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VEHICLE ROUTING PROBLEM ON JUICE DISTRIBUTION USING NEAREST NEIGHBOR METHOD

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Abstrak

Masalah distribusi produk menjadi topik yang penting dalam sistem transportasi suatu perusahaan. PT Amanah Prima Indonesia (API) merupakan perusahaan berskala Nasional yang bergerak di bidang produksi minuman juice. Dengan jumlah konsumen yang tersebar di wilayah Semarang, maka perlu suatu solusi dalam distribusi produk supaya didapatkan efisiensi operasional. Metode yang digunakan yaitu Algoritma Nearest Neighborhod. Hasil yang diperoleh yaitu: (a) Penghematan jarak sejauh 144,20 Km atau sebesar 40,06%, (b) Waktu pendistribusian produk dapat direduksi selama 5,15 jam atau sebesar 30,31%, (c) Biaya bahan bakar yang digunakan diperoleh penghematan sebesar Rp.108.150,- atau sebesar 40,06%, (d) Biaya pengeluaran untuk sopir dan pendamping tidak ada perbedaan yaitu sebesar Rp.600.000,- dan (f) Total biaya pendistribusian diperoleh penghematan sebesar Rp. 108.150 atau 12,43%.

***Kata kunci*:** *Biaya, VRP, Transportation.*

Abstract

Product distribution problem becomes an important topic in a company transportation system. PT Amanah Prima Indonesia (API), a company that focuses on national-scale juice production. With the sum of scattered consumers in Semarang, it is necessary a solution in the products distribution to obtain operational efficiency.The method used is Nearest Neighborh Algorithm. The results obtained are: (a) The total distance traveled by the truck results in a distance savings of 144.20 Km or 40.06%, (b) The time of product distribution can be reduced for 5.15 hours or by 30.31%, (c) The savings of fuel cost resulted Rp.108,150,- or 40.06%, (, d) There is no difference cost for the driver and partner, which is Rp.600,000, and (e) Total savings for product distribution cost obtained of Rp.108,150, - or 12.43%.

Keywords: Cost, VRP, Transportation.

1. INTRODUCTION

Transportation problems as well as inventory problems, which are activities in the logistics sector. This activity makes a possibility to make products somewhere and use them elsewhere. One indicator of developing cities is the speed and efficiency of transportation. According to Goldsby and Martichenko (2005), expenses costs of $600 billion are spent annually on transportation needs in the United States. More than 5 percent of US

gross domestic product or five cents of every dollar spent in the United States and nearly 83 percent is spent on transportation by vehicles (trucks), and the rest is consumed by other modes of transportation (trains, sea, air, and piping network). Davis & Company (2005) stated that the survey results on the logistics distribution elements showed that transportation was an important element with a composition of 45%, inventory carrying cost of 23%, storage/warehousing of 22%, and administration of 10%.

Transportation system existence aimed to meet the product delivery needs to customers by considering the factors of speed, timeliness, reliability, flexibility, availability, security, capacity, and cost efficiency. The problem often found in industry is the process of distributing goods from the company to customers. A distribution line from the vehicle is needed to determine the next delivery destination.Besides distribution channels, it is also defined the destination object and vehicle carrying capacity. Available distribution lines have different levels of efficiency such as efficiency at distance, time, operational costs, and vehicle quantity.

The above problem is known as Vehicle Routing Problem (VRP) model. PT Amanah Prima Indonesia (API), a company that focuses on national-scale juice production. The company has factories located in Semarang, Yogyakarta and West Java. In addition, the company also has several Distribution Centers (DC) to accelerate products supply to customers.

The customer service area is divided based on the availability of DC locations so the product distribution becomes more efficient. The discussion in this study focused on the use of product distribution channels through land routes with truck fleets. Products distribution process to customers requires planning and selecting the right distribution channels, so the transportation costs and time can be more efficient. PT API has consumers located in several locations in Central Java.Existing customers in Semarang are currently 20 customers from a total of 90 customers throughout Central Java.

