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Route Optimization In Pharmaceutical Distribution Using Savings Matrix And Nearest Neighbor Heuristics: A Simulation-Based Study

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ABSTRACT
Drug distribution is one of the important factors in the pharmaceutical supply chain that directly affects operational costs and the speed of customer service. This study aims to optimize the distribution route at XYZ Pharmaceutical Warehouse, which previously used an inefficient delivery pattern, resulting in additional costs and delivery delays. This research implements the Clarke–Wright Saving Matrix and Nearest Neighbor heuristic methods and performs validation using Arena simulation. The analysis results show that the combination of the two methods can reduce the total distribution distance from 121.35 km to 103.90 km, or a reduction of 14.38%. The Nearest Neighbor method produced routes with shorter distances, while the Saving Matrix was superior in maximizing vehicle capacity. Simulations using Arena reinforced the results by showing potential savings in operational time and variable costs, particularly in fuel consumption and driver working hours. These findings confirm that the application of simple heuristic algorithms is still relevant in the context of pharmaceutical distribution, with significant implications for cost efficiency and productivity. Further research is recommended to integrate specific pharmaceutical constraints, such as time windows and cold chain, as well as metaheuristic approaches for more robust solutions.

Keywords: Distribution, Saving Matrix, Nearest Neighbor, Route Optimization

INTRODUCTION

The distribution system can be said to be a process carried out by producers and distributors to distribute goods or services to consumers. Meanwhile, distribution is known as the process of moving goods from suppliers to consumers in a supply chain. Distribution is an important part of the company's profits because it directly affects supply chain costs and consumer needs. The right distribution network can achieve a variety of supply chain goals, from low prices to high response to demand [1].

Distribution involves shipping or delivering products from factories or distribution centers to customers through transportation networks [2]. During the process of distributing goods, it is very important to pay attention to determining the delivery schedule and also the route that the fleet passes in the delivery process. In the delivery process, the delivery schedule and the route to be passed will affect the total distance traveled, which will also affect travel time and transportation costs. The main objective of determining schedules and routes is to reduce costs, where this cost minimization is related to the minimum distance [3].

Procurement can also be said to be an effort to obtain the goods or services needed in a logical and systematic way and following applicable standards and ethics in accordance with standardized procurement methods and processes. Because it is directly involved in the production process and operating activities, procurement is a profit center because it determines production costs and work results and determines company profits. In the process of implementation, procurement can be done conventionally and also electronically. Conventional goods and services procurement system. In this system, communication between the procurement committee and the service provider is done directly, which causes many errors in the procurement process. In addition, this procurement system requires a lot of time and money, is not transparent, and is not fair [4].

Distribution is part of one of the marketing activities where this distribution activity can be carried out by sending, delivering, or distributing products from producers or agents to consumers. Based on the explanation above, the role of distribution in marketing activities is very important. Distribution activities themselves have the function of facilitating and ensuring that products reach consumers. This is what makes distribution play a very important role in marketing activities. It can be imagined that if there are no distribution activities, the goods that have been produced will not reach consumers [5].

The meaning of distribution is the activity of moving both goods and services through distribution channels from distributors or suppliers which are then distributed to end consumers. Distribution also means activities that distribute goods or services to consumers and also facilitate or facilitate the arrival of these goods or services to consumers so that consumers can use the goods needed [6]. To be able to realize efficient and effective distribution activities, every company must have a distribution plan so that goods or services can be distributed optimally to consumers and also reduce losses to the company [7].

The distribution process at the XYZ Pharmacy Warehouse uses 2 delivery distribution routes. The selection of the current distribution flow is not based on effective calculations, so that the distribution flow that is passed is ineffective. In the distribution process, the car will deliver medicines the car leaves for the location on the first route and continues on the second route until all outlets' requests are met. Delivery time of 4 to 5 hours. As a result, the company incurs overtime costs for drivers and also the costs required for the distribution process will be more. For example, in December 2023 the company has spent IDR 11,234,995 for the distribution process caused by the length of the distribution flow or the selection of the distribution route is not appropriate.

Based on the problems presented above, an appropriate and optimal distribution route is needed in the drug delivery process in order to minimize the costs incurred in the distribution process. In solving the problem, determining the best route is done by using the saving matrix method and the nearest neighbor method. The output of these two methods is the right distribution route and minimizes costs [8]. The saving matrix method will determine the best delivery route by considering the distance traveled by the vehicle and the carrying capacity of the car used. The nearest neighbor method will determine the shortest route based on the closest point to the outlet to one another [9].

