Data Analysis and Optimization Strategies for Delivery Operations in a Shenyang-Based Convenience Store Network

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Abstract. This study focuses on optimizing delivery operations in a Shenyang-based convenience store network by analyzing delivery time, cost, order distribution, and external factors such as weather and traffic. Using Python-based data analysis, inefficiencies in delivery times, rising costs due to fuel and labor, and uneven order distribution across routes were identified Visualizations are plotted to highlight the impact of longer routes on time and cost and evaluated external influences like traffic and weather. Solutions include route optimization, balancing order volumes, and adjusting delivery schedules to mitigate delays during peak hours or adverse weather conditions. Recommendations for improving delivery efficiency during holidays and special events, as well as contingency plans for external disruptions, are presented. The study suggests the use of machine learning for future order prediction and alternative delivery methods, such as drones or electric vehicles, for long-term cost reduction.

1 Introduction

Lawson, a globally renowned convenience store chain, operates an extensive network of stores in the Chinese market. With the rapid pace of urbanization and the increasing diversity of consumer needs, Lawson's delivery system faces growing challenges. Efficient delivery plays a crucial role in Lawson's operations, directly affecting both operational costs and customer satisfaction. Factors such as urban traffic congestion, unpredictable fluctuations in consumer demand, and rising delivery costs add significant complexity to managing deliveries. Therefore, optimizing delivery efficiency while keeping costs under control is vital for Lawson to maintain its competitive advantage in a highly competitive market.

Data analysis offers an effective tool for addressing these challenges by providing actionable insights into the delivery process. By examining historical delivery data, Lawson can identify key problems such as delays, inefficient order management, and escalating costs. These insights help pinpoint areas for improvement, enabling more informed decisions about streamlining the delivery process.

This study focuses on using Python to analyze Lawson's delivery data, particularly metrics such as delivery times, distances travelled, order volumes, and cost efficiency.

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Through detailed data analysis, the research will uncover patterns and inefficiencies that may not be immediately visible, allowing for the development of targeted optimization strategies. The goal is to propose specific, data-driven solutions that can enhance Lawson's overall delivery efficiency, reduce operational costs, and improve the customer experience, ensuring that Lawson continues to meet the demands of modern urban consumers while staying competitive in the market.

2 Delivery Time and Efficiency

2.1 Problem description

With the rapid development of e-commerce, the importance of logistics and distribution in the supply chain has become increasingly prominent. The length of distribution time not only affects customer satisfaction, but also has a profound impact on the operational efficiency of enterprises. Especially in longer distribution routes, such as long-distance distribution from one city to another, the optimization of distribution time becomes a key factor affecting the overall logistics efficiency.

This study aims to analyze the relationship between distribution time and operational efficiency, focusing on the impact of longer distance distribution routes on distribution efficiency. By analyzing real distribution data, this paper tries to find out the main influencing factors of distribution time and provide practical and feasible suggestions for improving logistics efficiency.

Logistics distribution, as an important part of supply chain management, has received extensive attention in recent years. Many scholars have conducted research in logistics management and route planning to explore how to improve the overall operational efficiency by optimizing distribution routes and time management.

First, research on distribution time and logistics efficiency is widely available. Distribution time is not only affected by the distribution distance, but also closely related to traffic conditions, weather and warehouse location [1]. Studies have shown that by shortening the time interval between single deliveries, companies can effectively reduce waiting time and improve order processing efficiency [2]. Similar studies have also shown that longer delivery routes are more susceptible to disruptions in road conditions, scheduling, and other factors, and thus require more route planning optimization measures [3].

However, although many studies have been conducted to explore the optimization scheme of delivery time, there are fewer studies on long-distance delivery between specific cities.

2.2 Data Analysis

This paper will analyze the relationship between delivery time and operational efficiency based on long-distance delivery data from Shenyang to Jinzhou and Chaoyang cities and propose optimization suggestions to fill the research gap in this area. The following is a sample of the data in table 1:

Table 1. The delivery data.

start time	end time	delivery route	delivery distance (km)	order volume
10:00	15:30	Shenyang Warehouse to Shenyang City Stores	160	500
11:30	18:30	Shenyang Warehouse to Jinzhou	350	600

13:00	20:00	Shenyang Warehouse to Chaoyang	460	350
14:00	18:30	Shenyang Warehouse to Yingkou	320	600
17:00	21:30	Shenyang Warehouse to Panjin	260	480
19:00	22:00	Shenyang Warehouse to Tieling	150	320

It is first converted that the start time and end time into hours to calculate the delivery time for each route. The results show that there are significant differences in the delivery time of different distances. By drawing the scatter plot of delivery distance and delivery time, following things are found:

(1) Longer distances (such as 350 km and 460 km) generally take longer to deliver, around 7 hours.

