

# Intelligent QR-Based Parcel Route Management with Dynamic Optimization for Scalable E-Commerce Logistics

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## Abstract

The rapid growth of e-commerce has significantly increased the volume of parcel deliveries, creating complex logistics networks and higher customer expectations for fast and transparent services. Traditional logistics systems that rely on static routing and manual parcel identification often fail to meet these demands, leading to delivery delays, higher operational costs, and increased human errors.

To address these challenges, this research proposes an **Intelligent QR-Based Parcel Route Management System with Dynamic Optimization**. The system integrates QR code-based parcel identification with adaptive route optimization techniques to enable real-time tracking, efficient delivery planning, and secure delivery verification. Each parcel is assigned a unique QR code containing essential delivery information, which is scanned at various stages of the delivery process. Dynamic optimization algorithms analyze factors such as traffic conditions, delivery priority, and geographical clustering to update routes efficiently. The proposed system aims to reduce delivery time, minimize fuel consumption, and improve overall logistics performance. Its scalable and modular design makes it suitable for large-scale e-commerce platforms and last-mile delivery services.

**Keywords:** QR Code, E-Commerce Logistics, Dynamic Route Optimization, Smart Delivery System, Parcel Tracking, Scalable Logistics.

## 1. Introduction

The e-commerce industry has experienced rapid expansion over the last decade, resulting in a substantial increase in parcel deliveries. Managing large delivery volumes efficiently has become a major challenge for logistics providers. Traditional delivery systems depend heavily on manual operations, static route planning, and limited tracking mechanisms, which often cause delivery delays, increased fuel consumption, and operational inefficiencies.

Advancements in digital technologies such as QR codes, real-time data processing, and route optimization algorithms have created new opportunities to enhance logistics operations. QR codes offer a cost-effective and reliable method for parcel identification, while dynamic route optimization supports real-time decision-making based on changing delivery conditions. This research focuses on integrating these technologies to develop a smart and scalable parcel route management system for modern e-commerce logistics.

### 1.1 Problem Statement

The rapid growth of e-commerce has resulted in inefficient delivery routes, high fuel consumption, and delayed deliveries due to the absence of intelligent routing systems. Traditional logistics methods lack real-time tracking, adaptive route planning, and secure parcel identification mechanisms. These limitations lead to operational inefficiencies, increased costs, and reduced customer satisfaction, especially in large-scale logistics environments.

### 1.2 Significance

There is a strong need for an automated and intelligent logistics solution capable of handling increasing delivery demands. A QR-based parcel management system combined with dynamic route optimization can significantly improve delivery efficiency, reduce operational costs, and enhance tracking transparency. Such a system ensures accurate parcel handling, secure delivery confirmation, and better monitoring for logistics managers, while improving customer trust and satisfaction.

### 1.3 Proposed Solution

The proposed Intelligent QR-Based Parcel Route Management System automates parcel identification, tracking, and route optimization. Each parcel is assigned a unique QR code containing delivery details. Delivery agents scan the QR code to retrieve parcel information and receive dynamically optimized routes. The system also incorporates OTP-based delivery confirmation to ensure secure and error-free parcel handover.

## 2. Literature Review

Technology-driven logistics systems have been widely studied for improving delivery efficiency and reducing operational costs. Researchers emphasize the importance of automation, real-time tracking, and optimized routing in modern supply chain management.

QR code technology has been extensively used in inventory management and parcel tracking due to its low cost and ease of implementation. Route optimization techniques such as shortest path algorithms and vehicle routing models have been applied to minimize delivery distance and time. However, most existing studies treat parcel identification and route optimization as separate processes.

### Research Gap:

There is limited research on integrated systems that combine QR-based parcel identification with dynamic route optimization in a unified framework. Existing solutions often lack scalability and real-time adaptability required for modern e-commerce logistics.

## 3. Methodology (Development Process)

### 3.1 Design of Research

This study adopts a system design and development methodology to build an intelligent logistics solution. The approach focuses on designing a modular and scalable system capable of automating parcel identification and optimizing delivery routes dynamically.

### 3.2 Information Gathering

#### Secondary Data

Relevant research papers, logistics case studies, and industry reports were reviewed to identify challenges in traditional delivery systems.

#### Technical Research

Technical analysis was conducted on QR code generation, route optimization techniques, web-based logis-

tics platforms, and secure delivery verification mechanisms.

