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Logistic caravan: A smart transportation system for green logistics and sustainable practices

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A B S T R A C T

This study introduces the logistic caravan, a delivery solution based on an advanced method called "Intelligent Penguin Optimizer tuned Logistic Regression (IPO-LR)." This system aims to improve delivery services in rural areas by offering timely, affordable, and environmentally friendly solutions. It uses advanced technologies such as predictive analytics and geospatial mapping to optimize routes, forecast demand, and plan schedules. Key features include joint ordering, real-time tracking, and scheduled deliveries, all designed to improve operational efficiency and customer satisfaction. The system also promotes green practices, such as using optimized routes, electric or hybrid vehicles, and recyclable packaging to reduce environmental impact. With strong data privacy and security measures, the system builds customer trust and supports wide adoption. By addressing current gaps in delivery services, the logistic caravan offers a complete solution that combines lower costs, better efficiency, and sustainability. It supports Saudi Arabia's Vision 2030 by enhancing logistics in underserved areas. The IPO-LR model shows strong performance, with low error rates (MAE = 0.69, RMSE = 0.81, MAPE = 0.6501), proving its accuracy in route planning and delivery time prediction. The main contributions of this system include better access for remote areas, environmentally responsible logistics, stronger customer loyalty through personalized services, and a scalable model for future delivery systems. The logistic caravan sets a new standard for reliable and sustainable delivery to challenging locations.

1. Introduction

The demand for effective and convenient delivery solutions is growing in today's fast-paced and networked world. In Saudi Arabia, with its extensive network of private compounds, university campuses, and beach resorts, traditional delivery systems tend to fail to meet the needs of restricted-access or out-of-the-way sites (Alharbi et al., 2022). While others attempt to provide solutions through conventional methods, their operations are frequently constrained by infrastructural constraints or issues of privacy. Despite continued efforts towards expanding delivery networks, businesses and customers in these remote locations still face difficulty in obtaining timely and quality service, and limited access to essential commodities forces them to rely on this inefficiency, not just to fill gaps in the market but also add trust and data privacy issues (Shuaibu et al., 2025). Against this context of challenges, the logistic caravan system is here suggested to address the needs of far-flung private spaces by providing a secure, convenient, and green service that fosters trust based on robust data protection mechanisms and easy-to-use interfaces. The logistic caravan software is an in-house-developed platform for direct delivery of products and services to customer doorsteps in these under-penetrated territories. It facilitates efficient and timely deliveries through sustainable logistics processes, which lower transportation costs and adverse environmental impacts. Cooperative actions by various stakeholders

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improve operations, improve user experience, and ultimately enhance customer satisfaction. Through its data-driven operation, the system ensures scheduling, routing, and inventory are well-tuned to address the demands of the users. Other aims involve maintaining a high level of customer service and using practices that promote environmental sustainability.

The logistic caravan system uses cutting-edge technologies and predictive algorithms to pinpoint remote areas and anticipate demand. By incorporating geospatial mapping systems, the platform optimizes delivery routes, ensuring timely service while minimizing environmental impact. Scheduling features can provide users with transparent information on delivery windows, while the platform's strong data privacy measures can foster user trust and encourage wider adoption. Overall, the system seeks to address prevalent gaps in current delivery models by prioritizing on-time service, cost-effectiveness, and eco-friendly practices. The contributions of the proposed platform lie in its multifaceted approach to improving both user experience and operational sustainability. However, the contributions could be summarized in the following:

- Multi-Faceted Optimization: Improves user experience and operational efficiency through cost reduction, route optimization, and collaborative ordering among neighbors and friends.
- Environmental and Predictive Focus: Promotes eco-friendly practices, such as electric or hybrid vehicles and recyclable packaging, while employing predictive analytics to anticipate user needs based on historical data and optimize delivery schedules.
- Loyalty and Holistic Framework: Fosters long-term user engagement and satisfaction through incentives and tailored suggestions, offering a reliable, secure, eco-friendly logistics solution for remote private areas in Saudi Arabia.

The remainder of this paper is structured as follows: Section 2 examines related studies that support the objectives and scope of the proposed platform, focusing on logistics and its seven Rs, predictive algorithms for determining customer demands, sustainability in delivery applications, and optimizing delivery services. Section 3 presents the proposed system, detailing its architecture, functional and non-functional requirements, and design and implementation. Section 4 provides an in-depth discussion of the results. Finally, Section 5 concludes the paper and outlines potential avenues for future research.

2. Related works

This section presents a thorough literature review and comparative analysis, concentrating on logistics and the seven Rs, predictive algorithms for assessing customer demands, sustainability in delivery applications, and strategies for improving delivery services. By exploring current research and methodologies in these fields, the discussion provides valuable insights that help enhance our application's efficiency, sustainability, and overall customer experience.

2.1. Logistics and its seven Rs

Logistics is a concept that refers to the management of processes responsible for the effective supply, storage, transportation, and distribution of goods and services. These processes aim to ensure that products or services are delivered to consumers or users at the right place, at the right time, and at the right cost (Kendirli and Turan, 2024). On the other hand, logistics can be defined in more detail as it is the possibility of providing the right product in the proper condition and quantity, at the right point, at the right time, and, of course, for the right consumer (Rashidi et al., 2025). It has been clarified that this definition is related to the Seven Rs of Logistics, as mentioned surprisingly by Shapiro and Heskett (1985).

There is a lack of sufficient research that talks in detail about the seven Rs of logistics, while each point of the Rs is handled separately. Thus, in this research, one of the aims is to present the seven Rs to researchers as a gap that needs to be filled.

2.2. Predictive algorithm for consumer demands

The development of machine learning has made planning and growth easier by determining the number of characteristics, such as target market, future sales, and buying behavior. Therefore, the research aims to thoroughly explain how machine learning techniques are applied to forecast retail sales using XGBoost, random forest, and linear regression models. Finding out which of them adds to the higher predictive value and which merchants can utilize for decision-making is the goal. The Big Mart sales recorded data, which is publicly accessible, was used to train and evaluate each of the models used. Random Forest Regression calculated the highest R-squared values (0.545) among the different regression models. The objective is to compare the performance of various machine learning algorithms in predicting retail sales to identify the most accurate model. One limitation is that the model's R-squared value of 0.545 indicates moderate predictive accuracy, leaving significant unexplained variance in sales predictions (Zubair et al., 2024). The methodologies assessed were Linear Regression, Support Vector Machines, Random Forests, Decision Trees, Gradient Boosted Trees, and Neural Networks. Another study also analyzed Linear Regression, Gradient Boosted Trees, and Neural Networks, collecting data from orders including location, time, and food types (Simoni and Winkenbach, 2023). The results driven by an evaluation conducted in Simoni and Winkenbach (2023) also revealed that the Gradient Boosting

Model was the best-achieving model with a mean absolute percentage error of 12%-15% on holdout data. The models captured complex nonlinear relationships between demand and various factors. The objective is to develop an optimized order batching and assignment algorithm for crowdsourced on-demand food delivery to improve efficiency and delivery time. One limitation is that the models may not generalize well to unseen data due to potential overfitting to specific demand patterns (Simoni and Winkenbach, 2023). The predicted demand was then optimized for real-time delivery partner assignments and routing.

Moreover, another study developed a conceptual framework to explore the connection between fundamental personality dimensions and users' online shopping styles. The researchers employed machine learning techniques to predict user preferences and behavior in e-commerce based on personality traits (Ketipov et al., 2023). They developed survey instruments to measure online shopping preferences and personality using the Ten Item Personality Inventory (TIPI) and administered the survey to 226 multinational respondents. Bivariate analyses revealed significant correlations between the Big Five personality traits and preferences for specific e-commerce website features. To predict user preferences from personality, we employed two machine-learning regression models: decision trees and random forests. Both models achieved highly suitable predictive accuracy according to these metrics, with random forests demonstrating slightly better performance than decision trees on average. The objective is to predict user behavior in e-commerce using machine learning models based on personality traits and online shopping preferences. Reliance on self-reported survey data may introduce biases, affecting the accuracy of personality-based predictions is a drawback of Ketipov et al. (2023).

