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Distribution Analysis to Minimize Transportation Costs Using the Nearest Neighbor Method at PT. Unilever Indonesia Depo Makassar

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Abstract

Based on the problem formulation in this research, the goal that can be formulated in this research is to be able to distribute products using optimal distribution routes and minimize transportation costs at PT. Unilever Indonesia Makassar Depot. This research uses the Nearest Neighbor method approach to determine the shortest route so that the distribution path can be done optimally. Optimal means the amount of goods sent, delivery time, and the distance required is right, in this case there are many routes. Based on calculations carried out in completing the CVRP using the Nearest Neighbor method, the total distance traveled was 1,940.2 km. Meanwhile, the company's current total mileage is 2,348 km. This shows that the Nearest Neighbor method is effective in determining the distribution route for Sariwangi Tea at PT. Unilever Indonesia Makassar Depot. This research focuses on the distribution of goods from the company's depot (warehouse) to its customers. Delivery of goods involves services provided by the company within a predetermined time period to a number of customers using certain vehicles where the depot location can be at one or more locations. The results of this research provide input for future deliveries. It is hoped that companies can use new distribution routes using the Nearest Neighbor method, so that delivery costs can be controlled by using shorter or closest delivery routes and the costs are optimal. PT Unilever Indonesia is a subsidiary of Unilever which was founded in 1933. Having produced many well-known products, PT Unilever Indonesia is one of the large companies that contributes to meeting various community needs. As a company operating in the distribution sector, determining delivery routes is very important to consider time efficiency and minimize transportation costs.

Keywords: ***Distribution, Vehicle Routing Problem, Saving Matrix, Nearest Neighbor, Transportation Costs.***

1. Introduction

PT Unilever Indonesia Depo Makassar as a company operating in the distribution sector, determining delivery routes is very important to consider time efficiency and minimize transportation costs. So accuracy is needed in determining the best route. The best route is the route with the shortest distance, which of course will affect the transportation costs incurred. The shorter the distance from the vehicle, the lower the transportation costs. Some examples of limitations given are vehicle capacity, limited consumer accessibility, pick-up 2 delivery requests and time windows or time constraints. To meet customer demand with a load that does not exceed capacity, the Capacitated Vehicle Routing Problem (CVRP) is used, namely each vehicle has a certain capacity. The CVRP problem that will be examined in this research is the distribution of goods at PT. Unilever Indonesia Makassar Depot covers several areas with high demand for products in the South Sulawesi region.

In completing CVRP there is a method that will be studied, namely the Nearest Neighbor method. Use of the Nearest Neighbor method in determining the sequence of locations and determining the best route.

2. Literature Review

2.1. Definition of Distribution

According to Basu swastha, distribution channels for goods are those used by producers to channel the goods from the hands of producers to the hands of consumers. Meanwhile, according to Kotler in the book Marketing Principles and Cases, it is explained that distribution channels are a collection of companies and individuals who take over rights or assist in the transfer of rights to goods or services as they move from producers to consumers (Irawan, 2001). Distribution of goods from producers to consumers can be done on time. Because the manufacturer has thought about the number of outlets and the type they want long in advance. If a company makes a mistake in choosing a distribution channel, it will result in waste. Distribution includes all aspects of sending goods to agents. In fact, distribution is part of material handling, because material handling is the movement of material at any time and at any point. There are several problems commonly faced in distribution related to distribution network optimization, namely:

a. Depot Point
   The depot point really determines the smooth distribution of goods, so that the goods can reach the agent on time.
b. Determining Delivery Routes and Schedules
   In general, the problem of scheduling and determining delivery routes has several goals to be achieved, such as minimizing shipping costs, minimizing time or minimizing travel distance. One of these goals can be an objective function and the other can be a constraint. For example, the objective function is to minimize distribution costs, but there are time window constraints and maximum travel distance constraints for each vehicle, in addition to other constraints such as capacity or other constraints. At the time of writing this thesis, distribution management is the management of activities to move newspapers from one depot to a number of agents where the transfer process will form or produce distribution routes that are limited by vehicle capacity.

