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Application of the Clarke and Wright Savings Algorithm to Solve the Vehicle Routing Problem in Optimizing Chip Distribution

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Abstract

Efficiency in the distribution process is crucial for companies to reduce operational costs while maintaining service satisfaction. This research aims to optimize the product delivery route for the Keripik Cinta Mas Hendro business by applying the Clarke and Wright Savings algorithm approach to solve the Vehicle Routing Problem (VRP). This method works by calculating the distance savings from combining distribution points, then constructing optimal routes based on the order of highest savings while still considering vehicle capacity. The data used consists of customer coordinates, which are processed into distances between locations using the Euclidean formula. The results show that the distribution route, which was initially divided into three lanes with a total length of 403.54 km, can be simplified into two lanes with a total length of 272 km. This study proves that the Clarke and Wright Savings algorithm is able to provide a more cost-effective distribution solution.

Keywords: *Distribution, Optimization, Chips, VRP, Clarke and Wright Savings*
MSC2020: 90B06, 68W40, 90C59

Abstrak

Efisiensi dalam proses distribusi sangat penting bagi perusahaan agar dapat menekan biaya operasional sekaligus menjaga kepuasan pelayan. Penelitian ini bertujuan untuk mengoptimalkan jalur pengiriman produk keripik pada usaha Keripik Cinta Mas Hendro dengan menerapkan pendekatan algoritma Clarke and Wright Savings dalam menyelesaikan permasalahan Vehicle Routing Problem (VRP). Metode ini bekerja dengan menghitung nilai penghematan jarak dari penggabungan titik-titik distribusi, lalu menyusun rute optimal berdasarkan urutan penghematan tertinggi yang tetap memperhatikan kapasitas kendaraan. Data yang digunakan berupa koordinat pelanggan yang diolah menjadi jarak antar lokasi menggunakan rumus euclidean. Hasil menunjukkan bahwa rute distribusi yang semula terbagi tiga jalur dengan total 403.54 km dapat disederhanakan menjadi dua jalur dengan total 272 km. Penelitian ini membuktikan bahwa algoritma Clarke and Wright Savings mampu memberikan solusi distribusi yang lebih hemat.

Kata kunci: Distribusi, Optimasi, Keripik, VRP, Clarke and Wright Savings
MSC2020: 90B06, 68W40, 90C59

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Introduction

Distribution plays a very vital role in a company's operational processes, especially for entities that operate large-scale production. A well-designed distribution process can provide a competitive advantage and contribute to increased customer satisfaction[1][2][3][4]. Efficiency in goods delivery is an important factor to consider, given the involvement of various factors such as time, cost, and resource availability. With the right distribution strategy, companies can ensure that products reach consumers quickly, cost-effectively, and in optimal condition[5]. Therefore, distribution becomes a key component in improving marketing performance and business sustainability[6].

Keripik cinta Mas Hendro, a business engaged in the production and sale of cassava, banana, and sweet potato chips, is located at Jl. Pangkalan Berandan, Air Hitam, Kec. Gebang, Langkat Regency. The product distribution process in this business still relies on finding locations using coordinate points without systematic delivery route planning. As a result, there is inefficiency in delivery, which impacts increased costs and transit time. This problem falls under the Vehicle Routing Problem (VRP), which is the problem of determining the optimal delivery routes from one or more depots to a number of customers, considering various constraints such as vehicle capacity and demand [7].

VRP is a combinatorial optimization challenge commonly found in logistics systems. This problem aims to find the best delivery route by considering cost efficiency, time, and resource constraints. Several heuristic approaches have been developed to solve this problem, one of which is the Clarke and Wright Savings algorithm[8]. This method works by calculating the savings generated from combining two routes into one, based on the potential reduction in travel distance or shipping costs. This savings value serves as the basis for gradually constructing routes until an efficient route is obtained that does not violate logistical constraints.

The effectiveness of the Clarke and Wright Savings method has been proven in various previous studies[9][10][11][12]. For example, the application of this algorithm to the distribution of glass products can reduce the distribution distance by up to 110.02 km, resulting in an efficiency of 64.79% [13]. Similar to the distribution of bottled drinking water, although it is still limited to specific cases and has not yet incorporated a comprehensive cost analysis [14]. These studies confirm the potential of this algorithm to be adapted in other distribution contexts with different geographical and demand characteristics.