These papers demonstrate how machine learning can be leveraged to predict customer demand accurately. Various algorithms were utilized to determine the most effective methodology for capturing demand drivers. These studies contribute to the field by providing valuable insights and recommendations for businesses to enhance operational efficiency and customer satisfaction based on predictive analytics. All the papers discussed above concurred that the most efficient algorithm is the Gradient Boosting Tree, achieving high accuracy percentages.

2.3. Optimizing delivery services: Time- and cost-saving strategies

Delivery applications have revolutionized how people order food and goods by providing a convenient, fast, and user-friendly platform that saves valuable time.

A study was conducted in Tallinn, Estonia, aimed to identify the factors and assess the impact on the behavioral intention toward OFDs according to the consumer's point of view. Findings of 137 responses were received and showed that Trust demonstrates the highest impact of 30.8% on the intention of using OFD service by customers, followed by time-saving benefits (21.0%), perceived ease of use (15.2%), and perceived usefulness (14.5%). The objective is to identify and analyze the factors that influence customers' behavioral intentions toward using online food delivery services. Customer behavior may change over time due to evolving market trends and external factors, reducing the study’s long-term applicability. Price-saving benefits and food safety risk perception are insignificant statistically (Paudel et al., 2024). Moreover, another study was conducted to identify to determine the factors that significantly influence users’ satisfaction with the online food delivery service. The factors evaluated include time-saving orientation (TSO), price saving (PS), security system (SS), information quality (IQ), and safety packaging (SP). To identify key factors influencing university students' satisfaction and usage of online food delivery service applications. The study's findings may not be generalizable to a broader population due to its focus on university students. A self-administered online questionnaire was used to gather 402 responses, and the results demonstrated that each of the five parameters assessed in this study had a substantial impact on users' happiness. It was discovered that the most important factor was information quality (IQ) (Humaidi et al., 2024).

The European capital goods industry is facing new challenges in delivering customized, one-of-a-kind products, necessitating the expansion of value-added services to meet growing customer demands and heightened competition from outside Europe. To explore the risks and service strategies associated with service infusion in manufacturing. The findings may be industry-specific and not fully applicable across different manufacturing sectors (Humaidi et al., 2024). This literature review examines the development and delivery of these services through extended product concepts and explores their role in creating win-win scenarios for suppliers and customers. These services include consulting, engineering, benchmarking, simulation, optimization, training, remote operation support, and on-site fast maintenance, all coordinated through a value-creating network. To examine the capabilities that support digital servitization from a multi-actor perspective in industrial marketing. Research insights may be context-dependent and not universally applicable across all industries. While the extended product model provides a strong framework, further research is needed to address emerging challenges in this unique industry (Marcon et al., 2022).

According to one study, Indian customers' use of meal delivery apps has grown significantly, particularly during COVID-19 and beyond, and has already accounted for a sizeable portion of the restaurant industry. The Theory of Planned Behavior is used to assist the current paper's exploration of consumer app uptake. Additionally, the study examines how attitude and intention to use the app are affected by perceived innovation, hedonic motives, price options, and food selections. To investigate the impact of hedonic and utilitarian motivations and the role of trust in using food delivery apps in a developing economy. The findings may not be fully generalizable to developed economies due to differences in consumer behavior and market conditions. Research indicates that when people order food online, hedonic and utilitarian factors affect their trust, food safety, and customer experience (Dutta et al., 2025). In addition, last-mile delivery (LMD), a critical and costly component of the supply chain, presents unique challenges, particularly for heavy, bulky, and oversized (HBO) products. To review existing literature on the last-mile delivery of heavy, bulky, and oversized products and propose a research agenda. Research may not account for rapidly evolving logistics technologies and emerging delivery solutions (Alidaee et al., 2023). While parcel delivery logistics are well-studied, the complexities of HBO transport, including specialized handling and delivery requirements, remain underexplored. Studies in recent times reviewed 195 reports and articles and found serious research gaps concerning LMD for HBO products. These gaps prompt the necessity to develop customized strategies to meet disparate customer segments, including rural vs. urban and older vs. younger customers. HBO delivery demands special logistical strategies to improve its performance and secure customer satisfaction. The focus on timesaving is certainly critical in determining customer behavior and their need for quick delivery service online. Businesses focusing on the same by offering fast, easy, and convenient alternatives stand to gain and retain customers in the fast-paced world of the present day. Though demand for time-saving devices is particularly high in urban areas, it also reflects broader changes in consumer habits and lifestyles. By adding features that make shopping easier, such as instant ordering, easy-to-use interfaces, and customized experiences, companies can better meet customers' needs and enhance their competitive advantage.

2.4. Research gap

Publicly available Big Mart sales data, which may not fully represent diverse retail environments. Additionally, external economic factors influencing sales, such as inflation or regional demand shifts, were not explicitly considered (Zubair et al., 2024). It focuses on historical order data, which may not capture sudden demand fluctuations due to external disruptions. Additionally, real-time logistics challenges, such as traffic congestion and delivery delays, were not directly modeled in the demand prediction (Simoni and Winkenbach, 2023). The primary examined correlations between personality traits and online shopping preferences did not account for cultural influences on consumer behavior. Moreover, the study's sample size of 226 multinational respondents may not be large enough for broad generalization (Ketipov et al., 2023). The reliance on survey-based responses introduces potential social desirability bias, affecting the accuracy of reported consumer intentions. Additionally, factors like regional infrastructure and internet accessibility, which influence online food delivery adoption, were not considered (Paudel et al., 2024). They primarily focused on university students, excluding working professionals and other demographics who may have different priorities when using food delivery services. Furthermore, the study did not analyze seasonal variations in demand, which could impact user satisfaction trends (Humaidi et al., 2024). The service infusion strategies do not deeply explore the cost implications for manufacturers transitioning to service-based models. Additionally, the research lacks real-world case studies demonstrating the long-term sustainability of these strategies (Humaidi et al., 2024). The digital servitization capabilities do not address cybersecurity challenges that may arise when integrating digital services. Moreover, the research does not consider small and medium enterprises (SMEs), which may have different technological adoption constraints (Marcon et al., 2022). It explores hedonic and utilitarian motivations but does not consider external factors like government regulations on food safety and delivery services. Additionally, the research does not examine how varying levels of internet penetration impact app adoption in developing economies (Dutta et al., 2025).

The research proposed that the Intelligent Penguin Optimizer tuned Logistic Regression (IPO-LR) enhances predictive accuracy by integrating real-time economic indicators and dynamic hyperparameter tuning, addressing data limitations in retail sales forecasting. It adapts to regional demand shifts, inflation, and diverse retail environments, overcoming the shortcomings of conventional models. IPO-LR improves demand prediction by incorporating real-time logistics constraints, such as traffic congestion and delivery delays, ensuring better adaptability to sudden fluctuations in food delivery services. It also enhances e-commerce behavior analysis by considering cultural influences and leveraging big data analytics instead of limited survey-based approaches. By reducing social desirability bias, IPO-LR integrates transaction-based behavioral data, addressing gaps in regional infrastructure and internet accessibility in online food delivery adoption. It models broader consumer demographics, considering seasonal demand variations to refine satisfaction analysis.

