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A Software-Driven AI Approach to Logistics Process Automation

Priyankaben Vashi[1], Harshilsinh Devadhara[2], Srikant Singh[3]

[1] Assistant Professor, Department of Computer Engineering, PP Savani University

[2] Department of Computer Engineering, PP Savani University

[3] Assistant Professor, Department of Computer Engineering, PP Savani University

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ABSTRACT

This paper presents the design and development of an AI-enabled, software-based system for automating logistics op- erations, aiming to upgrade conventional supply chain processes. The solution includes two dedicated mobile applications—one for customers and the other for delivery personnel—along with a comprehensive, web-based admin dashboard. All components are integrated to function cohesively, ensuring efficient management and real-time synchronization across the logistics chain.

The system provides complete lifecycle support for shipments, from initial booking to final delivery confirmation. Key features include user-friendly shipment request forms, automatic identi- fication of pickup and drop-off points via the Google Maps API, and optimized routing through Dijkstra's algorithm to reduce travel time. Real-time location tracking, powered by continuous GPS updates, enables both clients and administrators to monitor deliveries with accuracy and transparency.

For administrative users, the platform offers a powerful control panel to manage shipment approvals, assign delivery fees, allocate drivers, and oversee real-time progress. To minimize manual intervention, an AI-driven chatbot is integrated to re- spond to common customer queries, including delivery tracking, estimated arrival times, and issue reporting.

A built-in analytics module further enhances decision-making by visualizing key metrics such as delivery volume by location, commonly used routes, cost breakdowns, and preliminary rev- enue estimates. By merging automation, live data processing, and AI-driven insights, the platform delivers a scalable, efficient solution for optimizing logistics operations and modernizing traditional supply chain systems.

Index Terms: Logistics automation, Firebase, Google Maps API, React Native, AI chatbot, route optimization, data analytics, Dijkstra algorithm

INTRODUCTION

The logistics industry is undergoing a major transformation as companies embrace smarter, quicker, and more intercon- nected technologies to meet increasing customer demands. Traditional logistics systems are proving inadequate in today's landscape, where users expect faster deliveries, full visibility, and seamless service experiences. In response to these chang- ing expectations, businesses are increasingly adopting digital tools, live data sharing, and intelligent automation to enhance decision-making and service delivery.

This study introduces a comprehensive logistics automation system aimed at connecting clients, delivery agents, admin- istrators, and warehouse operations into a single cohesive network. Leveraging cloud-powered mobile applications, real- time location tracking, and AI-driven functionalities, the pro-posed solution streamlines communication and coordination across all supply chain participants.

In contrast to outdated methods that focus only on basic booking and tracking, this system incorporates smart decision- making features, real-time performance monitoring, and an AI- enabled chat interface to manage

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customer engagement. By embracing this digital upgrade, logistics operations become more flexible, transparent, and scalable—resulting in better service delivery and more efficient use of resources.

System Architecture

The logistics automation platform consists of two main parts: a unified mobile app designed for both customers and delivery personnel, and a web-based dashboard tailored for administrative use. These components are linked through a shared cloud infrastructure, ensuring synchronized data access and smooth interaction among all users in real time.

Client/Driver Mobile Application: A single cross- platform mobile app has been developed with a dynamic, role-based interface that automatically adjusts its features based on whether the user logs in as a client or a delivery driver.

Client Mode: Users can schedule shipments by se- lecting pickup and delivery points via an interactive map. They can monitor real-time delivery updates, review their shipment history, and interact with an integrated AI assistant to get instant answers to common questions.

Driver Mode: Authorized delivery personnel are provided with a dashboard to access their assigned delivery tasks, update shipment progress at various stages, and share their live location for real-time tracking. The system provides drivers with route suggestions optimized using the Google Maps API, further enhanced by Dijkstra's algorithm to ensure efficient navigation.

Admin Web Portal: The web-based dashboard offers compre- hensive administrative controls, including shipment request management, manual cost approval, driver assignment, and delivery status tracking. It also provides access to system- wide analytics through visual dashboards, enabling insights into route performance, delivery frequency, and cost trends.

Additional tools include access control, security logs, and performance audits to maintain system reliability and integrity. All components are fully synchronized through Firebase Realtime Database, ensuring that any update—whether from a mobile client, a driver, or an administrator—is immediately reflected across all platforms. This architecture ensures real- time visibility, consistency in data handling, and smooth end- to-end coordination among all stakeholders in the logistics workflow.

