COMPARATIVE ANALYSIS OF LAST MILE DELIVERY (LMD) COSTS BETWEEN OUTSOURCING AND IN-HOUSE WITH THE IMPLEMENTATION OF VEHICLE ROUTING PROBLEM (VRP) AT PT RDI LOGISTIK MEDAN DELIVERY CENTER (DC)

[*1]Dicky Dianta Sitepu, **Melia Eka Lestiani**

[1,2]Universitas Logistik dan Bisnis Internasional, Bandung, Indonesia

Author's email:
*[*1]cky.sitepu12@gmail.com;[2] meliaeka@ulbi.ac.id*

**Corresponding author: cky.sitepu12@gmail.com*

Abstract. *The logistics industry faces significant challenges due to increasingly fierce price competition, mainly driven by the rapid growth of the e-commerce sector. Last Mile Delivery (LMD) shipping costs can reach 28% to 60% of total logistics costs, making it a very important area for optimization. PT RDI Logistik faces a big challenge in maintaining price competitiveness in this dynamic market. This study aims to compare the cost of LMD between two models, namely outsourcing (with a success-based fee per package system) and in-house (fleet management and human resources itself), with the application of route optimization using Vehicle Routing Problem (VRP). This study was conducted at the Delivery Center (DC) of PT RDI Logistik Medan city area, which serves 22 urban villages. The research methodology involves calculating the cost per package for both scenarios by considering Capital Expenditure (CAPEX), Operational Expenditure (OPEX), as well as operational risks that may arise. This analysis shows that the in-house model with the implementation of VRP can result in a reduction in cost per package of up to 7.11% compared to the outsourcing model, despite the higher operational risks. This research is expected to provide strategic recommendations for PT RDI Logistik in determining the most optimal Last Mile Delivery (LMD) method to increase the efficiency and competitiveness of the company in the courier and logistics industry.*

Keywords: *In-house Logistics; Last Mile Delivery; Outsourcing; Route Optimization; Vehicle Routing Problem.*

1. INTRODUCTION

In the modern business landscape, cost efficiency is a key prerequisite for logistics companies to remain competitive in the market (Mogale et al., 2025). The e-commerce sector has experienced very rapid growth, especially since the COVID-19 pandemic, which has significantly increased the volume of shipments as well as the complexity of logistics operations (Escudero-Santana et al., 2022).

Last Mile Delivery (LMD), which is the last phase of getting products from the distribution center to the customer's doorstep, is known to be the most complicated and expensive segment of the supply chain (Badrinarayanan, n.d.). The costs associated with LMDs can be as high as 28% to 60% of the total shipping cost (Badrinarayanan, n.d.). This condition is a major challenge for many logistics companies, because the inability to optimize and streamline the process can reduce price competitiveness in the market (*Minimasi Biaya Distribusi Es Balok dan Es Kristal Menggunakan Metode Capacitated Vehicle Routing Problem di PT Agronesia Es Saripetojo Bandung*, n.d.).

Challenges in the LMD phase include time efficiency, distance travel, number of couriers, delivery success rate, and high operational costs, especially in urban areas such as Medan City. As the third largest city in Indonesia, Medan has the characteristics of a complex geographical distribution, high traffic density, and variations in population density levels in each region.

PT RDI Logistik is a company engaged in courier and logistics, providing transportation and warehousing services to various regions in Indonesia, including the city of Medan. The company faces various challenges during the rapid growth of e-commerce, not only due to the increasing number of competitors, but also due to the pressure of increasingly fierce price competition, as shown in the following table.

Table 1. Service Tariff

No	Origin	Destination	PT RDI	JNE	JNT	SAP	Tiki	IDE
1	Pekanbaru	Medan	23000	23000	22000	24000	20000	21600
2	Jambi	Medan	40500	41000	30000	38000	25000	35100
3	Palembang	Medan	32000	44000	32000	36000	34000	34100
4	Bengkulu	Medan	36000	62000	36000	42000	43000	39100
5	BandarLampung	Medan	41500	49000	34000	37000	34000	35100
6	Aceh Barat	Medan	29000	29000	29000	28000	33000	-
7	Batam	Medan	34000	36000	38000	36000	36000	32100
8	Padang	Medan	21000	23000	22000	20000	19000	20600
9	Medan	Medan	7000	5000	7000	8000	6000	7100
10	Jakarta	Medan	37000	47000	36000	37000	39000	36100

Source: Raja Ongkir, 2025.

From Table 1 above, from several routes sampled, PT RDI Logistik has not been able to compete in terms of existing tariffs with competitors. These challenges can also be seen from the limited selection of PT RDI Logistik services on the e-commerce platform. This is due to the tendency of sellers who prefer delivery service companies with the most competitive rates to maintain buyer satisfaction, who of course want cheaper shipping costs, a fast delivery process, and a guarantee of package security. Based on the facts that occur in the field, customers will think twice when they want to use PT RDI Logistik's services. This will have an impact on the number of markets shares that PT RDI Logistik has managed to obtain in the e-commerce and non-e-commerce sectors.

Table 2. Market Share of Courier Services

Company	% Market Share
J&T Express	51.5%
JNE Express	11.4%
Tiki	11.6%
PT RDI Logistik	4.1%
Other	21.4%

Source: Top Brand Index, 2025.

Based on table 2 above, it is known that the market share obtained by PT RDI Logistik is only 4.1%. If this condition lasts for a long time, it is possible that PT RDI Logistik will be further behind in the increasingly competitive courier and logistics industry. Therefore, to maintain and increase its competitiveness, PT RDI Logistik needs to focus attention on the area that has the greatest potential for efficiency, namely the Last Mile Delivery (LMD) process.

Currently, PT RDI Logistik applies the outsourcing method in the implementation of the LMD process. Through the scheme, outsourcing partners will receive a fee based on the number of packages successfully delivered with the status of "successfully delivered", as well as additional bonuses in accordance with applicable terms and conditions. The "delivered success" status means that the recipient has received the package, and the delivery status has been recorded in the company's system.