3. Logistic caravan: Smart logistics transportation system

This research describes the functional and non-functional requirements, design constraints, and techniques that are behind the development of the logistic caravan system to enable a smooth and efficient delivery service. The system must be blessed with features such as real-time tracking, collaborative shopping, support for multiple languages, ease of use, and be accessible in design, keeping in mind environmental sustainability. These demands are fulfilled by a robust system architecture with the help of sophisticated tools, programming frameworks, and DevOps practices to provide a stable, scalable, and cost-efficient solution. With optimized routing, secure data management, and prompt customer support, the logistic caravan application effectively solves the specific logistic challenges of serving distant places and areas with restricted access, according to contemporary engineering standards and green principles.

3.1. System architecture

The logistic caravan system architecture, as shown in Fig. 1, encompasses three key components: the User/Driver, the Frontend, and the Backend (Firebase). These elements work together to ensure a responsive and efficient application for placing and delivering orders.

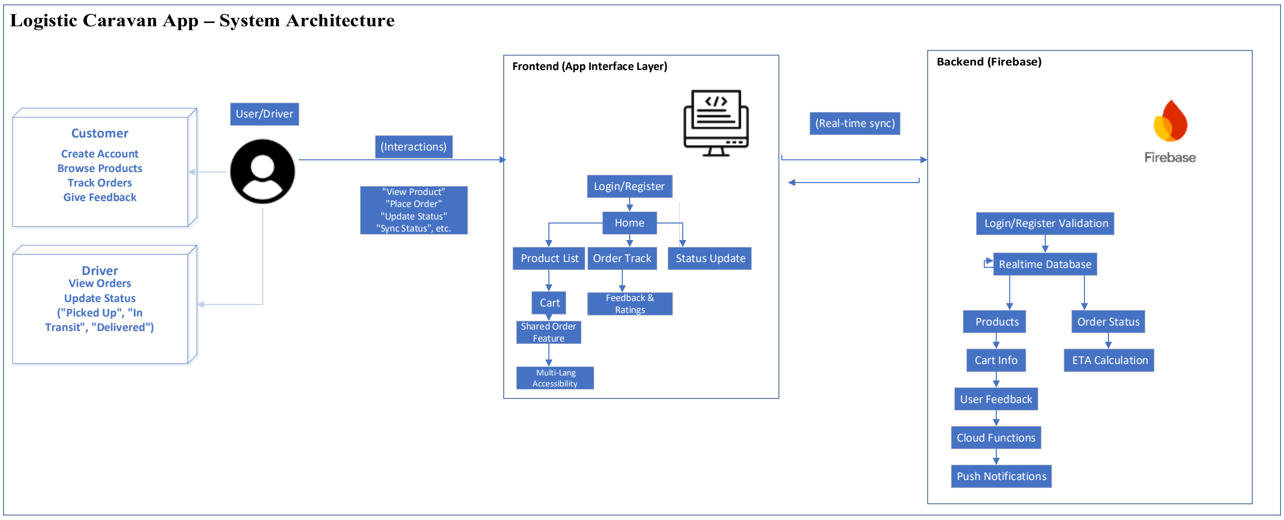

Fig. 1: System architecture: Backend and frontend

The User/Driver is used by both customers and delivery drivers. Customers interact with the system through account creation, product browsing, item selection, and order tracking. Drivers use the same application (with alternate permissions) to update order statuses in real-time, from pickup through final delivery. By providing one interface for users and drivers alike, the system facilitates good communication and keeps the data synchronized end-to-end through the delivery cycle. The front end is the primary user interface layer, comprising different pages or fragment classes. It has a Login/Register screen for handling user credentials, a home screen with available services and customized dashboards, and a Product list of items (including expired items) with details such as names, descriptions, prices, and images. Moreover, the Cart functionality allows buyers to choose items, see their totals, and go to check out, whereas the Order Track page provides live tracking of shipping progress. For drivers, the Status Update page provides real-time updates on the course of an order—e.g., "picked up," "in transit," or "delivered." The interface is multi-language, is designed to meet accessibility requirements, and features an easy, intuitive experience to appeal to a broad customer base.

The Backend leverages Firebase's real-time database and authentication system. User accounts and logins are safely authenticated by Firebase Authentication, while product listings, cart data, and order status are managed by the Realtime Database. When users are placing orders or drivers change delivery status, these are updated in real-time across the system, providing real-time insights into ongoing operations. Multiple simultaneous interactions can be supported by the app, delivering stability and responsiveness even under heavy loads. Relying on Firebase's real-time data synchronization, the logistic caravan app successfully responds to the complex needs of remote or restricted-access deliveries, offering accurate order information, quick updates, and a solid customer experience.

3.2. Functional and non-functional requirements

The logistic caravan app possesses one feature that makes it stand out from the rest – the ability to monitor a delivery caravan location and its approximate time of arrival in real-time. Consumers adore on-time timelines, and this platform allows them to know exactly when to expect packages. The application also receives key customer feedback and ratings on the overall delivery service, delivery staff, and satisfaction rating. Feedback and ratings can be left by users so that the app can improve its services and maintain its customer service standards. For the sake of improving user experience, the website design categorizes food items into groups, such as appetizers, main courses, and sweets. Also, it shows their names, descriptions, prices, and images. This makes it easy to find products for users and saves them valuable search time. Serving everyone is also a necessity. The application is implemented according to the guidelines of accessibility for disabled individuals so that anybody can use the interface with comfort, regardless of their physical or mental abilities.

The system accommodates various types of payments, including credit and debit cards, mobile wallets, and cash on delivery for secure payment transactions. Payment information of users is processed and stored under stringent conditions, which ensure sensitive data protection and foster trust in the reliability of the service. Additionally, users can contact the customer service department or the delivery unit directly via the app to enhance communication. Customers are provided with automated order confirmation, updates on progress, and alerts for any change in schedule. Such functionalities keep the customers informed about the delivery, which improves the overall experience. Another exclusive feature is the shared order. Customers from the same locality or distant places can band together to order one so that they can share the payment.

Non-functional requirements seek to create a smooth and efficient user interface. User satisfaction is greatly increased because the system ensures that it minimizes the steps required for placing orders, tracking delivery, and giving feedback. Customers can perform the required actions in the system through appropriate naming and navigation, as well as simplified interaction processes. The system also has to be able to handle high amounts of traffic and provide low response times during peak hours in terms of scalability and performance. The ability of the application to handle many users at the same time without getting slow is a result of optimized database queries and effective data management. This not only minimizes waiting time for clients but also enhances the service quality under varying load conditions. It is important to employ robust security and authentication systems to protect sensitive data and avoid unauthorized usage. Secure mechanisms of authentication reject operations such as ordering or retrieving personal data from uncontrolled users and authenticating credentials that permit sensitive operations. To ensure that data is safe and that the platform can be trusted, the application employs encryption and multi-factor authentication (MFA) as depicted. Multi-factor authentication (MFA) is applied, and the application also has mapping and navigation capabilities. The system offers the customer current information regarding the spot where the parcel will be picked up using GPS or other geographical positioning devices. This map planning function allows for dynamic rerouting when there is traffic congestion or unforeseen obstructions, thereby cutting down on the company's efficiency, and therefore, delivery times are elongated. The system's focus point is the committed focus on green practices. The dispatch decision puts the caravans at distant points based on the subsequent criteria: distance, load, and fuel consumption. The system utilizing route optimization algorithms takes fewer kilometers and thereby maintains the air cleaner by curtailing CO_2 emissions, aiding the logistics activities in achieving the environmental goal. It demonstrates an abstract sketch of how the caravans can be ingeniously managed to address both the sustainability and efficiency targets. The versatility of the application is evident in its cross-platform compatibility since it runs perfectly on different devices and operating systems. Whether users begin with a smartphone, a tablet, or a desktop, the device automatically recognizes that, and the software appears differently to accommodate the corresponding screen sizes and OS demands accordingly. Our approach to adaptability has beneficial outcomes both in terms of the growth of the user base and enhancing the user satisfaction guaranteed by replicating the experience for different technological environments.