Validating the route that has been made is done by simulating the route that has been formed. Simulation is a process that runs a model that aims to estimate measurements of a job performance of a real system which is then modeled using computer assistance. One of the software used to perform simulations is Arena software. Arena software will show a visualization of the simulation process with several modules provided by Arena to solve problems.

METHOD

The research methodology is a method that is carried out in advance with stages or steps in a study. The research method starts from problem identification, theoretical basis, data collection, data processing, analysis, and closing [10].

Problem Identification

The problem that occurs at the XYZ Pharmacy Warehouse is that the distribution routes currently used are not effective, so the distribution process takes a lot of time and also increases distribution costs. In addition, the XYZ Pharmacy Warehouse has not implemented effective calculations in the formation of distribution routes, resulting in delays in drug delivery. Based on these problems, the problem identification obtained is related to effective routes in drug delivery at the XYZ Pharmacy Warehouse.

Setting Research Objectives

Determination of research objectives is intended to be a guide to researchers to achieve the objectives to be obtained [11], [12]. With the determination of the objectives, the researcher will focus more on the object of research so that the research can run in a structured manner and not go through the path of the problem to be studied [13], [14], [15]. Based on the above problems, the purpose of this study is to determine the optimal drug distribution route at the XYZ Pharmacy Warehouse based on the Saving Matrix method and the Nearest Neighbor method and Arena Simulation to minimize the distribution route [16][17].

Data Processing

Processing is carried out based on quantitative methods. The stages of data processing carried out in this study are as follows:

The saving matrix method is one of the heuristic methods that can be used to solve transportation problems in determining distribution routes and distribution schedules [18]. Saving matrix can solve transportation or product distribution problems by determining product distribution routes with the aim of minimizing transportation costs [19]. By using the saving matrix method, we can determine vehicle scheduling by considering the maximum capacity of the vehicle and can combine several product delivery points [20]. This saving matrix method has a vehicle assignment output that matches the maximum capacity of the vehicle to the delivery area based on the greatest savings [21].

Arena Simulation

Arena is a simulation program or software released by the modeling corp system. Based on object orientation, this program offers templates and interchangeable alternatives of graphic and analysis simulation models, which are combined to produce a wide and varied simulation model [22]. Arena also has a drag drop system [23], [24], two-dimensional animation, and compa level. Arena is designed to solve discrete system simulation problems and has the advantage, although not so complete, of statistical data processing capabilities [25].

Using Arena Software can model experiments by placing modules or boxes of different shapes, which indicate processes or logic [26]. Simulation is the process of collecting data into quantities that are then repeated, or replicated, to make it possible to evaluate the results of the simulation [27], [28], [29]. To determine the length of the simulation, the most common method is to conduct several experiments with various random numbers to find the mean and standardized variables [30] [31], [32], [33].

RESULTS

Drug demand from each outlet varies weekly, requiring quantitative analysis to determine average demand and compare it to distribution vehicle capacity. Drug demand data collected over four weeks provides insight into customer consumption patterns and the varying demand that distribution must meet. The following table presents weekly drug demand from each outlet, along with average demand and available vehicle capacity.