Based on the available data, the average cost for each package successfully delivered by an outsourcing partner at PT RDI Logistik's Medan City Distribution Center (DC) ranges from 28% to 40% of the total shipping cost. So that if PT RDI Logistik can make efficiency in the Last Mile Delivery process, the company is expected to be able to compete with existing competitors.

Based on the explanation above, the problems faced in this study are the challenges experienced by PT RDI Logistik during very rapid e-commerce growth. This growth should be directly proportional to the increase in demand for package delivery services. However, the increase has not been followed by an increase in demand for PT RDI Logistik's services. This is due to the limited company services in the e-commerce sector and the high level of price competition in the logistics industry. Many sellers on various e-commerce platforms tend to choose shipping companies that offer the most competitive rates as their package delivery partners.

The purpose of this study is to conduct a comparative analysis of Last Mile Delivery (LMD) costs between the outsourcing model with the use of the fleet and its own employees, hereinafter referred to as the in-house model, combined through the application of Vehicle Routing Problem (VRP). It is hoped that with the implementation of VRP to optimize delivery routes and the optimal number of couriers, PT RDI Logistik can reduce operational costs, increase efficiency, and maintain its competitiveness in the market (Oloko, 2025).

The analysis follows several key stages, beginning with the calculation of Last Mile Delivery (LMD) costs under an outsourcing model, followed by a comprehensive assessment of in-house LMD costs that include Capital Expenditure (CAPEX), Operational Expenditure (OPEX), and associated risks. Next, the study simulates the impact of Vehicle Routing Problem (VRP) efficiency on overall in-house LMD costs to understand potential improvements. Finally, the results are used to determine the most optimal strategy for selecting an LMD model. After the most optimal method in the LMD strategy is determined, the results of this analysis will be used as a basis to provide recommendations to PT RDI Logistik to reconsider the policies currently implemented, if a more efficient and profitable method is found.

2. LITERATURE REVIEW

In recent years, various studies have been conducted focusing on Last Mile Delivery (LMD) optimization efforts. Research (Elvas et al., 2023) explains that companies need to look for technology-based solutions to improve LMD efficiency. All these intelligent solutions are built on the concept of Big Data, because large volumes of data allow predictions of future behavior based on historical knowledge.

The study (Loan et al., 2022) discusses the application of unattended delivery models, such as Crowd Delivery Platform (CDP) and Parcel Locker (PL), which are important trends in reducing delivery service companies' operational costs and are considered a key success factor in Business to Customer (B2C) delivery systems. Furthermore, the study (Nazari et al., 2018) proposes a new approach using reinforcement learning to solve computationally complex Vehicle Routing Problems (VRPs), and shows advantages in terms of solution quality, efficiency, and flexibility against more complex variants of the problem.

The research (Badrinarayanan, n.d.) highlights how AI and ML integration has brought major advancements to LMD operations, long known as the most complex and high-cost component of e-commerce logistics. Meanwhile, the study (Oloko, 2025) examines by applying predictive analytics, last-mile delivery routes can be optimized in real time using machine learning algorithms - such as decision trees and neural networks - trained on previous data to estimate traffic patterns, customer tendencies, and future delivery slots.

The study (Kumar Paul & Sarkar, n.d.) introduces a new machine learning method specifically designed to perform location-based last-mile delivery forecasting, with the main goal of reducing operational costs and improving the overall efficiency of companies in the supply chain and e-commerce sectors. Furthermore, the research (Pal, n.d.) explains that predictive analytics can provide solutions by combining machine learning, data, and advanced algorithms to optimize logistics decision-making in a proactive and data-driven manner. This approach aims to anticipate challenges, dynamically adjust routes, and ensure smooth logistics operations.

Research (Sekhar Veluru, n.d.) proposes an advanced framework that applies Generative Artificial Intelligence (Generative AI) to enhance delivery route planning by incorporating real-time traffic information and environmental factors. Its primary goal is to determine the most efficient routes to substantially lower operational expenses and delivery durations, while adjusting dynamically to fluctuations in traffic and weather. In contrast, study (Mogale et al., 2025) utilizes a case-based modelling method to solve the Multi-Depot Vehicle Routing Problem (MDVRP) encountered by Alpha Partnership Network (APN), the UK's leading retail company, as it seeks to expand its operations in the northern region.

Based on the description above, the researcher found a research gap, namely that most of the existing literature has not conducted a cost comparison analysis between outsourcing and in-house methods (fleet management and own employees) using the Vehicle Routing Problem (VRP) approach). Therefore, this study will focus on this analysis to determine the most optimal method for PT RDI Logistik's company.

3. RESEARCH METHODS

This study uses a quantitative approach with a case study at the Delivery Center (DC) Medan City of PT RDI Logistik. The analysis is carried out through numerical data processing which includes cost calculation, route optimization using Vehicle Routing Problem (VRP), and data validation through triangulation. The quantitative approach is strengthened by a mathematical formulation that includes the calculation of cost per package, total operating costs, as well as asset depreciation. The data collection process is carried out through observation and looking at documents.

The data used in this study were obtained through direct observations and interviews with management and operational staff at the Medan City Delivery Center (DC) of PT RDI Logistik, covering average vehicle capacity per trip, the number of daily delivery trips, and internal courier workload and productivity data such as travel time, shipments per route, and effective working hours. Additional information was collected from internal company documents, including financial reports, as well as external sources such as logistics industry publications and digital maps.

These data include the number of active outsourcing partners and their monthly fees, the average monthly volume of successfully delivered packages, six-month average LMD operational costs for outsourcing based on partner payment records, the addresses of 22 urban villages within the delivery area, their geographical coordinates obtained via the Google Maps API, inter-area road distance data, and the average daily package volume per sub-district, which serves as the basis for determining distribution workload per area.

Data Processing and Validation Techniques

All numerical data obtained were validated using three forms of triangulation: source triangulation, which involved operational data from the internal DC Medan report, interviews with operational staff, outsourced payment records, and delivery area address data; technique triangulation, which included field observations, internal documentation, and spatial data processing using distance matrices between delivery areas; and time triangulation, which utilized six-month average outsourcing cost data and six-month average inter-destination demand data to ensure stable and reliable demand patterns for comparison.