Client/Driver App $\Longleftrightarrow$ **Firebase Realtime DB**

Clients can view the driver's current location within their app, along with the remaining travel distance and a real- time estimated time of arrival (ETA). The driver's position is updated dynamically on the map, creating a smooth, animated tracking interface. This enhances user confidence by providing full delivery transparency without the need for manual com- munication.

At the same time, the administrative dashboard mirrors this tracking data, allowing backend users to monitor multiple active deliveries as they happen. This real-time visibility

Role-based UI Booking, Tracking

Live Location Chatbot Support

Cloud Sync Real-time Update

Data Storage Auth Management

helps administrators better manage field logistics and respond quickly to any unexpected delays or route deviations.

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Route Optimization

To promote timely deliveries and optimize fuel consump-

Admin Web Portal ⟺ **Firebase Realtime DB** tion, the system incorporates an advanced route planning

Cost Approval Driver Assignment Delivery Monitoring Analytics Dashboard

Read/Write Ops Access Control Firestore Rules

Live Syncing

feature. When a delivery task is assigned, the driver receives a suggested route generated through the Google Maps Directions API. This route is further refined by backend logic that applies a Dijkstra-based pathfinding algorithm, which calculates the

Core Features

Shipment Booking and Cost Approval

The logistics process begins when clients submit shipment requests through the mobile application. This form allows users to select pickup and delivery points using an interactive map interface, choose a preferred delivery date, and provide optional notes or specific instructions. To improve precision and ease of use, the system employs map-based address detection during the input process.

After a request is submitted, it is stored in the Firebase Realtime Database and instantly appears on the administrator's web dashboard. Admins then assess each request by consid- ering factors such as distance, package weight (if applicable), and route difficulty. Based on these criteria, a delivery charge is calculated and linked to the request. This approach allows administrators to manually fine-tune pricing while maintaining fairness and consistency for the end user.

Once the request is approved, the booking is finalized, and all shipment details are added to the client's booking history. Users can access both current and past deliveries along with their statuses and pricing. This streamlined workflow accelerates the shipment initiation process and ensures com- plete transparency in pricing and delivery handling, giving clients easy access to their shipment records and increasing accountability.

Live Driver Tracking

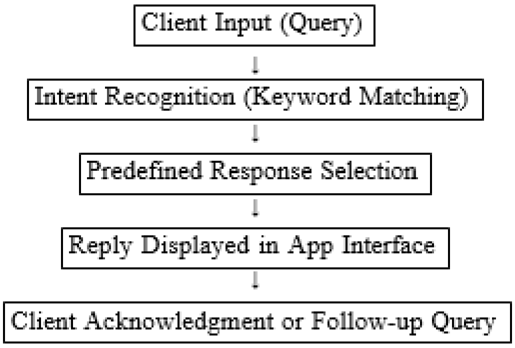
A key feature of the platform is its ability to track delivery drivers in real time, offering continuous updates to both clients and administrators throughout the delivery cycle. The mobile application collects the driver's live GPS coordinates and periodically syncs them with the Firebase database. These coordinates are then displayed on an interactive map powered by the Google Maps API.

shortest or most efficient path by considering road distances and current traffic conditions.

This dual-layer strategy ensures that navigation is both precise and adaptive. In cases where traffic congestion or unexpected road closures are detected, the system is capable of recommending alternate paths in real-time, helping drivers maintain punctuality. The algorithm also supports multi-stop deliveries, intelligently reordering the drop-off points to min- imize overall travel time.

By decreasing the total driving distance and reducing delays caused by heavy traffic, this optimization engine directly improves fuel efficiency and ensures more consistent on- time deliveries. Additionally, it contributes to eco-friendly operations by lowering carbon emissions through smarter, more efficient routing.

Chatbot Workflow Diagram:



Note: In future versions, this static flow can be replaced with dynamic NLP models capable of understanding intent and generating human-like responses using transformer-based language models.

The above diagram outlines the current working mechanism of the AI chatbot. The system processes the user's message by matching keywords or predefined phrases. Based on the identified intent, a corresponding response is selected from a static response library and presented to the user through the app interface. The interaction continues in a loop until the query is resolved or escalated.

