

SWEEP ALGORITHM IN CVRP TO OPTIMIZE DELIVERY AUTOMOTIVE SPARE PART

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Abstract

The CVRP to solve many optimization and application problems distribution especially of the automotive spare parts industry, West Java, Indonesia is presented has 120 customers who aim to optimize and maximize the capacity and cost of vehicles owned, namely 10 colts 6 diesel type vehicles. Vehicle routes are compared against the existing daily distribution routes showing that significant savings can be gained on the daily cost of transportation-related expenses. The objective of this research is to find a set of optimal routes that minimize the number of vehicles required and total distance traveled for all vehicles to serve customers with a result from 10 to 9 using vehicles with a total distance increase from the Sweep method of 253.8347 km and cost benefits or cost savings with a total usage cost of Rp 17.800.000 to be Rp 17,709,503 in cost efficiency of 4.47% or Rp 90,496.58 a day.

Keywords: *Capacitated Vehicle Routing Problem, Sweep Algorithm, Distribution, Automotive Spareparts.*

INTRODUCTION

Strive to generate higher competitive value for his company, demanding industry players conduct evaluations and improvements periodically to win competitive value against competitors (R Hanafi, M Rusman, F Mardin, S M Parenreng, 2020), (Kirci, 2016), (Cari et al., 2008), (Hertrich et al., 2019). The automotive industry is one of the five manufacturing sectors that are being prioritized for development in Indonesia, currently, the automotive industry shows a positive performance and also contributes quite a lot to national economic growth (GAIKINDO, 2020). But in 2020 due to the Covid-19 outbreak caused many automotive industries to reduce the ordering activities of motorcycle units or automotive spare parts, causing a decrease in turnover of about 40% from usual, until 2021 with the last data in September motorcycle sales increased in terms of a total percentage of 60% and is a good start for manufacturers and also manufacturing automotive spare parts to disrupt the trading process, proved successful in making the wheels of business continue to roll in 2021 (AISII, 2021).

Distribution is one of the important parts of the company, the key issues for distribution include the location of the consolidation center, truckload level, and scheduling and determination of pick-up and shipping routes (A. et al., 2017), (Reed et al., 2014). The goal is to minimize operating costs through consolidation without sacrificing delivery time and reliability (Akhand, M. A.H., Zahrul Jannat, 2017), (Li & Hae, 2016). Logistics performance is measured by availability (provision of goods), capability (delivery speed), and quality (quality of goods) (Thammano & Rungwachira, 2021). Companies that carry out a one-night delivery policy with a consistency rate of less than 95% (only concerned with the speed of goods reaching the customer) can easily lose their profits because it could be that the goods received some damages and orders are wrong so that it does not benefit the company or consumers (M. F. Ibrahim, M. M. Putri, D. Farista,

2021), (Toth P., 2002), (Zhong et al., 2017). The transportation process involves all stages of the production and distribution system and represents the relevant components (generally from 5% to 20%) of the final cost of goods (Liao & Liu, 2018), (Marinaki & Marinakis, 2016), (Islam et al., 2021). From that background, this study tried to apply a sweep algorithm to plastic injection distribution and manufacturing automotive spare parts in West Java Indonesia, which distributes vehicle plastic bodies to leading companies in Indonesia. This method is only applied to the company's distribution division and is expected to be able to solve vehicle capacity problems and optimize distribution costs.

LITERATURE REVIEW

Vehicle Routing Problem (VRP) is a model that has many variants, which describe transportation problems as graph models, which aim to find a route with a minimum cost for the delivery of a product to several customers in several different locations, using several vehicles (Yousefikhoshbakht & Sedighpour, 2012), (Chen, 2015), (Hannan et al., 2018). CVRP is one of the most common problems of VRP, described as a central depot or center, which uses a vehicle mode with a certain capacity to serve the demand of several agents (Altabeeb et al., 2019), (Akpınar, 2016), (Ng et al., 2017). CVRP completion can be helped by the Sweep Algorithm approach.

