OPTIMIZING POSTAL SHIPMENT DISTRIBUTION ROUTES THROUGH A COMPARISON OF TWO OPTIMIZATION METHODSD

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ABSTRACT

Efficient and effective postal shipment distribution from branch offices to assistant branch offices in each district is one of the key factors in the operational success of courier service companies. The primary challenge faced is determining tertiary vehicle distribution routes that minimize shipping costs, time, and distance. This study aims to determine effective delivery routes and optimize both fixed and variable costs currently incurred by comparing several route optimization methods. The methods used in this research include direct observation and the collection of primary and secondary data. The analysis and compared methods are Nearest Neighbor and Saving Matrix. This comparison is expected to recommend the most effective route for courier shipments in the Jombang area. The study results demonstrate that each method has its advantages and disadvantages, depending on the optimization criteria used, such as distance, time, and cost. This research significantly impacts courier companies by providing practical solutions to enhance route effectiveness and efficiency. Optimizing distribution routes can reduce operational costs, save time, and improve distribution effectiveness.

Keywords: Saving Matrix, Nearest Neighbors, fixed costs, Routes, Optimizing.

1. INTRODUCTION

Courier companies play a vital role in delivering mail and packages (Davidich et al., 2023; Zdolsek Draksler et al., 2023), particularly in facilitating the distribution of goods from main branch offices to subsidiary offices. Optimizing distribution routes is essential for reducing operational costs(Maniah et al., 2023) and enhancing service quality (Kushariyadi et al., 2024). In the Jombang branch, determining the most efficient distribution routes remains a significant challenge. Current operational costs are approximately IDR 1,272,000 per day, with routes largely based on drivers' experience, leaving the question of their optimality unresolved.

As the demand for fast and reliable delivery services grows, optimizing distribution networks has become increasingly critical. Companies must address challenges such as varying shipment sizes, delivery schedules, and the complexity of urban logistics . Additionally, considerations of budget constraints and environmental sustainability play a pivotal role in achieving operational efficiency (Lotfalian et al., 2022).

Optimizing delivery routes not only improves logistics processes but also contributes to sustainability and long-term operational effectiveness (Febriyanti et al., 2022). Advanced methods, such as the Saving Matrix, have proven effective in streamlining distribution by improving delivery schedules, maximizing vehicle capacity, and reducing travel distances. Meanwhile, the Nearest Neighbor method offers a simpler, faster alternative, especially in scenarios where computational resources are limited or when rapid solutions are required .

This study aims to compare the performance of the Nearest Neighbor and Saving Matrix methods in optimizing postal shipment distribution routes for Jombang's branch offices. By analyzing operational data and evaluating both methods, the research seeks to identify the approach that delivers superior results in cost reduction, time efficiency, and service quality (Nam & Park, 2020). The findings are expected to provide practical insights for courier companies striving to improve their operations and maintain a competitive edge in the dynamic logistics industry (Chen, 2022; Szabó et al., 2021; Utama et al., 2021; Zhu et al., 2020).Below are data regarding the existing tertiary vehicle routes at the jombang branch offices, determined based on driver experience.

Table 1. Table Daily Operational Costs at Jombang Branch Offices

ROUTE	DISTANCE	COST
ROUTE A	47.8 km	Rp 421.000
ROUTE B	48.3 km	Rp 422.000
ROUTE C	57.4 km	Rp 429.000
DAILY OPERATING COSTS		Rp 1.272.000

From the table above, it is explained that currently in the branch office in the postal distribution route pattern there are 3 routes with the following descriptions:

a. Route A is a branch office (JG) => Peterongan District (PTR) => Mojoagung District (MJG) => Sumobito District (SBO) => Kesamben District (KSE) => branch office (JG) with a total distance of 47.8 km and a cost of Rp. 421.000,-.
b. Route B is a branch office (JG) => Bandar Kedungmulyo District (BDM) => Perak District (PEK) => Ploso District (PSO) => Tembelang District (TBE) => branch office (JG) with a total distance of 48.3 km and a cost of Rp. 422.000,-.
c. Route C is a branch office (JG) => Jogoroto District (JGT) => Mojowarno District (MJW) => Bareng District (BRG) => Ngoro District (NRO) => Gudo District (GDO) => Diwek District (DWK) => branch office (JG) with a total distance of 57.4 km and a cost of Rp. 429.000,-.