3.3. Design constraints

The logistic caravan system, which must operate in remote and sometimes inaccessible places in Saudi Arabia (such as those not reachable by the common delivery services like Haimsons or Avicennas farmers market), depends critically on the geographical coverage. A remote estate, a college campus, and a dedicated beach hotel are some of the typical private places that are not part of the standard service, which makes the challenge more complicated. On-time delivery is the top priority, guaranteeing that goods and services can be delivered on the scheduled day and reducing lead times. Moreover, the platform should be adaptable and expandable, allowing it to be the platform that adjusts to new and changing customer wants, market trends, and technological developments. A customer-friendly portal is instrumental in helping clients feel at ease while interacting with the site, providing a quick option to customize product orders or trace product deliveries. Equally important, data security and privacy measures also play a significant role in shielding data against unauthorized access, carrying out data security compliance, and ensuring data user confidentiality. These are the essential elements of the system's design. When properly chosen, they are the components that can lead to the desired results of the system: availability, performance, and user safety.

Environmental conservation is the main target. It is achieved through design solutions such as route optimization, production of ecological materials, and using electric or hybrid vehicles to reduce carbon emissions. At the same time, the platform should be integrated seamlessly with existing logistical systems to enable communication between customers, delivery personnel, and third-party logistics providers. A good customer support system that allows feedback is the key factor. The support lines provided include dedicated channels for inquiries, complaints, and suggestions to minimize customer interaction. Other necessities that need to be met by the platform, such as saving time, resources, and cost-effectiveness through fleet management and route optimization, real-time tracking, and making sure mistakes and delays do not decrease accuracy, are the other essential conditions. These forces combine to form a high, flexible, and sustainable distribution infrastructure to accommodate various customer requirements.

3.4. Design and implementation

The design of the logistic caravan application entailed a deep dive into a diversity of diagrams commonly used in logistics that put a caravan-based model at the focal point. Valuable diagrams such as class, sequence, and activity diagrams were studied in detail to comprehend the system's dynamics and structure. Class diagrams correspond to the essential entities of the system (e.g., users, orders, and products) and their relationships. Sequence diagrams outline how the objects play out over time, ensuring that the course of the orders, from sending them to getting them, is clear. Activity diagrams, on the other hand, are the narrative of the workflow logic, which gives the best picture of the entrances and decision gates that the sequence of phone calls the users and the logistics staff take. These diagrams can enable the developer team to determine where bottlenecks are, adjust workflow transitions, and make decisions based on data to improve productivity and resource management. The application was connected to a database and relevant APIs to take the application through the implementation and testing stages. Several issues, such as data synchronization problems and HCI bugs, were effortlessly resolved through the iterative debug process. At different points in this journey, various engineering standards were implemented to ensure the development of high-standard software. One of the essential literatures used is ISO/IEC 25000, which was considered a successful approach in setting a model for software quality measurement. It introduces an organized methodology for defining, determining, and improving software's functional and non-functional attributes, such as performance, usability, security, and reliability (Miranda Arias, 2024). At the same time, DevOps practices emerged to optimize development and deployment processes, incorporating technologies such as continuous integration and delivery (CI/CD), automation, and proactive monitoring. Continuous integration and delivery are the automation of the building, testing, and deploying processes, which provides for the early detection of defects. Moreover, Infrastructure as Code (IaC) provides consistency, reliability, and scalability by defining the infrastructure components through code. DevOps also boosts cooperation and communication among project teams by eliminating the barrier between development and operations teams, which, in turn, facilitates quick decision-making and viable software service (Aiello, 2022). Automation tools (code reviews, testing, deployment, and monitoring) cut human error, deliver faster, and minimize risks and costs. To conclude, the project team decided to follow a holistic approach to the process by applying DevOps best practices and identifying key performance indicators (KPIs) as well as setting the development tools for all parties involved in the project. They also built an improving culture and kept the team engaged through regular feedback loops, also they had KPI-based iterative performance reviews.

A comprehensive strategy for testing, which entails both automated and manual tests, was implemented to ensure quality. The practices of the logistic caravan initiative to reduce time-to-market cycles, lower risks, and improve overall customer modules enabled one to develop an enterprise-level application by providing such features as dependency injection and modularity. Figma was used as the common interface that enabled team members to work on user interfaces collaboratively and at the same time (UIs) in real time. The application was both an online and a desktop app, which ran on Windows as well as macOS, and that helped in rapid prototyping and feedback collection. Lucid chart was, additionally, utilized for producing flowcharts, mind maps, organizational charts, and other key visual aids, which directed the design and architecture of the system. On the back end, Firebase offered services such as a real-time database, cloud storage, authentication, hosting, and analytics that cured data management and user handling. Besides, Android developers used Google's main Android JetBrains-based Integrated Development Environment, called Android Studio, to build, test, and troubleshoot the mobile application, which provided a single workspace for all app development stages. Finally, as the project and task management center, Jira was used to allow the team to effectively track tasks, report issues, collaborate on objectives, and monitor project progress, making it clear that every phase of development was clear and well-organized.

The application's landing screen, known as the Welcome Page, is the first viewport where there are two different secured access points that are custom-tailored to the user roles. As seen in Figs. 2, 3, and 4, the initial button takes customers to their order flow, where they can view, add, and delete items and track deliveries. The second button, on the other side, redirects couriers to their dedicated dashboard, allowing them to view the deliveries that were assigned to them, edit delivery statuses, and navigate their routes. This role-based mode of operation ensures that only the features that are relevant to each user are displayed, which in turn enhances security and user experience. The logistic caravan app, through smart design and sticking to the known engineering standards, balances the three factors of scalability, maintainability, and performance. The combination of strong technical practices and user-friendly interfaces effectively addresses the logistical challenges of delivering goods to remote and restricted-access locations, providing a solid foundation for future improvements and growth.

Fig. 2: Welcome page

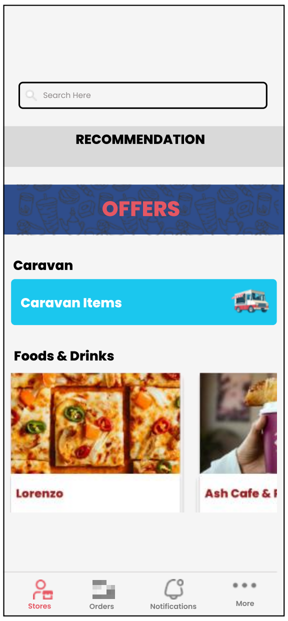

Fig. 3: Customer home page

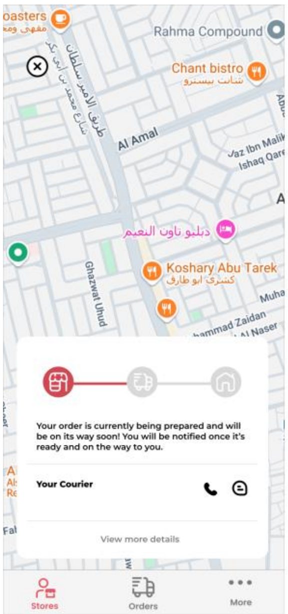

Fig. 4: Post order placement

3.5. Enhancing delivery services in remote areas through IPO-LR

In rural regions, conventional delivery services are confronted with enormous challenges in the form of scarce infrastructure and rugged terrain. Delays, high costs of operations, and inefficient routes tend to afflict these regions. Yet, with improvements in optimization algorithms, new avenues have emerged to optimize the efficiency of delivery systems. The Intelligent Penguin Optimizer is a new optimization method based on the foraging nature of penguins, which can be suitably used to optimize machine learning algorithms, like logistic regression, for solving intricate logistical issues.

