

Article

Determination Of Delivery Routes For Food Materials At Healthy Food Brand Outlets In Bandung City Using Nearest Neighbor And Nearest Insertion Methods

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ABSTRACT

Efficient distribution is a critical factor in the food sales industry to ensure product quality, cost effectiveness, and customer satisfaction. The reliance on third-party online delivery services for distributing raw food ingredients has created significant logistics costs for a healthy food company in Bandung. To address this issue, the company aims to manage its own logistics using available delivery vehicles. The main challenge lies in determining the optimal delivery route that minimizes time and cost while serving an increasing number of outlets. This study applies a constructive heuristic approach to the Vehicle Routing Problem (VRP), since no prior research has examined delivery routes for this company. Constructive heuristics are chosen for their ability to provide feasible solutions that are easy and quick to implement. Two methods are employed: the Nearest Neighbor and the Nearest Insertion. The results indicate that the Nearest Neighbor method produces a total distance of 70.3 km, while the Nearest Insertion yields 68.1 km. Thus, the Nearest Insertion method achieves a shorter route by 2.2 km, equivalent to a 3.1% reduction compared with Nearest Neighbor. Based on these findings, the Nearest Insertion method is selected as the optimal route. This research provides a practical initial framework for improving logistics efficiency in food distribution and can serve as a foundation for future optimization studies.

1. Introduction

For a long time, many industries have relied on experience or intuition when planning delivery routes. This approach often results in suboptimal routes, where vehicles travel longer distances, spend more time on the road, and consequently increase operational costs (fuel, vehicle maintenance, driver wages). Other consequences include delivery delays, reduced product quality (especially for fresh food), and ultimately, customer dissatisfaction. Furthermore, inefficient distribution practices also contribute to traffic congestion and air pollution in cities. The average cost of logistics in Indonesia in 2019 based on Gross Domestic Product (GDP) was 23.2% (Santoso et al., 2021).

In the case faced by the company, which still uses online delivery services to deliver raw food ingredients to each outlet, this causes significant logistics costs. This gave rise to the idea of logistics delivery management by the company, supported by the availability of delivery vehicles. The next problem faced is how to determine the optimal delivery route so that all outlets can be served with minimal time and cost with the increasing number of outlets for this healthy food company in Bandung. Efficiency in the delivery of raw food materials is critically important for reducing operational costs. To overcome this problem, a more systematic and structured approach to distribution route planning is necessary. One relevant solution that has proven effective across various industries is the Vehicle Routing Problem (VRP).

The Vehicle Routing Problem (VRP) is a combinatorial optimization problem that seeks the optimal transport routes to serve a number of customers using a fleet of vehicles (Dantzig & Ramser, 1959). The Vehicle Routing Problem (VRP) calls for the determination of the optimal set of routes to be performed by a fleet of vehicles to serve a given set of customers, and it is one of the most important, and studied, combinatorial optimization problems (Toth P. & Vigo D., 2002). Problem (VRP) is a problem of distributing goods or services from one or several depots to a number of different customer locations, with a previously known amount of demand and with a number of limitations/constraints (Yeun et al., 2008). VRP has characteristics, namely vehicles deliver packages from the initial depot to the destination depot and return to the initial depot at the same location, the

amount of demand varies according to customer wishes, and the fleet can only visit the destination location once, another condition related to VRP is that the number of shipments to each destination location cannot exceed the available fleet capacity (Octora et al., 2014)

A study on proposed package distribution routes at PT. Pos Indonesia mail processing center Bandung, using the VRP method, was able to provide an evaluation of effective and efficient delivery routes, thereby lowering the company's operational costs (Martikasari & Yulianto, 2024). By implementing VRP, the food industry in Bandung can plan distribution routes more efficiently, reduce operational costs, increase customer satisfaction, and contribute to a better urban environment.

2. Literature Riview

The goal of the transportation method is to determine the best route from the starting location to the destination location so as to minimize total transportation costs (Heizer et al., 2024). The Vehicle Routing Problem (VRP) is a combinatorial optimization problem that seeks the optimal transport routes to serve a number of customers using a fleet of vehicles (Dantzig & Ramser, 1959).