The transport fleet used for product distribution is a truck with a maximum transport capacity of 5,000 liters per fleet. The main problem faced by the company today is the determination of distribution channels for product delivery to customers. The addition of working hours raises overtime for drivers and partner which has an impact on the company's operating costs.

1.1 *Vehicle Routing Problem* (VRP)

VRP is a problem that focuses on the distribution of goods or products from companies (warehouses) to customers. The term VRP was first introduced by Dantzig and Ramser in 1959. VRP is a complex problem of combinatorial optimization which is a combination of two problems, namely Traveling Salesman Problem (TSP) and Bin Packing Problem (BPP). VRP is NP-Hard, so this problem is difficult to solve. The main problem in VRP is the determination of the route and arrangement of available transport vehicles so they can serve customer requests efficiently based on the given conditions. A network is a series of locations that must be visited by a vehicle to complete its services to customers.

VRP solution is the determination of the route and can also be a schedule of vehicles from the assigned route. Problems in VRP can be divided into two, namely static and dynamic problems. On static issues, customer requests have been known in advance.While in dynamic problems, some or all customer requests are known when the vehicle has started operating, ie when the distribution route has been determined or changes occur in the trip. VRP is a generalization of TSP. TSP is an unlimited VRP such as depots, customers and requests. m-TSP is a VRP with a depot and m transporter, including if there is no request from the customer. m-TSP is the transformation of TSP by increasing the number of depots. The core objective of VRP is to determine the vehicle scheduling strategy for shipping goods. The aim of VRP are (i) minimizing transportation costs, (ii) minimizing the number of vehicles to serve customers, (iii) balancing vehicle routes and loads, and (iv) minimizing penalties relating to customer service (Toth and Vigo, 2002).

VRP is applied as a guide in decisions making about determining the vehicle's operational route, sorting distribution, and scheduling. Routing is not only about operational planning issues, but also about strategic and tactical planning in the distribution system. The interaction between these strategies will build an optimal distribution system and can be developed into an interesting research topic for academics and practitioners. Toth and Vigo (2002) state that some of the characteristics in VRP that need to be considered are: customers, depots, drivers, and vehicles route.

PT API has determined product service in the first, distribution time, number of customers, and type of vehicle to deliver goods/products to customers. In one area there are one or more customers to be served. The solution generated from this VRP is the transport vehicle distribution channel that will be used to send all customer requests, where each route is taken by a vehicle that starts and ends at the same depot.

1.2 *Nearest Neighbor* Method

This method was first introduced in 1983 and is a very simple method. Each calculation step, closest customer location to the next customer is reached, until the last customer is on the route. The new route starts in the same way if there is no feasible position to place new customers because of capacity constraints or time windows (Braysy and Gendreau, 2005).

The Nearest Neighbor works method is to empty all vehicle routes first. Then starting from the first vehicle route, one by one the location of the nearest customer (nearest neighbor) that has not been visited and entered into the route with a condition that the transport vehicle does not exceed the maximum capacity of the vehicle (or the limitations described by other VRP variants). Then the same process is also carried out for the next vehicles, until the entire vehicle is full or all customers have been visited (Gunawan, 2012). The steps taken in the Nearest Neighbor Algorithm application (Pop, 2011) are as follows:

1. The process starts from the warehouse, then continues to find the location of customers who have not been visited with the shortest distance from the warehouse.
2. The process is continued to another location with the closest distance from

the previously selected location and the number of shipments does not exceed the maximum capacity of the vehicle by observing the following limitations:

a. If there is a location selected as the next location and there is a remaining capacity on the transport vehicle, then the process returns to step (2).
b. If the vehicle does not have the remaining capacity, then the process returns to step (1).
c. If no location is selected because the number of shipments exceeds vehicle capacity, then return to step (1).
d. The process starts again from the warehouse and visits unvisited customers and has the closest distance.

3. If all customers have been visited exactly once, the algorithm process ends.

VRP completion in this study applies the Nearest Neighbor Algorithm to obtain efficient distribution routes, reducing total mileage, travel time, and operating costs of product distribution. The problem of product distribution faced in this study is the problem of finding the shortest route to consumers whose locations are scattered with different demands. This research was conducted to evaluate the initial model of the distribution channel used, provide improvement proposals on the product delivery model, and develop knowledge experience from previous studies.