2.2. Definition of Transportation

Transportation is defined as the transfer of goods and people from their place of origin to their destination. The transportation process is a movement from the place of origin, where the transportation activity begins, to the destination, where the transportation activity ends. The role of transportation is very important in connecting raw material source areas, production areas, marketing areas and residential areas where consumers live. The transportation system of a region can be defined as a system consisting of infrastructure/means and a service system that allows movement throughout the region, so that (Santoso, 1996: 1): the mobility of the population is accommodated, the movement of goods is possible, and access to all regions is possible.

One of the important components in a company is transportation. Where transportation is very important for the smooth production of a company. Whether large or small scale companies. If transportation in a company is disrupted, the impact will greatly affect the company's production. Problems that may arise in transportation are the condition of the road network which is quite complex. Many alternative paths have also been found to be more effective and efficient. A common problem in transportation is the travel route for vehicles carrying out goods delivery activities to consumers. In transportation problems, network analysis is widely used to minimize transportation costs. The transportation method is a method used to organize distribution from sources that provide the same product to places that need it optimally. The allocation of this product must be arranged in such a way, because there are differences in allocation costs from one source to different destinations, and from several sources to different destinations.

2.3. Definition of Capacitated Vehicle Routhing Problem (CVRP)

Capacitated Vehicle Routing Problem (CVRP) is the most basic form of VRP. CVRP is an optimization problem to find a route with minimum cost for a number of vehicles with a certain homogeneous fleet capacity, which serves the requests of a number of customers whose quantity requested is known before the delivery process takes place.

Basically, in CVRP, the vehicle will start its journey from the depot to make deliveries to each customer and will return to the depot. It is assumed that the distance or travel costs between all locations are known. The distance between two locations is symmetrical, which means the distance from location A to location B is the same as the distance from location B to location A.

2.4. Definition of Algoritma K – Nearest Neighbor (KNN)

The k – Nearest Neighbor algorithm (k-NN or KNN) is a method for classifying objects based on learning data that is closest to the object. This technique is very simple and easy to implement. Similar to the clustering technique, namely grouping new data based on the distance of the new data to several data/nearest neighbors. Nearest Neighbor is an algorithm that is easy to implement and easy to execute, but does not guarantee that the resulting solution is optimal. In this algorithm, the rules only go to customers with the closest distance that have not been visited by including several restrictions.

The accuracy of the KNN algorithm is determined by the presence or absence of irrelevant features, or if the weight of the feature is equivalent to its relevance to classification. The K Nearest Neighbor algorithm has the advantage that it can produce strong or clear data and is effective when used on large data. Of these advantages, K-Nearest Neighbor also has disadvantages, namely that it requires a K value as a parameter, the distance from the experimental data cannot be clear with the type of distance used and with the attributes used to obtain the best results, you must use all attributes or just one definite attributes. K-Nearest Neighbor steps:

a. Determine the K parameter (number of closest neighbors). The K parameter in testing is determined based on the optimum K value during training.
b. Calculate the squared Euclidean distance of each object against the given sample data
c. Sort the objects into groups that have the smallest Euclidian distance
d. Collect category Y (Nearest Neighbor classification)
e. By using the majority category, you can get classification results.

The Nearest Neighbor method aims to determine the shortest route so that distribution routes can be carried out optimally. What is meant by optimal is the exact number of goods sent, the sending time, and the distance required. The Nearest Neighbor method is the simplest method for solving problems. First, choose one of the points to represent a starting point, then choose the destination to be visited next with consideration of only choosing the point that is closest to the previously visited point.

2.5. Definition of Saving Matrix Method

According to Rand (2009), the saving matrix method is a method that determines the distribution of products to marketing areas by determining the distribution route that must be taken and the number of vehicles based on the capacity of the vehicle in order to obtain the shortest route and minimal transportation costs. The saving matrix method is also a technique used to schedule a limited number of vehicles from facilities that have different maximum capacities.