The spatial data is then processed using digital map analysis software to produce maps of the distribution of the area between and using Google Maps to calculate the distance matrix, which is the basis for the foundation for implementing the Capacitated Vehicle Routing Problem (CVRP) algorithm. This step ensures that the results of route simulation and cost estimates are highly valid and representative of the actual operational conditions of PT RDI Logistik.

Outsourcing vs In-House

Outsourcing is the practice of handing over some of the work to a third party who is an expert in a particular field to keep costs down and improve efficiency, while in-house means that all of the work is done by the company's own internal team. Outsourcing provides advantages in the form of time efficiency, cost savings, and access to professionals without the need for a long recruitment process, but has risks such as reduced control, potential quality problems and high turnover. In this study, the components of outsourcing costs consist of:

1. Cost for each package successfully delivered,
2. Calculation of the bonus of each package that is successfully delivered,
3. Operational risks are fully borne by the partners (0 costs for the company).

The calculation of outsourcing costs is calculated by the following formula:

$$Unit\ Cost_{outs} = \frac{Total\ Partner\ Payment\ Costs}{Total\ Package\ Succesfully\ Delivered} \text{ .... (1)}$$

Information:
$Total\ Partner\ Payment\ Costs$ = Average total payment to all outsourced couriers including bonuses in a month.
$Total\ Package\ Succesfully\ Delivered$ = average total packets successfully delivered (delivery success status).

In contrast, an in-house system provides full control over work processes, service quality, and data confidentiality, but incurs higher operational expenses due to the need for salaries, training, and supporting facilities. In this study, the in-house cost components include CAPEX-consisting of motorbike purchases, helmets, boxes or bags, safety equipment, and courier attributes-and OPEX, which covers courier basic salaries, allowances, insurance, fuel, vehicle taxes, and vehicle maintenance. The calculation of in-house costs is calculated by the following formula:

$$\text{Total Cost}_{\text{inhouse}} = \text{CAPEX Depreciation} + \text{OPEX} \text{ .... (2)}$$

$$\text{Unit Cost}_{\text{inhouse}} = \frac{\text{Total Monthly Cost}}{\text{Total Packages every Month}} \text{ .... (3)}$$

$$\text{Annual Depreciation} = \frac{\text{Acquisition Cost} - \text{Residual Value}}{\text{Economic Age}} \text{ .... (4)}$$

$$\text{Monthly Cost Depreciation} = \frac{\text{Annual Depreciation}}{12} \text{ .... (5)}$$

Information:
CAPEX Depreciation= depreciation of the cost of asset investment
OPEX = the entire operational cost of running the in-house model
Total Monthly Cost = all in-house expenses incurred in one month
Total Packages every Month = number of packages successfully delivered over a month
Acquisition Cost = cost of purchasing an asset investment
Residual Value= the residual value of the asset investment at the end of its economic life
Economic Age = Asset Usage Period (years)

Furthermore, the two cost calculations between the outsourcing model and the in-house model will be combined to calculate the value of savings and see which model is best. The calculation of the comparison of outsourcing costs with in-house costs is calculated by the following formula:

$$\text{Unit Cost Comparison Index} = \frac{\text{Unit Cost}_{\text{outs}}}{\text{Unit Cost}_{\text{inhouse}}} \text{ .... (6)}$$

$$Unit\ \text{Savings}\ \% = \frac{\text{Unit Cost}_{\text{outs}} - \text{Unit Cost}_{\text{inhouse}}}{\text{Unit Cost}_{\text{outs}}} \times 100\% \text{ .... (7)}$$

$$Unit\ \text{Savings} = \text{Unit Cost}_{\text{outs}} - \text{Unit Cost}_{\text{inhouse}} \text{ .... (8)}$$

$$\text{Monthly Savings} = \text{Unit Savings} \times 30 \text{ .... (9)}$$

Clustering

Before implementing the VRP, K-Means Clustering is applied to group villages based on geographical proximity and regional characteristics, with the aim of reducing the complexity of the VRP, creating a more balanced division of work areas, and producing more realistic delivery routes.

Clustering itself aims to decomposition the problem by applying K-Means to group delivery areas based on geographical proximity, so that the work area can be divided more efficiently and structured. This process begins by determining the optimal total number of clusters created using the Elbow Method, which is by calculating the Within-Cluster Sum of Squares (WCSS) for various values and selecting the "elbow" point on the graph. The kWCSS formula used is

$$\text{WCSS}(k) = \sum_{j=1}^{k} \sum_{x_i \in c_j} \| x_i - \mu_j \|^2 \text{.......... (10)}$$

where x_i is the data point of the delivery location, μ_j is the Centroid cluster Jth, and c_j is the dataset within that cluster. This approach allows for a more homogeneous division of areas so that routes, workloads, and resource requirements can be optimized more effectively.

Vehicle Routing Problem (VRP)

This study presents a comprehensive end-to-end framework for addressing the Vehicle Routing Problem (VRP). The VRP is a complex combinatorial optimization challenge that has been widely studied for many years, with its primary aim being to optimize multiple routes to maximize overall efficiency-typically by reducing total travel distance or service time, which in turn lowers operational costs.

The technical steps for conducting the Vehicle Routing Problem (VRP) in this study include determining the coordinates of the delivery regions, creating a distance matrix, clustering the areas, formulating and applying the CVRP model, calculating potential savings, optimizing the routes, and finally validating and visualizing the resulting routes.