These problems have been widely studied for many years, mainly because of their applications in real-world logistics and transportation problems. This is in the creation of a more accurate distribution line. A heuristic approach based on the Sweep Algorithm was proposed as a methodology for developing itineraries for *distribution companies with minimum travel costs with optimal solutions* for each cluster using the Nearest Neighbor Algorithm (R Hanafi, M Rusman, F Mardin, S M Parenreng, 2020). Sweep algorithms that quickly solve problems to get optimal results in computer science, they especially explain the Sweep Algorithm and Elite Ant Colony Optimization for solving the multiple traveling (Yousefikhoshbakht & Sedighpour, 2012), an approach solving for CVRP which is a hybrid two-phase Sweep Algorithm and greedy search (Chen, 2015), for the case of CVRP using hybrid modified ant system with Sweep Algorithm and path relinking (Thammano & Rungwachira, 2021), using the Sweep Algorithm and Particle Swarm Optimization (PSO), in the route-making phase is not enough, as it is easy to implement and run quickly by sweeping across members (A. et al., 2017), the sweep algorithm that can deal with time windows and exploit the additional structure of the time windows (Hertrich et al., 2019), for solutions applicable to a distribution problem with drones using a new hybrid approach to improve the combination of sweep and genetic algorithms (Jalel Euch, 2020).

RESEARCH METHODS

CVRP can be described as a problem of modeling the following graph. If $G = (V, A)$ into a complete graph, in which $V = \{0, \dots, n\}$ is a vertex set and A is a bow set. Knot $i = 1, \dots, n$ according to the customer, while vertex 0 corresponds to the depot. Sometimes depots are associated with vertex $n + 1$. Graph G should be highly connected and generally assumed to be finished (Toth P., 2002). A central warehouse has k distribution vehicles, and the maximum load capacity of each distribution vehicle is Q . Now, we need to transport and distribute materials to n customers (nodes), how to arrange a certain number of vehicles to meet the needs of these customers, and make the total driving distance of vehicles shortest. The constraint of CVRP: All delivery vehicles start from the central warehouse and eventually return to the central warehouse, Each delivery vehicle is not allowed to exceed the maximum load capacity Q , Each customer can only be served once, and each vehicle can only take one route (Toth P., 2002).

Mathematical models in case studies

1. Mathematical model CVRP

$$\text{Graf } G = (V, E)$$

$$V = \{0, 1, 2, \dots, 121\} \text{ (Depots are 0 and 121)}$$

$$C = \{1, 2, 3, \dots, 120\}$$

$$E = \{(i, j) | i, j \in V, i \neq 201, j \neq 0\} \tag{1}$$

Units q_i it starts with depot 0.

For each agent $i \in V$ have a request d_i So that the length of the route is limited to the capacity of the vehicle.

For each point $i, j \in E$ have mileage c_{ij} and distance assumed to be symmetrical $c_{ij} = c_{ji}$.

Decision variables x_{ijk} ,

$$X_{ijk} = \begin{cases} 1, & \text{If there is a trip from customer point } i \text{ to } j \text{ with} \\ 0, & \text{another } k \text{ vehicle.} \end{cases}$$

2. CVRP model of delivery of goods

$$\sum_{i=0}^{120} \sum_{j=1}^{121} \sum_{k=1}^5 C_{ijk} X_{ijk} \tag{2}$$

Constraints:

$$\sum_{j=1}^{121} \sum_{k=1}^5 X_{ijk} = 1, \text{ for all } i \tag{3}$$

(For each point the customer will be visited exactly by 1 vehicle)

$$\sum_{i=0}^{120} d_i \sum_{j=1}^{121} X_{ijk} \leq 3500, \text{ for all } k \tag{4}$$

(Customer demand on one route must not exceed the capacity of the vehicle)

$$\sum_{j=1}^{121} X_{ojk} = 1, \text{ for all } k \tag{5}$$

(Each route starts from the initial depot)

$$\sum_{i=0}^{120} X_{ijk} - \sum_{j=1}^{121} X_{ijk} = 0, \text{ for all } k \tag{6}$$

(Every vehicle that has visited 1 point will leave that point)

$$\sum_{i=0}^{120} X_{ijk} = 1, \text{ for all } k \quad (7)$$

(Each route ends at the depot)

$$X_{ijk} \in 0,1, \text{ for all } i, j, k \quad (8)$$

Sweep Algorithm

Sweep Algorithm applies to VRP planar instances. A viable cluster was originally formed by rotating a depot-centered path. Some implementations include a post-optimization phase where nodes exchange between adjacent clusters and re-optimized routes. Steps to make nodes in improving route efficiency θ_i that is (Toth P., 2002):

- a. (Initialization of the route). Select a vehicle that is not used k .
- b. (Route construction). Starting from the vertex that is not traversed has the smallest angle, set the node to the vehicle k as long as the capacity or maximum route length is not exceeded. In close constraints, the CVRP can be applied after each iteration. If the unpassed node remains, go back to *step 1*.
- c. (Route optimization). Optimize each vehicle route separately by completing the appropriate cluster (precise or approximately).