This research will use Vehicle Routing Problem (VRP) methods, which are Construction Heuristics, which are the stages of building an initial solution. This study uses a constructive heuristic method because the company has never used the VRP method to determine delivery routes for each outlet. The solution needed in this case study is the initial route in this case study, which can be generated by the constructive heuristic method. The use of heuristic methods can be an alternative for solving VRPs with near-optimal results. Heuristic methods are divided into classical heuristics and metaheuristics (Kumar & Panneerselvam, 2012). The exact method, also known as optimization, uses a VRP solution approach by calculating each possible solution until optimal results are obtained, but it requires a fairly long time, while the heuristic method is used to solve complex route problems with near-optimal quality and shorter solution times compared to the exact method and metaheuristic method, because of this the heuristic method was chosen in solving route problems in this study (Asteria C., 2008).

In this case study, the company has never conducted research examining delivery routes using the Vehicle Routing Problem (VRP) method.

Therefore, this study will build an initial solution from the case study in determining delivery routes to each outlet. This study will use two Construction Heuristic methods: the Nearest Neighbor Method and the Nearest Insertion Method. The following is a brief explanation of the Vehicle Routing Problem (VRP) method, which is a Construction Heuristic and will be used in this study:

2.1. Nearest Neighbor

The Nearest Neighbor method is one of the simplest heuristics for solving the Vehicle Routing Problem (VRP), usually the computation time for this method is very fast. The nearest neighbor decision rule assigns to an unclassified sample point the classification of the nearest of a set of previously classified points (Cover & Hart, 1952). The Nearest Neighbor method is used to sort the routes created in the previous step. This route sorting process is carried out to reduce the distance traveled during the distribution process. This step is carried out by adding the store closest to the last visited store (Winangun & Baisa, 2023). Nearest neighbor has better and more realistic performance in route formation (Zheng et al., 2017).

The main goal of this method is to build a route by sequentially choosing the nearest customer. Here are the simple steps of the Nearest Neighbor method:

1. Start from the Depot: Begin at the depot (the starting point).
2. Find the Nearest Customer: From the current location (initially the depot), calculate the distance to all unvisited customers. Select the customer with the shortest distance.
3. Create the Route: Add the selected nearest customer to the route. This customer then becomes the current location for the next search.
4. Repeat the Process: Repeat steps 2 and 3 until all customers have been added to the route.
5. Return to the Depot: After all customers have been visited, return to the depot to end the route.

This method is "greedy" because it always makes the best decision at each step without considering its future impact. While it is fast and easy to implement, the results obtained may not always be globally optimal.

2.2. Nearest Insertion Method

Insertion Methods are a set of heuristic algorithms that build vehicle routes incrementally by inserting one unserved customer at a time into

an existing route. The Insertion method is a way of solving problems by inserting consumers between the sequence of consumers that have been formed to obtain maximum results (Abadi et al., 2014). The Insertion algorithm is used to form a tour by gradually building the shortest route with minimal weight. The Insertion algorithm is a method used to form a tour by gradually building the shortest route with minimal weight. This algorithm works by adding new points one by one to the route being built (Suparmi et al., 2020). Insertion begins by selecting a starting point with the criteria of the shortest distance from the depot to the first customer back to the depot, then continues by finding the shortest distance from the first customer, then the customer is inserted into the route sequence that has been formed so that the probability of getting the shortest distance is greater (Suryani et al., 2018).

This method often starts with a very simple initial route and then optimally adds other customers. There are several variants of this method, but the general main steps are as follows:

1. Initialize the Initial Route: Start with one or more empty routes, or a route consisting only of the depot and one customer. Determine the first customer to be visited.
2. Select Customers to Enter: Select unserved customers to enter, select the customer closest to one of the existing customers on the route.
3. Determine the Best Insertion Position: For the customer chosen in step 2, determine the best position to insert them into one of the existing routes. This best position is usually measured by the minimal increase in route distance. For example, if there is a route Depot \rightarrow A \rightarrow B \rightarrow Depot, consider inserting customer C between the Depot and A, A and B, or B and the Depot. Calculate the increase in distance for each possibility and choose the smallest one.
4. Insert the Customer: Once the best position is found and all constraints are met (e.g., vehicle capacity), insert the customer into the route.
5. Iterate: Repeat steps 2, 3, and 4 until all unserved customers have been successfully added to a route.

Overall, this method focuses on adding customers one by one in the most efficient location at that moment, resulting in a reasonably good solution with relatively fast computation time.