This research was conducted to optimize the distribution route for the Keripik Cinta Mas Hendro business using the Clarke and Wright Savings algorithm. Until now, the company has only used the coordinate points of a base as a reference for finding destination locations, but has not yet used them to determine optimal delivery routes. This condition often leads to problems in distribution planning, such as inefficient travel time, high fuel costs, and underutilization of vehicle capacity. By applying the Clarke and Wright Savings algorithm, it is hoped that a more efficient delivery route solution can be obtained, both in terms of distance travelled and operational costs. This research is expected to contribute to the development of more cost-effective, measurable, and adaptive distribution strategies, particularly for small and medium-sized enterprises with limited resources in logistics management.

Methods

This research is a type of quantitative research, aimed at optimizing product distribution routes using the Clarke and Wright Algorithm approach. This method is applied to solve the Vehicle Routing Problem (VRP), with a series of systematic steps as follows:

1. Determine customer data. The initial stage begins by identifying all customer and depot locations. The data collected includes the geographical coordinates of each point (latitude and longitude), as well as the quantity of demand for each customer.
2. Identifying the distance matrix. Determining the distance between the company and each consumer, as well as the distance between consumers, using the two-dimensional Euclidean formula:
$$d_{ij} = \sqrt{(x_i \; - x_j)^2 + (y_i + y_j)^2} \times 111.322$$
where:
d_n = Distance
x = Latitude or lines of latitude on Earth
y = Longitude or the Earth's meridian
3. Calculating the savings matrix. After all the distances are obtained, the next step is to calculate the savings value based on the difference in distance if two consumers are served on one route compared to being served separately.
4. Creating a savings table. All calculation results are entered into a table, which is then sorted in descending order of value. This aims to facilitate an efficient process for selecting customer pairs to be merged.
5. Forming routes based on the highest savings. The initial route is formed by first selecting the highest savings value. Customers who provide the greatest distance savings are paired together in one route first.
6. Capacity feasibility check. Each route formed is evaluated considering the maximum vehicle capacity limit. The route can only be used if the total customer demand on that route does not exceed the vehicle's carrying capacity.

Vehicle Routing Problem

The Vehicle Routing Problem was first introduced by Dathzing and Ramser in 1859. VRP plays an important role in distribution management and transportation costs within the widely studied optimization of combinations [16][17]. The basic formula for the VRP problem is as follows.

$$\text{Minimize } f = \Sigma_{i=0}^{n} \Sigma_{j=0}^{n} \Sigma_{k}^{n} d_{ij} x_{ijk} \quad (1)$$

Description:
i = Initial customer index
j = Target customer index
n = Number of customers
k = Many vehicles
d_{ij} =Distance between customer *i* and *j*
x_{ij} =Vehicle *k* serves customer *j* after visiting customer *i*.

Algorithm Clarke and Wright Savings

In 1964, scientists named Clark and Wright successfully discovered a method based on the concept of Savings. The Clarke and Wright Savings algorithm is a method for saving in a routing problem with the best distance at each problem object point[15]. The basic concept of the savings method aims to reduce operational costs by combining several distribution routes into a single, more efficient route. This is illustrated in Figure 1, where point 0 serves as the depot.

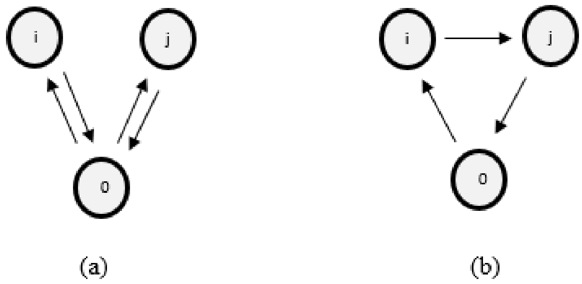

Figure 1. Illustration of the concept of saving

The image above shows customer *i* visited by customer *j* using different routes. To achieve minimal distance and savings, the destination from customer *i* to customer *j* will be visited by vehicles using the same route. The vehicle route shown between customer *i* and customer *j* is C_{ij}.

$$D_a = C_{0i} + C_{i0} + C_{0j} + C_{jo} \qquad (2)$$

Equivalent to vehicle route b in Figure 1

$$D_b = C_{0i} + C_{ij} + C_{j0} \qquad (3)$$

By connecting the two routes, savings are achieved S_{ij} :

$$S_i = D_a - D_b$$
$$S_{ij} = C_{0j} + C_{i0} + C_{0j} + C_{j0} - (C_{0i} + C_{ij} + C_{j0}) \qquad (4)$$
$$S_{ij} = C_{i0} + C_{0j} - C_{ij}$$

where:
D_a = Vehicle route (a)
D_b = Vehicle route (b)
C_{i0} = Distance between depots and customers i
C_{0j} = Distance between depot and customer j
C_{ij} = Distance from customer *i* to customer j
S_{ij} = The distance saving value from customer *i* to customer j

Results and Discussion

The data collection process was carried out through direct observation and a review of the company's historical data. The data collected includes: initial distribution routes, customer addresses, vehicle capacity, product demand, and the distance between locations. After all the data has been collected, data processing is carried out.

