Optimizing Warehouse Distribution Routes During Eid Season Using Saving Matrix and Nearest Insert Method

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ARTICLE INFO

Article history
Received : 29 April 2021
Revised : 19 May 2021
Accepted : 18 October 2021

Keywords
Routing
Saving Matrix
Nearest Insert
Distribution
Supply Chain

ABSTRACT

Arranging an optimal distribution system is a challenging step in every company who runs logistics activities because it is one of the crucial factors to achieve high customers' satisfaction level. This problem becomes more complex during the high or special seasons such as Christmas, new year, etc. In Indonesia, high season for logistics usually during the Eid season. During that special season, the demand increases while the resource decreases due to long national holiday. Failed to find an optimal distribution system might lead to a huge loss for the company. Therefore, to overcome this problem, logistics company should optimize the distribution system including optimizing the route and vehicles utilization. This paper aims to help a logistics company based in Bali, Indonesia, to find an optimal distribution route during the Eid Season. This company find difficulty to fulfil the customer demands especially during the Eid Season. To find an optimal route for the company, this paper applies Saving Matrix and Nearest Insert methods. These two algorithms are chosen because both of them have a simple procedure. Thus, it can save the computational time. Besides, a simple procedure will help the company to reuse the proposed methods for the next application. Data collection and observation in this paper were carried out during one week of Eid season in 2019. The computational results show that the optimal route is able to deliver all items before the due date with total distribution time 7 hours 16 minutes. Compare with the existing route, the proposed route reduces the total cost by 30%.

1. INTRODUCTION

To obtain a company's competitive edge, logistics as well as supply chain management has been recognized to be the crucial factor for any company [1]. Indonesia has national logistical problems that can be classified into problem group of commodities, infrastructure, logistics providers, human resources, information and communication technology, regulation and institutions [2]. In terms of logistics providers problem, any provider company whose quality and delivery records are poor may find difficulties to provide high level of customer service even in stable environments [3], therefore, effective distribution is one of the core elements in the logistics framework [4], aiming to move the materials in terms of saving time, financial resources and the optimal level of logistics service for final consumers [5]. However, achieving this optimal distribution can be challenging in certain seasons. Indonesia with its major Moslem population celebrates Eid Al-Fitr, a season when most of the population take holidays, which means lesser manpower to work. Hence, the logistics sector may also be affected due to the unpreparedness or poor logistical planning to face arising demands with less resources during the season. Such problems may resulted in high distribution costs and reduced company's profits [6]. Transportation itself is a logistics activity that requires the most considerably cost for nearly of 40% of the total company expenditures in the logistics sector, therefore the reduction of travel time should be implemented [7]. In other words, to accommodate high demand while maximizing profits, a company can create strategies by reducing empty legs, utilizing vehicle fleet effectively, and building of new more rational transport routes [8].

E-ISSN 2621-6442

As the main focus of this research, a direct observation was carried out by authors in a company engaged in the logistics sector in Denpasar, Bali, namely PT. XYZ. The company serves customers in Bali Island, Nusa Tenggara Island, West Nusa Tenggara, East Nusa Tenggara, and Java Island, especially in the Surabaya, Malang, and Jakarta. The customers are suppliers engaged in various fields, such as pharmaceuticals, electronics, and consumer goods. By providing transit warehouse and distribution services, the company distributes hundreds of goods to many regions in Indonesia daily. However, especially for the Bali region, most of the costumers of PT XYZ are pharmaceutical companies. Usually, the company was able to send hundreds of these pharmaceutical items in one day, but during Eid season, the company was unable to fulfil the one-day requirement and took two days to ship out all those items. This generated complaints from customers and profits were decreasing because there were so many shipment delays to each of the destinations.

Several problems draw the root cause of these complaints and lack of profits. Due to the limited number of vehicles owned by PT XYZ, the company was not able to serve customers at the same time. During observation in Eid season in 2019, authors found that nearly 50% of the couriers worked for the company took leave. In addition, the number of goods to be distributed was double than usual. Therefore, the company found difficulties in regulating the inbound and outbound flow in their warehouse. In normal season, the company sends one truck to each district in Bali, and this strategy was also implemented during Eid season. This logistics decision was poor, considering the high demand, limited vehicles and the customers' requirement for one day delivery time. Hence, the complaints became unavoidable for the company.