2. RESEARCH METHOD

2.1 Research Framework

This study began by describing the initial model of product distribution routes and proposed improvements in the implemented product distribution model. VRP in this case is described by a depot that will serve customers at various points. Each customer has a different number of demands. In this study also conducted an evaluation of initial distribution route model used and the proposed improvement of product distribution model recommended in accordance with obtained results of analysis.

2.2 Research Steps

The flow of implementations in this study are described as follows:

a. *Literature* and *Critical Review*

Some literature related to this research are:

1. Research with the title A Modeling and Optimization Framework for Real-World Vehicle Routing Problems conducted by Caric T. et al (2008). This research demonstrated an integrated modeling and optimization framework to solve complex and practical VRP. The modular framework structure, scripts for modeling languages, VRP algorithms, and GUI provided users with convenience and flexibility to make VRP prototypes quickly and complex.
2. The VRP concept Development, VRP Simultaneous Delivery Pick-up with Time Windows (VRPSDPTW). This concept can actually illustrate such as the bottled beverage distribution process, after completing demand in retailers, the truck needed to carry out the empty bottle to be refilled.Dethloff (2001) states that VRPSDPTW is a form of reverse logistic problem besides distributing demand also

transports a number of products back to the depot. Research conducted by Dethloff (2001) used the Cheapest Insertion Heuristic Method to find the minimum route.

3. Murata and Itai Research (2005). The study proposed problems with two different demand periods. In each period, VRP was treated as a multi-objective problem. In multi-objective problems, several objectives can be given such as minimizing total shipping costs, maximum costs, number of vehicles, and total delays with delivery dates.

In this process, previous research models were studied, basic and supporting models were used to support model development through the following steps:

a. The data used in this study were obtained from observation, interviews, and documentation. The next process is data processing.
b. Nearest Neighbor application, prepared data is processed with this algorithm.
c. Analysis results of the Nearest Neighbor application, the processing results from the application of this algorithm are analyzed for further conclusions and suggestions.
d. Conclusions and suggestions, the final process of this research is making conclusions from the research and giving suggestions for further research.

3. RESULT AND DISCUSSION

3.1 Distribution Area

All customers in Central Java are 90 customers. This study uses customer data in the Semarang distribution area as many as 20 customers which are divided into four groups, each groupis served by a truck.

Table 3.1. Customer Data Served by Truck 1

Code	Customer
BS	Grand Candi Semarang
BT	Gumaya Semarang
BU	Crown Plazs Semarang
BV	Novotel Semarang
BW	Santika Premier Semarag

Table 3.2. Customer Data Served by Truck 2

Code	Customer
BX	Ciputra Semarang
BY	Horison Semarang
BZ	Oak Tree Emerald Semarang
CA	Ibis Semarang
CB	Dafam Semarang

Table 3.3. Customer Data Served by Truck 3

Code	Customer
CC	Grasia Semarang
CD	Pandanaran Semarang
CE	Semesta Hotel
CF	Quest Aston Semarang
CG	Best Western Star

Table 3.4. Customer Data Served by Truck 4

Code	Customer
CH	Muria Hotel Semarang
CI	Hotel Batik
CJ	Whiz Semarang
CK	Amaris Semarang
CL	NugrahaWisata

From Table 4.1 to 4.4 it is known that each fleet serves five customers. The average customer demand is obtained from shipping data per day for one week taken in June 2017.

3.2 Vehicle and Vehicle Capacity

Vehicles that are functioned to distribute products to customers are using a truck. The maximum load capacity of the truck used is 5,000 liters.The maximum load capacity of the truck used is 5,000 liters.

3.3 Loading and Unloading Time

The time to load the product in the truck takes an average of 60 minutes and it takes an average of 15 minutes to unload the product.

3.4 Variable Costs for Transportation

The product distribution process to customers has variable costs, namely the fuel cost for trucks. The fuel cost needed per kilometer is Rp. 750, -.