Capacited Vehicle Routing Problem (CVRP)

Capacitated Vehicle Routing Problem (CVRP) is one of the variants of the Vehicle Routing Problem that focuses on determining the distribution route of goods by considering the maximum capacity of the vehicle so that the total mileage or distribution cost can be minimized without violating the load capacity limit. The assessment method is usually carried out using objective functions that measure the efficiency of the solution, such as total mileage, total distribution costs, number of vehicles used, or a combination of these factors; The results of the solution are compared with the optimal value or benchmark through optimization algorithms such as the exact method (branch and bound), heuristic (savings algorithm, nearest neighbor), or metaheuristic (genetic algorithm, tabu search, ant colony optimization). The mathematical formulations used are as follows:

$$\min \sum_{i=0}^{n} \sum_{j=0}^{n} c_{ij} x_{ij} \text{ .... (11)}$$

Information:

c_{ij}= distance from node i to node j

x_{ij}= 1 if a route is found, 0 if not

Clarke and Wright's Saving Heuristics

Clarke and Wright (CW) have created a Saving algorithm based on savings calculations that aims to combine two customers into a single route. CW is a heuristic method that has been widely used to solve VRP problems. This method starts by creating a solution with each customer served by a separate route. Next, two customer routes i and j are combined so that it results in savings in the form of mileage equal to $s_{ij} = c_{io} + c_{oj} - c_{ij}$ with c_{ij} = distance from customer i to customer j.

In the context of VRP, Clarks and Wright Saving works with the following general steps:

1. Starting from the initial solution in the form of an individual route, i.e. each customer is served by one vehicle: the initial route: for each customer.$0 \rightarrow i \rightarrow 0i$
2. Calculate the value of "savings" for each customer pair, using the formula:

$$s_{ij} = d_{i0} + d_{0j} - d_{ij}$$

The greater the value of savings, the more profitable it is to combine both customers in one route.

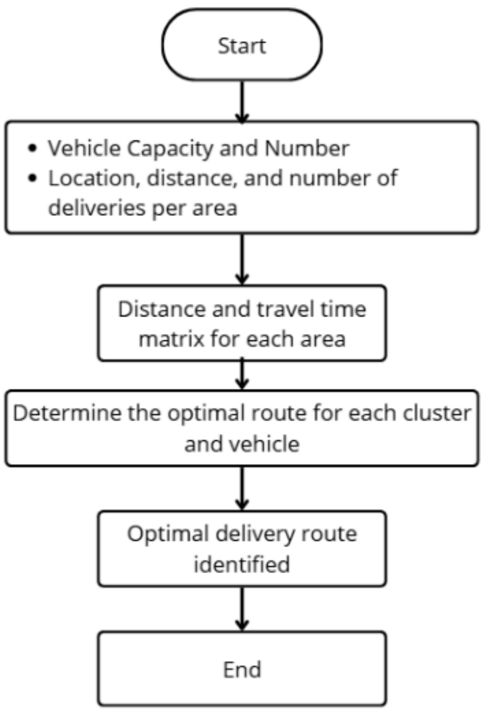
3. Sorts all customer pairs based on the largest to smallest savings value (greedy sorting). The greedy principle here: always choose the merger that provides the greatest savings first.
4. Check whether the two routes to be combined meet the capacity constraint. If the total demand of two routes ≤ the capacity of the vehicle, then merger is allowed.Q
5. Combining two routes into one new route, with structure:

$$0 \rightarrow \cdots \rightarrow i \rightarrow j \rightarrow \cdots \rightarrow 0$$

   This process is repeated in the order of the largest valid savings.
6. Repeat the merge process until:
   a. no longer have a customer pair with valid savings, or
   b. All possible routes have been combined according to capacity limits.
7. Resulting in a more optimal final route than individual initial solutions, as each greedy step maximizes total distance savings.

The steps to solve this research problem are presented in Figure 1 as follows:

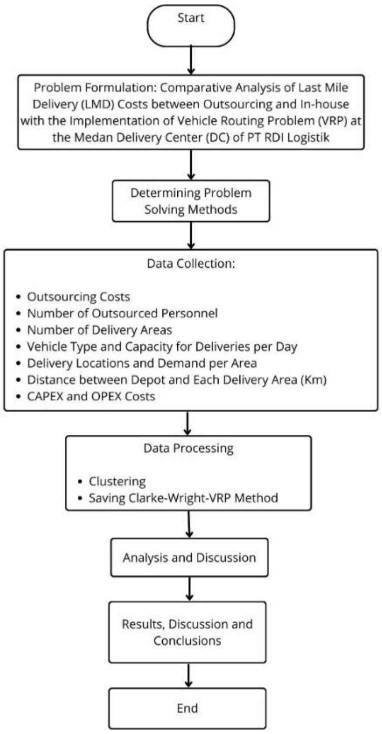
Figure 1. Flowchart of Troubleshooting Steps



Source: Author's Processing, 2025.

The algorithm of the route formation method can be explained in Figure 2 as follows:

Figure 2. Flowchart of Route Formation Steps



Source: Author’s Processing, 2025.

Last Mile Delivery (LMD)

The final phase of delivery, known as Last Mile Delivery (LMD), refers to the concluding step in the logistics chain where goods are transported directly to the customer’s doorstep. LMD is widely regarded as one of the most complex components of logistics due to the high level of uncertainty involved. Studies (Elvas et al., 2023) and (Milisavljevic & Vasić, 2024) define LMD as the last segment of the transportation process, specifically the movement of goods from the distribution center to the end customer. Despite being the shortest portion of the journey, LMD is the most costly-accounting for up to 50% of total logistics expenses-and the most difficult to execute effectively. Its performance plays a crucial role in shaping customer satisfaction and loyalty and serves as a key competitive differentiator for businesses.

4. RESULTS AND DISCUSSION

4.1 Demand Distribution and Delivery Area

Based on the results of data collection and processing, it was found that the Medan City Delivery Center (DC) serves 22 area with characteristics of demand volume and distribution distances. Each area has an average number of daily deliveries between 25 and 110 packages per day, with a total volume of around 12,000 packages per month. The geographic coordinate data of each area is obtained from Google Maps, which is used to map the company's main shipping nodes and depots.