2.6. Definition of Optimization

Optimization is the process of achieving ideal or optimal results (the effective value achieved). Optimization intuitively means doing work in the best way (Brogan, 1991). Optimization problems refer to the study of problems that try to find the minimum or maximum value of a real function. Many problems in the real world can be represented within this problem framework, for example maximum income, minimum costs and so on. If the thing being optimized turns out to be quantitative, then the optimum problem will become a maximum and minimum problem (Susanta, 1994).

3. Research Methodology

3.1. Time and Place of Research

This research was conducted at PT. Unilever Indonesia Makassar Depot. This company is engaged in manufacturing, marketing and distribution of consumer goods. PT. Unilever Indonesia Makassar Depot is located at Tidung, Kec. Rappocini, Makassar City, South Sulawesi 90222.

3.2. Data Collection

The data is secondary data obtained from the company:

a. Distribution Route
b. Consumer Data
c. Mileage
d. Carrying Capacity
e. Transportation Costs

3.3. Data Processing

a. Saving Matrix Method

The saving matrix method is a method used to determine the best route by considering the distance traveled, the number of vehicles to be used and the number of products that can be loaded by the vehicle in sending products to consumers so that the distribution process is optimal. The savings matrix method is also a technique used to schedule a limited number of vehicles from facilities that have maximum capacity. The saving matrix method consists of several steps as follows:

1) Determine The Distance Matrix

In determining this distance matrix, data on the distance between the company and the location and the location to other locations is very necessary. After knowing the coordinates of each location, the distance between the two locations can be calculated using the following formula:

J(1,2) =√(〖(X1- X2)^2+ 〖(Y1-Y2)^2) ……...……(1)

J (1,2) = Distance between point 1 to point 2 or vice versa

X1,Y1 = Coordinates of point 1

X2,Y2 = Coordinates of point 2

However, if the distance between the two coordinates is already known, then the calculation using the formula is not used and uses the existing distance.

2) Determine The Saving Matrix

After knowing the overall distance, namely the distance between the depot and the location and the location and other locations, in this step it is assumed that each location will be passed exclusively by one truck. This means that there will be several different routes that will be passed to each destination. Thus, there will be savings if there is a combination of routes that are considered one way with other routes. To find the savings matrix, the following formula can be used:

S(x1,x2) = J(Dc,x1) + J(Dc,x2) – J(x1,x2) ……..…...……(2)

Where :

S (X1,X2) = Observation of the distance between customer 1 and customer 2

J (Dc,X1) = Distance from Distributor to customer 1 or vice versa

J (Dc,X2) = Distance from Distributor to customer 2 or vice versa

J (X1,X2) = Distance from customer 1 to customer 2 or vice versa

3) Vehicle and Route Allocation Based on Location

Once the savings matrix is known, the next step is to allocate locations to routes or vehicles. This means that in this step a new delivery route will be determined based on the combined routes in the second step above. The result is that delivery to location 1 and location 2 will be carried out using 1 route.

4) Nearest Neighbor Calculation

Before entering consumers into the delivery route, the first thing that must be done is to sort the savings obtained from the largest to the lowest.

At this stage, consumers who are already on each delivery route will place an order. Consumer sorting is carried out to determine which customers will be visited first when delivery is made so that the distance between the delivery process is closer and which will also affect transportation costs.

5) Calculate Total Costs

Based on the calculation of costs associated with sending goods to consumers, you can calculate the costs incurred by the company for each delivery activity carried out.

4. Result And Discussion

In the data collection process carried out at PT Unilever Indonesia Depo Makassar, the researchers obtained several data on routes, agents and costs incurred during delivery, where this data was sufficient and as a reference for developing new, more optimal routes. These data include the following:

4.1. Unilever Customer Data and Product Demand

Table 1. Initial Delivery Route and Number of Requests

No	Customer's Name	Number of Requests/Box (Sariwangi)	Customer Code
1	PT Tompotika Raya	300	K1
2	PT Bintang Orient	270	K2
3	PT Tompotika Raya	240	K3
4	PT Sumber Alfaria Trijaya Tbk	225	K4
5	PT Sentral 88	288	K5
6	UD Sinar Surya	481	K6
7	PT Reski Laifasto	209	K7
8	Bintang Grosir	373	K8
9	PT Tompotika Raya	412	K9
10	CV Makro INDTIM	223	K10
11	CV Bintang Laut	279	K11
12	PT Tompotika Raya	130	K12
13	CV Ambassador Zulias	345	K13
14	CV Ambassador Zulias	265	K14
15	PT Wira Eka Persadatama	212	K15
16	PT Sumber Cahaya Megaberkah	265	K16
Total		**4.517**	