By integrating IPO within the logistic regression model, delivery systems can maximize route optimization, demand prediction, and scheduling to suit the unique requirements of remote areas. IPO-LR incorporates a population-based optimization approach to find the ideal parameters and solutions, enhancing the accuracy and predictive capabilities of the model. The IPO approach ensures the delivery process is both efficient and eco-friendly, keeping fuel usage and emissions in check through route optimization.

3.5.1. Logistic regression (LR)

The LR model is commonly used in various fields to classify data into specific categories. In logistic regression, the target variable is typically binary, meaning it has only two possible outcomes, usually represented as 1 or 0. In this context, these values indicate whether delivery services are available in remote areas. The main objective of the LR algorithm is to find the best possible relationship between the predictor variables and the binary target variable. The LR model shown in Eq. 1 forms the basis of the logistic regression process.

$$z = g_\theta(w) = \theta^S w \tag{1}$$

where, z is the linear combination (also called the logit) of the input features. $g_\theta(w)$ is a function that computes the linear combination of weights and input features. θ is the parameter vector (also called weights or coefficients) of the logistic regression model. w is the input feature vector, representing one data sample.

Since Eq. 1 is incredibly inefficient at predicting binary values, added a function in Eq. 2 that predicts the Delivery Services in Remote Areas can fall into the "1" (positive) class as opposed to the "0" (negative) class.

$$O\left(z = \frac{1}{w}\right) = g_\theta(w) = \frac{1}{1+\exp\left(-\theta^S w\right)} = \sigma(\theta^S w)$$
$$O(0|w) = 1 - O(z = 1|w) = 1 - g_\theta(w) \tag{2}$$

By using the sigmoid function, or Eq. 3, maintain the value of θ^S inside the [0, 1] range. After that, look for a value of θ that makes the likelihood

$O(z = 1|w) = g_\theta(w)$ is huge in the class "1" and tiny when in the class "0" (i.e., $O\ (z = o|w)$ is large).

$$\sigma(s) = \frac{1}{(1+f^{-s})} \tag{3}$$

3.5.2. Intelligent penguin optimizer (IPO)

IPO begins by initializing a population of emperor penguins, representing potential solutions within the search space. Penguin behavior is influenced by initial features, such as population, the amount, and temperature profile in delivery Services in Remote Areas. The quality of a solution is determined by evaluating each penguin's fitness. The huddling behavior of emperor penguins provides an inspiration for how solutions are assembled, with limits affecting their ability to interact. Like how temperature affects penguin behavior, the temperature profile has an effect on exploration and exploitation. Penguins move in search of better solutions, and their separations are estimated. Penguins move toward better solutions by receiving their positions updated depending on fitness values and calculated distances. Following it, the updated solutions' fitness is recalculated for Delivery Services in Remote Areas. The technique determines when stopping requirements, including convergence or iteration limitations, are satisfied before returning the most effective possible solution. When the stoppage requirements are satisfied, this process reaches an end.

Penguins withstand the bitter cold. The penguins' coordinated spiral-like movements assist in transferring heat, preventing heat loss, and maintaining warmth with the huddle Delivery Services in Remote Areas. The IPO algorithm imitates these actions after being inspired by this tactic. It is a nature-inspired metaheuristic algorithm that solves optimization issues by applying the concepts of heat radiation and coordinated motions. The IPO algorithm improves its effectiveness in searching for space by utilizing the collective dynamics and heat management seen in penguin huddles. Delivery Services in Remote Areas.

Attenuation coefficient (μ) Indicates the amount that a wave or signal decreases as it passes through a medium.R, denotes radiant intensity, B radiant flux, ε is the emissivity of the surface, σ represents Stefan Boltzmann constant, S_T^4 is the temperature of the surface in Kelvin using Eq. 4.

$$R_{penguin} = B\varepsilon\sigma S_T^4 \tag{4}$$

Eq. 5 adjusts the radiant intensity $R$by incorporating of $f^{-\mu w}$ attention factors.

$$R = B\varepsilon\sigma S_T^4 f^{-\mu w} \tag{5}$$

Spiral movement in a logarithmic spiral is described by Eqs. 6 and 7, denoting variables such as bf constants that determine the spiral's form and expansion, Delivery Services in Remote Areas. The tan^{-1}, isangle related to the position of z_j and w_j to move through the logarithmic spiral path according to the degree of the appeal phase.

$$w_l = bf^{a\frac{1}{a}In\left\{(1-R)f^{a\,tan^{-1}\frac{z_j}{w_j}}+Rf^{a\,tan^{-1}\frac{z_j}{w_j}}\right\}} \cos\left\{\frac{1}{a}\ In\left\{(1-R)f^{a\,tan^{-1}\frac{z_j}{w_j}} + +Rf^{a\,tan^{-1}\frac{z_j}{w_j}}\right\}\right\} \tag{6}$$

The penguins travel a discrete search space that is thought of as a hyperspace sigmoidal transfer function in IPO position update ensures binary values, in contrast to the continuous space in the original IPO. The penguins' path in space, which frequently resembles a spiral as it experiments with different combinations, is referred to as spiral-like movement. By gradually modifying binary positions in the direction of optimal solutions, this technique enables IPO to tackle optimization effectively and identify the problems.

$$z_l = bf^{a\frac{1}{a}In\left\{(1-R)f^{a\,tan^{-1}\frac{z_j}{w_j}}+Rf^{a\,tan^{-1}\frac{z_j}{w_j}}\right\}} \sin\left\{\frac{1}{a}\ In\left\{(1-R)f^{a\,tan^{-1}\frac{z_j}{w_j}} + +Rf^{a\,tan^{-1}\frac{z_j}{w_j}}\right\}\right\} \tag{7}$$

Penguins designate a polygon-shaped huddle boundary. The process of building huddle borders also takes the wind movement into account. Hutch boundary creation behavior is demonstrated using the complex variable of Delivery Services in Remote Areas. Assuming the wind's gradient and velocity are indicated φ and $\emptyset$ represents Eq. 8.

$$\varphi = \nabla\emptyset \tag{8}$$

This is the gradient of $O = \emptyset + j\mu$ function which is frequently used to determine the direction of the greatest ascent or descent in optimization issues using Eq. 9.

$$O = \emptyset + j\mu \tag{9}$$

This equation adjusts the scale or weight $s$based on the maximum number of iterations using Eq. 10.

$$S = \left(s - \frac{Max_{iteration}}{w-Max_{iteration}}\right) \tag{10}$$

Binary thresholding determines whether a variable s to be 0 or 1 based on a threshold Q and the static task-graph scheduling is IPO to be appropriate for systems with fixed tasks and processors in Delivery Services in Remote Areas, scheduling in a static environment is predefined using Eq. 11.

$$s = \begin{cases} 0, & Q > 1 \\ 1, & Q < 1 \end{cases} \tag{11}$$

Eq. 12 calculates the error $Abs(A(\vec{Z}))$ between the actual values $\vec{Y}.\overrightarrow{R_{ep}(t)}$ and the predicted values $\vec{C}$ is used to measure how well the current solution fits the desired outcomes, managing adjustments to improve accuracy Delivery Services in Remote Areas.

$$\vec{C} = Abs(A(\vec{Z}).\overrightarrow{R(t)} - \vec{Y}.\overrightarrow{R_{ep}(t)} \quad (12)$$