The Sweep Algorithm can be implemented using two different cluster formation methods, namely forward sweep and backward sweep. The Sweep Algorithm method is divided into two types, namely the first route second cluster and the second route first cluster. This research will use the way of cluster formation by forwarding sweep location grouped from the first node and continued to the next node by sweeping clockwise. While the first type of Sweep Algorithm method is the first route second cluster where this method is used at the clustering stage, namely by combining the dots in one cluster (Dantzig & Ramser, 1959).

RESULTS AND DISCUSSION

Define problem

From various types of existing manufacturers, the author made observations of work on the manufacturing of plastic injection & painting, by carrying out the process of plastic injection molding 130 - 480 T, painting line and automotive components with the type of body automotive appliances with a capacity of 300 tons/annum distributed to leading companies in Indonesia, seen in Indonesia **Image 1**. Delivery in many customers with a limited number of vehicles, making delivery has not been well planned, because the vehicle and driver usually travel 2-3 times with 1 type of vehicle plus a small pick-up car vehicle in a day without calculating the capacity of the vehicle and determining the destination of the route that effectively serves all customers by only traveling according to the nearest customer area, making the condition of the fleet of vehicles that are sometimes lacking and cause drivers to fatigue with increasingly bloated costs (Herry Gunawan, 2019), seen in **Image 2**. It is expected that optimization in the distribution travel route is tailored to the capacity of the vehicle and meets the total demand from customers using limited vehicles with the completion of the CVRP comparison Sweep Algorithm.