4.2. Mileage Data

Table 2. Mileage Data

No	Customer's Name	City	Distance (KM)
1	PT Tompotika Raya	Pare Pare	150
2	PT Bintang Orient	Rantepao	314
3	PT Tompotika Raya	Palopo	366
4	PT Sumber Alfaria Trijaya Tbk	Makassar	20.5
5	PT Sentral 88	Maros	20.6
6	UD Sinar Surya	Barru	108
7	PT Reski Laifasto	Pinrang	161
8	Bintang Grosir	Sidrap	182
9	PT Tompotika Raya	Polman	265
10	CV Makro INDTIM	Gowa	8.8
11	CV Bintang Laut	Takalar	22.5
12	PT Tompotika Raya	Bulukumba	150
13	CV Ambassador Zulias	Soppeng	161
14	CV Ambassador Zulias	Sengkang	193
15	PT Wira Eka Persadatama	Bone	174
16	PT Sumber Cahaya Megaberkah	Sinjai	161

4.3. Transport Capacity Data

The distributor has a Hino 500 Ranger FG 245 JK type vehicle with a maximum carrying capacity of the truck of 5.7 tonnes = 1,584 boxes and diesel fuel consumption of 1 liter/8 km\

4.4. Preliminary Transportation Cost Data

Table 3. Preliminary Transportation Cost Data

Transportation Cost	Information
Route 1 : K0 – K1 – K2 – K3 – K0	IDR. 861.980
Route 2 : K0 – K4 – K5 – K6 – K0	IDR. 273.892,5
Route 3 : K0 – K7 – K8 – K9 – K0	IDR. 664.815
Route 4 : K0 – K10 – K11 – K12 – K0	IDR. 360.607,5
Route 5 : K0 – K13 – K14 – K15 – K16 – K0	IDR. 597.605
Total	**IDR. 2.758.900**

4.5. Data Processing

a. Distance Matrix from Company to Each Agent

The distance matrix will create a distance matrix whose entries are the distance between the depot (agent) and the base (node) and between bases (nodes).

Table 4. Distance Matrix (Km) in January 2022

	DC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	150	0															
2	314	165	0														
3	366	188	52.6	0													
4	20.5	137	302	352	0												
5	20.6	134	298	348	9.7	0											
6	108	42.1	206	229	95.8	94.9	0										
7	161	11.4	154	176	148	147	52.7	0									
8	182	32.9	148	171	169	166	74.2	26.8	0								
9	265	116	188	209	252	249	42	104	113	0							
10	8.8	156	320	370	23.7	28.4	114	167	188	271	0						
11	22.5	168	332	384	35.5	40.2	126	179	200	283	14.1	0					
12	150	273	391	363	163	168	231	270	243	355	140	134	0				
13	161	84.2	209	214	146	143	50.9	88.1	61.9	174	165	176	186	0			
14	193	87.2	200	174	180	177	87.4	81.1	55.7	164	200	210	220	40.4	0		
15	174	153	269	218	161	158	120	152	127	236	181	191	147	72.6	72	0	
16	161	203	320	292	149	145	160	199	173	284	143	179	72.6	112	146	74.2	0

b. Create a Savings Matrix

After the distance matrix has been created, the next step is to create a savings matrix based on the distance matrix, so that the savings matrix is a symmetric matrix. Using the same method, enter the distance value, then the savings value is obtained. To see the savings value for all nodes, you can see the following table:

