Application of nearest neighbour search and 1-insertion local search to improve the distribution route of a textile company

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Abstract. This study aims to optimize the distribution system of a textile company that delivers products to 31 locations in Bandung and the surrounding areas. The company faces issues, including inefficient delivery routes. To address these challenges, three heuristic methods are applied: the Clarke and wright Savings Algorithm, the Nearest Neighbor Search, and 1-insertion intra-route. The Savings method is used to determine initial routes based on distance savings; Nearest Neighbor Search is applied to organize customer visits by proximity; and 1-insertion intra-route is used to improve the existing routes for greater efficiency. The distances used in this study are obtained using Google Maps. The results show that the combination of these three methods can reduce the total distance by 18,2% compared to the company's current distribution routes. The implementation of these methods led to a more efficient distribution process, resulting in cost reduction and improved service quality.

1   Introduction

Efficient route planning for distribution is a critical factor in improving the competitiveness and sustainability of supply chains. Distribution is a part of the supply chain that plays a vital role in ensuring the smooth flow of products from producers to consumers through various channels, including wholesalers, retailers, and direct sales. PT. XYZ is a textile company that produces yarn and embroidery. These products are distributed to various regions, including 31 locations in Bandung City and its surrounding areas. Currently, the distribution process is carried out using two 20-ft trucks and two 40-ft trucks. However, the distribution routes currently implemented have not been optimised using optimisation techniques. The company's distribution challenge can be classified as a variant of the vehicle routing problem (VRP), the Heterogeneous Fixed Fleet Vehicle Routing Problem

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(HFFVRP), in which customer demand, vehicle capacity, vehicle operating cost, and fleet size are predefined

There are many methods have been developed to solve the HFFVRP and its variants. [1] proposed a column generation method and Tabu Search. [2] presented the backtracking threshold accepting (BATA). Here, a more flexible threshold is applied. [3] developed a record-to-record travel algorithm (RRT) to address the HFFVRP. [4] used a greedy randomised adaptive memory programming search (GRAMPS) algorithm with a visual interactive approach to tackle HFFVRP. [5] deals with the HFFVRP using an adaptive memory programming metaheuristic and path relinking. [6] proposed a Tabu Search algorithm. A method based on ILP was developed by [7]. [8] proposed a method that uses a reactive adaptive memory metaheuristic and Tabu Search as an improvement procedure. [9] developed method based on structure-redesign-based bacterial foraging optimization. [10] solved the HFFVRP using the Variable Neighborhood Search. [11] proposed a Hybrid Algorithm for the HFFVRP. A method that uses particle swarm optimisation and sine cosine algorithm was put forward by [12]. [13] addressed the HFFVRP using Nearest Neighbour Search and 2-Opt Method.

Variants of the HFFVRP also have been investigated, for instances the heterogeneous fixed fleet open vehicle routing (HFFOVRP) was addressed by [14]. [15] studied the variant that considers vehicle emissions. The problem solved using a split-based adaptive tabu search. [16] used a hybrid metaheuristic approach based on simulated annealing and local search to address a variant that includes simultaneous pick-up and delivery. [17] proposed a simulated annealing to tackle the two-dimensional HFFVRP.

2 Methodology

In this research, we apply the Clarke and Wright Saving algorithm, the Nearest Neighbour search, and the 1-insertion intra-route algorithm to improve the company's distribution route. The solution is initially obtained by applying Saving's algorithm and the Nearest Neighbour Search. The 1-insertion intra-route algorithm improves that solution.

2.1. The Initial Solution

The initial solution is obtained by applying The Clarke and Wright Savings algorithm and the Nearest Neighbour Search. The Clarke and Wright Savings algorithm was introduced by [18]. This algorithm aims to reduce the distance while considering constraint in distribution network. There are two steps in this algorithm, first, determine the distance matrix and then establish the saving matrix. Saving is calculated by using (1).

$$S(x,y) = J(D,x) + J(D,y) - J(x,y) \tag{1}$$

where,

$S(x,y)$: reduced distance.
$J(D,x)$: distance between depot and customer x.
$J(D,y)$: distance between depot and customer y.
$J(x,y)$: distance between customer x and customer y.

The results obtained by the Savings algorithm are used by the Nearest Neighbour Search to create routes. The method will allocate the customers into a route by considering the smallest distance between customers and capacity constraints.

2.2. 1-Insertion Intra-Route Algorithm

In the 1-insertion intra-route procedure, a customer is removed from its position in a route and try to insert it elsewhere within that route in order to have a better solution. As we remove customer within a route, the capacity does not need to be checked. This algorithm often used to solve the VRP and its variants. For instances it is used by [19] and [20] to solve the ulti-depot vehicle routing problem and the open vehicle routing problem. Fig. 1. Illustrates the 1-insertion intra-route algorithm.
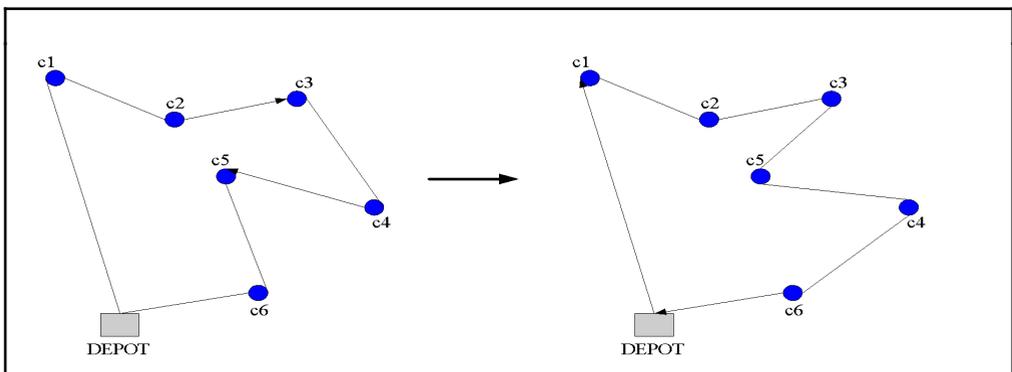

Fig. 1. 1-Insertion Intra-Route

In Fig.1 customer c_5 is removed its position between customer c_6 and customer c_4 and inserted between customer c_4 and customer c_3. The initial route $D - c_1 - c_2 - c_3 - c_4 - c_5 - c_6 - D$ becomes $D - c_1 - c_2 - c_3 - c_5 - c_4 - c_6 - D$. The procedure is applied for each customer.