The distance between penguins is calculated during the formation of the emperor penguin huddle barrier to ascertain the penguins' relative positions. The position of the best-fit emperor penguin is crucial to this computation Delivery Services in Remote Areas. Eq. 13 Euclidean distance formula, which computes the straight-line distance between two locations in space, is used in the mathematical formulation of the distance computation. This separation is essential for precisely updating the positions of every other penguin, guaranteeing that each one is positioned inside the huddle limit, where M represents the movement parameter for maintaining the gap among penguins using Eq. 14.

$$\vec{Z} = \left(M \times \left(S + R_{grid}(Accuracy)\right) \times Rand()\right) - S \quad (13)$$

$$R_{grid}(Accuracy) = Abs(\vec{Z} - \overrightarrow{Z_{ep}}) \quad (14)$$

Eq. 15 denotes the $\vec{Z}$ initializes the vector with random values. By ensuring a variety of beginning positions, random initialization assists the algorithm in avoiding getting bound in local optima while assisting in exploring other areas of the solution space Delivery Services in Remote Areas.

$$\vec{Z} = Rand() \quad (15)$$

The adjustment functions of $\overrightarrow{A(Z)}$ based on parameters $\left(h.f^{-\frac{t}{k}} - f^{-t}\right)^2$ it adjusts values to account for time-dependent changes and other factors, ensuring that the solution evolves appropriately over iterations using Eq. 16.

$$\overrightarrow{A(Z)} = \sqrt{\left(h.f^{-\frac{t}{k}} - f^{-t}\right)^2} \quad (16)$$

Eq. 17 updates the expected value $\overrightarrow{Z_{ep}}(t+1)$ for the next iteration, based on the current value $\vec{Z}.\vec{C}$ and the error $\vec{Z}(t)$. It refines the solution by incorporating adjustments based on the observed errors, guiding the optimization process toward better outcomes Delivery Services in Remote Areas.

$$\overrightarrow{Z_{ep}}(t+1) = \vec{Z}(t) - \vec{Z}.\vec{C} \quad (17)$$

The IPO shows significant improvement in task allocation efficiency for distributed system task allocation. Dynamically modifying the distribution of tasks among nodes based on their performance metrics and current load maximizes load balancing. Its adaptable design makes it a strong option for intricate distributed situations by ensuring better management of dynamic workloads and system conditions.

IPO-LR allows the system to dynamically adjust to real-time fluctuations in delivery requirements and environmental conditions. For example, quick weather conditions or traffic congestion can be factored in, enabling the model to quickly adjust delivery times and routes. This flexibility provides timely deliveries even under adverse conditions, enhancing customer satisfaction and reliability. IPO-LR helps decrease operational expenses by lowering fuel consumption and streamlining the number of delivery trips required. It also facilitates improved resource allocation through demand forecasting in far-flung regions, so the right number of vehicles and personnel are sent at the correct times. This not only increases efficiency but also supports sustainability by eliminating unnecessary transportation.

4. Results and discussion

Following the application's implementation, four distinct testing approaches were applied: acceptance, unit, system, and integration testing. These methods ensured comprehensive validation of the application's features, performance, and reliability. Subsequent sections offer more detailed insights into each testing phase, highlighting the importance of rigorous quality assurance before the application's deployment.

4.1. Testing

A key aspect is user-interface testing, where the communication of the different system components is checked, the data exchange is complete, and there are no gaps. This process is based on the interfaces and not the individual software components. With the constant demand for new features and the need to update existing technologies, an application must commit to thorough testing to ascertain its features and reliability from the end-user's point of view.

4.2. Unit testing

Unit testing is the practice of evaluating a software system's modules or components. Developers usually implement it in the early stages of development, where they isolate and test each part of the code before it goes through integration and system-level testing. This method shows its effectiveness by locating defects and inconsistencies in the early stages of writing code, thus preventing errors from appearing later when other parts of the codebase are written as well. Table 1 contains a set of test cases for user registration, covering each scenario to control the system's operations for different input data entries. In the registration process, after clicking on the register button, the user can be required to submit all the necessary information, which can include email addresses of different types, both valid and invalid, phone numbers, and passwords. If the user types in a proper email address, the system can verify it and enable the user to register smoothly without any issues. Conversely, if the user enters an incorrect email address that does not meet the standard formatting rules, the user can be shown a message that tells them to enter a valid email address. Validation also concerns the registered phone number, which needs to be in a specific number format to be able to register. As for passwords, two proof-of-concept sets of tests are designed so users can interact with the system's literacy. The right kind of passwords with letters, numbers, and symbols with a minimum of six characters are accepted without problems. On the contrary, passwords shorter than six characters are rejected, ensuring the system complies with necessary security standards. A final test consists of testing that the method of presenting a valid password is repeated the same way, thus protecting the system from any unwanted influence on the registration process. These results indicate that the system effectively manages both expected and erroneous user inputs, providing clear prompts or acceptance messages as needed. The ability to accurately validate emails, phone numbers, and passwords enhances the registration experience and strengthens data integrity and security within the application.

Table 1: Unit testing table (registering customer account) during runtime

Test case name	Test step	Description	Test data	Expected result	Actual result	Remarks
Enter user email	The user can go to the register button and click it to fill in the email information	Enter the valid format of an unregistered email	English email format	Acceptance of the new email that is being registered	User registered with email input accepted	Pass
Enter user email	The user can go to the register button and click it to fill in the email information	Enter an invalid format of an unregistered email	English words	Rejection of the new email that is being registered	The user is asked to register with a valid email	Pass
Enter the user's phone number	The user can go to the register button and click it to fill in the required information	Enter valid format of a phone number	Numbers in English	Acceptance of the new number that is being registered	Phone number input accepted	Pass
Enter user password	Fill in the password label	Enter a valid password that contains letters, numbers and symbols with a minimum of 6 characters	English password	Acceptance of the new password	Password input accepted	Pass
Enter the wrong format of the user password	Fill in the password label	Enter a valid password format with fewer than 6 characters	English password	Rejection of the new password	Password input rejected	Pass
Re-enter the password to confirm it	Fill in the confirmation password label	Enter the same password written above	English password	Acceptance of the new password	Password input accepted	Pass

Table 2 provides an overview of unit testing scenarios for customers and couriers during the login process. It outlines each test case along with the trigger (i.e., the moment a user initiates the login), the specific actions taken by the user, and the corresponding test data used. Table 2 also presents the expected and actual results, culminating in a remarks column indicating whether each scenario passed. In the first test case, the system verifies its handling of a valid registered email. Upon clicking the login button and entering a properly formatted email address, the system is expected to accept the input, allowing the user to proceed. The second test case focuses on verifying a password composed of numeric characters in English, confirming that the system accepts legitimate login credentials.

The final scenario evaluates how the system responds to invalid email/password inputs. When the user enters incorrect information, a prompt instructs them to submit valid credentials. If the revised input meets the requirements, the system accepts it. Across all these test cases, Table 2 confirms that the login functionality operates correctly, processing valid credentials and rejecting incorrect ones, ensuring a secure, user-friendly experience for customers and couriers alike.

Table 2: Unit testing table (customer and courier login) during runtime

Test case name	Test step	Description	Test data	Expected result	Actual result	Remarks
Enter user email	The user can go to the login button and click it to fill in the information	Enter a valid format of a registered email	English email format	Acceptance of the email	Users with email input accepted	Pass
Enter user password	The user can go to the login button and click it to fill in the information	Enter password	Numbers in English	Acceptance of the number that is being logged in	Phone number input accepted	Pass
Enter invalid email/password	The user can be displayed a message: "Enter a valid email/password"	Re-enter email and password	English letters and numbers	Acceptance of the new input	User input accepted	Pass

Table 3 showcases unit testing for actions taken on the after-launching-app page—the first screen that appears when the application is opened. Each test case confirms whether choosing to register or log in redirects the user to the correct page or, conversely, whether not selecting leaves the user on the same screen. In the initial test scenario, the user selects the register option, leading the system to display the appropriate registration page. The second scenario mirrors this logic with the log-in option, verifying that the correct log-in page appears. Finally, the third scenario checks what happens if the user does not choose either option, ensuring the page remains unchanged without proceeding to any subsequent screen. Across all three test cases, the application's behavior aligns with the expected results, indicating that the system reliably handles user decisions on the main welcome page.