Table 5. Savings Matrix (Km) in January 2022

	DC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	150	0															
2	314	299	0														
3	366	328	627.4	0													
4	20.5	33.5	32.5	34.5	0												
5	20.6	36.6	36.6	38.6	31.4	0											
6	108	215.9	216	245	32.7	33.7	0										
7	161	299.6	321	351	33.5	34.6	216.3	0									
8	182	299.1	348	377	33.5	36.6	215.8	316.2	0								
9	265	299	391	422	33.5	36.6	331	322	334	0							
10	8.8	2.8	2.8	4.8	5.6	1	2.8	2.8	2.8	2.8	0						
11	22.5	4.5	4.5	4.5	7.5	2.9	4.5	4.5	4.5	4.5	17.2	0					
12	150	27	73	153	7.5	2.6	27	41	89	60	18.8	38.5	0				
13	161	226.8	266	313	35.5	38.6	218.1	233.9	281.1	252	4.8	7.5	125	0			
14	193	255.8	307	385	33.5	36.6	213.6	272.9	319.3	294	1.8	5.5	123	313.6	0		
15	174	171	219	322	33.5	36.6	162	183	229	203	1.8	5.5	177	262.4	295	0	
16	161	108	155	235	32.5	36.6	109	123	170	142	26.8	4.5	238.4	210	208	260.8	0

c. Route Grouping Based on Savings Value

After the savings matrix is formed, then determine the route group based on the largest to smallest savings value from the savings matrix. This step is an iteration of the savings matrix, where if the largest savings value is found at nodes i and j then row i and column j are crossed out, then i and j are combined into one route group, and so on until the last iteration.

Table 6. Iteration of Node Grouping Based on Savings Matrix

	DC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	150	0															
2	314	299	0														
3	366	328	627.4	0													
4	20.5	33.5	32.5	34.5	0												
5	20.6	36.6	36.6	38.6	31.4	0											
6	108	215.9	216	245	32.7	33.7	0										
7	161	299.6	321	351	33.5	34.6	216.3	0									
8	182	299.1	348	377	33.5	36.6	215.8	316.2	0								
9	265	299	391	422	33.5	36.6	331	322	334	0							
10	8.8	2.8	2.8	4.8	5.6	1	2.8	2.8	2.8	2.8	0						
11	22.5	4.5	4.5	4.5	7.5	2.9	4.5	4.5	4.5	4.5	17.2	0					
12	150	27	73	153	7.5	2.6	27	41	89	60	18.8	38.5	0				
13	161	226.8	266	313	35.5	38.6	218.1	233.9	281.1	252	4.8	7.5	125	0			
14	193	255.8	307	385	33.5	36.6	213.6	272.9	319.3	294	1.8	5.5	123	313.6	0		
15	174	171	219	322	33.5	36.6	162	183	229	203	1.8	5.5	177	262.4	295	0	
16	161	108	155	235	32.5	36.6	109	123	170	142	26.8	4.5	238.4	210	208	260.8	0

Based on the savings matrix grouping, 3 product distribution routes are obtained in January 2022 as follows:

1. Route 1 is marked in yellow: 2 – 3 – 9 – 14 – 8
   Number of Products: 270 + 240 + 412 + 265 + 373 = 1,560 boxes
2. Route 2 is marked in red: 7 – 6 – 1 – 15 – 13
   Number of Products: 209 + 481 + 300 + 212 + 345 = 1,547 boxes
3. Route 3 is marked in blue: 16 – 12 – 5 – 11 – 4 – 10
   Number of Products: 265 + 130 + 288 + 279 + 225 + 223 = 1,410 boxes

d. Consumer Sorting With Nearest Neighbor

Table 7. Sorting of Consumers by Nearest Neighbor

Route	Vechile	Consumers	Distance
1	Box	K0 – K8 – K14 – K9 – K2 – K3 – K0	1.008,3
2	Box	K0 – K6 – K1 – K7 – K13 – K15 – K0	496,2
3	Box	K0 – K10 – K11 – K4 – K5 – K16 – K12 – K0	435,7

e. Transportation Cost Calculation

After applying the Nearest Neighbor Method, new costs and routes are obtained as follows:
Route X=Customer Distance×1/(Distance traveled in 1 liter)×Rp.9,400
Route 1=1,008.3×1/8×Rp.9,400=Rp.1,184,752.5
Route 2=496.2×1/8×Rp.9,400=Rp.583,035
Route 3=435.7×1/8×Rp.9,400=Rp.511,947.5