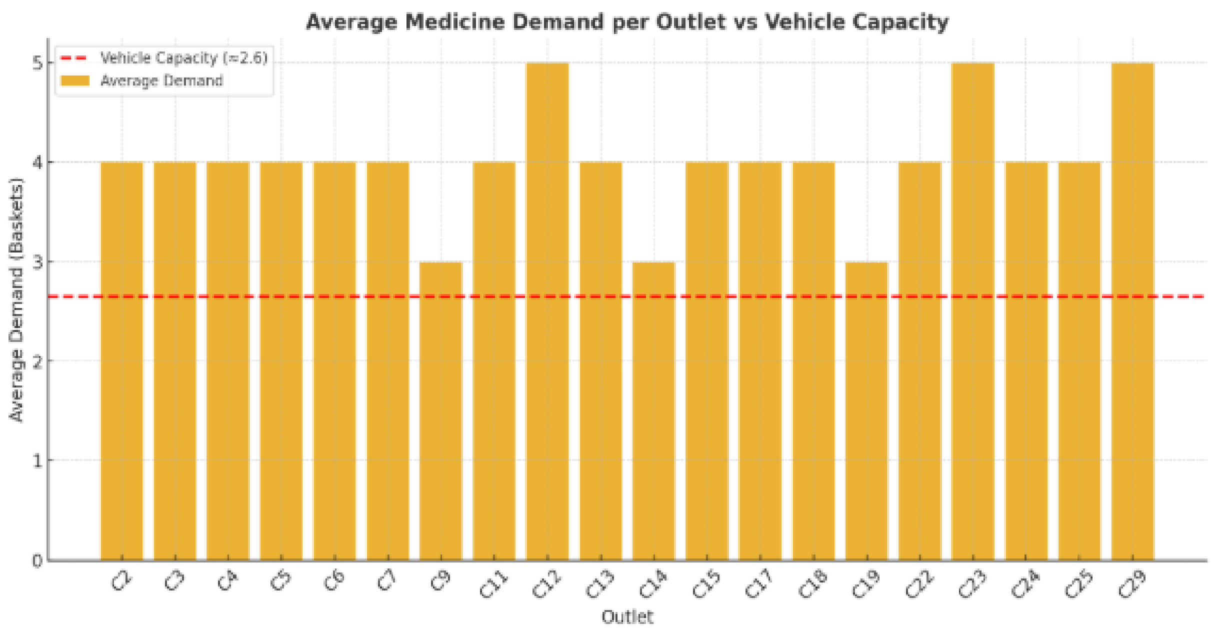


Figure 1. The Average Demand Per Outlet

Figure 1 shows that the average demand per outlet ranges from 3 to 5 baskets per week. Compared to the distribution vehicle capacity of 53 baskets, this capacity is relatively adequate to accommodate distribution needs in a single trip. However, variations in demand between outlets require a more efficient distribution planning strategy to maximize vehicle load while ensuring delivery delays are avoided. Therefore, these results serve as the basis for formulating an optimal distribution model.