Therefore, the total daily distribution cost for the third route is Rp. 1.272.000,-. The main issues addressed in this research are as follows :

1. How to minimize shipping or operational costs
2. How to optimize postal shipment distribution routes from the branch office to assistant branch offices in the districts.
3. Which optimization method is most suitable for application in courier companies.

This research is significant as it will bring positive impacts to companies by ensuring more efficient resource utilization and lower operational costs. By comparing these methods, this study aims to provide the most appropriate recommendations for courier companies in Jombang Regency to optimize tertiary vehicle distribution routes. This research not only contributes academically to the field of distribution route optimization but also offers practical solutions for courier companies to enhance operational efficiency.

2. LITERATURE REVIEW

Route optimization is a critical aspect of logistics and supply chain management, aiming to minimize costs while improving service efficiency (Alweshah et al., 2022; Gunawan et al., 2023; Kurnia et al., 2021; Novelan et al., 2023; Xin et al., 2022). Two well- known methods for optimizing distribution routes are the Nearest Neighbor (NN) and Saving Matrix (SM) techniques (Ary Arvianto et al., 2023; Bolodurina et al., 2020; Hakim Gusti & Aryanny, 2023). The Nearest Neighbor method is a heuristic approach that selects the closest unvisited location at each step (Razita & Basaria, 2024), making it simple and efficient for smaller datasets or quick decision-making (Jin, 2022; Lubis et al., 2020; Masdzarif et al., 2023). However, it may result in suboptimal routes in complex networks where proximity does not guarantee efficiency (Pratiwi & Lubis, 2023; Setyo Oetomo et al., 2022).

In contrast, the Saving Matrix method, also known as the Clarke-Wright Savings Algorithm, evaluates potential savings by combining customer routes (Xin et al., 2022). This systematic approach is particularly effective in larger logistics networks, often producing more optimal solutions. However, it requires significant computational resources and time, which can be a drawback in real-time applications (Liu, 2020).

Both methods have been successfully applied to optimize logistics systems (Behmanesh & Pannek, 2021). For example, the Nearest Neighbor method has reduced travel distances in parcel distribution, while the Saving Matrix method has improved delivery efficiency in urban logistics by minimizing travel distances across multiple delivery points (S. Li et al., 2021).

Advances in technology have further enhanced these traditional methods. By integrating real-time data and machine learning algorithms, logistics systems can now predict traffic patterns and make dynamic route adjustments, improving efficiency, reducing costs, and enhancing customer satisfaction (He, 2022; J. Li et al., 2022).

The choice between the Nearest Neighbor and Saving Matrix methods depends on the logistics network's complexity (Riadhi et al., 2020). The Nearest Neighbor method is suitable for simpler problems with fewer stops, offering fast and efficient solutions (Ariyanto & Suseno, 2023). On the other hand, the Saving Matrix method is better suited for complex networks where cost-efficiency and optimality are critical, despite its computational demands (Masdzarif et al., 2023).

In conclusion, both methods contribute to improved route efficiency and reduced costs, supporting the effective use of resources in logistics and distribution (Prasertwit & Kanchanasuntorn, 2021). Selecting the appropriate method depends on the specific needs of the network and operational requirements (Maniah et al., 2023).