4.6. Distribution Route Analysis

The results of data processing using the Nearest Neighbor method are obtaining 3 new routes. PT Unilever Indonesia Depot Makassar distributes using a Hino 500 Ranger FG 245 JK truck. Each delivery route gets one vehicle, gets 2 people in 1 truck, and the route is divided into route 1, route 2 and route 3. Allocation of customer loads to each vehicle, namely route 1 carries a load of 1,560 boxes, route 2 with 1,547 boxes and route 3 with 1,410 boxes.

a. The New Route Uses the Nearest Neighbor Method

Route sorting uses the nearest neighbor method, according to Suparjo (2009) using the nearest neighbor method can produce vehicle routes for selected customers based on the closest customers. The new route uses the nearest neighbor method, namely:

Table 8. New Route Using the Nearest Neighbor Method

Route	Customer Code	Regional Name	Store Name
Route 1	K0	Gudang	PT. Unilever Indonesia Depo Makassar
	K8	Sidrap	Bintang Grosir
	K14	Sengkang	CV Ambassador Zulias
	K9	Polman	PT Tompotika Raya
	K2	Rantepao	PT Bintang Orient
	K3	Palopo	PT Tompotika Raya
	K0	Gudang	PT Unilever Indonesia Depo Makassar
Route 2	K0	Gudang	PT Unilever Indonesia Depo Makassar
	K6	Barru	UD Sinar Surya
	K1	Pare Pare	PT Tompotika Raya
	K7	Pinrang	PT Reski Laifasto
	K13	Soppeng	CV Ambassador Zulias
	K15	Bone	PT Wira Eka Persadatama
	K0	Gudang	PT Unilever Indonesia Depo Makassar
Route 3	K0	Gudang	PT Unilever Indonesia Depo Makassar
	K10	Gowa	CV Makro INDTIM
	K11	Takalar	CV Bintang Orient
	K4	Makassar	PT Sumber Alfaria Trijaya Tbk

K5	Maros	PT Sentral 88
K16	Sinjai	PT Sumber Cahaya Megaberkah
K12	Bulukumba	PT Tompotika Raya
K0	Gudang	PT Unilever Indonesia Depo Makassar

The following is the change in the initial delivery distance and the distance after using the nearest neighbor method.

Table 9. Proposed Nearest Neighbor Distance

Total Starting Distance (Km)	Total Nearest Neighbor Distance (Km)	Distance Difference (Km)	Economical (%)
2348	1940,2	407,8	15%

b. Shipping Cost Analysis

Fees are a means of payment, something that must be considered to support the delivery of the company. The following are the proposed costs after using the nearest neighbor method:

Table 10. Nearest Neighbor Proposal Costs

Total Initial Costs (IDR)	Total Nearest Neighbor Costs (IDR)	Cost Difference (IDR)	Economical (%)
IDR. 2.758.900	IDR. 2.279.735	IDR. 479.165	6%

5. Conclusion [Heading 12pt, Garamond, Bold, Justified]

Based on the results of the research that has been carried out, a conclusion is obtained, namely: In the initial distribution, the company used 5 routes, after using the saving matrix method it changed to 3 new routes, where the sequence of proposed routes using the nearest neighbor method became 1940.2 km with the total number of products distributed being 4,517 boxes of Sariwangi Tea. The proposed route obtained after using the nearest neighbor method is as follows: Route 1: (K0 – K8 – K14 – K9 – K2 – K3 – K0) with 1,560 boxes of products distributed, route 2: (K0 – K6 – K1 – K7 – K13 – K15 – K0) with a total of 1,547 boxes of products distributed, and route 3: (K0 – K10 – K11 – K4 – K5 – K16 – K12 – K0) with a total of 1,410 boxes of products distributed.

After getting a new route order using the nearest neighbor method, the shipping cost on the initial route is IDR. 2,758,900, after using the nearest neighbor method, you get shipping cost savings of IDR 479,165. So the shipping cost on the new route is IDR 2,279,735

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