Determination of Multi-Product Distribution using Capacitated Vehicle Routing Problem (CVRP) and Product Cubication Dimensions Restriction

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Abstract. CVRP is one of the transportation problems with the characteristic of the limited capacity of the vehicle. PT. Trikarsa Mitra Utama experienced transportation problems in the distribution of 3 types of paint products to 12 consumers, with 2 different units of vehicles. This research discuss how to determine the distribution route of paint products by considering the capacity of the vehicle based on weight and different cubication dimensions of the product. The method used for this problem is the Saving Clarke and Wright method besides that the Cube IQ software is used to loading products on the vehicle based on cubication dimensions. Besides being able to influence the process of preparing transportation routes, the results of the optimum loading process will also be used as a plan for product preparation in vehicle. The routes formed from the calculation results are classified into 3 clusters. Cluster 1 with route 0-H-K-D-I-L-0, cluster 2 with route 0-G-F-J-E-C-0, cluster 3 with route 0-A-B-0 gives a total mileage of 288 km and a travel time of 695 minutes using the same vehicle by colt diesel engkel (CDE).

Keywords: CVRP, Saving Clarke and Wright, cubication dimension, loading process, Cube IQ.

1. Introduction

Transportation activities have a big role in the level of customer satisfaction and business interests of the company. Transportation problems are commercial problems that must be resolved by companies that carry out logistical activities. A case study conducted at a company that makes the production of various types of paints with various uses such as protective coatings, floor coatings, marine coatings, industrial metal coatings. The problem that occurs in this company lies in the logistics system, the cost of transportation out of logistics companies that are considered high enough to distribute goods from depots to 12 different locations of consumers. This is indicated as a result of the suboptimal determination of transportation routes for the distribution of paint products to 12 consumers resulting in high transportation costs.

Different vehicle transport capacities make transportation problems classified into Capacitated Vehicle Routing Problems (CVRP) [1]. The choice of transportation equipment of the company must be in accordance with the number of consumers concerned, so that the demand can be fulfilled exactly once and there is no double shipping [2]. The choice of the vehicle will not only be considered from the weight of the product but also from its dimensions, so that the feasibility of planning is determined by both the weight and dimension. The addition of the cubication dimension restriction was made due to the fact
that the process of distributing various types of paint products at this company was not carried out in bulk, but was packaged in a different package.

The problem formulation of this research is how to determine the distribution route of paint products by considering the capacity of the vehicle based on different cubication dimensions of the product. The objective to be achieved in this research is to get the results that are close to optimum from a Capacitated Vehicle Routing Problem (CVRP) model using the Saving-Clarke & Wright (saving) method by considering the transport capacity based on cubication dimensions through the product loading process. So that it is expected to provide minimum mileage accompanied by a product preparation plan on the vehicle.

2. Methods
In the transportation system determining the route and scheduling of vehicles is an important component that can affect the high transportation costs. Vehicle route problems are often referred to as Vehicle Routing Problems (VRP). Vehicle routing problem (VRP) is an extension of the basic traveling salesman problem (TSP) [2].

Along with the development of VRP that has been done and hence the limited capacity of the term vehicle VRP called the Capacity Vehicle Routing Problem (CVRP). The CVRP problem model has the following constraints [3]:
1. Each route will start and end at one depot.
2. Each consumer will only be visited by one vehicle.
3. The total demand for each route must not exceed the vehicle capacity.

The purpose of VRP is to deliver the product to a group of consumers whose request is known by only spending a minimum cost and starting and ending at one or more depots. The output of this problem is a route that produces a low cost and is feasible for each vehicle.

The process of moving goods / materials from the the polling area to a delivery vehicle is called loading. This process is a form of warehouse services to users and consumers. The loading process is largely determined by the type, classification and characteristics of the product. The Framework of methods can be seen in Figure 1.

![Figure 1. Methods Framework](image-url)
Loading activity is raising the product (raw material, parts, goods-in-process, finished goods) to the truck that has gone through checking, then it will be sent according to the destination of each consumer [4]. Activities that include in the loading process are checking products (raw materials, parts, goods-in-process, finished goods), whether they are in accordance with the number of requests, the type of product and the quantity in accordance with consumer demand.

Cube IQ is a software to help in planning loading activities properly and regularly, which will result in the most efficient compilation. Cube IQ has operating modes for container loading, truck loading, palletization and cartonization. There are various possibilities for Cube IQ in loading activities, are [5]:

1. Create a 3D load diagram of the plan that uses complex loading rules that include loading sequences, partial loads, and load distribution.
2. Optimizing the load under the stack as a whole, in accordance with the rules.
3. Keep loading cases in full.
4. Distribute loading instructions in a 3-D diagram.

