Determination of route for estimating number of truck needed in periodic distribution: A case study

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Abstract. Transportation is an important supply chain element. Lowering logistics costs can be effectively carried out by lowering transportation costs. PT. IAP is a distributor company that supplies fast-moving consumer goods products to more than 500 Modern Trade. There was 77% of delivery have been carried out by PT. IAP has achieved the targeted service level. The root cause of this problem is delivery which is triggered by purchase order (PO) from retailers. IAP plans to change the delivery procedure that has been triggered by the PO to periodic delivery based on historical data of each retailer's demand. Therefore, this research aims to determine the route to estimate the number of trucks needed is periodic delivery. The distribution route will be developed using a saving matrix algorithm for clustering retailers in one route while the order of delivery is obtained by the Nearest Neighbor method. Based on the results of the saving matrix developed in visual basic for application (VBA), it is found that the number of vehicles needed by Colt Diesel Double (CDD) trucks is 23 units and Colt Diesel Engkel (CDE) trucks are 11 units. The reduction in the number of trucks needed is significant, before the study, the company needs 40 trucks CDD and 15 trucks CDE.

1. Introduction
Transportation is responsible for the physical movement of materials between points in the supply chain [1]. Transportation is an important supply chain element because products are rarely produced and consumed in the same location [2]. Transportation costs are costs that dominate the total logistics costs. The amount of these costs can reach 60% of the total logistics costs of the company. Therefore, lowering logistics costs can be effectively carried out by lowering transportation costs. Transportation costs can be reduced by increasing the utility of transport vehicles, balancing capacity between stages of distribution, determining efficient routes of distribution and good coordination between companies and consumers. In many cases, distribution is carried out by several different parties. Therefore, good coordination is also needed between the parties involved at all stages of distribution.

The Case Study in this research is conducted at IAP, a distributor company. The company distributes products produced by 24 companies to hundreds of retailers located throughout Surabaya. These retailers send POs to IAP and IAP make deliveries to fulfill these POs tomorrow. This causes the number of trucks needed every day to keep changing. IAP classifies retailers into two categories of retailers namely general trade and modern trade. In general trade, product shipments are carried out in two stages: the product is sent to the stocking point, the product is sorted and then sent to retailers. IAP has a target service level for delivering goods to retailer not more than 24 hours after receiving a
Purchase Order (PO). Based on historical data in October 2018 to September 2019, there was 116,023 PO and only 77% of the POs which can be delivered not more than 24 hours. Figure 1 explains flow of good in general and modern trade.

![Figure 1. Flow of good in general and modern trade](image)

Currently, IAP has a total of 55 trucks with details of 40 Colt Diesel Double (CDD) trucks with a capacity of 4 tons and 11 m$^3$ and 15 Colt Diesel Engkel (CDE) trucks with a capacity of 2.5 tons and 7 m$^3$. Currently, the IAP has not been able to achieve the expected target service level so it has to rent 8 vehicles when there is a surge in demand or POs that do not follow the RPS. The addition of this vehicle is quite helpful to cover delivery when the IAP gets a surge in demand from the retailer, but on the other hand the rented truck will be idle when demand is not more than average demand. This causes the truck utility to be low.

Moreover, IAP delivery team determines the distribution route manually or according to the knowledge and experience of drivers. Therefore, the routes are not optimal. The root cause of this problem is delivery which is triggered by PO from retailers. IAP plans to change the delivery procedure that has been triggered by PO to routine delivery based on historical data of each retailer's demand. So the formulation of the problem in this research is if routine delivery is applied, how to determine the delivery route and how many trucks are needed.

2. Methods
This study aims to determine the number of trucks needed by determining a good (near optimal) route. The determination of the route is done using a saving matrix algorithm. This study was carried out in three main stages:

1. Estimating the distance between each retailer and between each retailer with distribution center which is required in the saving matrix algorithm.
   Distance is estimated using google maps and haversine formula. Google maps are used for retailers that are located with quite a high circularity factor.

2. Converting demand that is stated in units into units of volume.
   Historical demand data contains the number of products that need to be sent to each retailer. Truck capacity is not measured in units but in weight and volume so conversion is needed. Conversion becomes even more complicated because there are many types of products and packaging that need to be distributed. Based on experience, the volume capacity is met before the weight capacity. Therefore, the capacity parameter that needs to be considered is only the volume capacity.

3. Determine the route with a saving matrix algorithm using visual basic for application (VBA) software.
   At this stage, the node is grouped points into one cluster using the Saving Method and then sorted using the Nearest Neighbor with the help of Visual Basic for Application (VBA) tools. The algorithm which can be seen in Figure 2 becomes a reference for making algorithms in VBA to simplify and precipitate the calculation of all modern trades served by PT. IAP.
Prior to use the developed VBA was verified and validated to ensure that the VBA was developed correctly. Validation is done by testing VBA with a group of destination points with certain demands. VBA solutions will be compared with manual calculations, if the results are the same then VBA can be said to be valid so that it can be used to determine the overall route. The samples used were retailers located in Semampir District, Surabaya. The results of manual calculations and VBA software can be seen in Table 1 and Table 2.
Table 1. The result of VBA