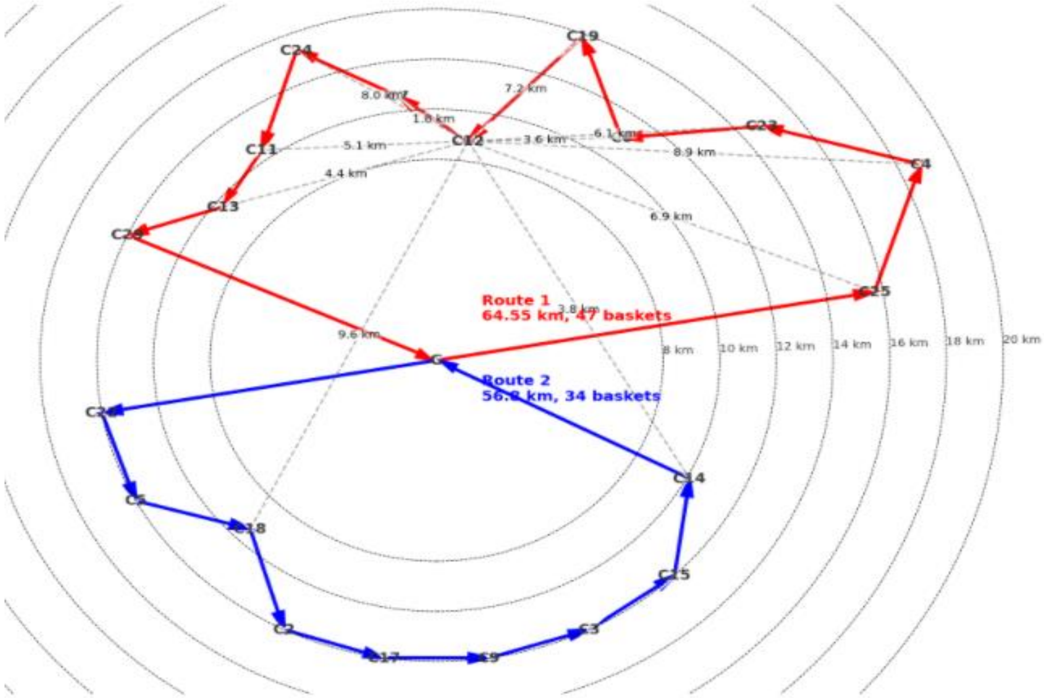


Figure 2. Distribution Route to Demand

The analysis results show differences in characteristics between the two distribution routes. The first route covers a distance of 64.55 km with a load of 47 baskets, while the second route is shorter at 56.8 km with 34 baskets. Although the operating time of the first route is longer (±5.5 hours) than the second route (±4.25 hours), the distribution productivity of the first route is higher, namely 8.55 baskets/hour compared to 8.00 baskets/hour on the second route. The difference in fuel costs is relatively small, so the more influential aspect is the operating duration.

The implication of these findings is the need for a route optimization strategy to balance the workload. The first route shows a higher customer density, so it has the potential to be partially transferred to the second route to reduce travel time imbalances. By applying the Vehicle Routing Problem (VRP) method or similar optimization algorithms, companies can achieve greater efficiency in distribution, both in terms of time and the even distribution of drivers' workloads.

Saving Matrix Method and Nearest Neighbor Method

Spatial analysis is conducted to measure the distance between distribution points representing customer locations. Compiling a distance matrix is an important first step in route modeling, as this matrix provides information on the distance between nodes, which is necessary for transportation optimization and vehicle route planning. Each row in the table shows the distance from one point to another, including the starting point (depot), making it easy to identify the closest and furthest distances. Thus, this distance matrix serves as the basis for calculations in the optimization approach that will be used in the next stage of analysis.