Table 1. Data and address of Keripik Cinta Mas Hendro consumers

Address	Demand	Symbol
Jl. Pangkalan Berandan, Air hitam, Kec. Gebang	-	0
Pekan gebang, kec. Gebang, kabupaten langkat	35	1
Perkebunan Tj. Beringin, kec. Hinai	35	2
Jl. Rawa, Timbang deli, Kec. Medan Amplas	40	3
Jl. Perniaga No. 27, Kec. Stabat	25	4
Jl. Perniaga no.55, kec. Stabat	25	5
Jl. Ikan paus, tanah tinggi, kec. Binjai kota	35	6
Jln. Besar orangutan, bukit lawang, Kec. Bohorok	40	7
Pasar buah sukaramai kuala simpang, kuala simpang	45	8
Jl. Wahidin, Brandan Bar, Kec. Babalan	35	9
Jl. Kota baru 3, kel. Petisah tengah, kec. Medan petisah	40	10

Table 2. *Latitude* dan *Longitude*

Symbol	latitude	Longtitude
0	3.928574	98.389737
1	3.940373	98.376773
2	3.849922	98.427777
3	3.538078	98.720596
4	3.762455	98.456693
5	3.766089	98.460959
6	3.609197	98.497764
7	3.548838	98122324
8	4.284575	98.059325
9	4.017977	98,285113
10	3.591774	98.667108

Table 3. Initial route of the company

Route	Initial order	Distance
1	0-3-10-7-0	178.04
2	0-1-2-9-8-0	130.45
3	0-5-4-6-0	94.7
	total	403.54

The company pays the driver a wage of Rp. 85,000. In addition, the company also provides a meal allowance of Rp. 20,000. The current price of vehicle fuel is recorded at Rp. 6,800 per litre. The company's distribution cost details are shown as follows:

Distribution cost = Number of transport vehicles × (driver's wage + fuel cost + meal allowance)

$$= 3 \times \left(Rp. 85{,}000 + \left(Rp. 6{,}800 \times \frac{Total\ distance}{10\ Km/Litre}\right) + Rp. 20{,}000\right)$$

$$= 3 \times \left(Rp. 85{,}000 + \left(Rp. 6{,}800 \times \frac{403{,}54}{10\ Km/\ Litre}\right) + Rp. 20{,}000\right)$$

$$= Rp. 1{,}138{,}221$$

Calculating the distance from the depot to the first customer using the latitude and longitude coordinates for each customer.

$$
\begin{aligned}
d_{0.1} &= \sqrt{(3.928574 - 3.940373)^2 + (98.389737 - 98.376773)^2} \\
&= \sqrt{(-0.011799)^2 + (0.012964)^2} \\
&= \sqrt{(0.0003073} \\
&= 0.017526 \times 111.322 \\
&= 1.95\ km
\end{aligned}
$$

Table 4. Distance matrix

	0	1	2	3	4	5	6	7	8	9	10
0	0										
1	1.95	0.00									
2	9.72	11.5	0.00								
3	56.9	55.6	47.6	0.00							
4	19.9	21.7	10.2	38.5	0.00						
5	19.7	21.5	10	38.4	0.61	0.00					
6	37.5	39.2	28	26.0	17.6	17.9	0.00				
7	51.7	51.9	47.7	66.6	44	44.7	42.3	0.00			
8	54	52.1	63.4	111	73	73	89	82.2	0.00		
9	15.3	13.3	24.5	72.1	34.2	34	51	55	38.8	0.00	
10	48.5	50.4	39	8.44	64.4	30	18.9	60.8	102.5	63.7	0.00