Figure 3. Demand Distribution and Delivery Area

Wilayah	Label	Lat	Long	Demand
DC - Depot	Depot	3.594343	98.6809599	0
20111 - KEL. KESAWAN KEC. MEDAN BARAT, KOTA MEDAN	Area 1	3.5926463	98.6657803	354
20112 - KEL. PETISAH TENGAH KEC. MEDAN PETISAH, KOTA MEDAN	Area 2	3.5878858	98.6638695	186
20151 - KEL. A U R KEC. MEDAN MAIMUN, KOTA MEDAN	Area 3	3.5798205	98.6763897	29
20151 - KEL. HAMDAN KEC. MEDAN MAIMUN, KOTA MEDAN	Area 4	3.5708207	98.6667196	11
20152 - KEL. ANGGRUNG KEC. MEDAN POLONIA, KOTA MEDAN	Area 5	3.568924	98.6640281	8
20152 - KEL. MADRAS HULU KEC. MEDAN POLONIA, KOTA MEDAN	Area 6	3.5769463	98.6717091	21
20152 - KEL. J A T I KEC. MEDAN MAIMUN, KOTA MEDAN	Area 7	3.5745549	98.6669251	10
20157 - KEL. POLONIA KEC. MEDAN POLONIA, KOTA MEDAN	Area 8	3.5619039	98.6547458	15
20157 - KEL. SARI REJO KEC. MEDAN POLONIA, KOTA MEDAN	Area 9	3.5497068	98.6612443	6
20157 - KEL. SUKA DAMAI KEC. MEDAN POLONIA, KOTA MEDAN	Area 10	3.5590194	98.6631247	11
20158 - KEL. KAMPUNG BARU KEC. MEDAN MAIMUN, KOTA MEDAN	Area 11	3.5539729	98.6763637	10
20159 - KEL. SEI MATI KEC. MEDAN MAIMUN, KOTA MEDAN	Area 12	3.5674225	98.6815555	5
20159 - KEL. SUKARAJA KEC. MEDAN MAIMUN, KOTA MEDAN	Area 13	3.5730595	98.6821175	4
20217 - KEL. PASAR MERAH BARAT KEC. MEDAN KOTA, KOTA MEDAN	Area 14	3.5701709	98.6889546	6
20217 - KEL. PASAR MERAH TIMUR KEC. MEDAN AREA, KOTA MEDAN	Area 15	3.570964	98.6980981	4
20217 - KEL. TELADAN BARAT KEC. MEDAN KOTA, KOTA MEDAN	Area 16	3.564101	98.6878692	4
20217 - KEL. TELADAN TIMUR KEC. MEDAN KOTA, KOTA MEDAN	Area 17	3.5657445	98.6973581	7
20218 - KEL. SUDIREJO 1 KEC. MEDAN KOTA, KOTA MEDAN	Area 18	3.5601364	98.6958256	9
20218 - KEL. SUDIREJO II KEC. MEDAN KOTA, KOTA MEDAN	Area 19	3.555007	98.6969507	3
20219 - KEL. SITIREJO I KEC. MEDAN KOTA, KOTA MEDAN	Area 20	3.557743	98.6878311	7
20249 - KEL. SITIREJO II KEC. MEDAN AMPLAS, KOTA MEDAN	Area 21	3.5498697	98.6763229	7
20249 - KEL. SITIREJO III KEC. MEDAN AMPLAS, KOTA MEDAN	Area 22	3.548929	98.7013856	4

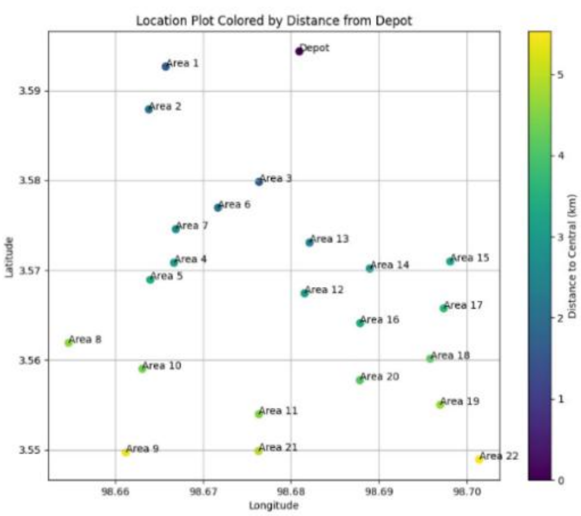
Source: Author's Processing, 2025.

This distribution of demand shows an uneven distribution pattern - urban areas such as Petisah and Medan Baru area have a high density of deliveries, while suburban areas such as Suka Maju and Helvetia Tengah show a relatively low volume of deliveries. This distribution inequality is an important basis for designing an efficient route model so that the allocation of courier workloads is more balanced.

4.2 Analysis of the Distribution Map of the Delivery Area

The results of the mapping based on latitude and longitude coordinates produced a map of the distribution of 22 points of the area between them, with one central point of the main depot.

Figure 4. Map of the Distribution of the Delivery Area



Source: Author's Processing, 2025.

This map depicts the geographical position and relative distance between regions which is then used to form a distance matrix between nodes. The distance matrix is the main input in the Capacitated Vehicle Routing Problem (CVRP) model developed in this study.

Figure 5. Matrix of Distance of Areas Between Areas (Km)

