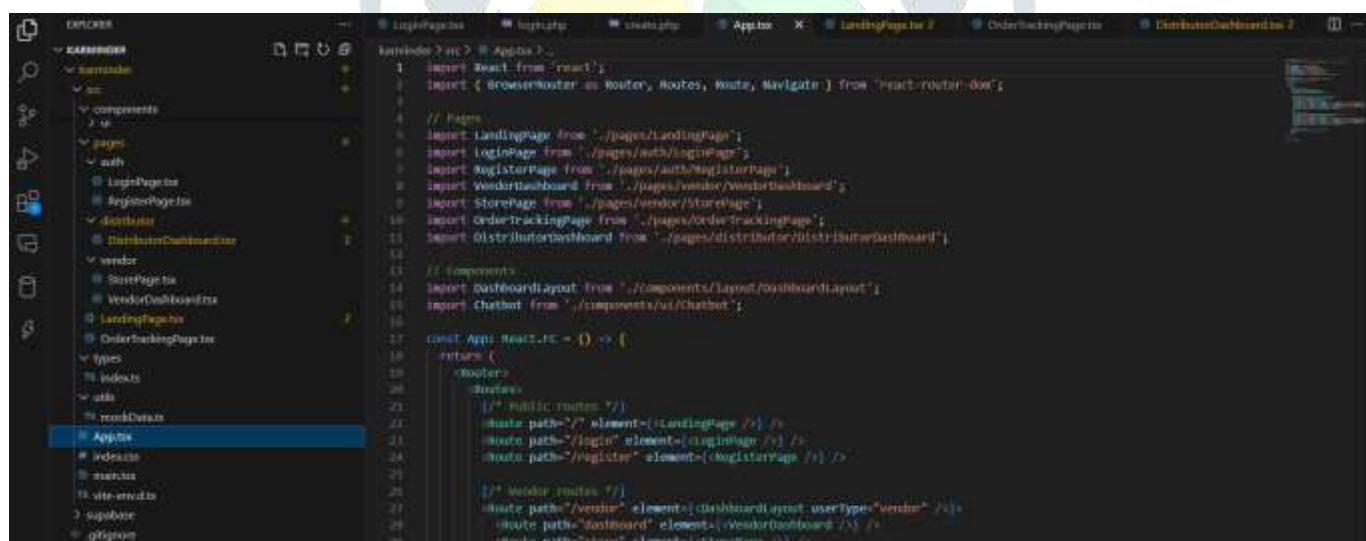


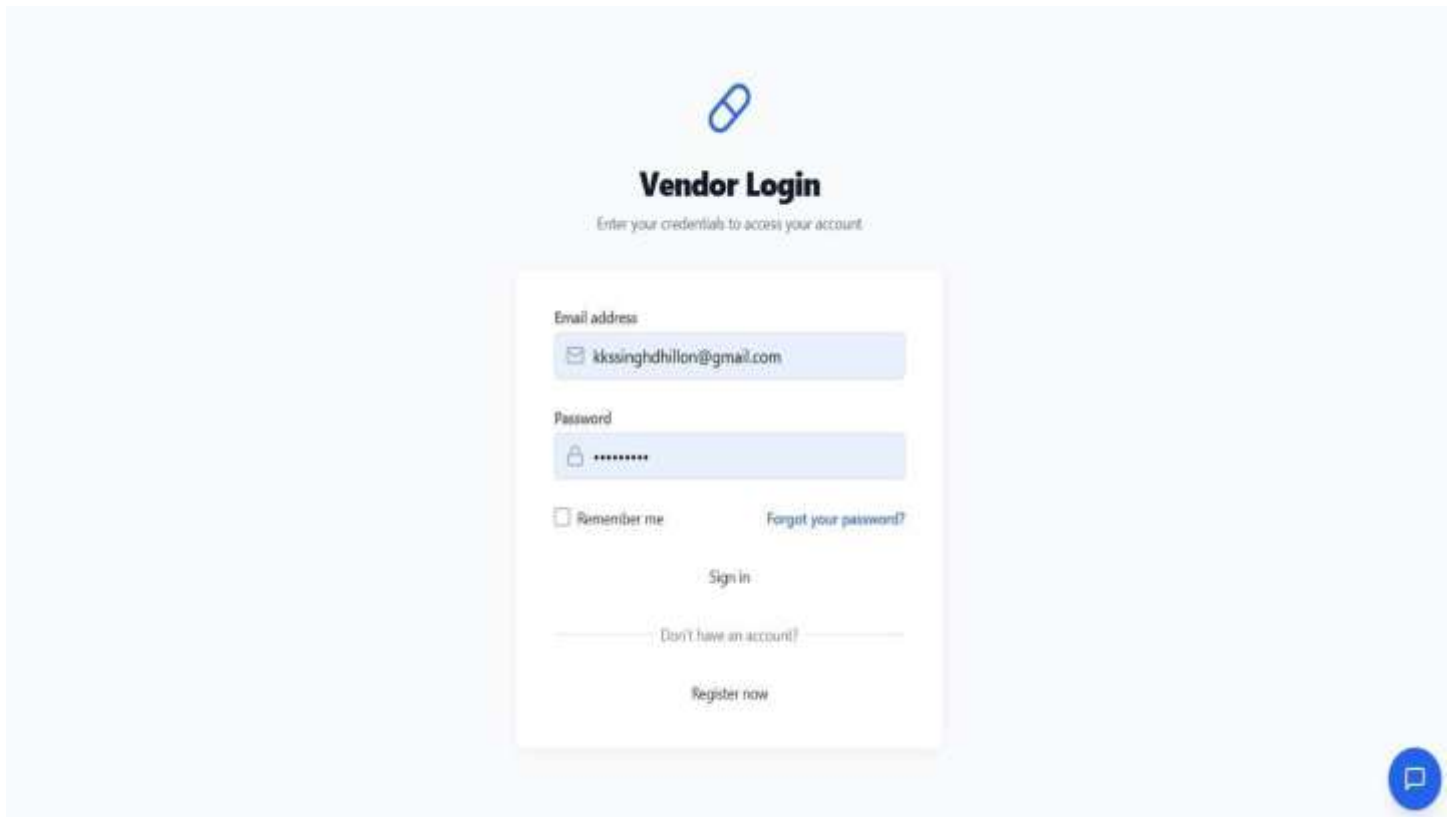
Figure 5.5

The image presents the "Order Tracking" interface of the MedTrack Vendor Portal, designed to help vendors efficiently monitor and manage their order activities. The interface includes a search bar that allows users to look up orders using order IDs or customer names, along with filter options to narrow down results by order status and date range. Below the search panel, the page lists individual orders with detailed information such as the order number, date of order, list of purchased products, their respective quantities and dosages, and itemized prices. Additionally, the total amount for each order is clearly shown. Each order is accompanied by a status indicator, such as "Delivered" or "Dispatched," helping vendors stay updated on the fulfillment progress. The sidebar navigation also includes options like Dashboard, Inventory, Billing, Store, Reports, and AI Features, indicating that the portal offers comprehensive tools for inventory and order management. This structured layout ensures a smooth and organized workflow for vendors dealing with pharmaceutical product distribution.

The image showcases the “Vendor Dashboard” section of the MedTrack portal, which provides a comprehensive overview of the vendor's pharmaceutical inventory, sales performance, and recent order activities. The top portion displays key metrics such as the total inventory, which currently stands at 975 units with a positive growth of 12.5% from the previous month, and total sales amounting to \$5,248.32, reflecting an 8.2% increase. The dashboard also highlights critical inventory insights, including the number of low-stock items (3 products) and products nearing expiration (12 products), helping vendors manage supply chain efficiency and avoid potential shortages or waste.

To the right, the dashboard indicates the last update timestamp, ensuring users know they are viewing the most current data. The "Recent Activity" panel offers a quick glance at notable events such as inventory updates, new orders received, and alerts for expiring products, with timestamps to track operational timelines. Adjacent to it, the “Recent Orders” section lists recent transactions with details like order ID, customer name, order amount, and current status — categorized as Ordered, Dispatched, or Delivered — offering a transparent order fulfillment overview. The layout, complemented by an intuitive side navigation menu, facilitates access to other critical modules such as Inventory, Billing, Store, Orders, Reports, and AI-powered features, making the platform both functional and user-friendly for vendors managing medical products.