(2) Some shorter distances (such as 160 km) take longer to deliver, which may be due to other factors such as traffic congestion.

Fig. 1. Relationship between delivery distance and delivery time.

From the above data in figure 1, it can be seen that longer distribution distances (e.g. 350km and 460km) take longer to distribute, suggesting that longer routes may have a negative impact on overall operational efficiency. In addition, some of the shorter and medium distances also took longer to deliver (e.g., 160 km delivery took 5.5 hours), which may be due to traffic conditions or poor route planning.

2.3 Solutions and Suggestions

(1) Shorten or Increase Distribution Intervals For longer distribution routes (e.g., Shenyang to Chaoyang and Jinzhou), the total time-consuming time for a single delivery can be reduced by dividing the delivery task into several smaller batches or increasing the frequency of delivery to improve the overall efficiency.

(2) Route Optimization For some short- to medium-distance, highly time-consuming distribution routes, the use of GIS or real-time traffic data can be considered to optimize route selection in order to avoid traffic congestion. In addition, it can also try to dynamically adjust the distribution time according to the traffic situation in different time periods to reduce the time wasted on the road.

3 Order Distribution and Route Optimization

3.1 Problem description

As fuel and labor costs rise, the profitability of distribution operations is significantly impacted [4]. To better understand the impact of these costs on distribution operations, it is necessary to compare fuel and labor costs across different distribution routes to identify higher-cost routes and make optimization recommendations. Key issues include Rising fuel and labor costs are squeezing profit margins [5]. Significant cost differences exist between different distribution routes, especially long-distance routes such as Shenyang to Jinzhou and Chaoyang. How to optimize high-cost routes to improve cost-effectiveness.

3.2 Data Analysis

To evaluate the cost of different routes, data was collected on fuel cost, labor cost, and total distance for each distribution route. This data was analyzed using Python to calculate the total cost (fuel + labor) as well as the average cost per kilometer for each route. The table below shows a summary of the data in table 2:

Table 2. The cost data

Delivery Route	Fuel Cost per Trip (Yuan)	Labor Cost per Day (Yuan)	Total Cost per Trip (Yuan)	Distanc e (km)	Cost per km (Yuan)
Shenyan g City	320	270	590	160	3.69
Jinzhou	700	270	970	350	2.77
Chaoyan g	920	270	1190	460	2.59
Yingkou	640	270	910	320	2.84
Panjin	520	270	790	260	3.04
Tieling	300	270	570	150	3.8

Fig. 2. Total cost of different distribution routes.

Fig. 3. Cost per kilometer comparison.

As can be seen from the data in figure 2 and figure 3, Chaoyang has the highest total cost of 1,190 yuan per time, while Shenyang has the lowest total cost of 590 yuan per time.

The cost per kilometer in Shenyang is the highest, reaching 3.69 yuan/km, while the cost per kilometer in Jinzhou and Chaoyang is lower, at 2.77 yuan/km and 2.59 yuan/km, respectively.

3.3 Solutions

(1) Fuel-efficient vehicles or alternative modes of transportation: For delivery routes with higher costs, especially routes within Shenyang city, it is possible to consider introducing more fuel-efficient vehicles or using alternative modes of transportation, such as electric vehicles or smaller delivery vehicles, to reduce fuel costs.

(2) Optimize delivery frequency: For high-cost routes, such as Chaoyang and Shenyang city, operating costs can be reduced by reducing delivery frequency. In addition, the introduction of multi-station route planning, combined with multiple lines for joint distribution, can also improve the overall distribution efficiency, reduce the total cost of a single distribution.

4 Order Distribution and Route Optimization

4.1 Problem Description

Uneven distribution of orders across different routes creates inefficiencies in the overall system. For instance, routes such as Shenyang to Jinzhou are handling a significantly larger volume of orders (600 orders) compared to Shenyang to Tieling, which only manages 320 orders. This imbalance can lead to both resource overuse on certain routes and underuse on others. Uneven order distribution across routes often results in inefficiencies such as vehicle underutilization and increased fuel consumption [6].