3. METHODS

The research methodology employed in this study involves direct observation of distribution route data from one of the largest and oldest courier companies in Jombang Regency. Additionally, primary data were collected from the company, including initial distribution route data, vehicle capacity, average daily load Assistant branch office, distances to Assistant branch office locations, and transportation costs categorized as fixed costs vehicle rental, personnel, security fees) and variable costs (fuel) (Supriyadi et al., 2021) Using this data, optimization was carried out using the Nearest Neighbors and Saving Matrix methods. Each method takes a different approach to solving distribution route problems, and the choice of the appropriate method significantly determines the success of route optimization. The Nearest Neighbors method is a straightforward approach that selects the nearest point as the next step in the route, while the Saving Matrix method combines points on routes that yield the highest cost savings (Setyo Oetomo et al., 2022).

3.1 Saving Matrix Method

The Saving Matrix method is utilized to determine distribution routes and the required number of vehicles to achieve the shortest possible routes and minimize transportation costs, taking vehicle capacity into account. This approach reduces both costs and travel distances by considering existing constraints(Salsabila Islami Yusnindi & Handayani, 2022): The process of applying the Saving Matrix method involves the following steps :

a. Determining distances
   The process starts by measuring the distances between customers. This step helps applications like Google Maps accurately calculate the distances between one customer and another.
b. Calculating distance matrices
   The distance matrix can be calculated using the matrix formula, allowing the magnitude of the distance values to be determined. The calculation is performed using the formula: $S_{ab} = C_{Da} + C_{Db} - C_{ab}$

   where:
   S_{ab} = Savings in distance
   C_{Da} = Distance from the depot to customer A
   C_{Db} = Distance from the depot to customer B
   C_{ab} = Distance between customer A and B.

3.2 Nearest Neighbor Method

The Nearest Neighbor method is an optimal route determination method for combinatorial problems. Unlike solutions that aim for the fastest result, this method approaches problem-solving by seeking the optimal value from a specific part of the main problem(Kurnia et al., 2021). The steps for route formation using the Nearest Neighbor method are as follows :

a. Select the central point as the starting point for delivery.
b. Determine the point with the smallest distance from the starting warehouse, then combine the two points.
c. The last visited point becomes the new starting point, and then find the nearest point from the starting point.
d. Repeat the process until the vehicle's capacity is no longer sufficient for delivery.
e. Connect the points with a single line; this becomes one travel route, with vehicle capacity being the constraint in forming a delivery route.
f. Repeat steps one to five (point e) for all remaining points.

4. RESULT

The observed courier company employs box trucks for postal shipment distribution to assistant branch office's. These vehicles are Daihatsu Grandmax Box units with the following specifications: dimensions of P x L x T (237 cm × 155 cm × 129 cm), a capacity of 4 CBM (cubic meters), and a maximum weight limit of 1 ton (1,000 kg). The following steps outline the data processing conducted to provide optimal postal shipment delivery routes

4.1 Distance Matrix

Measure travel distances from the branch office to each assistant branch office and between assistant branch office to assistant branch office using tools such as Google Maps.

Table 2. Table Distance Matrix (Kilo Meter)