### 3.3 Architecture of the System

The system follows a modular architecture consisting of a frontend interface, backend processing layer, and centralized database. Technologies such as Python, Flask, QR libraries, route optimization logic, and MySQL database are used to ensure scalability, flexibility, and reliable performance.

## 4. Design and Implementation

### 4.1 System Architecture

The **Intelligent QR-Based Parcel Route Management System** is designed using a modular three-tier architecture to ensure scalability, flexibility, and efficient communication among different system components. The architecture is divided into three main layers: Frontend Layer, Backend Layer, and Database Layer. This layered approach ensures separation of concerns, easy maintenance, and high system performance.

**Frontend Layer (Client Side):** The frontend layer provides an interactive web-based interface for delivery personnel and administrators. Delivery agents can log in to the system, scan parcel QR codes, view optimized routes, confirm deliveries using OTP, and reschedule deliveries if required. The frontend is developed using **HTML, CSS, and JavaScript, ensuring responsiveness across desktops, tablets, and mobile devices.**

**Backend Layer (Server Side):** The backend layer is responsible for processing requests, managing business logic, and generating optimized delivery routes. **Python and Flask framework** are used to implement server-side APIs that handle parcel scanning, OTP verification, route generation, and delivery status updates. This layer also performs dynamic routing computations and interacts with the database to fetch and store parcel data.

**Database Layer:** The database layer stores parcel details, customer information, delivery status, route information, and delivery history. **MySQL** is used as the database management system to ensure secure and structured data storage. The database supports real-time data updates and report generation for logistics management.

**System Workflow:** The delivery boy registers and logs into the web-based delivery management system using a mobile number/email and password.

After successful login, the system displays all assigned parcels provided by the logistics company (**Flipkart, Meesho, or other platforms**).

The delivery boy scans the QR code or barcode of each parcel using the built-in scanner feature in the website.

The backend system processes scanned parcel data and generates an optimized delivery route based on area-wise parcel locations.

The system displays the delivery route in a step-by-step line format, including customer name, address, and phone number for each parcel.

The delivery boy follows the suggested route and delivers parcels to customers.

At the time of delivery, the delivery boy scans the parcel again to confirm delivery.

The system generates a One-Time Password (OTP) and sends it to the customer's registered mobile number.

The customer provides the OTP to the delivery boy, and the delivery is confirmed in the system.

If the customer is unavailable or does not answer the call, the delivery boy can mark the parcel as Rescheduled.

After completing deliveries, the delivery boy logs out, and the system displays a summary report showing: Total parcels assigned, Successfully delivered parcels, Pending parcels, Rescheduled parcels, The backend stores all delivery data in real-time for monitoring and analytics purposes.

## 4.2 Technologies Used:

Component	Technology Used
Frontend	HTML, CSS, JavaScript
Backend	Python, Flask
Database	MySQL
QR Code Generation	QR Libraries
Route Optimization	Algorithm-based logic
Authentication	OTP Verification
API Communication	REST API

## 4.3 User Interface (UI) & Screenshots:

The system provides a clean, professional, and user-friendly interface designed to support delivery agents and administrators efficiently. The UI is developed with a white theme and card-based layout to ensure clarity and ease of use.

The interface is responsive and accessible on laptops, tablets, and smartphones, enabling delivery agents to operate the system in real-time field conditions.

### 4.3.1 User Interface Overview:

The AI-based logistics platform includes the following major user interface screens:

- 1. Registration Page:** This page allows delivery agents to create an account by entering their phone number, password, and personal details. The registration ensures secure access to the system.
- 2. Login Page:** A secure login interface for delivery agents and administrators. Users enter their phone number and password to access the system dashboard.
- 3. Home Page:** The home page displays the system overview, navigation menu, and project purpose. It provides links to Login, Register, About, and Contact pages.
- 4. Parcel Scan Page:** This page allows delivery agents to scan parcel QR codes using the device camera. After scanning, customer details and parcel information are displayed.
- 5. Route Display Page:** The system automatically generates optimized routes after all parcels are scanned. The route page shows delivery order in area-wise sequence.
- 6. OTP Verification Page:** At delivery time, this page allows the delivery agent to enter the OTP received from the customer to confirm parcel delivery.
- 7. Reschedule Page:** If the customer is unavailable, the delivery agent can mark the parcel as rescheduled. The system updates the status in the database.
- 8. Delivery Dashboard:** This dashboard displays parcel statistics such as total parcels assigned, delivered parcels, pending parcels, and rescheduled parcels.