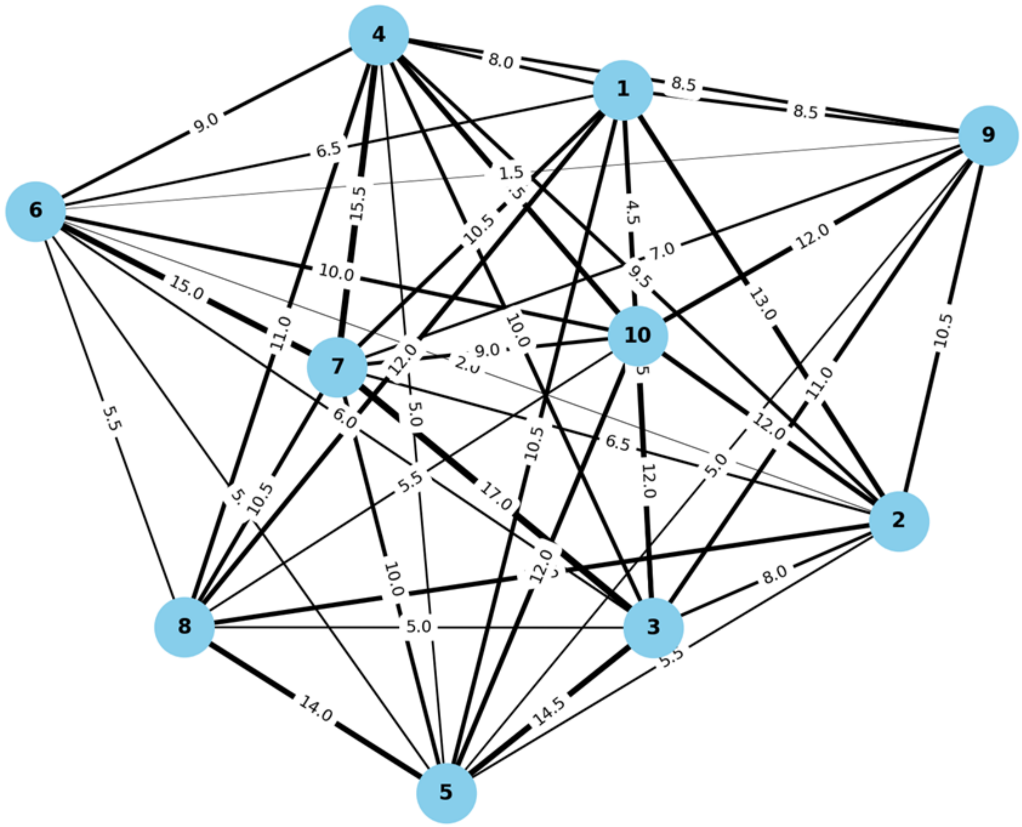
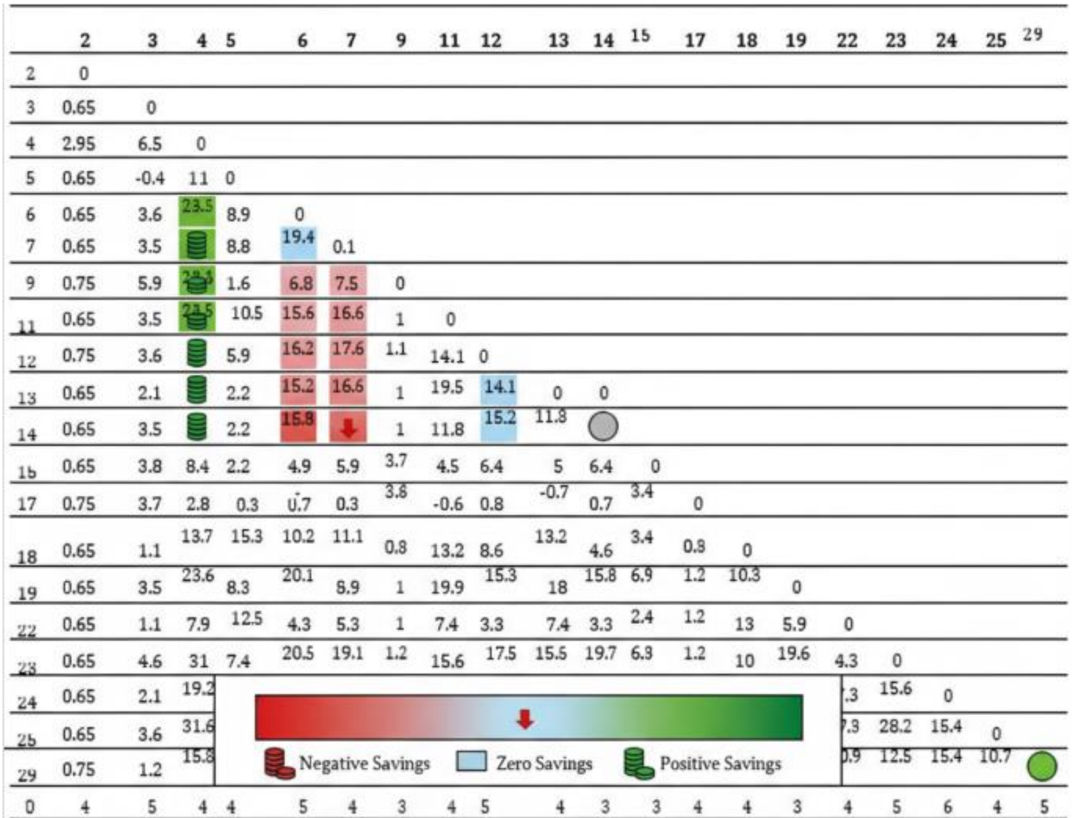


Figure 3. Distance Matrix Outlet to Basket

The distance matrix describes the distance between distribution points, which in this context represent customer locations and warehouse centers (G). The table shows that the closest distance from the warehouse is to customer 2, with a distance of 0.35 units, while the furthest distance is more than 18 units (for example, between the warehouse and customer 25, which is 18.4 units). This distance distribution pattern shows that there is significant spatial variation, which will affect the optimization of distribution routes.

Some customer groups are relatively close to each other, for example, customers 6 and 7 (2.2 units), customers 8 and 9 (1.8 units), and customers 18 and 19 (2.0 units). These proximity groups have the potential to be used as route clustering to make distribution more efficient. Conversely, there are also pairs with considerable distances even though they are within the same network scope, for example, customers 23 and 25 (18.4 units), which indicate the existence of points that are isolated far from the main group.

Points with the closest distance to the warehouse should be prioritized in route determination because they can reduce transportation costs. Second, groups of customers who are close to each other need to be considered as one visit route in order to achieve travel efficiency. Third, customers who are extremely far away need to be arranged as separate routes or integrated with alternative distribution strategies such as drop points or consolidation.