3. Research Methodology

The following is a description of the research methodology that will be used in the study titled

"Determining Food Ingredient Delivery Routes to Healthy Food Brand Outlets in Bandung City Using the Vehicle Routing Problem (VRP) Heuristic Method."

The preliminary study begins with an initial field study, where researchers conduct direct observation, unstructured interviews, and preliminary surveys to identify problems, context, and real-world conditions relevant to the research topic. In line with this, initial data is also collected, including the addresses of the warehouse and sales outlets, the capacity of the transport vehicles, their maximum travel distance, and the average weekly needs of the outlets. The preliminary study also includes a literature review, where the researchers search for and analyze various references related to the Vehicle Routing Problem (VRP).

This research will use Vehicle Routing Problem (VRP) methods that are Construction Heuristics, which is the stage of building an initial solution. In this case study, there has been no previous research that has examined delivery routes using the VRP method, so this study will build an initial solution for this case. This research will use two Construction Heuristics methods: Nearest Neighbor and Insertion Methods. In this study, the VRP Calculator software will be used for the path determination process using the Nearest Neighbor method and Google Sheets for the calculation process for determining the shortest path using the Nearest Insertion method. The research methodology flowchart can be seen in Figure 1.

After obtaining the input, which consists of the addresses of the warehouse and sales outlets, the coordinates will be determined using Google Maps. Once the coordinates are obtained, data will be collected, including the distance from the warehouse to each outlet and the distance between each outlet. After this data is obtained, the next stage will be to find the optimal route using the Nearest Neighbor and Insertion Methods.

After the results from both methods are obtained, an analysis will be conducted to determine the best route solution. The criterion for the best travel distance is the route that has the shortest total travel distance compared to the route results obtained from the data processing

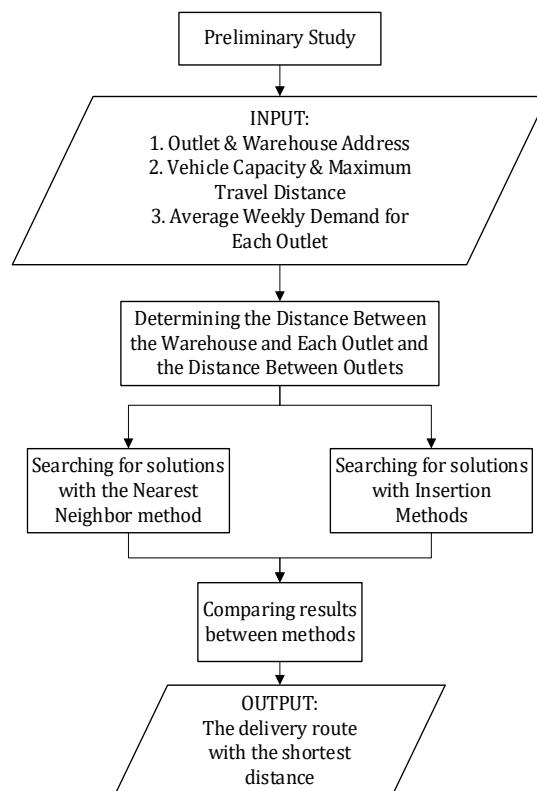


Fig. 1 Research methodology flowchart

4. Results and Discussion

4.1 Data Collection

This study identified one warehouse (depot) and seven outlets across Bandung. The delivery vehicle's load capacity is 1,500 kg, with a maximum delivery distance of 100 km per day. The average weekly needs of each outlet, converted into kilograms, can be seen in Table 1. A summary of the distance between the depot and each outlet, as well as the distance between each outlet in kilometers, can be seen in Table 2.

Table 1 The average weekly needs of each outlet, converted into kilograms

Outlet	Needs (Kg)
A	113.772
B	72.341
C	206.312
D	171.970
E	272.444
F	98.152
G	121.518
TOTAL	1,056.508

Based on the total average weekly requirements of all outlets in Bandung, a total

weight of 1,056.508 kg was obtained. This data leads to the conclusion that the vehicle's capacity is sufficient to accommodate the entire average weekly demand of all seven Bandung outlets; consequently, only one vehicle is needed for raw

material delivery. The results of the delivery route determination from the warehouse to the Bandung outlets, utilizing the Nearest Neighbor method, are presented in Table 3.