The above explanation brings the purpose of our study to create efficient distribution system, by minimizing time and cost in its distribution by using a vehicle routing problem method, namely Saving Matrix. Additionally, using the Nearest Insert method, we found the best route. With the results, the authors provide suggestions for improvement of the company's activities, where hopefully it will increase company's profits, reduce customer complaints, reduce transportation cost, and identifying the best distribution route especially when high demands occur.

2. LITERATURE REVIEW

Reference [9] showed that using a saving matrix method can reduce routes that previously had 16 routes to only three routes because the existing route can be merged with another route. The first route will serve 6 SPBU, the second route will serve 5 SPBU, and the third route will serve 5 SPBU. Unlike the study as in [10], which showed that after the data is processed using the DPR (Distribution Requirement Planning) method, the processed data is refined again using the saving matrix method. From the results of data processing using a saving matrix, the resulting route is more optimal. In Basriati and Sunarya's research, which discusses the CVRP (Capacitated Vehicle Routing Problem) problem, a saving matrix is also used to overcome this problem [11]. After processing the data using the saving matrix, the results show that the saving matrix method can solve the problems experienced. Research conducted by Rahayu and Yuliana [12] also found that the saving matrix method is suitable for shipping automotive components because the researcher gets the result shows that the companies can optimize the route with a more efficient time using the saving matrix method. Research conducted by Kholil, Mangaraja and Yosan [13] concluded that by using the saving matrix method, PT Denso could optimize the use of trucks needed to deliver goods every day. That study reveal that Farthest Insert method is the best approach. In addition, research conducted by Sriwana, Madusari and Sari [14] also concluded that the saving matrix method can produce a more optimal route for PT XYZ. A comparison between the Cross Entropy method and the Saving Matrix method was applied to solve problems in a company that is engaged in printing services that products based on orders [15]. The results show that the cross Entropy method are better than the Saving Matrix method because by using the Cross Entropy method, companies can save more costs.

3. METHOD

To obtain an optimal distribution route, this research follows the research framework shown in Fig.1. First step is problem observation to understand the real problem. The observation is focused on distribution problem during Eid season in PT XYZ. From the observation, a suitable mathematical model can be developed. Furthermore, this research collects the real data including the

number of trucks that owned by the company, the number of districts to be visited, the needs of each district, the cost of fuel for each truck, the capacity of each truck, the cost of traveling from one district to another district, and other supporting data from the internet and companies. This research uses demand one week before the Eid. List of distances and times between cities in Bali and between each city with the transit warehouse location, Denpasar, is obtained from Google maps. The next step is sorting the distance between each city. After sorting the distance between each city, the saving matrix method is applied to combine the routes. If the merged route is higher than the truck's capacity, then a new combination route should be generated. The result from this step is an initial route. This route is further improved by the nearest insert method. For validation, the optimal route is compared with the existing route in terms of time and cost.

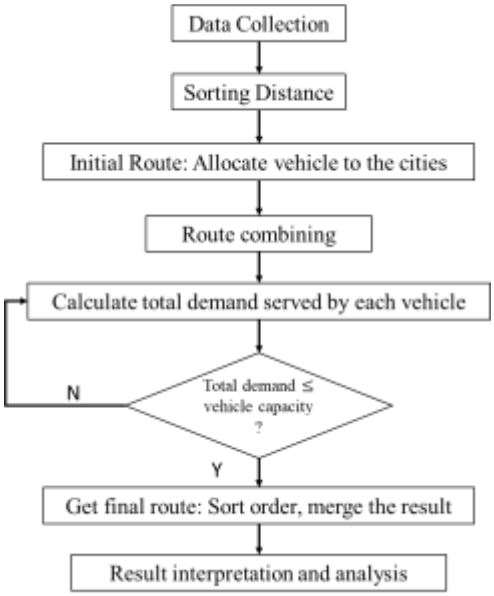

Fig. 1. Research Methodology

4. RESULTS AND DISCUSSION

The first step before processing data is to sort the distance between cities in Bali. After knowing the distance between each city in Bali, the next step is to identify the distance between cities in Bali using the saving matrix method. At this stage, the following formula is used:

$$s(x,y)=J(g,x)+J(g,y)+J(x,y) \quad (1)$$

where,

- $s(x,y)$ = saving distance from city x to city y.
- $J(g,x)$ = distance of city x with warehouse or can be said distance between city x and city of Denpasar.
- $J(g,y)$ = distance of city y with warehouse, or it can be said distance between city x and city of Denpasar.
- $J(x,y)$ = distance of city x with city y.