	JG	PTR	MJG	SBO	KSE	BDM	PEK	PSO	TBE	JGT	MJW	BRG	NRO	GDO	DWK
JG	0	6.6	14.6	13.1	19.4	13.2	10.3	12.2	9.4	7.5	13.6	20	19.3	12.1	6.7
PTR	6.6	0	7.6	7.6	13.5	19.7	18	15.1	10.7	7.2	14.7	22.1	19.3	21.7	12.4
MJG	14.6	7.6	0	6.6	14.7	28.1	26.4	22.6	19.1	9.7	10.1	16.2	22.1	24	17
SBO	13.1	7.6	6.6	0	7.6	26.7	25	22.1	17.7	14.9	14.4	20.6	26.4	25.7	21.3
KSE	19.4	13.5	14.7	7.6	0	34.8	35.4	14.6	15.6	20.2	22.3	27.9	32.5	31.3	25.6
BDM	13.2	19.7	28.1	26.7	34.8	0	2	24.7	17	16.9	20.5	27.2	21.1	12.3	14.9
PEK	10.3	18	26.4	25	35.4	2	0	19.3	20.5	14.9	18.1	25.2	18.8	9.4	11.3
PSO	12.2	15.1	22.6	22.1	14.6	24.7	19.3	0	4.4	22.2	25.8	33.3	26.8	23	18.9
TBE	9.4	10.7	19.1	17.7	15.6	17	20.5	4.4	0	17.8	21.4	28.9	22.4	19.4	14.6
JGT	7.5	7.2	9.7	14.9	20.2	16.9	14.9	22.2	17.8	0	7.7	13.4	13.3	14.8	6.3
MJW	13.6	14.7	10.1	14.4	22.3	20.5	18.1	25.8	21.4	7.7	0	8.3	12.2	15.2	6.9
BRG	20	22.1	16.2	20.6	27.9	27.2	25.2	33.3	28.9	13.4	8.3	0	4.2	15.9	13.3
NRO	19.3	19.3	22.1	26.4	32.5	21.1	18.8	26.8	22.4	13.3	12.2	4.2	0	14.4	8.7
GDO	12.1	21.7	24	25.7	31.3	12.3	9.4	23	19.4	14.8	15.2	15.9	14.4	0	8.6
DWK	6.7	12.4	17	21.3	25.6	14.9	11.3	18.9	14.6	6.3	6.9	13.3	8.7	8.6	0

4.2 Route Optimization Using Saving Matrix

The Saving Matrix was calculated by connecting two or more districts into one route. Savings were computed using the formula : $S_{ab} = C_{Da} + C_{Db} - C_{ab}$

$$S_{PTR\text{-}MJG} = C_{JG\text{-}PTR} + C_{JG\text{-}MJG} - C_{PTR\text{-}MJG}$$

$$S_{PTR\text{-}MJG} = 6{,}6 + 14{,}6 - 7{,}6$$

$$S_{PTR\text{-}MJG} = 13{,}6$$

This process was repeated until the entire saving matrix table was filled :

Table 3. Table Saving matrix

	PTR	MJG	SBO	KSE	BDM	PEK	PSO	TBE	JGT	MJW	BRG	NRO	GDO	DWK
PTR	0	13.6	12.1	12.5	0.1	-1.1	3.7	5.3	6.9	5.5	4.5	6.6	-3	0.9
MJG		0	21.1	19.3	-0.3	-1.5	4.2	4.9	12.4	18.1	18.4	11.8	2.7	4.3
SBO			0	24.9	-0.4	-1.6	3.2	4.8	5.7	12.3	12.5	6	-0.5	-1.5
KSE				0	-2.2	-5.7	17	13.2	6.7	10.7	11.5	6.2	0.2	0.5

BDM					0	21.5	0.7	5.6	3.8	6.3	6	11.4	13	5
PEK						0	3.2	-0.8	2.9	5.8	5.1	10.8	13	5.7
PSO							0	17.2	-2.5	0	-1.1	4.7	1.3	0
TBE								0	-0.9	1.6	0.5	6.3	2.1	1.5
JGT									0	13.4	14.1	13.5	4.8	7.9
MJW										0	25.3	20.7	10.5	13.4
BRG											0	35.1	15.5	5.5
NRO												0	17	17.3
GDO													0	10.2
DWK														0

4.2.1 Sorting of Saving Values

The saving values obtained are sorted from the highest to the lowest. The highest saving value is selected, and in the next iteration, the row and column containing the highest saving value are crossed out. The iteration will stop when all entries in the rows and columns have been selected, resulting in the sequence of iterations based on the saving values.