Label	Depot	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	A21	A22
Depot	0	1.5	2.5	2.3	2.6	4	2.7	3.3	5.7	7.8	5.5	5.6	3.9	3.3	3.8	4.7	4.5	5.4	5.4	5.7	5.1	6.6	6.8
A1	1.4	0	2.5	3.7	4	4.9	3.1	4.6	6.6	8.7	6.5	7	5.3	4.8	5.2	6.1	5.9	6.9	6.8	7.1	6.6	8	8.2
A2	3.3	3	0	3.5	3.2	2.7	1.6	3.6	4.4	7.8	5.5	6.6	4.9	4	5.1	6.1	5.5	6.8	6.7	7	6.2	7.9	8.1
A3	2.6	2.8	3.1	0	1	2.5	2.3	1.3	4.2	5.8	3.9	3.3	1.6	1.1	1.8	2.8	2.3	3.5	3.4	3.7	2.9	4.6	4.8
A4	3	3.2	3.5	1.2	0	2.2	2.6	0.8	3.5	5.4	3.1	3.8	2.2	1.2	2.3	3.2	2.7	4.1	3.9	4.2	3.4	5.1	5.4
A5	4.5	4.4	3.5	2.8	2.4	0	1.9	2	1.9	6.1	3.8	5	3.3	2.3	3.5	4.4	3.9	5.2	5	5.3	4.6	6.3	6.5
A6	3.3	3	1.2	2.4	2	1.3	0	2.3	3.3	6.4	4.1	5.3	3.6	2.7	3.8	4.7	4.2	5.4	5.3	5.7	4.9	6.6	6.8
A7	3.7	3.9	3.6	1.2	0.9	1.8	2.4	0	3.1	5	2.7	3.1	1.4	0.4	1.5	2.5	2	3.3	3.1	3.4	2.6	4.3	4.5
A8	6.5	6.3	4.5	4.7	4.5	3	4.5	4	0	5.4	5.8	7.2	5.3	4.3	5.4	6.4	5.9	7.2	7	7.3	6.5	8.2	8.4
A9	8	8.2	7.6	5.5	5.4	5.8	6.5	5.3	6.8	0	2.1	3.3	3.9	5	5.3	5.9	3.8	5.4	5	5.3	4.1	4.3	6.5
A10	6	6.2	5.8	3.5	3.4	3.7	4.3	2.8	4.7	2.3	0	1.4	1.9	3	3.2	3.6	1.8	3.4	3	3.3	2.1	3.5	4.4
A11	5.8	6	6.3	3.3	3.9	4.8	5.4	3.1	6.1	3.5	2.2	0	1.7	2.9	3	3.7	1.7	3.2	2.8	3.1	1.3	2.2	2.7
A12	4.1	4.3	4.7	1.7	2.2	3.1	3.7	1.4	4.4	4.3	3	1.8	0	1.2	2.1	2.7	0.7	2.2	1.8	2.1	1.4	3	3.2
A13	3.3	3.5	3.6	0.8	1.7	2.6	3	1	4.1	5.5	3.7	3	1.3	0	1.6	2.4	1.9	3.1	3	3.3	2.6	4.2	4.5
A14	3.6	4.5	4.9	1.8	2.4	3.3	3.9	1.6	4.6	5.6	4.2	3.1	1.9	1.4	0	0.8	1.7	1.8	2	2.8	2.8	3.7	3.9
A15	4.4	5.3	5.7	2.6	3.6	4.1	4.7	2.4	5.4	6.3	5	4.1	2.7	2.2	1	0	2.4	1	1.6	3.5	3.4	4.4	3.2
A16	4.7	5	5.3	2.3	2.8	3.7	4.3	2.1	5	4.2	3	1.7	0.7	1.8	1.7	2.3	0	1.8	1.4	1.7	1.3	2.6	2.9
A17	5.7	6.3	6.6	3.6	4.5	5	5.7	3.4	6.3	5.7	4.5	3.2	2.2	3.2	1.8	1	1.8	0	0.9	2.1	2.8	3.8	2.5
A18	5.6	6.1	6.5	3.5	4.4	4.9	5.5	3.2	6.2	5.3	4.1	2.9	1.8	3	2	1.5	1.4	0.95	0	1	3.3	2.7	1.8
A19	5.9	6.4	6.8	3.8	4.3	5.2	5.8	3.5	6.5	5.2	4	2.9	2.2	3.4	2.6	2.8	2.4	2.1	1	0	1.9	1.4	1.6
A20	5.1	5.7	6	3	3.9	4.4	5.1	2.8	5.7	4.2	3	1.3	1.4	2.6	2.1	2.5	0.7	2.2	1.8	2.1	0	3	3.2
A21	7.4	7.9	8.3	5.2	6.2	6.7	7.3	5	8	4.7	4.6	2.8	3.6	4.8	4.3	4.7	2.9	4.4	4	2.6	2.5	0	2
A22	7.1	7.7	8	5	5.5	6.6	7.1	4.8	7.7	5.7	4.3	3.3	3.4	4.6	4.1	3.2	2.7	2.6	1.9	1.5	2.3	1.7	0

Source: Author's Processing, 2025.

Figure 6.Matrix Time Travel Time Between Areas (Minutes)

Label	Depot	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	A21	A22
Depot	0	5	9	8	9	11	9	10	14	20	14	16	11	11	11	13	13	15	15	15	14	17	17
A1	4	0	8	11	12	13	10	12	16	22	16	19	15	14	15	15	17	18	18	19	18	20	21
A2	11	9	0	10	10	7	7	9	11	18	12	17	13	11	14	16	15	18	18	18	16	20	20
A3	8	9	10	0	4	8	8	4	11	15	9	9	5	4	5	8	7	9	9	10	8	11	12
A4	9	10	11	4	0	6	6	3	9	14	8	12	7	4	8	10	9	12	11	12	10	14	14
A5	13	13	8	8	7	0	5	5	6	14	9	13	9	6	10	12	11	14	13	14	12	17	16
A6	12	11	4	7	6	4	0	6	8	16	10	14	10	7	11	13	12	15	14	15	13	17	18
A7	10	12	11	4	3	6	7	0	7	12	6	10	5	2	7	9	7	11	10	10	8	12	12
A8	17	17	11	13	11	7	9	9	0	16	13	17	14	11	15	17	16	19	19	19	17	21	22
A9	20	22	18	14	13	13	15	11	14	0	5	9	9	13	14	15	10	14	13	13	10	12	15
A10	16	18	13	9	8	8	10	7	10	6	0	5	5	8	9	11	6	10	8	9	6	9	11
A11	15	17	18	9	10	13	14	8	15	9	5	0	4	8	9	10	5	9	8	8	4	6	8
A12	11	13	14	5	7	9	10	4	11	12	10	6	0	4	7	8	3	7	6	6	4	8	9
A13	9	11	12	3	5	9	10	4	10	15	9	9	4	0	6	7	6	9	9	10	8	12	12
A14	11	13	14	5	8	10	11	6	12	16	11	10	6	5	0	3	5	5	6	8	8	10	10
A15	12	15	16	7	9	11	12	7	14	18	12	11	7	6	3	0	7	4	6	9	10	11	11
A16	13	14	15	7	8	10	11	5	12	12	8	6	2	6	5	7	0	6	5	5	4	7	7
A17	14	18	18	9	11	13	15	9	15	16	12	9	6	9	6	4	6	0	3	6	8	9	8
A18	14	18	18	9	11	13	15	9	15	15	12	9	5	9	6	6	5	3	0	3	7	7	6
A19	15	18	19	10	12	14	16	10	17	14	11	7	7	10	8	9	6	6	3	0	5	5	5
A20	13	17	17	8	10	13	14	8	14	12	8	5	5	8	6	7	2	6	5	6	0	8	8
A21	18	21	22	13	15	17	18	12	19	13	12	7	9	13	11	12	7	11	10	8	6	0	6
A22	17	21	21	13	15	16	18	12	18	15	11	8	9	12	11	10	7	7	6	5	6	5	0

Source: Author's Processing, 2025.