From the results of those equations, the saving matrix table can be created as in table 1 below.

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Table 1. Distance Matrix (km)

	BDG	BGL	BLL	GNR	JBR	KRG	KLK	TBN
BDG	0							
BGL	16.6	0						
BLL	24.9	26.8	0					
GNR	18.4	53.8	28.8	0				
JBR	26.1	18.7	112.4	20.8	0			
KRG	9.1	61.8	37	45.4	10.8	0		
KLK	9.1	51.8	21.4	48.4	10.8	58	0	
TBN	26.1	18.7	44.6	20.8	44.6	13.1	10.9	0

Remarks: (BDG = Badung; JBR = Jembrana; BGL= Bangli ; KRG = Karangasem; BLL= Buleleng; KLK = Klungkung; GNR = Gianyar; TBN = Tabanan)

After getting the results of the saving matrix between cities in Bali, the next step is to allocate the existing city to each vehicle or route. Because the company only has four types of trucks, the eight routes must be combined. Table 2 below is the type and capacity of each truck owned by PT XYZ.

Table 2. Truck Types and Capacities

Type of Truck	Carrying Capacity (kg)
Grand Max Box	1250
Volt Diesel Engkel Box	2750
Colt Diesel Double	6250
Wina Box 1	13750
Wina Box 2	13750

While table 3 are the total and average weight of goods that come in a day for each city in Bali during the Eid season.

Table 3. Total and Average Weight of Goods Sent to Each Town in Bali

Date the Goods Arrived	Total Weight of Goods (kg)							
	BDG	BGL	BLL	GNR	JBR	KRG	KLK	TBN
May 22 2019	20	169	169	1344	209	217	663	157
May 23 2019	21	251	251	856	135	112	126	167
May 24 2019	15	117	117	1265	74	107	138	212
May 25 2019	5	103	103	332	458	62	32	125
May 27 2019	7	153	153	1773	217	369	144	314
May 28 2019	34	375	375	393	287	153	130	460
May 29 2019	2	43	43	588	214	328	142	219
AVERAGE	19.4	173	639.71	935.86	227.71	192.57	196.43	236.29

Combining each of these routes is done by looking at the value of the largest saving matrix. This is because, the greater the results of the saving matrix, the greater the savings generated. In table 1, it can be seen that Jembrana and Buleleng have the greatest value of saving matrix, which is 112.4 km. And if the average total weight of goods based on table 3 sent to the two cities is combined, the result will be 867.42 kg. That is, goods from these two cities can be combined into one truck and will be brought together. Table 4 illustrates the route changes after Jembrana and Buleleng were combined.

Table 4. Route Changes after Jembrana and Buleleng Were Combined (km)

		BDG	BGL	BLL	GNR	JBR	KRG	KLK	TBN
BDG	Route 1	0							
BGL	Route 2	16.6	0						
BLL	Route 3*	24.9	26.8	0					
GNR	Route 4	18.4	53.8	28.8	0				
JBR	Route 3*	26.1	18.7	112.4*	20.8	0			
KRG	Route 5	9.1	61.8	37	45.4	10.8	0		
KLK	Route 6	9.1	51.8	21.4	48.4	10.8	58	0	
TBN	Route 7	26.1	18.7	44.6	20.8	44.6	13.1	10.9	0
AVERAGE		19.4	173	639.71	935.86	227.71	192.57	196.43	236.29

* Chosen route

Furthermore, the second biggest savings are Karangasem and Bangli, with the acquisition of a saving matrix value of 61.8 km. And if the total weight of each city is combined, the result is 365.57 kg, which means the routes of the two cities can be combined. Table 5 below, shows a saving matrix table after Bangli and Karangasem are combined.