Table 4. Table of Saving Values Sorted from Highest to Lowest

	PTR	**MJG**	**SBO**	**KSE**	**BDM**	**PEK**	**PSO**	**TBE**	**JGT**	**MJW**	**BRG**	**NRO**	**GDO**	**DWK**
PTR	0	13.6	12.1	12.5	0.1	-1.1	3.7	5.3	6.9	5.5	4.5	6.6	-3	0.9
MJG		0	21.1	19.3	-0.3	-1.5	4.2	4.9	12.4	18.1	18.4	11.8	2.7	4.3
SBO			0	24.9	-0.4	-1.6	3.2	4.8	5.7	12.3	12.5	6	-0.5	-1.5
KSE				0	-2.2	-5.7	17	13.2	6.7	10.7	11.5	6.2	0.2	0.5
BDM					0	21.5	0.7	5.6	3.8	6.3	6	11.4	13	5
PEK						0	3.2	-0.8	2.9	5.8	5.1	10.8	13	5.7
PSO							0	17.2	-2.5	0	-1.1	4.7	1.3	0
TBE								0	-0.9	1.6	0.5	6.3	2.1	1.5
JGT									0	13.4	14.1	13.5	4.8	7.9
MJW										0	25.3	20.7	10.5	13.4
BRG											0	35.1	15.5	5.5
NRO												0	17	17.3
GDO													0	10.2
DWK														0

Table 5. Table of Saving Values Sorted from Highest to Lowest Along with Routes

NO	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
SAVING VALUE	35.1	25.3	24.9	21.5	21.1	17.2	17,0	17,0	13.6	13.4	13,0	7.9
ROUTE	BRG-NRO	MJW-BRG	SBO-KSE	BDM-PEK	MJG-SBO	PSO-TBE	KSE-PSO	NRO-GDO	PTR-MJG	DWK-MJW	BDM-GDO	JGT-DWK

4.2.2 Sorting of Delivery Routes Using the Saving Matrix Method

From the sorted saving data above, two routes can be determined with a maximum vehicle load of 1 Ton or 1.000 kg and a fuel efficiency of 13 Km/L as follows:

Table 6. Table of Route Determination Results Using the Saving Matrix Method

NO	ROUTE	LOAD	DISTANCE	COST
1	JG-JGT-DWK-MJW-BRG-NRO-GDO-BDM-PEK-JG	1.000 kg	72,2 km	Rp. 440.000
2	JG-PTR-MJG-SBO-KSE-PSO-TBE-JG	900 kg	56,8 km	Rp. 428.000
TOTAL		1.900 kg	129 km	Rp. 868.000

4.3 Solution Using the Nearest Neighbor Method Approach

The Nearest Neighbor method, in each iteration, searches for the nearest assistant branch office to the last visited assistant branch office to be added to the end of the route. This chapter explains the steps involved in using the Nearest Neighbor algorithm as follows:

a. In this step, the process begins at the Branch Office (JG), where the distances to all 14 Assistant Branch Offices are measured. The distances vary, with the shortest being 6.6 km and the longest 20 km. Using the Nearest Neighbor algorithm, the closest Assistant Branch Office, located 6.6 km away in District Peterongan (PTR), is selected as the first destination.

Table 7. Table of Distances from Branch Office (JG) to HUB District Peterongan (PTR)

NO	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
HUB	**PTR**	**MJG**	**SBO**	**KSE**	**BDM**	**PEK**	**PSO**	**TBE**	**JGT**	**MJW**	**BRG**	**NRO**	**GDO**	**DWK**
DISTANCE	6.6	14.6	13.1	19.4	13.2	10.3	12.2	9.4	7.5	13.6	20	19.3	12.1	6.7
LOAD	250	200	100	50	50	150	200	100	50	200	100	150	50	250

b. The next step begins at District Peterongan (PTR), where distances to the remaining 14 districts are calculated. These distances range from 7.2 km to 22.1 km. Using the Nearest Neighbor algorithm, the closest district to PTR, which is District Jogoroto (JGT) at a distance of 7.2 km, is selected as the second destination.