4.2 Data Analysis

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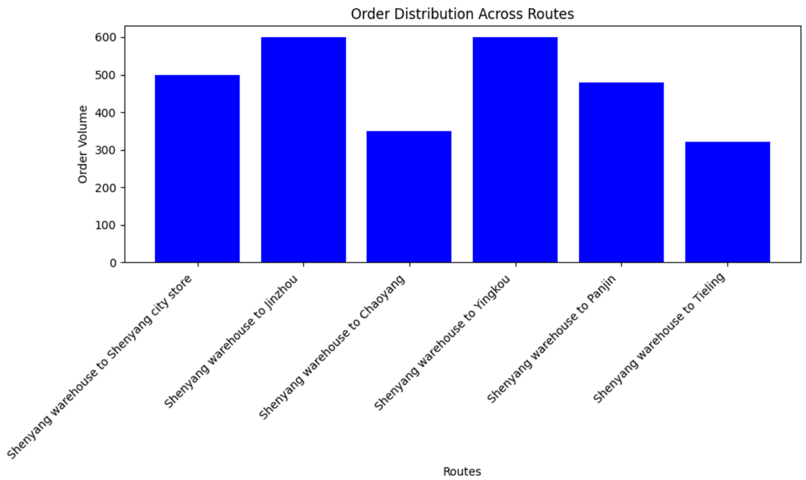

Fig. 4. Distribution of Orders Across Routes.

Figure 4 shows the number of orders distributed across the six major routes. As observed, the route from Shenyang to Jinzhou handles the highest volume of 600 orders, while the route to Tieling manages just 320 orders, highlighting the disparity in load.

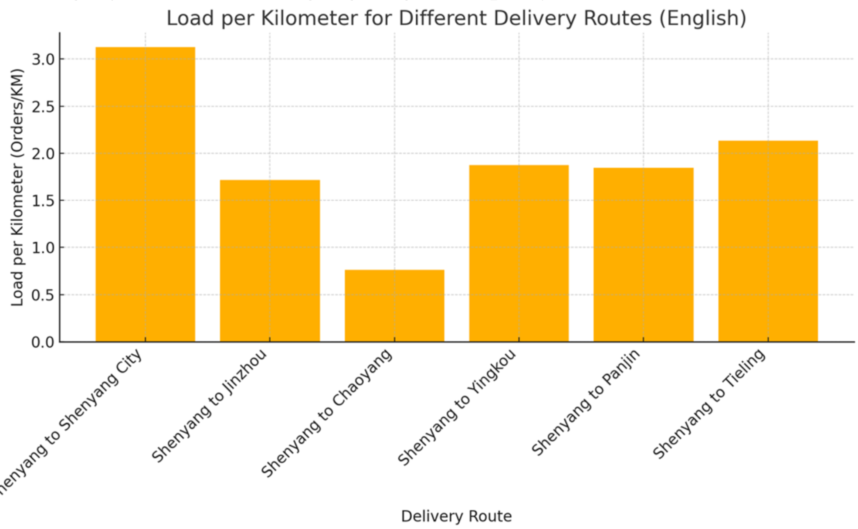

Fig. 5. Load per Kilometer for Different Routes.

Figure 5 presents the load per kilometer (orders per KM) for each route. Routes such as Shenyang to Jinzhou and Shenyang to Yingkou show significantly higher loads compared to others like Shenyang to Tieling, indicating an uneven allocation of resources.

4.3 Solutions

(1) Balancing Order Volumes Across Routes: Balancing order volumes across routes is a critical aspect of optimizing vehicle routing and reducing. inefficiencies [7]. Suggest redistributing the orders more evenly to maximize vehicle utilization. For example, excess

orders on the Shenyang to Jinzhou route can be shifted to less congested routes such as Shenyang to Tieling. This balance will enhance delivery efficiency and reduce travel costs.

(2) Adjusting Delivery Schedules: Dynamic adjustment of delivery schedules can help balance workloads and prevent route overloading [8]. Propose revising delivery schedules to avoid overloading certain routes at peak times while leaving others underused. For instance, scheduling deliveries to Jinzhou at off-peak hours could help redistribute workloads without compromising delivery times.

5 External Factors Affecting Delivery (Weather and Traffic)

5.1 Problem Description

Weather conditions, especially rainfall, have a significant impact on traffic flow and delivery times, often leading to increased delays due to reduced visibility and road safety concerns [9]. For example, during the research period in Shenyang, July 2024 had approximately five days of heavy or torrential rain, impacting delivery schedules. Traffic congestion can cause substantial delays in delivery operations, particularly during peak hours, when vehicle flow is heavily restricted [10].