Table 5. Route Changes after Bangli and Karangasem Were Combined (km)

		BDG	BGL	BLL	GNR	JBR	KRG	KLK	TBN
BDG	Route 1	0							
BGL	Route 2*	16.6	0						
BLL	Route 3*	24.9	26.8	0					
GNR	Route 4	18.4	53.8	28.8	0				
JBR	Route 3*	26.1	18.7	112.4*	20.8	0			
KRG	Route 2*	9.1	61.8*	37	45.4	10.8	0		
KLK	Route 5	9.1	51.8	21.4	48.4	10.8	58	0	
TBN	Route 6	26.1	18.7	44.6	20.8	44.6	13.1	10.9	0
AVERAGE		19.4	173	639.71	935.86	227.71	192.57	196.43	236.29

* Chosen route

Because the truck owned by PT XYZ only consists of five, it is necessary to merge the route one more time so that the route and the number of vehicles owned are just right. Therefore, because Karangasem and Klungkung is the third-largest savings matrix producer, with a value of 58 km, these two cities need to be combined. However, because Karangasem had previously been combined with Bangli, the total weight of goods to be transported to the two cities must be added to the total weight of goods to be delivered to Klungkung. Once combined, the total weight of the three districts is 562 kg. This means that Klungkung can be combined with Karangasem and Bangli. Table 6 below, illustrates the saving matrix table if the three districts are combined into one route.

Table 6. Route Changes after Bangli and Karangasem Were Combined (km)

		BDG	BGL	BLL	GNR	JBR	KRG	KLK	TBN
BDG	Route 1	0							
BGL	Route 2*	16.6	0						
BLL	Route 3*	24.9	26.8	0					
GNR	Route 4	18.4	53.8	28.8	0				
JBR	Route 3*	26.1	18.7	112.4*	20.8	0			
KRG	Route 2*	9.1	61.8*	37	45.4	10.8	0		
KLK	Route 3*	9.1	51.8	21.4	48.4	10.8	58*	0	
TBN	Route 5	26.1	18.7	44.6	20.8	44.6	13.1	10.9	0
AVERAGE		19.4	173	639.71	935.86	227.71	192.57	196.43	236.29

* Chosen route

E-ISSN 2621-6442

After merging routes for several districts, the final routes are:

- Route 1 serves Badung with an average total weight to be delivered at 19.4 kg, which means it can be transported by any type of truck.
- Route 2 serves Bangli, Karangasem, and Klungkung with an average total weight of 562 kg which means that it can be transported by any type of truck.
- Route 3 serves Buleleng and Jembrana with an average total weight to be delivered at 867.42 kg, which means it can be transported by any type of truck.
- Route 4 serves Gianyar with an average total weight to be delivered at 935.86 kg, which means it can be covered by any type of truck.
- Route 5 serves Tabanan with an average total weight to be delivered at 236.29 kg.

After obtaining a better route, the next step is to sort the order from the route that was made before. Because route 2 and route 3 serve more than one city, to determine the order of destination of the trucks, it is necessary to use the nearest insert method. The first step in this method is to find the distance from the warehouse to one of the districts, and then back to the warehouse.

- Route 2

  DPS – BGL – DPS = 38.6 km + 38.6 km = 77.2 km

  DPS – KRG – DPS = 66.6 km + 66.6 km =133.2 km

  DPS – KLK – DPS = 31.3 km + 31.3 km = 62.6 km

From the calculation above, the first route visited by trucks is the Klungkung district. This is because, the distance from the warehouse, to Klungkung, and back to the warehouse, has the least distance, which is 62.6 km, compared to the distance from the warehouse, to Bangli, and back to the warehouse, which is 77.2 km, and the distance from warehouse, towards Karangasem, and back to the warehouse, which is 133.2 km. Because Route 2 serves more than two routes, it is necessary to calculate the distance from the warehouse, to Klungkung, then to Karangasem, then to Bangli, and back to the warehouse, and the distance from the warehouse, to Klungkung, then to Bangli, then to Karangasem, and back again to the warehouse.

- Route 2

  DPS – KLK – BGL – DPS = 31.3 km + 18.1 km + 38.6 km = 88 km

  DPS – KLK – KRG – DPS = 31.3 km + 39 km + 66.6 km = 136.9 km

The distance to visit Buleleng and Jembrana is as the following:

- Route 3

  DPS – BLL – DPS = 86.4 km + 86.4 km = 172.8 km

  DPS – JBR – DPS = 94 km + 94 km = 188 km

From the calculation above, we can conclude that the first route to visit is Buleleng. It because, the distance from the warehouse, to Buleleng, and back to the warehouse, has a smaller distance, which is 172.8 km, compared to the distance from the warehouse, to Jembrana, and back to the warehouse, which is 188 km. So, now we know that the better route for each route is:

- Route 1 = DPS - BDG - DPS
- Route 2 = DPS - KLK - BGL - KRG - DPS
- Route 3 = DPS - BLL - JBR - DPS
- Route 4 = DPS - GNR - DPS
- Route 5 = DPS - TBN - DPS

Based on the data processing above, five routes will be served by five trucks owned by PT XYZ. If previously PT XYZ needed two days to deliver all goods to the destination location, then, using

the saving matrix method, the following is the time required for each route to return to the warehouse.