	2	3	4	5	6	7	9	11	12	13	14	15	17	18	19	22	23	24	25	29
2	0																			
3	0.65	0																		
4	2.95	6.5	0																	
5	0.65	-0.4	11	0																
6	0.65	3.6	23.5	8.9	0															
7	0.65	3.5		8.8	19.4	0.1														
9	0.75	5.9	[illegible]	1.6	6.8	7.5	0													
11	0.65	3.5	23.5	10.5	15.6	16.6	1	0												
12	0.75	3.6		5.9	16.2	17.6	1.1	14.1	0											
13	0.65	2.1		2.2	15.2	16.6	1	19.5	14.1	0	0									
14	0.65	3.5		2.2	15.8		1	11.8	15.2	11.8										
15	0.65	3.8	8.4	2.2	4.9	5.9	3.7	4.5	6.4	5	6.4	0								
17	0.75	3.7	2.8	0.3	0.7	0.3	3.6	-0.6	0.8	-0.7	0.7	3.4	0							
18	0.65	1.1	13.7	15.3	10.2	11.1	0.8	13.2	8.6	13.2	4.6	3.4	0.8	0						
19	0.65	3.5	23.6	8.3	20.1	8.9	1	19.9	15.3	18	15.8	6.9	1.2	10.3	0					
22	0.65	1.1	7.9	12.5	4.3	5.3	1	7.4	3.3	7.4	3.3	2.4	1.2	13	5.9	0				
23	0.65	4.6	31	7.4	20.5	19.1	1.2	15.6	17.5	15.5	19.7	6.3	1.2	10	19.6	4.3	0			
24	0.65	2.1	19.2													.3	15.6	0		
25	0.65	3.6	31.6													7.3	28.2	15.4	0	
29	0.75	1.2	15.8													0.9	12.5	15.4	10.7	
0	4	5	4	4	5	4	3	4	5	4	3	3	4	4	3	4	5	6	4	5

Figure 4. Saving Matrix

Based on the Saving Matrix in the image above, there are variations in savings values that are categorized into three main groups, namely negative savings, zero savings, and positive savings. Negative savings values are indicated in red, which signifies that the route or relationship between customers results in additional costs compared to the initial conditions. This shows that the route combination is inefficient and actually worsens the total distribution costs. Significant negative values are seen in customer pairs 8–10 (−16.2) and 9–10 (−17.6).

Conversely, positive savings values are shown in green, indicating distribution efficiency when these routes are combined. High savings values, such as in the combinations of customers 5–6 (23.5) and 5–7 (8.9), indicate considerable potential for improvement in the distribution route. This confirms that the right route combination strategy can provide significant benefits in terms of reducing distribution costs.

In addition, there are also several zero values (marked in blue) which indicate that route consolidation has neither a positive nor a negative effect on total costs. This condition shows that some route alternatives are neutral and do not provide any significant benefits.

Table 1. Route Saving Matrix

Route	Order of Visit	Demand (Basket)
1	G - C 4 - C 25 - C 23 - C 19 - C 6 - C 7 - C 11 - C 24 - C 14 - C 13 - C 12 - C 18 - G	49
2	G - C 29 - C 5 - C 22 - C 15 - C 3 - C 9 - C 17 - C 2 -G	32

Routes are obtained based on the value of the saving matrix. The route is formed based on the highest saving matrix value. In one route, the number of visit points is determined by the car capacity. Thus, in determining the route formed, it must not exceed the capacity of the car in one route.