5.2 Data Analysis

Figure 6 illustrates the increased delivery times on rainy days compared to clear days, showing a significant increase during the five days of torrential rain in July 2024.

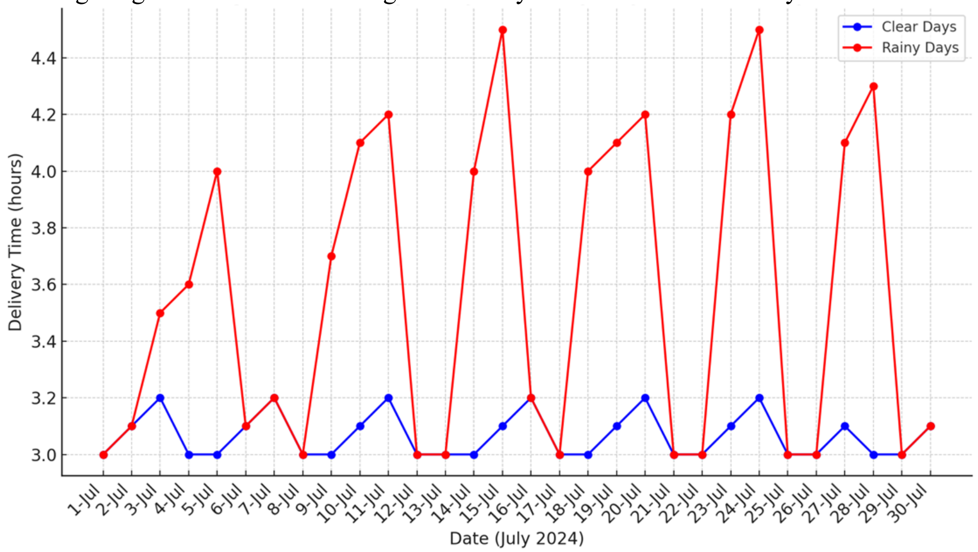

Fig. 6. Delivery Delays on Rainy Days vs. Clear Days.

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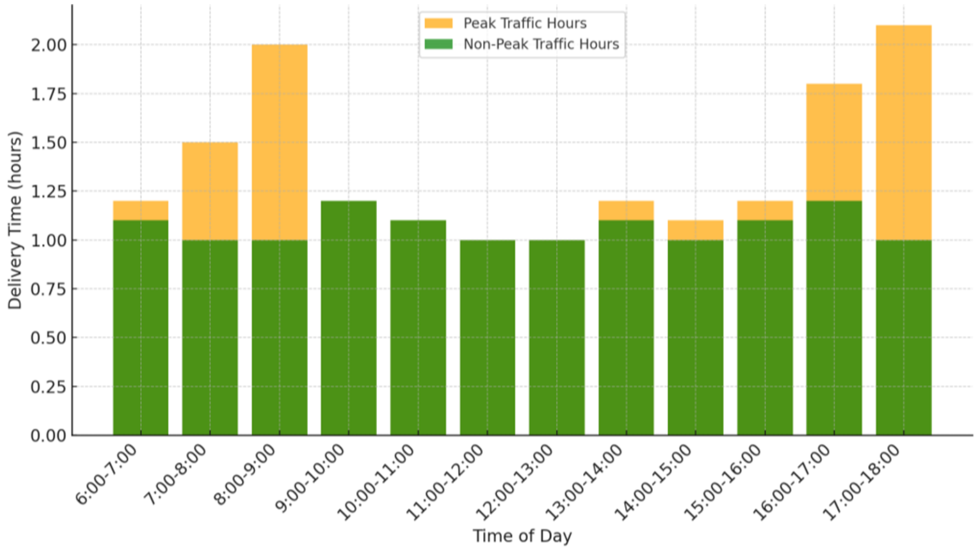

Fig. 7. Delivery Delays Due to Peak Traffic Restrictions.

Figure 7 highlights the traffic restrictions during peak hours and the corresponding delivery delays due to restricted truck access on major roads in Shenyang.

5.3 Solutions

(1) Contingency Plans for Severe Weather: Propose adding buffer times to account for weather-related delays. This can help maintain delivery schedules. even during unexpected storms. Suggest planning alternative routes that avoid flood-prone areas or road closures during severe weather.