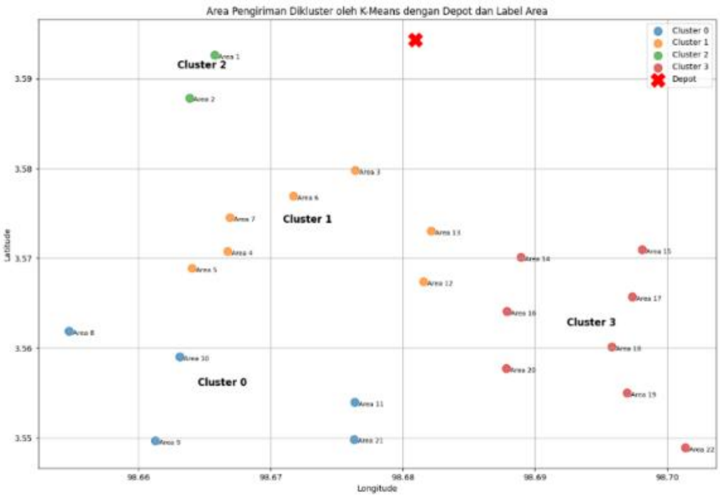
From the results of the visualization of the map, distnace matrix and the time travel matrix between the areas, it can be seen that areas with tight mileage between nodes (for example, in Medan Petisah and Medan Baru Districts) have the potential for more efficient route grouping, while farther areas demand route sharing with greater vehicle capacity to avoid excess travel time.

4.3 Results of the Delivery Area Cluster

To obtain an efficient division of work areas, a cluster process is carried out using the Elbow Method, which aims to determine the optimal number of clusters based on the within-cluster sum of squares (WCSS). From the results of the analysis, it was obtained that the optimal number of clusters is four (4), which are then defined as clusters 0, 1, 2, and 3. Important findings from the clustering results are:

1. Cluster 0 has 5 delivery areas with a total of 86 requests.
2. Cluster 1 has 7 delivery areas with a total of 110 requests.
3. Cluster 2 has 2 delivery areas with a total of 100 requests.
4. Cluster 3 has 8 delivery areas with a total of 104 requests.

Figure 7. Results of the Delivery Region Cluster



Source: Author's Processing, 2025.

This cluster process is the first step to determine the optimal number of couriers and routes for each area, with the aim of reducing the total distance traveled and delivery time.

4.4 Fleet Capacity and Operational Analysis

From direct observation data, it was obtained that each vehicle has an average carrying capacity of 40 packages per trip, with three trips per day. The type of vehicle used is a two-wheeled vehicle, generally using a duck or automatic motorcycle with a capacity of 110-150 cc because it is more efficient and agile for daily distribution. This motorcycle is equipped with a left-right double pannier bag made of waterproof canvas/tarpaulin with a capacity of about 20-25 kg per side and a size large enough to accommodate mail and package shipments. With this capacity, one courier is able to deliver around 120 packages per day, depending on the distance and traffic conditions. This capacity is the basis for calculating fleet needs in the in-house model, as well as the limiting variable in the Capacitated Vehicle Routing Problem (CVRP) method developed.

4.5 Determination of the Optimal Number of Couriers

Based on the simulation results of the 4 clusters that have been formed, it was obtained that the optimal number of couriers is 4 people, with a maximum capacity of 120 packages per courier per day. This value is obtained by considering the vehicle capacity of 40 packages per trip and the average number of trips three times per day. With this configuration, the company can serve all delivery areas with a balanced workload without increasing the number of couriers excessively.

4.6 Cost Analysis of Outsourcing Model

Based on PT RDI Logistik's internal data, the average monthly cost for seven outsourcing partners is IDR 27,000,000, with an average delivery volume of 12,000 packages per month. From the calculation, a cost of IDR 2,250 per successful delivery package is obtained. The outsourcing model provides operational flexibility and does not require an upfront investment, but cost efficiency is difficult to improve due to the fixed rate per package that must be paid to the partner, without considering route optimization or vehicle capacity.

This suggests that outsourcing systems, while effective in terms of labor control and asset risk, tend to result in relatively high fixed costs if shipping volumes increase, as well as being less adaptive to changing customer demand patterns.

4.7 In-house Model Cost Analysis

The in-house cost simulation considers Capital Expenditure (CAPEX) and Operational Expenditure (OPEX) over a 5-year period. The number of motorcycles and couriers in this simulation is taken from the determination of the optimal number of couriers, which is 4. The results are shown in the following Table.

Table 3. In-house Model Cost

Component	Total 5 Years	Monthly Average
CAPEX Depreciation	IDR 32,349,925	IDR 539,165
Salary	IDR 1,082,440,353	IDR 18,040,673
Allowances	IDR 238,000,000	IDR 3,966,667
Insurance	IDR 36,000,000	IDR 600,000
FUEL	IDR 96,000,000	IDR 1,600,000
Maintenance	IDR 15,000,000	IDR 250,000
Tax	IDR 5,000,000	IDR 83,333
Total	Rp. 1,504,790,278	IDR 25,079,838

Source: Author's Processing, 2025.

Calculations show that the cost to be incurred if using the in-house model is IDR 2,090 per package, slightly lower than the cost of outsourcing. Thus, the in-house model provides potential cost savings of around 7.11%, conditions that do not include the potential for additional efficiencies from route optimization.