The image displays the Vendor Login interface for the MedTrack system, designed to provide vendors with secure access to their individual dashboards and inventory management tools. The interface features a clean, minimalistic layout that prioritizes user experience and simplicity. Positioned prominently at the center of the screen is the login form, where users are prompted to enter their email address and password to authenticate their identity. The design includes visual cues such as a mail icon for the email field and a lock icon for the password input, enhancing clarity and usability. To improve convenience and accessibility, the interface offers a “Remember me” option, allowing users to stay logged in on their device for quicker access in future sessions. Additionally, a “Forgot your password?” link is available for users who need to recover access to their account, redirecting them to a password reset workflow. For new vendors who have not yet registered, the form includes a clearly labeled “Register now” link, encouraging easy onboarding and account creation. The visual hierarchy, subtle color palette, and intuitive input fields contribute to a seamless user experience. This login interface plays a crucial role in maintaining system security, ensuring that only authorized personnel can access sensitive data related to inventory, sales, billing, and order tracking within the MedTrack ecosystem. By combining functionality with user-centered design principles, the MedTrack login page ensures both efficiency and security for all vendor users.

final Output: The platform showcased through the images is a robust, modern healthcare supply chain management system named MedTrack, designed to streamline and secure the distribution process for medical products. The Vendor Login interface demonstrates a clean and secure authentication system, allowing verified suppliers to access their accounts with encrypted credentials. Once logged in, users are introduced to an intuitive dashboard featuring cutting-edge functionalities such as Secure Tracking, AI Analytics, and Smart Logistics. Secure Tracking offers real-time visibility and encrypted monitoring across the supply chain, ensuring transparency and security. The AI Analytics component enhances operational efficiency by delivering predictive insights and inventory optimization, reducing waste and improving demand forecasting. Smart Logistics automates delivery routing and real-time tracking, significantly enhancing delivery accuracy and speed. From the development side, the OrderTrackingPage.tsx code snippet reveals a well-structured React component that implements dynamic filtering using search terms and order status. This user-centric functionality enables users to quickly locate orders based on order number or customer name, making order management efficient and user-friendly. The use of hooks like useState and modular design indicates a scalable and maintainable codebase, built using modern JavaScript (TypeScript) standards. Overall, MedTrack reflects a comprehensive approach to addressing the challenges in healthcare logistics through technology, emphasizing security, intelligence, and usability in its ecosystem.