## 4.3.2 UI Screenshots:

The following figures illustrate the main user interface screens of the system:

Login Page Screenshot

Registration Page Screenshot

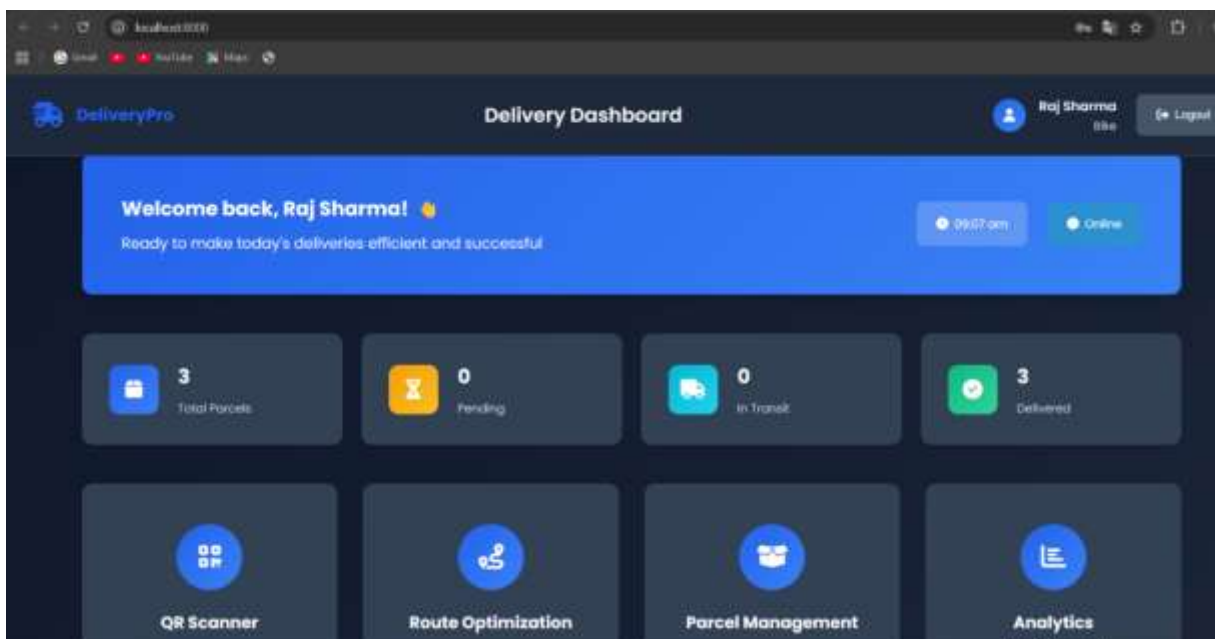
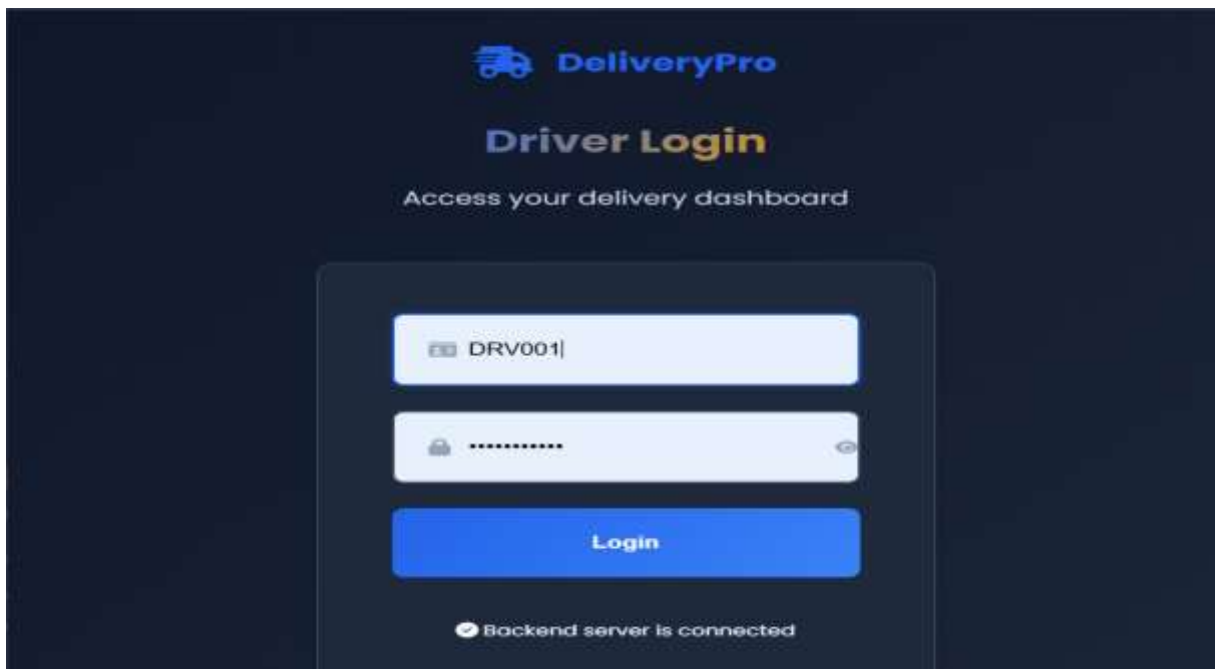
Delivery Boy Dashboard