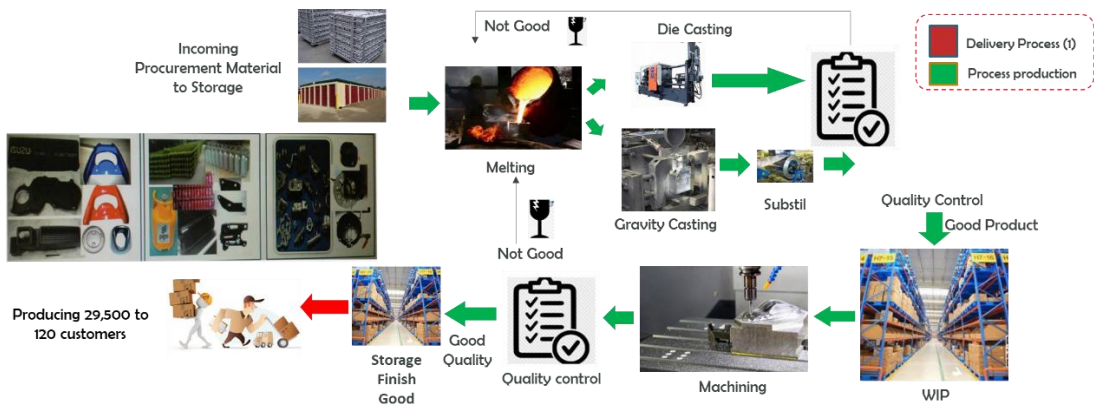


Image 1. Manufacturing spare-part automotive industry

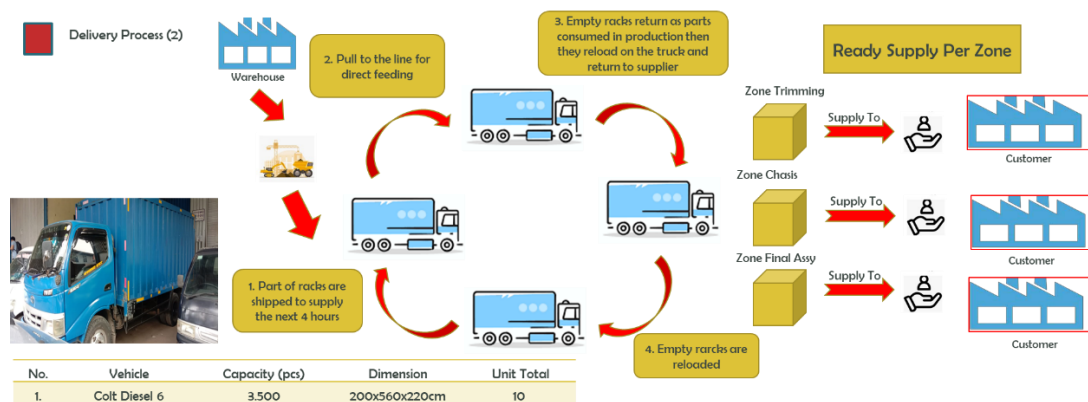


Image 2. Delivery system

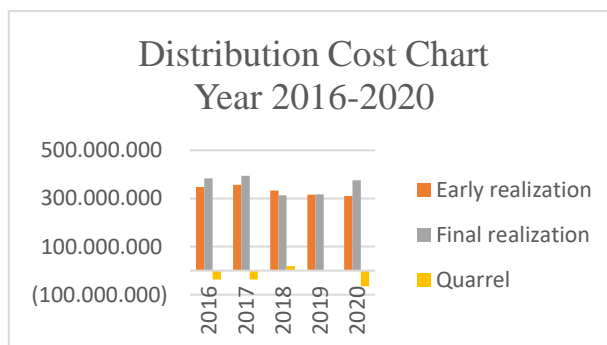


Image 3. Graph of distribution costs of spare parts manufacturing industry

The graphic in **Image 3** shows the occurrence of imbalances in distribution costs so that costs are needed that make the initial realization costs can be realized with the details of current costs, namely FOB destination, zone pricing, and base point pricing (Mikael Hang Suryanto, 2016) with the cost for one transportation is Rp 2,200,000 incurred by the distribution division.

1. Data collection

In distributing products, the number of operators for each vehicle is as many as 2 people, namely the operator of the conveyance (driver) and the loading/unloading operator. CVRP's problems in research focus on the evaluation of capability on distribution based on the delivery of a single product, single commodity, one depot goods with the cost of one vehicle distribution, namely car rental costs and road money adjusted to the initial realization. There is no window of time on the customer, but it is necessary to adjust to the factory hours. The data in the distribution used can be seen in **Table 1**.

Table 1. Distribution facilities and infrastructure

Supplier	Demand	Product	TYPE OF Vechile	Capacity (pcs)	Dimension (cm)	Number of Vechiles (unit)
1 Warehouse Finishing Good	29.500 for 120 Customer	Body Plastic of Motorcycle	Colt Diesel 6	3.500	200x560x220	5 Private Vehicle (Rp. 2.200.000/day)
						5 Rental Vehicle (Rp. 1.700.000/day)

Source: PT Wijaya Karya Industri & Konstruksi – Otomotive Division

a. Data analysis results

Distribution of customer points with 120 customers spread across the Jabodetabek area where the distribution of real customer data is done randomly by the distribution section, especially the driver who delivers the goods so that analysis is needed using the CVRP method, seen in **Image 4**.

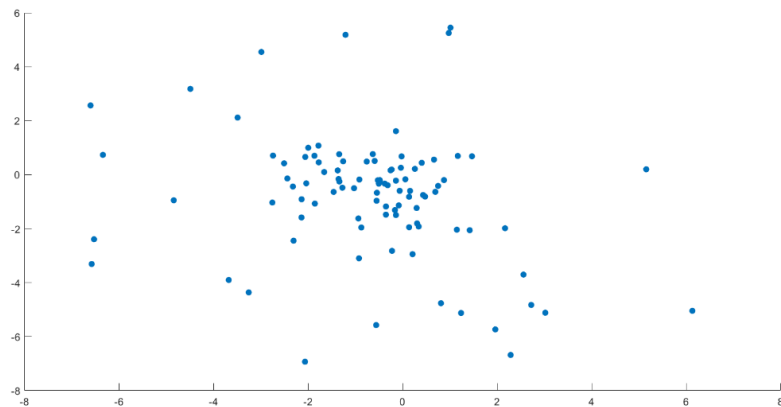


Image 4. Scatter plot diagram

Customer coordinates data with its polar angle, the initial stage in data processing so that the next stage is data clustering so that it is also visible to form cluster members, seen in **Image 5**.