- Route 1 = DPS – BDG – DPS = 32 minutes + 32 minutes = 64 minutes
- Route 2 = DPS – KLK – BGL – KRG – DPS = 52 minutes + 30 minutes + 104 minutes = 186 minutes
- Route 3 = DPS – BLL – JBR – DPS = 149 minutes + 120 minutes + 150 minutes = 419 minutes
- Route 4 = DPS – GNR – DPS = 48 minutes + 48 minutes = 96 minutes
- Route 5 = DPS – TBN – DPS = 46 minutes + 46 minutes = 92 minutes

So, from the results of the above calculation, it can be said that the saving matrix method can make PT XYZ only takes one day to deliver its shipments to each district in Bali. It because each route takes less than eight hours to return to the warehouse. Based on the results of these calculations, the total time of the five routes is 857 minutes, or 14 hours 17 minutes. Whereas if it stays in eight routes, then the time needed is:

- Route 1 = DPS – BDG – DPS = 32 minutes + 32 minutes = 64 minutes
- Route 2 = DPS – KLK – DPS = 52 minutes + 52 minutes = 104 minutes
- Route 3 = DPS – BLL – DPS = 149 minutes + 149 minutes = 298 minutes
- Route 4 = DPS – GNR – DPS = 48 minutes + 48 minutes = 96 minutes
- Route 5 = DPS – TBN – DPS = 46 minutes + 46 minutes = 92 minutes
- Route 6 = DPS – BGL – DPS = 64 minutes + 64 minutes = 128 minutes
- Route 7 = DPS – JBR – DPS = 150 minutes + 150 minutes = 300 minutes
- Route 8 = DPS – KRG – DPS = 104 minutes + 104 minutes = 208 minutes

Based on these results, the time required if still using eight routes is 1,290 minutes, or 21 hours 30 minutes. So, it can be said, using the saving matrix and nearest insert method can save up to 7 hours 16 minutes. However, from the routes that have been obtained, the researchers can also find out the number of costs needed for each route in this study because the researcher only calculated the cost based on the fuel spent considering the connecting roads between districts since there are no tolls cost in Bali.

- Route 1 = DPS – BDG – DPS = Rp10,936 + Rp10,936 = Rp21,874
- Route 2 = DPS – KLK – BGL – KRG – DPS = Rp23,287 + Rp13,466 + Rp32,290 + Rp49,550 = Rp118,594
- Route 3 = DPS – BLL – JBR – DPS = Rp64,282 + Rp50,592 + Rp69,936 = Rp184,810
- Route 4 = DPS – GNR – DPS = Rp21,130 + Rp21,130 = Rp42,260
- Route 5 = DPS – TBN – DPS = Rp17,038 + Rp17,038 = Rp34,076

Based on the results above, the total cost of the five routes is Rp401,586. Whereas if it stays in eight routes, then the cost needed is Rp569,755 with the details below:

- Route 1 = DPS – BDG – DPS = Rp10,936 + Rp10,936 = Rp21,874
- Route 2 = DPS – KLK – DPS = Rp23,287 + Rp23,287 = Rp46,574
- Route 3 = DPS – BLL – DPS = Rp64,282 + Rp64,282 = Rp128,564
- Route 4 = DPS – GNR – DPS = Rp21,130 + Rp21,130 = Rp42,260
- Route 5 = DPS – TBN – DPS = Rp17,038 + Rp17,038 = Rp34,076
- Route 6 = DPS – BGL – DPS = Rp28,718 + Rp28,718 = Rp57,436

Jurnal Logistik Indonesia Vol. 5 , No.2 , Oktober 2021 pp. 111-119
E-ISSN 2621-6442

- Route 7 = DPS – JBR – DPS = Rp69,936 + Rp69,936 = Rp139,872
- Route 8 = DPS – KRG – DPS = Rp49,550 + Rp49,550 = Rp99,100

Based on the above calculations show that data processing using the saving matrix method can produce a much more efficient route than not using any method. It because the total costs incurred by using the Matrix saving method yields approximately Rp401,586, while the total cost, if not using any method, is approximately Rp569,755. Thus, it can be concluded that PT XYZ can save costs around Rp168,169, or around 30% cheaper when compared to the costs generated by not using any method. And here is the following type of truck owned by PT XYZ that is suitable for each route based on each city's road conditions and a load of carries.