Data Analytics Dashboard

The administrative interface includes a data analytics mod- ule that visualizes key operational metrics such as:

- Delivery volume segmented by geographic regions
- Most commonly traveled delivery routes
- Trends in average delivery expenses
- Preliminary revenue projections based on past perfor- mance

These visual insights assist administrators in making informed decisions, improving workflow efficiency, and guiding long- term strategic planning through enhanced business intelli- gence.

Technology Stack

- **Frontend:** React Native (client + driver apps), React.js (admin portal)
- **Backend:** Firebase Realtime Database, Google Maps API
- **AI/ML:** Chatbot with NLP logic (proposed), Data ana- lytics using JS charting libraries

Use Case Scenario

To demonstrate the practical application and coordination capabilities of the proposed logistics system, consider a sce- nario in which a customer requests a parcel delivery from Surat to Ahmedabad. The process begins when the user opens the mobile app and selects the pickup and drop-off points using an intuitive, map-enabled interface. These locations are precisely captured using geolocation services and stored in the Firebase Realtime Database.

Once the booking is made, the shipment request is immedi- ately visible to administrators on their web-based dashboard. The admin then reviews the delivery details, estimates the delivery fee based on factors such as distance, estimated travel time, and current traffic conditions, and proceeds to approve the request. Following approval, a notification is automatically sent to an available driver who is logged into the mobile application in

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driver mode.

The driver receives the assignment along with navigation instructions optimized through the Google Maps Directions API and further refined using a Dijkstra-based algorithm on the backend. This routing logic helps avoid traffic congestion, roadblocks, and delays, ensuring faster and more reliable deliveries.

As the delivery proceeds, the driver's live location is contin- uously updated and displayed within the mobile application. Clients can track the vehicle's movement in real time, view the estimated time of arrival (ETA), and receive live updates at key checkpoints. This level of visibility greatly improves the customer experience by offering complete transparency throughout the process.

Simultaneously, the admin panel provides real-time mon- itoring of the delivery. The dashboard displays the driver's position, current delivery status, and route information. If unexpected delays or route deviations occur, administrators have the ability to intervene, communicate with the driver, or reassign the task if needed.

This scenario highlights the seamless interaction among the client, driver, and administrator, showcasing how the system streamlines task management, communication, and navigation. It reflects the practical impact of integrating automation and artificial intelligence into logistics operations, resulting in smarter, faster, and more transparent delivery workflows.

Security and Data Privacy

To maintain a secure environment, the system utilizes Firebase Authentication combined with role-based access con- trol (RBAC) and PIN-locked access to map interfaces. All communication between the client and server is encrypted via HTTPS, protecting data from potential eavesdropping or tampering. Firestore security rules are carefully configured to restrict access to sensitive logistics information, allowing only verified users with appropriate permissions to perform authorized actions.

In addition, the system keeps detailed access logs and audit trails to track user interactions across the platform. These records support system integrity monitoring and provide crit- ical insights for investigating security breaches or suspicious activity.

Limitations

While the proposed logistics automation system delivers notable improvements in areas such as real-time tracking, streamlined booking, and administrative control, there are several limitations that present opportunities for enhancement in future versions.

One key constraint lies in the manual process of delivery cost estimation. Currently, administrators assess pricing based on their judgment of factors like distance and route com- plexity. Although this approach allows flexibility, it restricts scalability and introduces the risk of inconsistency or human error. The lack of a dynamic pricing engine—driven by data such as historical delivery metrics, package weight, and distance—prevents the system from offering automated, real- time cost suggestions.

Another limitation is the use of a static, keyword-based AI chatbot in the client application. While it is effective for responding to predefined user queries, it lacks the capability to understand user intent or handle natural, free-form conversa- tion. This reduces the system's ability to offer personalized support and limits the user experience to fixed command inputs.

In addition, features related to delivery scheduling and warehouse management are still in their foundational stages. Deliveries are currently assigned without leveraging pre- dictive models or automated dispatch algorithms. Similarly, deeper warehouse functions—such as inventory validation, environmental condition monitoring (e.g., temperature), and in-warehouse package tracking—are not yet integrated into the system.

Lastly, the platform's dependence on third-party services, particularly the Google Maps Platform, creates an external vulnerability. Any disruptions, API quota limits, or pricing model changes from these services could

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directly impact the system's route optimization, live tracking, and overall performance.

Addressing these challenges will be crucial in enhancing the system's intelligence, autonomy, and reliability as it scales to handle more complex logistics operations.