Table 3: Unit testing table (after launching the app page) during runtime

Test case name	Test step	Description	Test data	Expected result	Actual result	Remarks
Choose your option: Driver or customer	The first main page can be displayed, and the user can choose the register option	Select register option	Register page information in English	Register page displayed	Successful register	Pass
Choose your option: Driver or customer	The first main page can be displayed, and the user can choose the log-in option	Select the log-in option	Log-in page information in English	Log-in page displayed	Successful log-in	Pass
Choose your option: Driver or customer	The first main page can be displayed with the option to register and log in	Unselected option	The same page is displayed	The same page is displayed	Unsuccessful Login/register to the home page	Pass

4.3. Integration and system testing

Integration testing is crucial for checking how different units or modules within the software interact with each other. By combining these program units and evaluating their overall performance, integration testing detects interface or communication problems that might not appear when modules are tested separately. Integration testing makes sure that all pieces interact harmoniously with each other and are accountable for the system's function.

Apart from integration testing, system testing tests the entire application, ensuring it meets the quality requirements. This phase ensures that software fulfils both business requirements and end-users' needs by providing end-to-end processes that function under actual use conditions and adhering to functional and non-functional specifications. Any significant errors or inconsistencies are corrected through system testing before taking the application to end-users, enhancing overall reliability and satisfaction.

4.4. Comparison with error rates

The Smart Logistics Transport System maximizes logistics in outlying regions through forecasting models. MAE minimizes errors in prediction, enhances route scheduling and planning, and increases operational efficiency and sustainability. RMSE optimizes routes, minimizing fuel consumption and environmental effects. This reduction in error rates demonstrates the model's ability to make more accurate predictions, particularly in route optimization and delivery time forecasting.

MAPE enhances delivery forecasts, maximizing service reliability and customer satisfaction, facilitating green logistics. The system incorporates green practices, e.g., electric vehicles, recyclable packaging, to reduce the carbon footprint. MAE, RMSE, and MAPE assist in minimizing operation inefficiencies, optimizing delivery schedules, and ensuring customer confidence. It enhances logistics for remote locations and aligns with green practices while promoting green logistics objectives. Table 4 illustrates the values of error rates of MAE, RMSE, and MAPE.

Table 4: Quantitative values of error rates

Methods	MAE	RMSE	MAPE
DT (Ketipov et al., 2023)	0.79	0.97	0.7244
RF (Ketipov et al., 2023)	0.94	0.97	0.7248
IPO-LR [Proposed]	0.69	0.81	0.6501

MAE is essential in measuring the precision of forecasting models in the Smart Logistics Transportation System. By expressing the average size of prediction errors as a numerical value, MAE optimizes route planning, delivery scheduling, and demand forecasting. In green logistics, it makes sure that the system reduces deviations in delivery performance, maximizing both operational efficiency and sustainability in rural regions. The value of MAE in IPO-LR has attained a low value of 0.69 than the other methods of DT at 0.79 and RF at 0.94. RMSE is an important measure of the accuracy of route optimization and demand forecasting in the Smart Logistics Transportation System. By reducing RMSE, the system is able to more precisely forecast delivery times, optimize routes, and minimize fuel usage. This has a direct impact on sustainable practice, increasing efficiency and minimizing the environmental footprint of logistics in remote locations. The value of RMSE in IPO-LR has attained a low value of 0.81 than the existing methods of DT at 0.97 and RF at 0.97.

MAPE is also responsible for assessing the precision of delivery forecasts in the Smart Logistics Transportation System. By quantifying the difference between forecasted and actual delivery times or expenses, MAPE optimizes route planning, demand forecasting, and scheduling. This ultimately increases the reliability of service, improves customer satisfaction, and facilitates the system's sustainability activities in isolated areas. The value of MAPE in IPO-LR has attained low values at 0.6501 compared to the other methods of RF at 0.7248 and DT at 0.7244. Fig. 5 shows the values of error rates (a) MAE, (b) RMSE, and (c) MAPE.

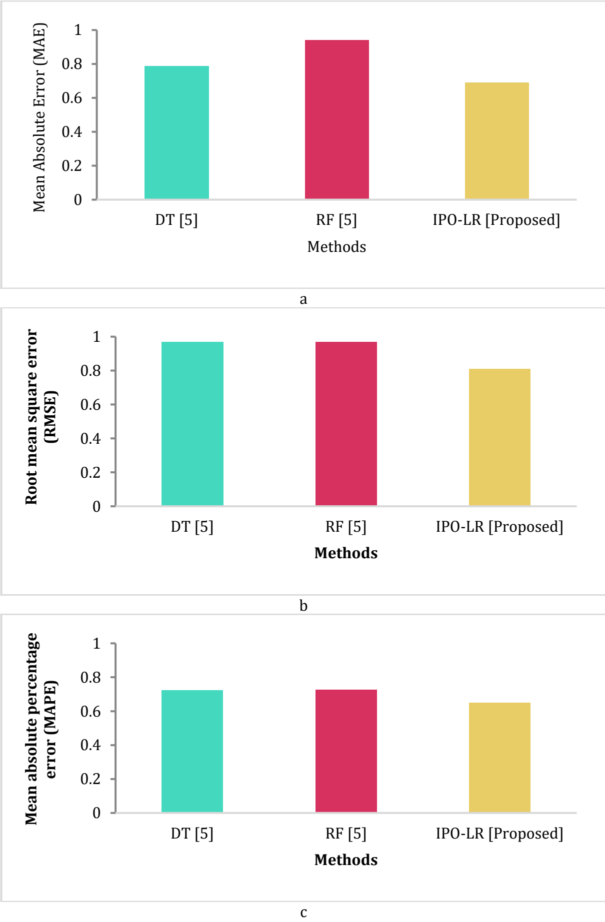

Fig. 5: Graphical representation of error rates (a) MAE, (b) RMSE, and (c) MAPE

4.5. Comparison with existing systems

Several established delivery applications in Saudi Arabia cater to various consumer needs, mainly focusing on remote areas and smaller towns. Sary is an online grocery delivery platform that serves smaller communities, providing safe, convenient access to essential items. Jahez, a popular food delivery app, has recently broadened its scope to include other products, extending its service to rural regions to ensure a wider selection for village customers. Meanwhile, Mrsool adopts a crowd-sourced approach by connecting individuals needing deliveries with those willing to fulfill them. This model spans multiple locations, including rural areas, to enhance accessibility and safety. Wssel similarly delivers food, groceries, and miscellaneous goods across an array of locations, including remote regions, prioritizing the convenience of residents.

Table 5 underscores the main features that distinguish our proposed application from existing platforms. Notably, our application and Sary deliver to secluded or remote areas, ensuring that customers in such locales can readily access delivery services. By contrast, Jahez and Mrsool do not offer specialized remote-area delivery options, thus limiting their reach. What sets our application apart is its assignment of a dedicated “caravan” to specific regions characterized by private or remote conditions. This approach and targeting a defined user community foster strong customer loyalty.