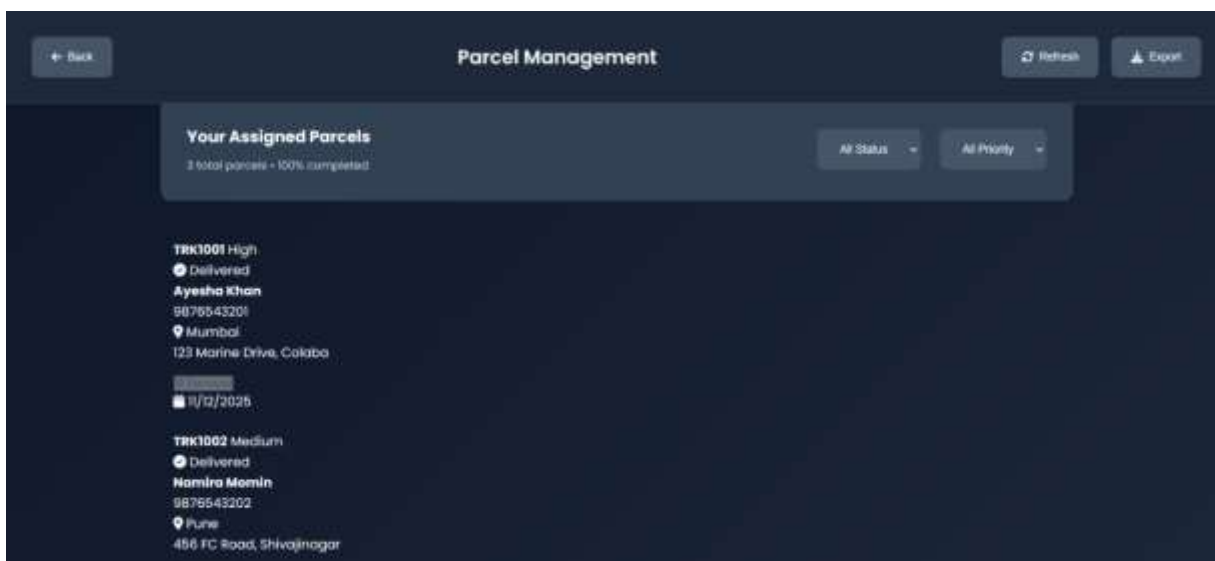
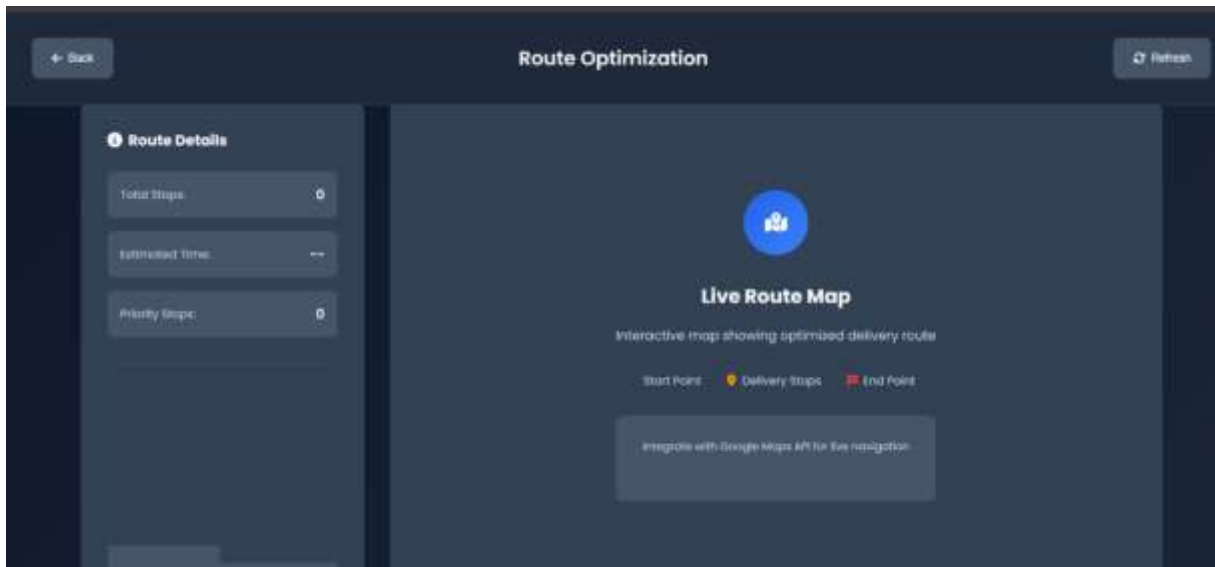