(2) Adjusting Delivery Schedules for Traffic: Propose rescheduling deliveries to avoid the early morning and evening peak traffic periods when truck. restrictions are in place. Deliveries can be planned for late morning or afternoon when traffic is lighter and trucks are permitted. For time-sensitive deliveries, suggest pre-loading trucks and staging them at nearby locations to move. immediately when restrictions lift.

6 Impact of Special Events and Holidays

6.1 Problem Description

During holidays and special events, the order volumes typically surge beyond the usual levels, potentially overwhelming the delivery system. The impact of promotional events on supply chain performance highlights the importance of flexibility in logistics operations during peak demand periods [11]. For example, during holidays or promotional events, there is often a significant increase in orders, which can cause delays in deliveries, overwork staff, and increase operational costs.

6.2 Data Analysis

Figure 8 compares the average daily order volumes with holiday order volumes, showing the surge during holiday periods. The sharp increase in order volume during holidays signifies a major challenge for logistics and delivery systems, which must accommodate the surge in demand within a limited time frame. This surge can lead to delivery delays, as shown by the strain placed on resources such as vehicles, drivers, and warehouse capacity. The data suggests that the logistics system operates near capacity on regular days. With a surge during holidays, this capacity is exceeded, causing potential inefficiencies such as delays and increased operational costs. Without proper planning, the system may struggle to meet customer expectations for timely deliveries.

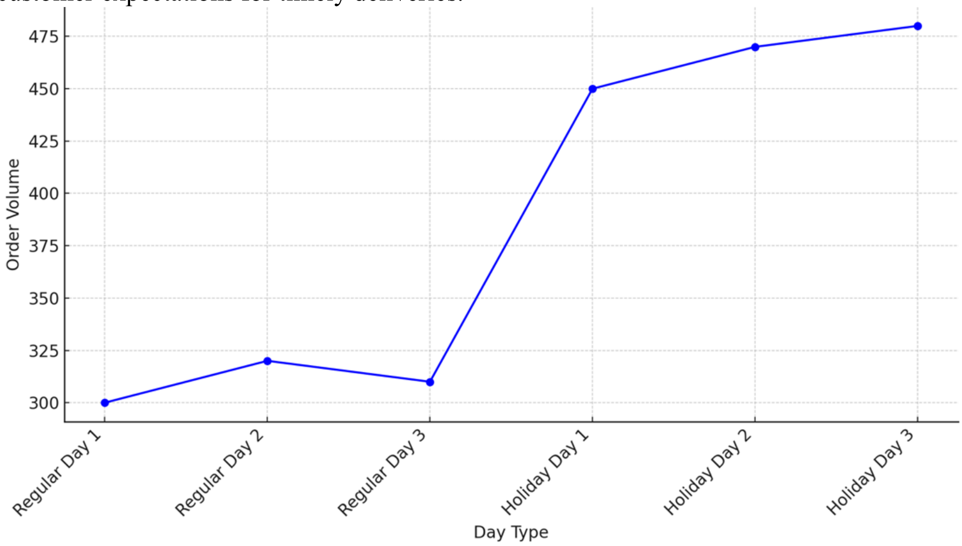

Fig. 8. Comparison of Average Daily Orders vs. Holiday Orders.

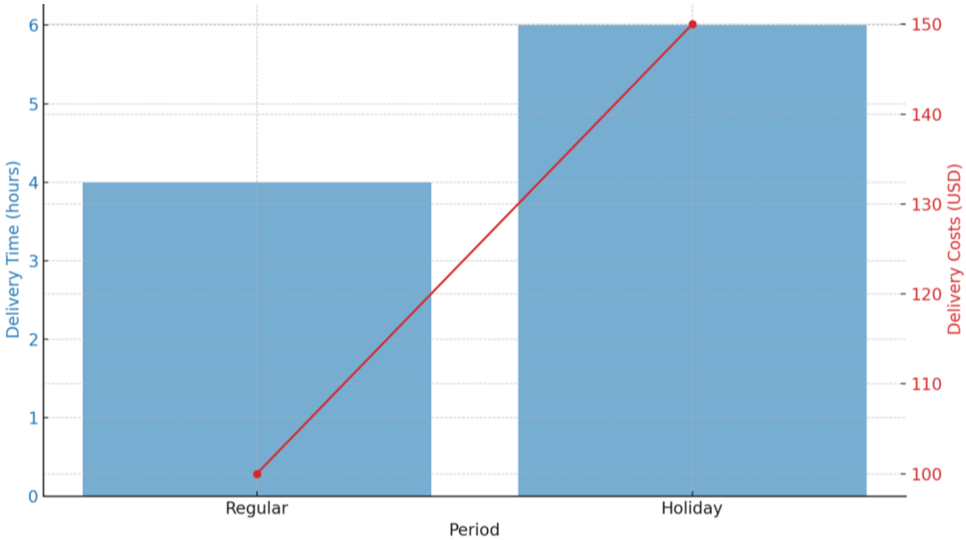

Fig 9. Delivery Times and Costs During Regular vs. Holiday Periods.