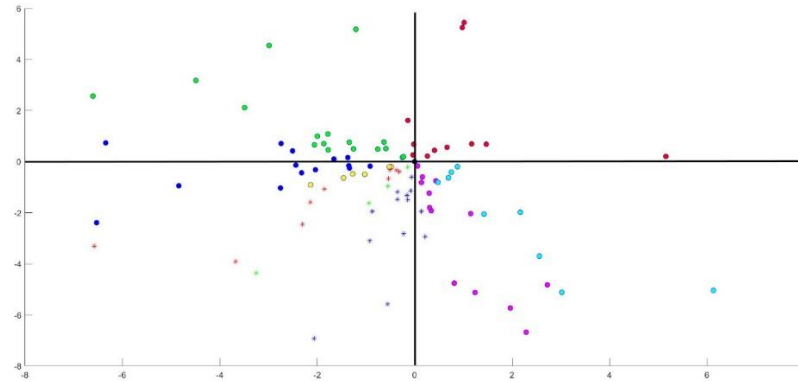


Image 5. Coordinate data

Below is a table of cartesian coordinate data and polar coordinates for depots and customers by capacity, The formation of routes in the Sweep Algorithm method starts from the search of the distance matrix for each delivery point in each cluster then looking for the nearest route between points, where it is seen the grouping of 9 clusters marked with colors (indicates the total capacity of the vehicle as much as 3,500 pcs) in which there are members in the form of customer point members. Below is the output of clustering results and the total route distance, in **Table 2**.

Tabel 2. Total route distance of Sweep Algorithm method

Cluster	Route Order	Total Distance (km)	Lots of Charge (pcs)
1	0 – 87 – 82 – 74 – 12 – 68 – 44 – 72 – 105 – 31 – 95 – 62 – 0	325010	3498
2	0 – 78 – 84 – 88 – 32 – 120 – 50 – 73 – 106 – 7 – 100 – 9 – 20 – 34 – 38 – 28 – 27 – 6 – 0	439147	3379
3	0 – 6 – 40 – 3 – 63 – 25 – 24 – 11 – 22 – 14 – 45 – 1 – 61 – 89 – 41 – 0	329951	3408
4	0 – 107 – 35 – 30 – 49 – 48 – 46 – 0	63250	3491
5	0 – 42 – 75 – 36 – 85 – 76 – 71 – 118 – 47 – 109 – 0	285755	3133
6	0 – 96 – 2 – 39 – 69 – 0	141011	3023
7	0 – 108 – 51 – 80 – 92 – 90 – 18 – 5 – 65 – 19 – 37 – 15 – 26 – 86 – 21 – 0	326764	3155
8	0 – 52 – 81 – 93 – 29 – 17 – 77 – 23 – 82 – 94 – 33 – 43 – 199 – 8 – 0	415124	3231
9	0 – 10 – 70 – 79 – 91 – 4 – 64 – 117 – 16 – 13 – 0	302335	3182
Total Mileage		2538347	

Based on the table above it is seen that the output of manual for clustering using the Sweep Algorithm method displays the same total lots of capacity. Below is an image of the route for each cluster using the Sweep Algorithm method, which is seen in **Image 6**. Depot centers are in the middle where this is a strategic location to reach a large number of customers, but it is seen that the results of the formation of routes with Sweep Algorithm do not look efficient in terms of the total mileage of 253.8347 km and only visit a few customers on the way. From the results of the total distance of 9 vehicles, the cost efficiency of Rp 90,496.58 or 4.47% of the total use of initial realization was Rp 17,709,503.42.

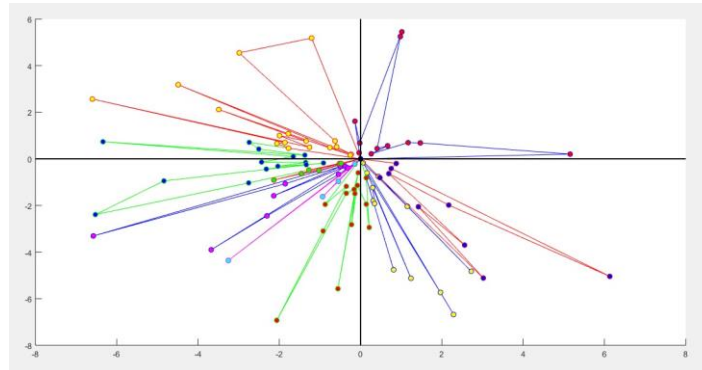


Image 6. Distribution route Sweep Algorithm method

CONCLUSION

Maximizing vehicles used with vehicle capacity utilization using the Sweep Algorithm is used to distribute automotive spare parts the company has 10 vehicles used only 9 vehicles for 9 clusters of 120 customer points and back to the depot. Sweep Algorithm can form routes where calculations are done to get total route distance and total cost although the cost efficiency obtained is not more than 5% of the total use of the vehicle (Liao & Liu, 2018) but 4.47% can increase the saving costs of the company even don't meet the standards it is expected that other methods can be comparative. Getting efficient vehicle route results with the most optimal distance and distribution costs, for further research can compare other methods with the implementation of smart bin data adding algorithm constraints on time and the completeness of problems during the journey.

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