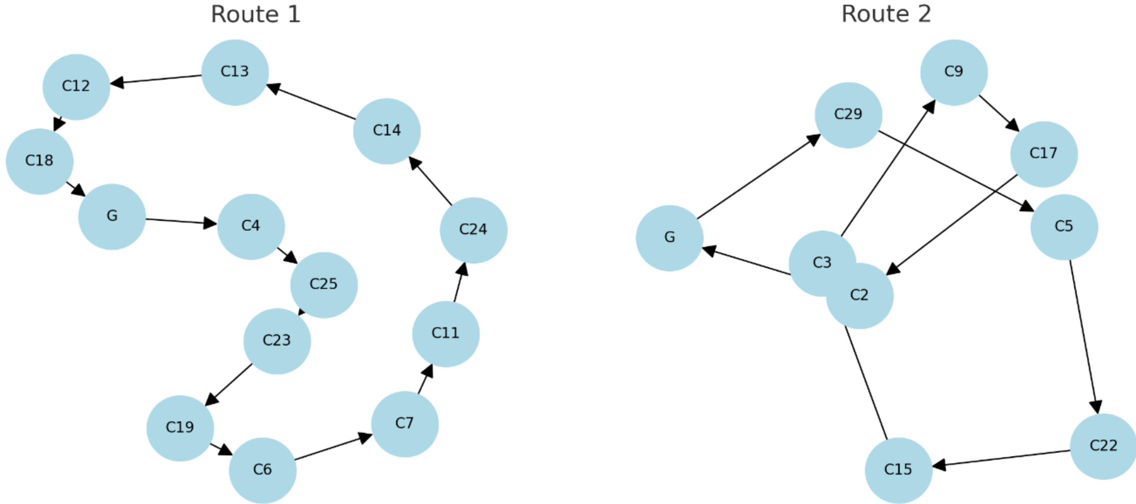


Figure 4. Route Saving Matrix

Table 2. Route based on Nearest Neighbor Method

Route	Outlet	Total Distance (km)
1	G - C 12 - C 7 - C 6 - C 14 - C 23 - C 25 - C 4 - C 19 - C11 - C 13 - C 24 - C 18 - G	64.35
2	G - C 2 - C 17 - C 9 - C 3 - C 15 - C 29 - C 5 - C 22 - G	39.55
	Total	103.9

The total mileage obtained in determining the proposed route with calculations using the saving matrix method and the nearest neighbor method is 103.9 km. the total mileage on the first route is 64.35 km and the total mileage on the second route is 39.55 km. The first route the vehicle visits 12 customers and on the second route the vehicle visits 8 customers.

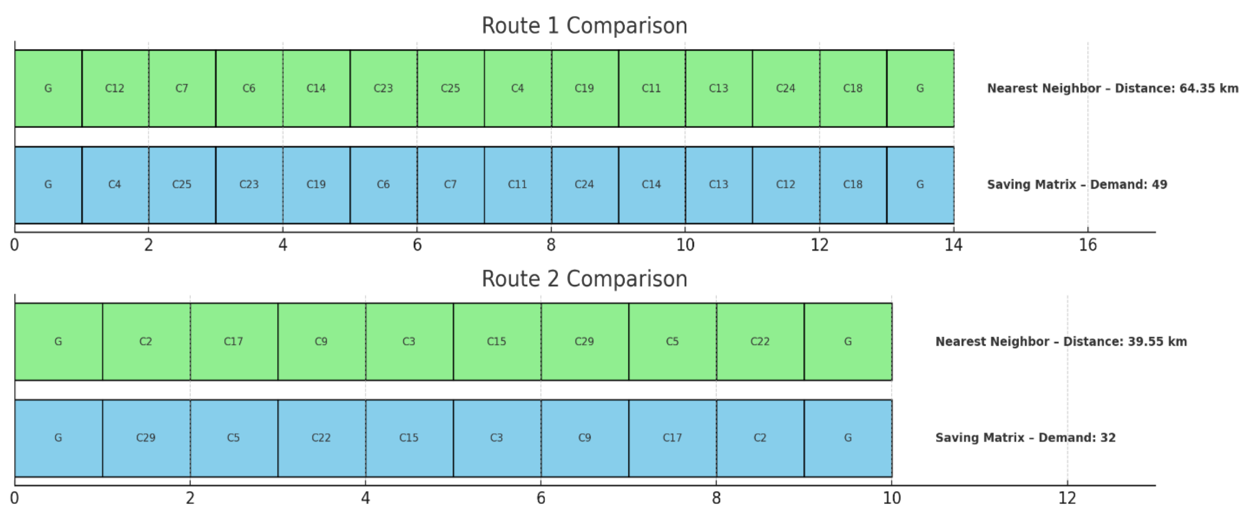


Figure 5. Grand Char Route Saving Matrix vs Nearest Neighbor Method

A comparison of routes using the Nearest Neighbor and Saving Matrix methods reveals differences in focus. Nearest Neighbor produces shorter distances (64.35 km for Route 1 and 39.55 km for Route 2), making it more efficient in terms of travel. Meanwhile, Saving Matrix emphasizes the even distribution of load with a demand of 49 units on Route 1 and 32 units on Route 2. This means that Saving Matrix is more suitable if the main objective is to maximize vehicle capacity, while Nearest Neighbor is superior if the main objective is to reduce travel distance.