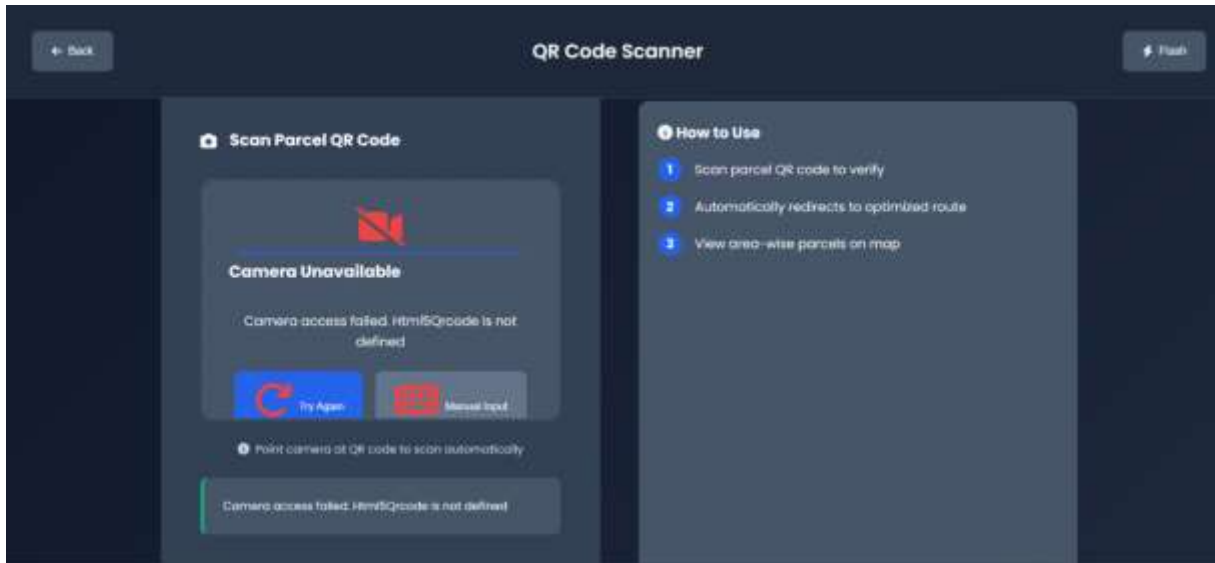
Parcel Scanning Screen