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Advanced tools for modern healthcare supply chain management



Secure Tracking

End-to-end encryption and real-time monitoring of your entire supply chain



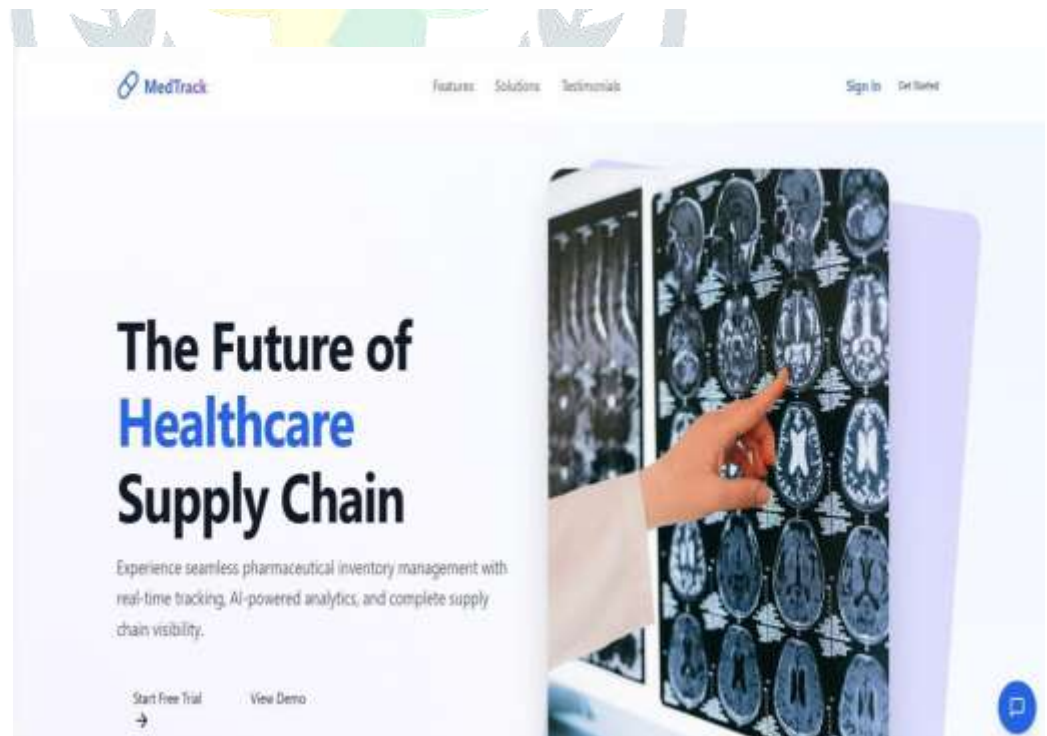
AI Analytics

Predictive insights and intelligent inventory optimization



Smart Logistics

Automated routing and real-time delivery tracking



METHODOLOGY

The methodology adopted for developing the MedTrack system involves a modular and user-centric approach, integrating both frontend and backend technologies to ensure seamless functionality and performance. The frontend is built using React with TypeScript, enabling the creation of dynamic and responsive user interfaces. Key components such as order tracking are designed with filtering logic to enhance user experience, allowing real-time search and status-based filtering. On the backend, secure data handling and API integration ensure encrypted communication and efficient data retrieval. The system is structured to support features like real-time monitoring, AI-driven analytics for inventory optimization, and automated logistics, all aimed at streamlining the healthcare supply chain. This approach not only enhances operational transparency and decision-making but also improves the reliability and security of medical product distribution.

VII. CONCLUSION

In conclusion, the MedTrack system serves as a comprehensive solution for modernizing the healthcare supply chain through the integration of advanced digital technologies. By combining secure login features, real-time order tracking, AI-powered analytics, and intelligent logistics management, the platform addresses critical challenges such as inventory mismanagement, delivery delays, and lack of transparency. The intuitive vendor login interface ensures ease of access while maintaining security through encrypted credentials. Features like AI analytics enable predictive insights that support proactive inventory decisions, reducing waste and improving efficiency. Smart logistics automate delivery processes and optimize routes in real time, enhancing both speed and accuracy in the distribution of medical supplies. Additionally, the use of React and TypeScript in the frontend enables a smooth user experience with scalable design patterns, while the backend ensures robust data handling and integration capabilities. Altogether, MedTrack not only enhances operational workflows for vendors and distributors but also contributes significantly to the overall quality and reliability of healthcare delivery systems, making it a valuable asset in the evolving landscape of health technology.

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