Table 8. Table of Distances from PTR to JGT

NO	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
HUB	**PTR**	**MJG**	**SBO**	**KSE**	**BDM**	**PEK**	**PSO**	**TBE**	**JGT**	**MJW**	**BRG**	**NRO**	**GDO**	**DWK**
DISTANCE	0	7.6	7.6	13.5	19.7	18	15.1	10.7	7.2	14.7	22.1	19.3	21.7	12.4
LOAD	250	200	100	50	50	150	200	100	50	200	100	150	50	250

c. Repeat the steps above until only the last destination remains, as shown in the table below:

Table 9. Table of Distances from PEK to BDM

NO	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
HUB	**PTR**	**MJG**	**SBO**	**KSE**	**BDM**	**PEK**	**PSO**	**TBE**	**JGT**	**MJW**	**BRG**	**NRO**	**GDO**	**DWK**
DISTANCE					2	0								
LOAD	250	200	100	50	50	150	200	100	50	200	100	150	50	250

The courier company's postal distribution route has been optimized effectively using the Nearest Neighbor method. This approach determines the sequence of the closest hubs as follows: PTR - JGT - DWK - MJW - BRG - NGR - TBE - PSO - KSE - SBO - MJG - GDO - PEK - BDM. Considering the vehicle's capacity of 1 ton (1000 kg), the two most efficient distribution routes are:

- Route A is JG - PTR - JGT - DWK - MJW - BRG - NGR - JG
- Route B is JG - TBE - PSO - KSE - SBO - MJG - GDO - PEK - BDM - JG.

Table 10. Table of Route Optimization Using the Nearest Neighbor Method

NO	ROUTE	LOAD	DISTANCE	COST
1	JG-PTR-JGT-DWK-MJW-BRG-NGR-JG	1.000 kg	58,8 km	Rp. 430.000
2	JG-TBE-PSO-KSE-SBO-MJG-GDO-PEK-BDM-JG	900 kg	91,2 km	Rp. 455.000
TOTAL		1.900 kg	150 km	Rp. 885.000

4.4 Comparison Analysis of Methods

The comparison of costs and distances between the initial route and the proposed route after using the Saving Matrix method, compared with the Nearest Neighbor method, is as follows :

Table 11. Table of Comparison Between Saving Matrix and Nearest Neighbor

NO	ROUTE	LOAD	DISTANCE	COST
1	SAVING MATRIX METHOD	1.900 kg	129 km	Rp. 868.000
2	NEAREST NEIGHBOR METHOD	1.900 kg	150 km	Rp. 885.000
DIFFERENCE		0 kg	21 km	Rp. 17.000

The table summarizes cost calculations using two methods to determine the total distance for each route. This paper aims to compare these optimization methods to identify the more effective one, helping the company minimize distribution costs.

Various factors, such as route distances, influence cost calculations and significantly affect fuel expenses. By applying the Nearest Neighbor and Saving Matrix methods, more effective route planning can lead to substantial reductions in transportation costs.

Daily cost analysis shows that using the Nearest Neighbor method costs Rp. 885,000, while the Saving Matrix method costs Rp. 868,000, which is lower. Both methods successfully optimize routes and reduce operational costs from the original route cost of Rp. 1,272,000. However, the Saving Matrix method proves superior, saving an additional Rp. 17,000 per day compared to the Nearest Neighbor method.

5. CONCLUSIONS

Calculations using the Nearest Neighbor and Saving Matrix methods show that both approaches successfully minimized the total distribution distance for postal shipments. However, the Saving Matrix method was more effective in reducing both distance and costs. This method resulted in a daily cost of Rp. 868,000, which is Rp. 17,000 less than

the Nearest Neighbor method. It also reduced the route distance by 16% (24.5 km) and lowered daily costs by 32% (Rp. 404,000) compared to the original route. In conclusion, the Saving Matrix method is more efficient for reducing travel distances and distribution costs for the courier company. Future research should focus on developing a system to help drivers find alternative routes when encountering obstacles. Additionally, equipping vehicles with sensors to monitor loads could prevent overloading, reduce accidents, and further optimize costs.

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