Table 2 Summary of the distance between the depot and each outlet, as well as the distance between each outlet in kilometers

Form \ To	Depo	Outlet A	Outlet B	Outlet C	Outlet D	Outlet E	Outlet F	Outlet G
Depo	0	5,2	5,9	7,2	5	10,3	14,3	9,1
Outlet A	5,3	0	6,1	6,5	3,9	10,5	12,7	16,4
Outlet B	5,8	7	0	11,6	3,9	5,9	20,5	13,7
Outlet C	6,4	7	10,5	0	8,4	15	8	20,9
Outlet D	3,7	4,1	3,9	9,6	0	8,5	17,6	14,4
Outlet E	8,5	9,7	4,9	14,3	6,2	0	21,3	15,1
Outlet F	13,9	13,9	20,1	9,8	17,9	24,7	0	21,1
Outlet G	10,2	17,1	10,6	17,2	10,9	17	22,2	0

Table 3 The results of the delivery route determination with nearest neighbor method

Depo	D	B	E	A	C	F	G	Depo	
→	→	→	→	→	→	→	→		
	5	3,9	5,9	9,7	6,5	8	21,1	10,2	
Total	70,3 Km								

Based on the route obtained using the Nearest Neighbor method, the total travel distance is 70,3 km. The vehicle route generated by the Nearest Neighbor method is shown in Figure 2.

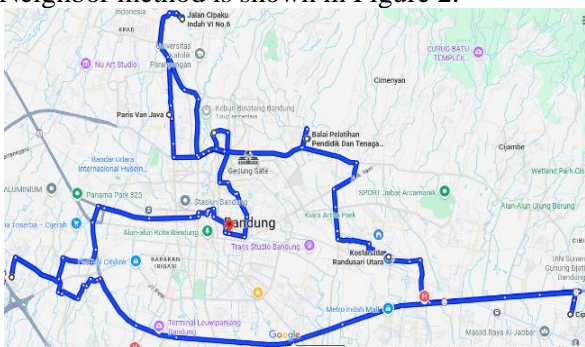


Fig. 2 The vehicle route generated by the Nearest Neighbor method

This study employs the Nearest Insertion method. The determined delivery routes for raw materials from the warehouse to the Bandung outlets, as generated by the Nearest Insertion method, are presented in Table 4.

Table 4 The results of the delivery route determination with nearest insertion method

Depo	C	F	A	D	B	E	G	Depo
→	→	→	→	→	→	→	→	
	7,2	8	13,9	3,9	3,9	5,9	15,1	10,2

Total Jarak	68,1 Km
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Based on the route obtained using the Nearest Insertion method, the total travel distance is 68,1 km. The vehicle route generated by the Nearest Insertion method is shown in Figure 3.



Fig. 3 The vehicle route generated by the nearest insertion method

Based on the results from both methods, the Nearest Insertion method yielded a shorter travel distance of 68.1 km compared to the Nearest Neighbor method's 70.3 km. Therefore, the route to be used will be based on the Nearest Insertion method.

Depo C → F → A → D B → E → G → Depo
→ → → → → → → → →

5. Conclusion

Based on the results of determining the raw material delivery route using both methods, the distance traveled by the Nearest Neighbor method

was 70.3 km and by the Insertion method, it was 68.1 km. In this research case, the method chosen to determine the route is the Nearest Insertion Method, because the distance is shorter than the Nearest Neighbor method. If the vehicle's fuel consumption is known to be 12.5 km/L, the fuel consumption using the Nearest Neighbor method is 5.624 liters, and the fuel consumption using the Nearest Insertion method is 5.448 liters. The Nearest Insertion Method 's distance was 3,1% or 2,2 km shorter than the Nearest Neighbor method.

This is because in the route determination process, all destination points are compared and the shortest path is selected one by one, resulting in better results than the Nearest Neighbor method. The disadvantage of the Insertion method is that it requires longer iterations than the Nearest Neighbor method. While the Nearest Neighbor method's steps are simpler than the Insertion method, the results are not as optimal.

The Nearest Neighbor and Nearest Insertion Methods are heuristic methods in the Vehicle Routing Problem, so the resulting solution for determining the path is still locally optimal. Therefore, this research can still be developed to find a better solution by using improvement methods or metaheuristic methods with adding time windows.

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