Route Optimization Result Page

OTP Verification Screen

Delivery Summary Report Page







## 6. Discussion

### 6.1 Strengths of the System

- **Efficient Route Optimization:** The system automatically generates optimized delivery routes based on scanned parcel data and area-wise clustering, reducing travel distance and fuel consumption. This significantly improves delivery efficiency and reduces operational costs.
- **Real-Time Parcel Tracking:** The platform provides real-time tracking of assigned parcels, delivered parcels, pending deliveries, and rescheduled orders, helping delivery personnel and logistics companies monitor operations effectively.
- **QR Code-Based Automation:** Using QR code scanning eliminates manual data entry, reduces human errors, and ensures accurate parcel identification. This automation speeds up parcel processing and route planning.
- **Improved Delivery Confirmation:** OTP-based delivery verification ensures secure and authenticated parcel delivery, preventing fraud and false delivery reports.
- **User-Friendly Dashboard:** The system provides a clean and intuitive dashboard for delivery boys, displaying delivery statistics, routes, and parcel details, improving usability and reducing training time.
- **Scalable for Large E-Commerce Platforms:** The proposed system is designed to support scalable logistics operations for platforms such as Flipkart, Meesho and other e-commerce companies handling large volumes of deliveries.
- **Time and Cost Efficiency:** Automated route planning and parcel management reduce delivery time, manpower effort, and transportation costs, increasing productivity and profitability.

### 6.2 Challenges and Limitations

- **Internet Dependency:** The system requires a stable internet connection for real-time route optimization, QR scanning synchronization, and OTP verification, which may be challenging in rural or low-network areas.
- **Hardware Requirements:** Delivery personnel must have smartphones with cameras and GPS functionality to scan QR codes and access routes, which may not be available to all users.

- **Data Accuracy Issues:** Incorrect parcel data, wrong addresses, or incorrect QR codes can affect route optimization accuracy and delivery tracking.
- **Security and Privacy Concerns:** Customer data such as phone numbers and addresses must be protected using encryption and secure authentication mechanisms to avoid data breaches.
- **System Training Requirement:** Delivery boys and logistics staff may require training to use the system effectively, especially for scanning and OTP confirmation features.
- **Limited Offline Functionality:** Currently, the system does not fully support offline mode for route planning and parcel updates, which is a limitation in low-connectivity environments.

### 6.3 Future Scope

- **Mobile Application Development:** Developing Android and iOS mobile applications would enhance usability and allow delivery personnel to use the system seamlessly on handheld devices.
- **AI-Based Route Prediction:** Future enhancements could include AI and machine learning algorithms to predict traffic conditions, weather impact, and delivery delays to generate smarter routes.
- **Integration with GPS and Maps APIs:** Integration with Google Maps or OpenStreetMap APIs can provide real-time navigation and traffic-based dynamic route updates.
- **Multilingual Support:** Adding multiple language support will help delivery boys from different regions use the system easily.
- **Cloud-Based Deployment:** Deploying the system on cloud platforms such as AWS, Azure, or Google Cloud would improve scalability, reliability, and real-time data synchronization.
- **Advanced Analytics Dashboard:** Future versions can include analytics dashboards for logistics companies to analyse delivery performance, parcel trends, and employee efficiency.
- **IoT Integration:** Smart IoT sensors can be integrated in parcels for temperature-sensitive goods to ensure safe delivery of medicines and food products.

## 7. Conclusion

The rapid growth of e-commerce platforms has significantly increased the demand for efficient and scalable logistics systems. Traditional parcel delivery management systems rely heavily on manual route planning, manual tracking, and paper-based documentation, which often leads to inefficiencies, delays, and human errors. To address these challenges, this project presents an Intelligent QR-Based Parcel Route Management with Dynamic Optimization System designed to automate parcel scanning, route planning, and delivery confirmation.

The proposed system utilizes QR code scanning to identify parcels, dynamically generates optimized delivery routes, and provides real-time delivery status updates. The integration of OTP-based delivery confirmation ensures secure and authenticated delivery, reducing fraud and incorrect delivery records. The user-friendly dashboard enables delivery personnel to monitor assigned parcels, completed deliveries, pending orders, and rescheduled deliveries efficiently.

Although the system has certain limitations such as internet dependency, hardware requirements, and data security concerns, it provides a strong foundation for modern smart logistics management. By automating repetitive tasks and improving route planning accuracy, the system enhances operational efficiency, reduces delivery time, and minimizes transportation costs.

Future enhancements such as AI-based predictive routing, mobile application development, GPS integration, multilingual support, and cloud deployment can further improve system performance and

scalability. Overall, this system has the potential to transform traditional logistics operations into a smart, automated, and intelligent delivery management platform suitable for large-scale e-commerce applications.

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