3.5 Daily Wages

Each vehicle is driven by one driver and his partner. The more days needed for product distribution, the greater wages spent on drivers and his partners. Daily wages for drivers Rp. 90,000 and Rp. 60,000, for partner. Overtime for drivers Rp. 17,500, - / hour and Rp. 12,500, - for partner.

3.6 Distribution Time

The total time for product distribution to customers is as follows:

1. Average time of warming up the truck's engine is 30 minutes.
2. Average loading time of a truck is one hour.
3. Travel time = distance traveled divided by truck's speed.
4. Customer service time = sum of customer x service time (average 15 minutes).
5. Total time = (warming up time + loading time + travel time + customer service time).

3.7 Data Processing

Data processing is carried out by calculating the needed costs for product distribution, distance, and travel time on existing product distribution conditions. The next process is to determine the route with the Nearest Neighbor Method. The next step is to recalculate the product distribution cost, distance, and travel time for the comparison.

3.7.1 Initial Distance of Distribution and Sum of Products

Total initial distance is obtained from the total mileage of product distribution calculation and the sum of products distributed. It is showed in Table 3.5. Total distance traveled by all truck before the Nearest Neighbor method application is 360 Km.

Table 3.5. Distance and Product Capacity for Each Truck

No	Truck	Distance (Km)	Product Capacity (Liter)
1.	I	19,2	4.700
2.	II	22,2	3.200
3.	III	20,8	3.280
4.	IV	297,8	3.280
	Total	**360**	**14.460**

3.7.2 Distribution Time

The initial time for product distribution for each truck route is as follows:

Table 3.6. Distribution Time for Each Truck

No	Truck	Time (hours)
1.	I	3,07
2.	II	3,12
3.	III	3,10
4.	IV	7,71
	Total	**17**

The initial total time for product distribution for all product shipments is 17 hours.

3.7.3 Fuel Costs

Before applying the Nearest Neighbor Method, the fuel consumption cost of trucks is as follows:

Table 3.7. Fuel Cost for Each Truck

No	Truck	Fuel Costs (Rupiah)
1.	I	14.400
2.	II	16.650
3.	III	15.600
4.	IV	223.350
	Total	**270.000**

The total cost of fuel spent on product distribution is Rp.270,000,-.

3.7.4 Cost of Driver and Partner

Product distribution costs to customers allocated to the driver and partner are Rp. 600,000,- (consisting of a normal wage of Rp. 600,000,-). Total initial expenses for truck fuel consumption, drivers and their partners are Rp. 870,000.

3.7.5 Determination of Routes Using the Nearest Neighbor Method

The calculation process used the Nearest Neighbor Method to achieve the new route sequence that will be taken by the truck in distributing products to customers. The new route is expected to be an efficient route than before. The distance matrix is used as a basis for calculation and the distance of this matrix is provided by using the help of Googlemaps. Application of Nearest Neighbor Method for each operationalized truck is as follows:

Table 3.8. Application Results of the New Route for Truck I

No	Code	Distance (Km)
1	CP	9,6
2	BS	5,9
3	BW	1,9
4	BT	1,6
5	BV	0,1
6	BU	0,1
Total		**19,2**

By using the Nearest Neighbor Method, a new route for Truck I is generated. The new route is CP-BS-BW-BT-BVV-BU with a distance of 19.2 Km.

Table 3.9. Application Results of the New Route for Truck II

No	Code	Distance (Km)
1	CP	9,6
2	BY	6,8
3	BX	0,6
4	CA	1,2
5	CB	0,9
6	BZ	0,1
Total		**19,2**

A new generatedroute for Truck IIis CP-BY-BX-CA-CB-BZ with a distance of 19.2 Km.

Table 3.10. Application Results of the New Route for Truck III

No	Code	Distance (Km)
1	CP	9,6
2	CG	4,5
3	CD	3,5
4	CC	0,6
5	CE	1
6	CF	0,2
Total		**19,4**

A new route for Truck III is CP-CG-CD-CC-CE-CF with a distance of 19.4 Km.

Table 3.11. Application Results of the New Route for Truck IV

No	Code	Distance (Km)
1	CP	40
2	CH	7,5
3	CJ	1,6
4	CK	0,2
5	CL	30,7
6	CI	78
Jumlah		**158**

A new route for Truck IV is CP-CH-CJ-CK-CL-CI with a distance of 158 Km.