Table 5: Comparison of similar applications

Functionality	Our application	Sary	Jahez	Mrsool	Wssel	Talabat	Uber Eats	Zomato
Delivery to secluded/remote areas	✓	✓	✗	✗	✓	✓	✓	✗
Environment-friendly	✓	✗	✗	✗	✗	✗	✗	✗
Scheduled delivery	✓	✓	✓	✗	✗	✓	✓	✓
Collaborative ordering	✓	✗	✗	✗	✗	✗	✗	✗
Real-time tracking	✓	✓	✓	✓	✓	✓	✓	✓
Wide product variety	✓	✓	✓	✓	✓	✓	✓	✓
Flexible payment options	✓	✓	✓	✓	✓	✓	✓	✓
Customer support	✓	✓	✓	✓	✓	✓	✓	✓
Service in urban areas	✓	✓	✓	✓	✓	✓	✓	✓

Our application emphasizes environment-friendly practices, integrating route optimization, energy-efficient transportation (such as hybrid or electric vehicles), and responsible packaging methods. Unlike most existing services, which do not display any discernible green policies, our application aspires to minimize carbon emissions and environmental impact. Regarding scheduling capabilities, our application, Sary and Jahez, supports scheduled deliveries, allowing users to plan their orders in advance. Mrsool and Wssel currently lack this functionality, making them less flexible for users with demanding schedules.

A unique offering of our system is collaborative ordering, enabling users, especially those in remote or neighboring communities, to group their purchases into a single delivery. This reduces transportation costs, lowers vehicle usage, and promotes collective engagement. None of the other applications currently provides such a feature. Additionally, real-time tracking is a shared feature across all platforms, giving users continuous insight into delivery progress. Yet, our application seeks to develop this capability with precision to guarantee correct, minute-by-minute reporting instead of proximity estimates, which would be more transparent and trustworthy to the user. It supports real-time tracking and scheduled delivery, but does not support remote areas and collaborative ordering. It is effective in urban areas with a large product offering and varied payment terms. It supports real-time tracking and scheduled delivery, but does not emphasize environmental sustainability or collaborative ordering. It operates in urban areas but does not prioritize remote areas. As is the case with Uber Eats, with scheduled deliveries and live tracking, but without environmental friendliness and co-ordering, it to urban boundaries.

Together, these qualities show how our suggested platform covers the shortcomings of current solutions. With its emphasis on sustainable practices, purposeful service in remote areas, flexible scheduling, and forward-thinking collaborative ordering, our app is a complete and user-oriented solution to the Saudi Arabian delivery space.

This study submits a series of seminal contributions in logistics and delivery services with direct applicability in underserved and remote communities across Saudi Arabia. By deploying cutting-edge features and responsiveness to strategic national goals, the logistic caravan application introduced improves operational efficiency, promotes sustainable solutions, and supports scholarly discourse in last-mile logistics.

The logistic caravan app successfully addresses the needs of remote and secluded areas, including compounds, university campuses, and exclusive resorts. Offering timely and assured delivery services fills service gaps in places that conventional logistics companies usually find difficult to access. This guarantees equitable access to necessities for residents and firms, enhancing inclusivity in the national delivery network. The most significant achievement is the group ordering functionality. The collective ordering system for groups enables individuals to order collectively, thereby reducing delivery fees and diminishing total car usage with the encouragement of green behavior. Besides making it easier for people to share with neighbors or office mates, the system builds camaraderie and simplifies logistics processes for remote or off-the-map areas. Eco-friendly use of natural resources is the focus of the application's design. Utilizing route-optimization software, geospatial mapping, and green forms of transport—hybrid or electric vehicles, for instance—the system works towards minimizing carbon footprint and facilitating cleaner logistics.

Such initiatives support broader national and global objectives of cutting down ecological footprints and conserving natural resources. The design also complements the principles of the 7 Rs of logistics, i.e., Right Product, Quantity, Condition, Place, Time, Customer, and Cost. Global alignment ensures deliveries are cost-efficient, customer-focused, and operationally efficient. This means that deliveries happen quickly and accurately to the customers, while the service providers get to use the maximum number of resources without waste. The modular structure of the application allows it to be scaled based on increasing user demands, emerging technology, and shifting market trends. This helps ensure that the system can keep up with future updates and remain effective and relevant. Companies and community stakeholders are rewarded with a solution that scales with them. Through the analysis of areas like last-mile logistics, predictive delivery technology, and green transport mechanisms, this study adds to the scholarly literature. It brings important information to practitioners and scholars wishing to create more effective, environmentally friendly, and socially responsive delivery models. Lastly, these findings form the basis for further research and best practices in the world of logistics.

The proposed IPO-LR model showcases a distinct advantage by achieving significantly lower error rates across key evaluation metrics. This reduction in error rates demonstrates the model's ability to make more accurate predictions, particularly in route optimization and delivery time forecasting. By minimizing discrepancies between predicted and actual outcomes, the IPO-LR model enhances overall operational efficiency, reducing delays and improving service reliability. The proposed approach’s superior performance allows for more precise demand forecasting, better resource allocation, and optimized routing, all contributing to reduced operational costs and environmental impact. These improvements make the IPO-LR model a highly effective tool for smart logistics, particularly in remote areas where accuracy and efficiency are critical.

5. Conclusions

This research developed the logistic caravan, an Android phone app designed to assist poor and far-flung areas by streamlining deliveries. Clients can create and personalize their accounts, search for products in stock, and get special offers. The app also allows clients to consolidate orders with other clients, thus cutting costs and saving on environmental print. The most preferred products are placed in the user's shopping cart for payment, where they can monitor their orders and engage with couriers for information. Users are also offered personalized recommendations based on previous shopping history, increasing convenience. The proposed method of IPO-LR has attained lower values in error rates of MAE at 0.69, RMSE at 0.81, and MAPE at 0.6501, demonstrating the model's ability to make more accurate predictions, particularly in route optimization and delivery time forecasting. The most important objectives of this application were timesaving, cost reduction, environmental conservation, and meeting user requirements dynamically and conveniently. By putting ultimate stress on early delivery to remote regions, the logistic caravan fulfils these functions with innovative added components such as group ordering that enhance consumer satisfaction and environmental stewardship with minimized vehicle exhaust emissions. Upgrades in the future can consist of incorporating shortest-path optimization to reduce fuel consumption further, improving the "Offers" section to display near-expiring products more prominently, providing online payment capabilities, and including accessibility features like voice assistance and high-contrast modes for the visually impaired. Such updates can improve the application even further and make it more relevant to changing user requirements. Currently, research outlines the conceptual and technical design of the logistic caravan system. To strengthen the research, real-world pilot testing should be conducted in a remote area. This can involve deploying the system in a controlled environment, such as a private compound or university campus, to gather data on delivery efficiency, response time, and user satisfaction. The results can be analyzed to validate the system's effectiveness and refine its predictive models for further optimization. Future work can incorporate case studies and performance evaluations to substantiate the proposed methodology.

List of abbreviations

IPO	Intelligent penguin optimizer
LR	Logistic regression
IPO-LR	Intelligent penguin optimizer tuned logistic regression
MAE	Mean absolute error
RMSE	Root mean squared error
MAPE	Mean absolute percentage error
Rs (Seven Rs)	Right product, right quantity, right condition, right place, right time, right customer, right cost
TIPI	Ten item personality inventory
TSO	Time-saving orientation
PS	Price saving
SS	Security system
IQ	Information quality
SP	Safety packaging
OFD	Online food delivery
LMD	Last-mile delivery
HBO	Heavy, bulky, oversized (products)
SME	Small and medium enterprises
CI	Continuous integration
CD	Continuous deployment
IaC	Infrastructure as code
HCI	Human-computer interaction
UI	User interface
KPI	Key performance indicator
MFA	Multi-factor authentication
DT	Decision tree
RF	Random forest

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Compliance with ethical standards

Conflict of interest

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