3. Result and Discussion

3.1. Data of Product Size, Vehicle and Saving Ranking Matrix

Distance Measurement Tools TM application Google Maps is used for collecting some data includes the vehicle's mileage and travel time.

It is known that products X, Y and Z have cylinder shape so the dimensions are owned in the form of diameter and height. For product X lot contains 12 units of product X packed in cartons with arrangement 3 elongated units, 2 widened units, and stacked 2 stacks for product height with a carton thickness of 0.3cm each its side. For more details can be seen in Table 1 below.

| Dimension | Product Size (cm) |
|-----------|------------------|
|           | X (1 kg) | Y (10 kg) | Z (18 kg) | X (Lot) |
| Length    | 13.05    | 27.30     | 30.00     | 39.75   |
| Width     | 13.05    | 27.30     | 30.00     | 26.70   |
| Height    | 12.00    | 26.30     | 33.80     | 24.60   |

In addition to company-owned product data, transport capacity data is also a main data used in research. Vehicle data used consists of two types of vehicles, the CDE standard and Suzuki Pick-Up. For more details can be seen in Table 2 below.

| Vehicle Type       | Capacity (Maximum) |
|--------------------|--------------------|
|                    | L(cm) | W(cm) | H(cm) | Vol(m3) | Weight(kg) |
| CDE Standard       | 237   | 155   | 129   | 4.739   | 2000       |
| Suzuki Pick-Up     | 220   | 148   | 100   | 3.256   | 800        |

Technological advancements in the field of Intelligent Transport System (ITS) provide sophisticated equipment that can be used as a consideration to assist the operation of the transportation system [6]. One of the ITS technologies that is integrated with software as a transportation system aids is the Global Positioning System (GPS). Related to transportation problems in this study, the use of ITS technology, the Global Positioning System (GPS) in the Distance Measurement Tools Google Maps application, is
used to collect some data which includes mileage and vehicle travel time. Distance data between nodes taken using the Google Maps application are as follows in Table 3.

| 0 | A | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 24.8 | 37.4 | 5.3 | 33.3 | 15.4 | 25.1 | 3.1 | 57.3 | 30.4 | 29.7 | 55.9 | 30.4 |
| A | 22.5 | 21.6 | 53.4 | 23.2 | 44.7 | 27.7 | 76.7 | 51 | 49.1 | 79.2 | 51 |
| B | 30.9 | 62.8 | 34.1 | 55.5 | 37.4 | 87.6 | 61 | 60.3 | 86.1 | 61 |
| C | 37.9 | 11.8 | 27.6 | 7.1 | 59 | 32.1 | 33.5 | 60.2 | 32.1 |
| D | 41.6 | 10.3 | 38.9 | 18.9 | 2.5 | 3.1 | 16.1 | 2.5 |
| E | 35.1 | 17.3 | 67.2 | 38.9 | 38.3 | 65.3 | 38.9 |
| F | 26.9 | 36.5 | 7.9 | 7.3 | 35.1 | 7.9 |
| G | 58.6 | 27.8 | 27.1 | 57.2 | 27.8 |
| H | 24.9 | 25.6 | 3.8 | 24.9 |
| I | 1.4 | 19.5 | 0.0 |
| J | 19.7 | 0.7 |
| K | 18.2 |
| L |

The saving matrix is obtained from distance matrix data has been calculated using the equation saving that is $s_{ij} = c_{ij0} + c_{0j} - c_{ij}$ with $c_{ij}$ is the distance from customer $i$ to customers $j$ and 0 are depots [7]. Score of saving that has been obtained from the results calculations using these equations presented in the form of ranking in Table 4.