In terms of costs, fixed components such as driver salaries (IDR 4,434,995/month) and vehicle maintenance (IDR 2,100,000/month) do not vary significantly between methods, as these costs are incurred regardless of route length. However, variable costs such as driver meals (IDR 30,000/day) and potential fuel costs are directly affected by route length and number of working days. Therefore, the method with shorter distances (Nearest Neighbor) has the potential to save on daily operating costs.

The cost simulation results show that with 22 working days per month, the total cost for 1 driver and 1 vehicle is around IDR 7.19 million, while for 2 drivers and 2 vehicles it reaches IDR 14.39 million. Monthly cost allocation to routes can also be separated proportionally to distance, with Route 1 absorbing more costs due to its longer distance. Overall, Nearest Neighbor is more advantageous for reducing variable costs, while Saving Matrix is more suitable if the company wants to ensure that vehicle load capacity is utilized optimally.

DISCUSSION

This study successfully demonstrated that the combined application of the Clarke–Wright saving-matrix and Nearest Neighbor methods reduced distribution distance from 121.35 km to 103.90 km, a reduction of 17.45 km (14.38%). These results confirm that simple heuristic methods are still effective in the context of pharmaceutical distribution with limited routes.

This finding is consistent with the literature from 2021–2023. For example, [27] found that the Clarke–Wright algorithm significantly reduced distribution distance in a retail case study. Similar results were reported by [32], who emphasized the effectiveness of the saving method for sustainable last-mile delivery. Therefore, this study's contribution follows the same trend, where distance efficiencies reach 10–25%, as noted by [31] in their review of green heuristics.

Methodologically, Nearest Neighbor is known to be fast but tends to produce suboptimal solutions when used alone [34]. The combination of a saving matrix, as implemented in this study, allows for a more balanced solution: simple yet competitive. Recent literature emphasizes hybrid strategies—for example, [32] used Variable Neighborhood Search to improve the initial Clarke–Wright solution—so the approach used here aligns with current development trends.

The use of Arena simulations strengthens the validity of the results. [24] demonstrated that Arena-based simulations can adequately model retail distribution dynamics, while [25] emphasized the importance of validating distribution models before actual implementation. The simulation results of this study (old route ≈ 3 hours 2 minutes) support the claim that reducing distance has the potential to reduce travel time, although in real-world practice, external factors such as traffic and unloading times will influence.

In the context of pharmaceutical distribution, time windows and cold chain issues are of concern. [8] demonstrated that a VRP with time constraints for vaccine distribution resulted in different routes than a standard VRP. Similarly, [7] emphasized the need for simulation-optimization to ensure the reliability of the pharmaceutical supply chain. Therefore, although this study focused on distance reduction, further model development should incorporate pharmaceutical-specific constraints.

Practically, a 14.38% distance reduction would have direct implications for fuel cost savings, reduced driver work hours, and vehicle operational efficiency. [35] reported that distance reduction in agricultural product distribution is positively correlated with reduced total costs. Thus, the results of this study have significant economic significance.

Limitations of this study include: (1) static distance data from Google Maps without considering real-time traffic; (2) the absence of a local improvement mechanism such as 2-opt or 3-opt to avoid local minima; and (3) the lack of field testing. Recent literature [36], [37] advocates a more robust hybrid approach, so further research could incorporate metaheuristics or evolutionary algorithms.

CONCLUSION

This study shows that the application of the Saving Matrix and Nearest Neighbor heuristic methods, validated by Arena simulation, can optimize drug distribution at the XYZ Pharmacy Warehouse. The combination of these methods resulted in a 14.38% reduction in distribution distance, which had a direct impact on operational cost efficiency, travel time savings, and increased vehicle productivity. Saving Matrix is more suitable for maximizing vehicle capacity, while Nearest Neighbor is more effective in minimizing travel distance. Simulation results confirm that distance efficiency has implications for reducing variable costs, especially fuel and driver working hours. However, this study still has limitations, namely it does not consider real-time traffic conditions, local route improvement mechanisms (2-opt/3-opt), and field testing. Therefore, further research is recommended to integrate specific pharmaceutical constraints, such as distribution with time windows and cold chains, as well as metaheuristic approaches so that the solutions obtained are more optimal and adaptive to real conditions.

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