4.8 Vehicle Routing Problem (VRP)

To ensure maximum efficiency, VRP is carried out based on the CVRP method based on the route pattern and the optimal number of couriers that have been found previously. The method used in building this CVRP model is Clarke and Wright Saving.

Table 4.In-house Model Cost Analysis

Courier	Area Cluster	Route	Distance Travel (Km/Trip)	Travel Time (Minutes/ Trip)	Demand (Unit/Day)	Trip / Day
1	0	Depot - Area 8 - Area 9 - Area 10 - Area 11 - Area 21 - Depot	24,2	64	86	2-3 Trip
2	1	Depot - Area 3 - Area 4 - Area 5 - Area 12 - Area 7 - Area 13 - Area 6 - Depot	16,9	55	110	3 Trip
3	2	Depot - Area 1 - Area 2 - Depot	7,3	24	100	3 Trip
4	3	Depot - Area 14 - Area 16 - Area 20 - Area 15 - Area 17 - Area 18 - Area 19 - Area 22 - Depot	20,9	59	104	2-3 Trip
Total			**69,3**	**202**	**400**	

Source: Author's Processing, 2025.

With the implementation of VRP that has been developed, operational efficiency has increased due to a reduction in total couriers, shorter delivery times, and a more balanced workload between regions

4.9 Comparison of Efficiency and Risk of the Two Models

Table 5. In-house Model Cost Analysis

Aspects	Outsourcing	In-house (VRP)
Cost per plan	IDR 2,250	IDR 2,090
Initial investment	None	Yes (CAPEX vehicle)
Operational risk	Low	Higher (vehicles, HR)
Quality control	Limited	Higher
Flexibility of scale	Tall	Intermediate
Route efficiency	Not optimal	Optimal with VRP
Long-term efficiency potential	Limited	Tall

Source: Author' Processing, 2025.

From the table above, the in-house model with VRP is superior in terms of cost efficiency and operational control. However, companies need to prepare adequate risk management, especially related to fleet maintenance, courier training, and performance monitoring systems to maintain operational reliability.

CONCLUSION

Based on the analysis and development of the Capacitated Vehicle Routing Problem (CVRP) model, it can be concluded that the cost of Last Mile Delivery (LMD) using an outsourcing model is Rp 2,250 per package, while the in-house model is more efficient at Rp 2,090 per package. The implementation of the CVRP model also generates significant operational savings, reducing total distance by 134 km and delivery time by 357 minutes. Overall, the CVRP enables companies to optimize the number of couriers and delivery routes, ultimately minimizing travel distance and improving delivery time efficiency.

REFERENCES

Badrinarayanan, A. (n.d.). *AI-Driven Optimization of Last-Mile Delivery*. www.ijfmr.com

Chandra, A., & Setiawan, B. (2018). *Optimasi Jalur Distribusi dengan Metode Vehicle Routing Problem (VRP) Optimizing the Distribution Routes Using Vehicle Routing Problem (VRP) Method*. *05*(02). http://ejournal.stmt-trisakti.ac.id/index.php/jmtranslog

Elvas, L. B., Tokkozhina, U., Martins, A. L., & Ferreira, J. C. (2023). Implementation of disruptive technologies for the last mile delivery efficiency achievement. *Transportation Research Procedia*, *72*, 32–39. https://doi.org/10.1016/j.trpro.2023.11.319

Kumar Paul, R., & Sarkar, B. (n.d.). AI-Powered Forecasting Algorithms to Optimize Last Mile Delivery. In *International Journal of Data Science Research and Development (IJDSRD)* (Vol. 1, Issue 2). https://iaeme.com/Home/issue/IJDSRD?Volume=1&Issue=2

Loan, N. T. C., Huyen, N. T., Loan, B. T. T., Giang, T. T. T., Trinh, H. T., Dat, K. M., & Mai, P. T. N. (2022). Last–Mile Delivery in B2C E-Commerce – Common Practices in Some Countries, But What Do They Mean for Businesses in Vietnam? *Journal of Hunan University Natural Sciences*, *49*(5), 21–32. https://doi.org/10.55463/issn.1674-2974.49.5.3

Milisavljevic, S., & Vasić, S. (2024). *Last mile delivery service as a crucial factor for business success: Companies' and consumers' perspectives and challenges*. www.iksadkongre.org

Minimasi Biaya Distribusi Es Balok dan Es Kristal Menggunakan Metode Capacitated Vehicle Routing Problem di PT Agronesia Es Saripetojo Bandung. (n.d.). https://doi.org/10.47491/landjournal.v4i1

Mogale, D. G., Ghadge, A., & Jena, S. K. (2025). Modelling and optimising a multi-depot vehicle routing problem for freight distribution in a retail logistics network. *Computers and Industrial Engineering*, *207*. https://doi.org/10.1016/j.cie.2025.111315

Nazari, M., Oroojlooy, A., Snyder, L. V., & Takáč, M. (2018). *Reinforcement Learning for Solving the Vehicle Routing Problem*. http://arxiv.org/abs/1802.04240

Oloko, O. (2025). Dynamic Route Optimization in Last-Mile Delivery Using Predictive Analytics: A Case Study of E-commerce in the U.S. *European Journal of Logistics, Purchasing and Supply Chain Management*, *12*(3), 1–32. https://doi.org/10.37745/ejlpscm.2013/vol12n3132

Pal, S. (n.d.). *Optimizing the Last Mile: Advanced Predictive Analytics for Delivery Time Estimation in Supply Chain Logistics INTERNATIONAL JOURNAL FOR INNOVATIVE RESEARCH IN MULTIDISCIPLINARY FIELD Optimizing the Last Mile: Advanced Predictive Analytics for Delivery Time Estimation in Supply Chain Logistics*. https://doi.org/10.2015/IJIRMF/202311010

Sekhar Veluru, C. (n.d.). A comprehensive study on optimizing Delivery Routes through Generative AI using Real-Time Traffic and Environmental Data. *Available Online Www.Jsaer.Com Journal of Scientific and Engineering Research 168 Journal of Scientific and Engineering Research*, *2023*(10), 168–175. www.jsaer.com