| Route | Demand (m²) | Load (m²) | Delivery Time (min) | Arrived Time | Finish Service |
|-------|-------------|-----------|---------------------|--------------|----------------|
| Truck CDD 1 Day 1 | | | | | |
| 0 | 0.1473 | 0.1473 | 1.0000 | 08:00 | 08:25 |
| 2 | 0.6147 | 0.7620 | 0.8583 | 08:26 | 14:26 |
| 6 | 4.8174 | 5.5794 | 1.0000 | 14:27 | 14:57 |
| 3 | 2.1557 | 7.735 | 0.9142 | 14:58 | 17:58 |
| 0 | | | 2.1920 | | 18:00 |
| Truck CDD 1 Day 2 | | | | | |
| 0 | 5.71 | 5.71 | 2.07679 | 08:00 | 13:00 |
| 4 | 2.6368 | 8.3468 | 2.17193 | 13:02 | 14:02 |
| 5 | 2.5992 | 10.946 | 2.13776 | 14:04 | 14:34 |
| 0 | | | 2.11096 | | 14:36 |
| Truck CDD 2 Day 1 | | | | | |
| 0 | 1.9027 | 1.9027 | 1.28101 | 08:00 | 08:30 |
| 4 | 9.1 | 11.0027 | 0.79576 | 08:31 | 13:31 |
| 0 | | | 2.07679 | | 13:33 |
| Truck CDE 1 Day 1 | | | | | |
| 0 | 7 | 7 | 0.79576 | 08:31 | 13:31 |
| 0 | | | 2.07679 | | 13:33 |
| Truck CDE 1 Day 1 | | | | | |
| 0 | 2.5804 | 2.5804 | 2.45754 | 08:00 | 13:00 |
| 0 | | | 2.45754 | | 13:02 |

Table 2. The route as a result of manual calculation

| Vehicle ID | Type of Vehicle | Route |
|------------|-----------------|-------|
| 1 | CDD | 0(1) -> 2(1|08:25|0.15) -> 6(1|14:25|0.61) -> 3(1|14:55|4.82) -> 8(1|17:55|2.16) -> 0 |
| | | 0(2) -> 4(2|13:00|5.71) -> 1(2|14:00|2.64) -> 5(2|14:30|2.6) -> 0 |
| 2 | CDD | 0(1) -> 9(1|08:30|1.9) -> 4(1|13:30|9.1) -> 0 |
| 3 | CDE | 0(1) -> 4(1|13:30|7) -> 0 |
| | | 0(2) -> 7(2|13:00|2.58) -> 0 |

Based on the verification process, it can be concluded that the route algorithm built on the VBA tools is valid.

3. Result and Analysis

The results of the route are formed using a routine delivery scenario for one month. Algorithm is run once for all modern trades served. The number of trucks needed under the routine delivery scenario every month is 23 CDD trucks and 11 CDE trucks. The scenario of routine delivery every month can
reduce the need for vehicles up to 42.5%. This is because of the application of VMI, where delivery to the retailer is fully regulated by PT. IAP as a supplier of FMCG in retailers.

Sensitivity analysis is performed to determine changes in the solution if there are changes in the model parameters [2]. In this case, the parameter that is most likely to change in demand.

- **Demand Increased by 20%**
  The need for trucks increased to 28 CDD trucks and still needed 11 CDE trucks. Retailers that are visited are reduced because trucks load more demand for the same retailer, so the need for trucks increases. The route formed changes from normal conditions. However, there are 20% of the unchanged routes. Utilities have increased from 96.07% to 97.64% due to the greater amount of demand carried.

- **Demand is increased 100%**
  The number of trucks needed increased to 43 CDD trucks and 19 CDE trucks. This is because the load carried by the vehicle is greater than usual so that the vehicle volume capacity limit is easily reached even though the number of retailers sent is less. Utilities increased to 98.06%.

- **Demand Decreased by 15%**
  The need for trucks has decreased from what was originally needed to be 20 CDD trucks and 10 CDE trucks. As many as 28% of the routes have not changed due to the decrease in demand which is not too significant.

- **Demand Decreases 50%**
  The need for trucks decreased to 12 CDD trucks and 10 CDE trucks. This can occur because of the increase in retailers visited in one route. The route formed changes from normal conditions. However, from the sampling of 100 routes from CDD trucks and CDE trucks with ID Vehicle 1, 2 there is 1 unchanged route, namely CDD 1 truck with routes going to retailers 2, 6, 9, 3.

This study has not yet implemented the levelling criteria or the equalization of vehicle loads to the retailers visited has not been done so it cannot prevent imbalances. The clustering process is only used as a tool to simplify the algorithm to find out which retailers are the closest to visit afterwards, but in the reality the closer retailers may be different retailers in the sub-district. Therefore, determining the route cannot be done separately between one cluster with another cluster. The distance used in this study does not use the distance calculated by Google Maps (using estimates with the Haversine Formula) so that it is less representative of the actual distance. In addition, the amount of demand entered is the average demand every month, so the demand processed has not accommodated the surge in demand during the season. Vehicle assignments do not consider which locations are only able to be passed by CDE trucks. The algorithm that was formed also did not consider shipping for the second, third and so on. Because of these limitations, easing time windows in the sensitivity analysis does not significantly influence the route formed and the number of vehicles needed.

4. Conclusion
The conclusions of this study are the schedule and route obtained are better than existing conditions because routine delivery can reduce the possibility of trucks to experience idle without having to reduce the level of demand fulfillment. From the 40 CDD trucks provided by the company, only 23 were needed and only needed 11 CDE trucks out of 15. With routine deliveries, higher trucking utility is generated. Based on a comparison of existing routes and running results, utility utilization of trucks has increased from 80% to 90%.

The sensitivity analysis that has been carried out proves that the modified parameters are able to influence the route decisions made. The demand parameter that was changed to double shows the need for 43 CDD trucks and 19 CDE trucks. The total demand for these trucks has increased by 80% of the needs of normal trucks using the routine shipping business process. On the other hand, the demand for trucks decreased by 47% when the demand dropped to half. This shows that the demand parameters are very sensitive to the decision of the route and the number of trucks needed.
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