Future Scope

To further enhance the efficiency, scalability, and intelli- gence of the logistics automation platform, several advanced features and technologies can be integrated into future versions of the system:

- **Machine Learning-Based Cost Estimation:** The current manual cost estimation process can be replaced with ma- chine learning models trained on historical shipment data. These models would consider factors such as delivery distance, package weight, time of day, traffic patterns, and past pricing behavior to automatically generate ac- curate and consistent delivery cost estimates. This would significantly reduce admin workload and improve pricing transparency.

- **Real-Time Traffic-Aware Routing:** While the present system relies on Google Maps for route suggestions, future enhancements could incorporate third-party APIs such as TomTom or Mapbox, which offer more granular traffic data. These APIs can dynamically reroute drivers in real-time to avoid congestion, construction zones, or accidents, thereby reducing delivery times and fuel usage.

- **IoT-Enabled Warehouse Monitoring:** By integrating In- ternet of Things (IoT) sensors within warehouse facilities, the system could monitor key parameters such as inven- tory levels, humidity, and temperature in real time. These sensors would provide automated alerts for conditions like low stock, overheating, or expired goods, enabling proactive warehouse management and improving safety in cold-chain logistics.

- **Voice Assistant Integration:** Adding a voice assistant module would allow users—especially clients—to in- teract with the application hands-free. This could in- clude voice-activated shipment booking, delivery track- ing, rescheduling, or receiving real-time ETA updates. Such functionality would enhance usability and acces- sibility, especially for users with limited screen access.

- **AI-Powered Anomaly Detection:** Anomaly detection models can be trained to flag unusual behavior such as unexpected route deviations, missed delivery checkpoints, or unexplained delays. These AI models would help ad- ministrators identify and respond to operational issues in real time, improving reliability and customer satisfaction.

- **Predictive Analytics for Logistics Planning:** Future versions of the system could include predictive analytics tools that analyze historical delivery trends, seasonal demand fluctuations, and route performance data. These tools would support data-driven decision-making, helping logistics managers forecast delivery volumes, optimize vehicle deployment, and plan resource allocation more effectively.

- **Blockchain-Based Shipment Validation:** Blockchain technology could be introduced to ensure tamper-proof recording of delivery logs, shipment handovers, and cus- tomer receipts. Smart contracts can be used to automate payment release upon successful delivery, improving transparency and security across stakeholders.

- **Reinforcement Learning for Driver Scheduling:** By employing reinforcement learning algorithms, the sys- tem can automatically generate optimal delivery sched- ules based on driver availability, historical performance, and vehicle capacity. This adaptive scheduling approach would improve delivery efficiency while reducing idle time and fuel consumption.

Implementing these future enhancements would signifi- cantly expand the system's capabilities, transforming it into a robust, intelligent, and highly adaptive platform tailored to the evolving needs of modern supply chain and logistics operations.

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CONCLUSION

This project demonstrates the successful creation of an integrated, AI-assisted logistics management platform aimed at automating core processes ranging from shipment scheduling to final delivery tracking. The system unifies a cross-platform mobile application—adaptable for clients and drivers through role-based access—with a feature-rich web dashboard for administrators. Its architecture leverages Google Maps API, Firebase Realtime Database, and AI-driven elements like a keyword-based chatbot to deliver a seamless, real-time user experience across all stakeholder roles.

Core functionalities such as live driver monitoring, opti- mized routing powered by Dijkstra's algorithm, and struc- tured cost approval workflows collectively provide a scalable and practical alternative to conventional delivery systems. The centralized data management enabled through Firebase ensures synchronized communication and consistent perfor- mance, making the platform adaptable to varying operational scales and environments.

Moving forward, the platform holds great potential for advancement through the integration of emerging intelligent technologies. These may include machine learning algorithms for automated pricing, reinforcement learning models for efficient driver assignment, and predictive analytics to antic- ipate delivery patterns and resource demands. Furthermore, implementing blockchain for secure shipment validation, IoT- enabled warehouse monitoring, voice-command interfaces, and real-time anomaly detection could significantly elevate the platform's performance, transparency, and responsiveness.

In summary, this work establishes a strong technological foundation for future advancements in the logistics domain. The proposed system enhances operational workflows and enables data-informed strategies, ultimately contributing to smarter logistics infrastructure and improved customer satis- faction. As the industry continues to embrace digital transfor- mation, solutions like this will play a pivotal role in shaping faster, more secure, and intelligent delivery networks.

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