| No | Route | Saving | No | Route | Saving | No | Route | Saving |
|----|-------|--------|----|-------|--------|----|-------|--------|
| 1  | H-K   | 109.4  | 23 | B-E   | 18.7  | 45 | A-H   | 5.4    |
| 2  | D-K   | 73.1   | 24 | A-E   | 17.0  | 46 | A-J   | 5.4    |
| 3  | D-H   | 71.7   | 25 | B-C   | 11.8  | 47 | A-F   | 5.2    |
| 4  | K-L   | 68.1   | 26 | C-E   | 8.9   | 48 | A-D   | 4.7    |
| 5  | I-K   | 66.9   | 27 | A-C   | 8.5   | 49 | A-I   | 4.2    |
| 6  | J-K   | 65.9   | 28 | B-D   | 7.9   | 50 | A-L   | 4.2    |
| 7  | H-I   | 62.8   | 29 | B-K   | 7.2   | 51 | C-H   | 3.6    |
| 8  | H-L   | 62.8   | 30 | D-E   | 7.1   | 52 | C-I   | 3.6    |
| 9  | H-J   | 61.4   | 31 | B-H   | 7.1   | 53 | C-L   | 3.6    |
| 10 | D-I   | 61.2   | 32 | B-F   | 7.0   | 54 | B-G   | 3.1    |
| 11 | D-L   | 61.2   | 33 | E-I   | 6.9   | 55 | C-F   | 2.8    |
| 12 | I-L   | 60.8   | 34 | E-L   | 6.9   | 56 | G-H   | 1.8    |
| 13 | D-J   | 59.9   | 35 | B-I   | 6.8   | 57 | G-K   | 1.8    |
| 14 | J-L   | 59.4   | 36 | B-J   | 6.8   | 58 | C-J   | 1.5    |
| 15 | I-J   | 58.7   | 37 | E-J   | 6.8   | 59 | A-K   | 1.5    |
| 16 | D-F   | 48.1   | 38 | B-L   | 6.8   | 60 | C-G   | 1.3    |
| 17 | F-I   | 47.6   | 39 | E-K   | 6.0   | 61 | F-G   | 1.3    |
| 18 | F-L   | 47.6   | 40 | G-I   | 5.7   | 62 | E-G   | 1.2    |
| 19 | F-J   | 47.5   | 41 | G-J   | 5.7   | 63 | C-K   | 1.0    |
| 20 | F-H   | 45.9   | 42 | G-L   | 5.7   | 64 | C-D   | 0.7    |
| 21 | F-K   | 45.9   | 43 | E-H   | 5.5   | 65 | A-G   | 0.2    |
| 22 | A-B   | 39.7   | 44 | E-F   | 5.4   | 66 | D-G   | 0.0    |
3.2. Transportation Routes Calculation and Arrangement

The experiment was carried out into three proposed transportation routes presented in experiment 1 (P1), experiment 2 (P2), and experiment 3 (P3), the results were obtained in the form of total mileage and total time distribution of paint to 12 consumer points is 306 km and 744 minutes for the model Experiment 1 (P1). The experimental model 2 (P2) is 307 km and 744 minutes, and experiment model 3 (P3) are 288 km and 695 minutes, respectively.

From the results of calculations, experiment 3 is the route chosen in this study, because it provides a minimum total distance and travel time compared to experiments 1 and 2. The routes are formed from experiment 3 is 0-K-H-D-I-L-0 joined in cluster 1, route 0-G-F-J-E-C-0 incorporated in cluster 2, and routes 0-A-B-0 incorporated in cluster 3. The final output through capacity loading process which can be seen in sequence in Figure 2, 3, and 4.

![Figure 2](image1.png)

**Figure 2.** Vehicle capacity for node H and K, D, I and L, through the loading process using Cube IQ software after manual merging for Cluster 1.

In Figure 2 the merging of points I and L into Cluster 1 is the remaining transport capacity as described is the optimum decision (feasible route) because it is no longer possible to merge. The feasible route formed is the 0-H-K-D-I-L-0 route or referred to as Cluster 1.

There are 12 consumers who will be designated as product distribution nodes, determined 5 nodes that already have distribution routes namely H, K, D, I, and L which are incorporated in a cluster, namely cluster 1. While 7 points that do not have a distribution route, will be formed in the next cluster with the same process. The formation of cluster 2 is based on the ranking of ranking that is not related to the previous cluster (H, K, D, I, and L).

![Figure 3](image2.png)

**Figure 3.** Vehicle capacity for node G, F, J, E and C, through the loading process using Cube IQ software for Cluster 2.
From Figure 3, it can be seen that the volume capacity of vehicles is still available at 58.46%, but the optimum route in Cluster 2 has been formed because there are no more nodes that need to be merged. Then the feasible route formed is 0-G-F-J-E-C-0 or referred to as Cluster 2.

The merging point conducted in experiment 3 is point B with cluster 3, so that the main ledge conducted in this experiment is to determine the feasibility of loading the merge point B with cluster 3 using Cube IQ software. Point A has a demand of 1907 kg (52 units of product X lot, 1 unit of product X, 40 units of product Y, and 49 units of product Z) and point B has demand of 54 kg (3 units of product X lot, and 1 unit of product Z) then the loading process can be seen in Figure 4.

![Figure 4. Vehicle capacity for node A and B, through the loading process using Cube IQ software for Cluster 3.](image)

The results of experiments that determine the chosen distribution route consisting of distance and travel time can be seen in Table 5.