From Table 4.8 to 4.11, it can be summarized the total distance traveled by all trucks after the Nearest Neighbor Method application. The distance for each truck for the new route summarized in Table 4.12.

Table 3.12. Summary of Distance Travel

No	Truck	Distance (Km)
1.	I	19,2
2.	II	19,2
3.	III	19,4
4.	IV	158
	Total	**215,80**

The total distance traveled by all trucks for product distribution is 215.80 Km.

3.8 Verification of Calculation Results

The new routes generated by using Nearest Neighbor Method are verified by checking the compatibility of the calculation results with the required demand of deliveries, ie not exceeding the truck capacity and passing all customer places exactly once. Based on the data obtained, the transportedproducts do not exceed the truck capacity. The sum of transported products is smaller than truck capacity (5,000 liters).

Table 3.13. Verification of Vehicle Capacity

No	Truck	Load Capacity (liter)	Maximum capacity (liter)
1	I	4.700	5.000
2	II	3.200	
3	III	3.280	
4	IV	3.280	

Based on Table 4.13, loading capacity of the truck I is 4,700 liters, 3,200 liters for truck II, 3,280 liters for truck III, and 3,280 liters for truck IV.So, the total amount of product loading for each truck does not exceed the capacity which is a maximum of 5,000 liters.

3.9 Calculation of Distance, Time and Cost

The next process is to calculate the total distance for each truck. The distance is

obtanined from multiplication by variable cost and then added to Total Fixed Cost. The travel time needed for product distribution after Nearest Neighbor method application presented in Table 4.14.

Table 3.14. Travel Time After Nearest Neighbor Method Application

No	Truck	Time (Hours)
1	I	3,07
2	II	3,07
3	III	3,07
4	IV	2,63
	Total	**11,85**

In the transportation process after the Nearest Neighbor Method application, the results for fuel consumption are Rp. 163,850. The cost of customers products distribution allocated to the driver and partner after the Nearest Neighbor Method application is of Rp. 600,000 (consists of normal wage costs only of Rp. 600,000), so the total expenses isRp. 761,850.

3.10 Results Analysis

The results obtained using the Nearest Neighbor Method are then compared between the initial and new routes. The following Table is a Distance Comparison of the Nearest Neighbor Method application.

Table 3.15. Distance Comparison (Km)

Initial Distance	New Distance
19,2	19,2
22,2	19,2
20,8	19,4
297,8	158
Total=360	**Total=215,8**

The distance traveled on Table 4.15 presented the reduction as far as 144.20 Km.

The next comparison is the traveled time for each route. It showed the application of before and after Nearest Neighbor Method.

Table 3.16. Time Comparison (Hours)

Initial Times	New Times
3,07	3,07
3,12	3,07
3,10	3,07
7,71	2,63
Total=17,00	**Total=11,85**

Based on Table 4.16, the time taken can be reduced by 5.15 hours.

The next table showed the comparison of truck fuel consumption. The initial and new routes are shown in Table 4.17.

Table 3.17. Fuel Comparison (Rp)

Initial Route	New Route
14.400	14.400
16.650	14.400
15.600	14.550
223.350	118.500
Total=270.000	**Total=161.850**

Fuel savings reached at Rp.108,150,-. Cost of Driver and partner before and after the Nearest Neighbor Method application is Rp.600.000,- because there are no additional hours outside working hours, no overtime costs are needed.

4. CONCLUSION

Based on the data analysis, things that can be concluded are:

1. The total distance traveled by the truck results in a distance savings of 144.20 Km or 40.06%.
2. The time of product distribution can be reduced for 5.15 hours or by 30.31%.
3. The savings of fuel cost resulted Rp. 108,150,- or 40.06%.
4. There is no difference cost for the driver and partner, which is Rp. 600,000.
5. Total savings for product distribution cost obtained of Rp.108,150,- or 12.43%.

The above analysis can be used as references to provide recommendations for the company, to adopt new routes that have been proposed into this study.

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