- Preferably, route 1 is from Denpasar to Badung, and back to the warehouse, used a Grand Max Box truck because there is only a small amount of goods carried, and the road conditions in Badung are good.
- Preferably, route 2 from Denpasar to Klungkung, from Bangli, then to Karangasem, and return to the warehouse, used a Volt Diesel Engkel Box truck because the road conditions in Klungkung, Bangli, and Karangasem are not that good. Besides, Klungkung and Karangasem have a small road.
- Preferably, route 3, which is the route from Denpasar, going to Buleleng, then to Jembrana before returning to Denpasar, used a Wina Box 1 truck because Jembrana and Buleleng are roads to Java. So, the road is quite big.
- Preferably, route 4, which is Denpasar, goes to Gianyar, and returns to Denpasar, used a Wina Box 2 truck because the road in Gianyar is quite large, and they carry quite a lot of goods.
- Preferably, route 5, which is serves Denpasar, to Tabanan, and back again to Denpasar, used a Colt Diesel Double truck because Tabanan has a large road, although it is slightly damaged.

5. CONCLUSION

PT XYZ is one of the companies that must deliver hundreds of goods to many regions in Indonesia, especially to several towns in Bali. Usually, this company just needs one day to deliver their goods to the consignees. But when Eid season, this company took two days to send goods from consignor to consignee, and it makes both consignor and consignee complain. The researcher hope that this study can obtain a delivery route of goods from the warehouse to the destination, which is more appropriate than before, by optimizing the routes that PT XYZ took.

To be able to analyze the determination of these routes, saving matrix method and nearest insert method are used in this research. To optimizing the routes that PT XYZ took, the first thing to do is look for a district that needs to be combined because of the limited number of fleets, and the position of each destination is quite far away. Because PT XYZ just has five vehicles to deliver their goods, so the researchers combined some towns, and new five routes are derived by using Saving Matrix calculation. After the five new routes are obtained, the researchers need to use the nearest insert method to determine the order of destination of each route. Based on these results, these methods can make PT XYZ have more appropriate routes than before because by using saving matrix method and nearest insert method, PT XYZ can save up 7 hours and 16 minutes, as summarized below:

- Route 1 serves Badung with the total delivery time from the warehouse, goes to Badung, and returns to the warehouse for 64 minutes or one hour and four minutes by Grand Max Box truck.
- Route 2 serves Klungkung, Bangli, and Karangasem with the total delivery time from the warehouse, to Klungkung, then to Bangli, and to Karangasem, before finally returning to the warehouse for 186 minutes, or three hours six minutes by the Volt Diesel Engkel Box truck.
- Route 3 serves Buleleng and Jembrana with the total delivery time from the warehouse, goes to Buleleng, then to Jembrana, before finally returning to the warehouse for 419 minutes, or six hours 59 minutes by Wina Box 1 truck.

- Route 4 serves the Gianyar with the total delivery time from the warehouse, goes to the Gianyar, and returns to the warehouse for 96 minutes, or one hour 36 minutes by Wina Box 2 truck.
- Route 5 serves Tabanan with total delivery time from the warehouse, goes to Tabanan, and returns to the warehouse for 92 minutes, or one hour 32 minutes by Colt Diesel Double truck.

By using the saving matrix and nearest insert method, it is proven that these methods generated a better distribution route for PT XYZ, especially during Eid season compare with the existing route. Currently the company spend more than two days to deliver the items. The proposed route requires 17 hours and 16 minutes. The company can send all goods to each destination within only one day, because the total time generated until returning to the warehouse is less than eight hours, or it can be said that the driver can return before the time to go home. Additionally, the new routes generate 30% cheaper transportation cost. Future research can be done by adding elements to be considered such as volume of goods carried, more detailed transportation cost, etc.

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