**Table 5. Transportation Route for Cluster 1, 2 and 3**

| Cluster | Route       | Route Between | Distance (km) | Total Distance (km) | Speed (Km/hr) | Route Time (minute) | Total Time (minute) |
|---------|-------------|---------------|---------------|---------------------|---------------|---------------------|---------------------|
| 1       | 0-H-K-D     | 0-H           | 57.3          | 57.3                | 24.91         | 138                 | 138                 |
|         | 1-L-0       | K-D           | 16.1          | 77.2                | 27.60         | 35                  | 185                 |
|         |             | D-I           | 2.5           | 79.7                | 18.75         | 8                   | 193                 |
|         |             | I-L           | 0             | 79.7                | 0             | 0                   | 193                 |
|         |             | L-0           | 30.4          | 110.1               | 16            | 114                 | 307                 |
|         |             | 0-G           | 3.1           | 3.1                 | 31.00         | 6                   | 6                   |
|         |             | G-F           | 26.9          | 30                  | 28.82         | 56                  | 62                  |
|         |             | F-J           | 7.3           | 37.3                | 21.90         | 20                  | 82                  |
|         |             | J-E           | 38.3          | 75.6                | 20.70         | 111                 | 193                 |
| 2       | 0-G-F-J-E-C-0 | 0-G           | 3.1           | 3.1                 | 31.00         | 6                   | 6                   |
|         |             | G-F           | 26.9          | 30                  | 28.82         | 56                  | 62                  |
|         |             | F-J           | 7.3           | 37.3                | 21.90         | 20                  | 82                  |
|         |             | J-E           | 38.3          | 75.6                | 20.70         | 111                 | 193                 |
|         |             | E-C           | 11.8          | 87.4                | 33.71         | 21                  | 214                 |
|         |             | C-0           | 5.3           | 92.7                | 28.91         | 11                  | 225                 |
|         |             | 0-A           | 24.8          | 24.8                | 29.76         | 50                  | 50                  |
|         |             | A-B           | 22.5          | 47.3                | 32.93         | 41                  | 91                  |
|         |             | B-0           | 37.4          | 84.7                | 31.17         | 72                  | 163                 |

Total Distance | 288 | Total Time | 695
There is an operating time that is owned by the company as well as all 12 consumers, all of which have the same operating time from 08:00 to 17:00. In principle, the distribution time should not exceed the company's operating hours. In this case both the sender and receiver have operating hours because consumers are manufacturing companies, so the operating time is not a time window.

The feasibility of delivery time can be seen in a scheduling. Scheduling product delivery to 12 consumer points involves data such as travel time, loading and unloading time, rest time, start time, finish time, and operational time. From the results of the study it was found that the distribution of products divided into 3 clusters distributed within 2 working days. Cluster 1 is distributed on day 1 with distribution time starting at 08:00 in the morning until 14:17 in the afternoon. Whereas cluster 2 and cluster 3 are distributed on the 2nd day with the distribution starting at 08:00 am to 04:28 pm. With the distribution schedule as follows, it can be said that the distribution process is still in the safe category because it does not come out of the operating time of the company's product delivery, and does not come out of the operating time of 12 consumers as the time of receipt of the product.

4. Conclusion
Cluster 1 which contains route 0-H-K-D-I-L-0 with a total distance of 110.1 km and total distribution lead time is 387 minutes. Cluster 2 which loads route 0-G-F-J-E-C-0 with a total distance amounting to 92.7 km and total travel time distribution of 300 minutes. Cluster 3 contains the route 0-A-B-0 with a total distance of 84.7 km and total distribution travel time in the amount of 208 minutes. Future research needs to be developed with add limits First In First Out (FIFO) into the loading process can provide more result representative because it can make it easy operator at the time of product decline (unloading). The compiling of loads using the Cube IQ software deliver the most efficient process, may also be used for joint shipment.

5. References
[1] Ballou R H 2004 Business Logistics/Supply Chain Management 5th Edition (USA: pearson Prentice Hall)
[2] Yogaswara Y 2015 Proceeding 8th International Seminar on Industrial Engineering and Management I (Malang: East Java Indonesia), p. 137
[3] Toth P and Vigo D 2002 And Overview of Vehicle Routing Problem (Society of Industrial and Applied Mathematics), pp. 1-26.
[4] Heragu S 2008 Facilities Design 3rd edition (CRC Press)
[5] Olsson 2017 Solving a Highly Constrained Multi-level Container Loading Problem from Practice (Linkoping University: Division of Optimization/Dept. of Mathematics)
[6] Pop P C, Sitar C P, Zelina I, Lupse V and Chira C 2011 Heuristic Algorithms for Solving the Generalized Vehicle Routing Problem. International Journal Computers, Comunication, and Control, 11(1), pp. 158-165.
[7] Altinel I K and Öncan T 2005 A new enhancement of the Clarke and Wright savings heuristic for the capacitated vehicle routing problem. The Journal of the Operational Research Society 56(8), pp. 954–961.