Figure 9 compares the delivery times and costs during regular and holiday periods. The simultaneous rise in both delivery times and costs during holiday periods shows a direct correlation between operational overload and expenses. As deliveries take longer due to high demand, companies face increased operational costs, such as compensating drivers for overtime or running additional shifts. The data reveals a clear challenge for logistics companies to maintain efficiency during special events. This inefficiency leads to longer waiting times for customers and a considerable increase in logistics costs for the company.

6.3 Solutions

(1) Increasing Fleet Size or Hiring Temporary Staff: Hiring temporary staff or increasing fleet size during peak periods like holidays can significantly reduce. delivery times and costs [12]. During peak holiday seasons, such as Black Friday, Cyber Monday, and the Christmas holiday season, Amazon. experiences a dramatic surge in order volumes, much like the surge depicted in Figure 1. To handle this increase, Amazon employs a comprehensive seasonal workforce strategy, which is a prime example of how companies can scale operations efficiently during high-demand periods.

(2) Adjusting Inventory and Warehouse Management: Managing inventory effectively during special events requires dynamic adjustment strategies to mitigate. delivery delays and stock shortage [13]. The logistics center, with its expandable space and auxiliary tools, can accommodate sudden increases in order volume. Propose reorganizing the warehouse layout or streamlining pick-and-pack processes to handle the higher. volume of orders more efficiently.

7 Conclusion

7.1 Key Findings

This study analyzed delivery operations within Lawson network, focusing on delivery times, costs, order distribution, and external factors such as weather and traffic. Several key inefficiencies were identified:

(1) Delivery Times: Longer routes such as Shenyang to Chaoyang and Jinzhou contributed significantly to increased delivery times, which negatively impacted operational efficiency.

(2) Costs: Rising fuel and labor costs, particularly on longer or less efficient routes, increased overall operational costs. Certain routes showed a disproportionately high cost per kilometer, highlighting the need for cost optimization.

(3) Order Distribution: The uneven distribution of orders across routes, with some routes like Shenyang to Jinzhou handling significantly higher volumes than others, resulted in inefficiencies. Underutilized routes could have been better leveraged to balance the load across the network.

(4) External Factors: Weather and traffic restrictions were found to be major external factors impacting delivery efficiency. Rainy days and peak-hour traffic restrictions led to delivery delays and higher operational costs.

7.2 Recommendations

Based on the data analysis, several strategies are proposed to optimize delivery operations:

(1) Route Optimization: Implement dynamic route optimization algorithms to reduce delivery times by avoiding traffic bottlenecks and using alternative routes during peak hours or severe weather.

(2) Balancing Order Volumes: Redistribute orders more evenly across routes to maximize vehicle capacity and reduce the strain on overburdened routes. This will also prevent underutilization of less-busy routes.

(3) Cost Efficiency: Reduce costs by introducing fuel-efficient vehicles on high-cost routes and considering multi-stop delivery options. Reducing delivery frequency on costlier routes or combining orders from different regions could also lead to cost savings.

(4) Handling External Factors: To mitigate the impact of weather and traffic, contingency plans such as buffer times or fleet expansion during peak demand periods are recommended. Adjusting delivery schedules to avoid peak traffic periods could further enhance efficiency.

7.3 Future Research

Future research could explore more advanced solutions to further optimize delivery operations:

(1) Machine Learning: Utilizing machine learning models to predict order volumes and delivery delays based on historical data, weather patterns, and traffic trends could enable more proactive and data-driven decision-making.

(2) Alternative Delivery Methods: Exploring alternative delivery methods such as drones and electric vehicles could result in long-term cost savings and improved environmental sustainability. Drones, for example, could be deployed to reach remote areas more quickly, bypassing traditional road networks, while electric vehicles would help reduce fuel consumption.

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