After obtaining the distance matrix values, the next step is to calculate the savings matrix values. An example of the savings matrix calculation can be seen as follows:

$$
\begin{aligned}
&S(1,2) = C(i0,1) + C(0j,2) - C(1,2) \\
&S(1,2) = 1.95 + 9.72 - 11.55 \\
&S(1,2) = 0.12
\end{aligned}
$$

Table 5. Savings matrix

	1	2	3	4	5	6	7	8	9	10
1	0									
2	0.12	0.00								
3	3.25	19.2	0.00							
4	0.15	19.4	38.3	0.00						
5	0.15	19.4	38.2	38.9	0.00					
6	0.25	19.2	68.4	39.8	39.2	0.00				
7	1.75	13.7	42.0	26.9	26.7	46.9	0.00			
8	3.85	0.32	-0.1	0.9	-15.3	9.3	23,5	0.00		
9	3.95	0.52	0.1	1.0	-16.0	-2.2	12.0	30.5	0.00	
10	0.05	19.2	96.9	4.00	38.2	67.1	30.4	0.0	0.1	0.00

The matrix distance calculation process will result in a new matrix containing the previously calculated distances between points. After obtaining the distance matrix using the savings method approach, the vehicle capacity is calculated for each recommended route. The savings matrix, also known as the savings method, is calculated based on the difference in travel distance that can be saved.

Table 6. Sorting the values of the savings matrix

Route	Results	Demand	Route	Results	Demand	Route	Results	Demand	Route	Results	Demand
3.10	96.9	80	4.7	26.9	65	1.8	3.85	80	1.10	0.05	75
3.6	68.4	75	5.7	26.7	65	1.3	3.25	75	8.10	0.0	85
6.10	67.1	75	7.8	23.5	85	1.7	1.75	75	3.8	-0.1	85
6.7	46.9	75	2.4	19.4	60	4.9	1.0	60	6.9	-2.2	70
3.7	42.0	80	2.5	19.4	60	4.8	0.9	70	5.8	-15.3	80
4.6	39.8	60	2.3	19.2	75	2.9	0.52	70	5.9	-16.0	60
5.6	39.2	60	2.6	19.2	70	2.8	0.32	80			
4.5	38.9	50	2.10	19.2	75	1.6	0.25	70			
3.4	38.4	65	2.7	13.7	75	1.4	0.15	60			
3.5	38.2	65	7.9	12.0	75	1.5	0.15	60			
5.10	38.2	65	6.8	9.3	80	1.2	0.12	70			
8.9	30.5	80	4.10	4.00	65	9.10	0.1	75			

To determine vehicle allocation, we start with the largest savings matrix value, which is 96.9. This value represents the combination of consumers 3 and 10, with respective demand quantities of 40 kg and so on. From the calculation results, a new route sequence was obtained, which can be seen in the table.

Table 7. New Route

Route	Route Order	Distance
1	0-10-3-7-6-0	178.24
2	0-5-4-2-1-9-8-0	94.16
	Total	272

The vehicle used by Keripik Cinta Mas Hendro to distribute products to consumers is an L300 type with a capacity of 2,500 kilograms per vehicle.

Here is the distribution expenditure keripik cinta, which consists of:

Driver's Salary = Rp. 85,000

Meal allowance = Rp. 20,000

Fuel costs = Rp.6,800 /litre

The distribution cost calculation is as follows:
Distribution cost = Number of transport vehicles × (driver's wage + fuel cost + meal allowance)

$$= 2 \times \left(Rp.85{,}000 + \left(Rp.6{,}800 \times \frac{Total\ distance}{10\ Km/Liter}\right) + Rp.20{,}000\right)$$
$$= 2 \times \left(Rp.85{,}000 + \left(Rp.6{,}800 \times \frac{272}{10\ Km/\ Liter}\right) + Rp.20{,}000\right)$$
$$= Rp.579{,}920$$

Conclusion

Based on the research results, the application of the Clarke and Wright Savings algorithm in solving the Vehicle Routing Problem (VRP) has proven capable of optimizing the distribution routes of Keripik Cinta Mas Hendro. The use of this algorithm resulted in a reduction in total travel distance from 403.54 km to 272 km and a decrease in transportation costs from Rp. 1,138,221 to Rp. 579,920. These results indicate that the method is effective in minimizing distribution costs and supporting the company's operational efficiency. However, this research is still limited to distance and demand factors without considering delivery time, dynamic capacity, and road conditions. Therefore, further research is suggested to develop an approach that includes time parameters, alternative routes, or integration with other metaheuristic methods to obtain more comprehensive results.

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