3   Results and Discussion

The distances between the depot and customers are obtained from Google Maps. There are four vehicles available: two type 1 vehicles with a capacity of 450 boxes and two type 2 vehicles with a capacity of 210 boxes. C denotes the customer number, and D denotes the depot. Fig 2 shows the current distribution routes for the companies. The distance of the current route is given in Table 1.
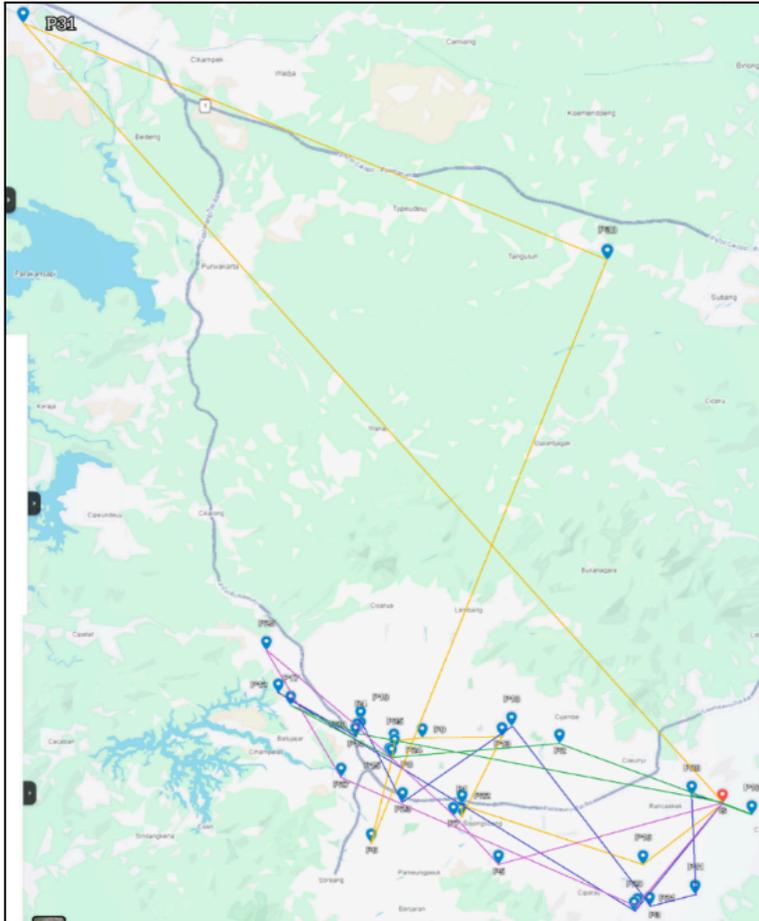
Fig. 2. The Current Routes

Table 1. Current Routes

Route Number	Vehicle Type	Route	Demand (box)	Distance (Km)
1	Type 1	D-C16-C1-C22-C13-C9-C25-C8-C6-C30-C31-D	445	361,9
2	Type 1	D-C28-C11-C21-C18-C23-C4-C14-C12-C3-D	450	164,7
3	Type 2	D-C10-C2-C15-C17-C20-D	205	119,3
4	Type 2	D-C5-C7-C19-C26-C27-C29-D	210	161,3
Total Distance				807,2

Table 2 shows the results of the Nearest Neighbour Search.

Table 2. Routes Obtained by Using the Nearest Neighbour Search

Route Number	Vehicle Type	Route	Demand (box)	Distance (Km)
1	Type 1	D-C28-C2-C18-C27-C6-C26-C21-C31-C30-D	440	426,3
2	Type 1	D-C11-C3-C16-C7-C13-C19-C4-C20-C14-C17-C12-D	450	127,7
3	Type 2	D-C10-C29-C22-C7-C9-C24-D	210	92,3
4	Type 2	D-C5-C1-C23-C15-C8-C25-D	210	87,3
Total Distance				733,6

The Clarke and wright Savings algorithm and the Nearest Neighbour Search can reduce the route from 807.2 km to 733.6 km. The 1-insertion intra-route is then used to improve the routes in Table 2. The route obtained is shown in Table 3 and Fig. 3 shows the routes after applying 1-insertion intra-route.

Table 3. Routes Obtained by Applying Using 1-Insertion Intra Route Algorithm

Route Number	Vehicle Type	Route	Demand (box)	Distance (Km)
1	Type 1	D-C28-C21-C2-C18-C6-C27-C31-C30-D	440	356,6
2	Type 1	D-C11-C3-C16-C13-C19-C4-C20-C14-C17-C12-D	450	127,7
3	Type 2	D-C10-C29-C22-C7-C9-C24-D	210	92,3
4	Type 2	D-C1-C23-C15-C8-C25-C5-D	210	83,7
Total Distance				660,3

Table 3 shows that the 1- insertion intra-route can reduce the total distance. It is obtained by reducing the traveling distance of the Route #1 (426,3 km – 356,6 km) and Route #4 (87,3km - 83,7km).
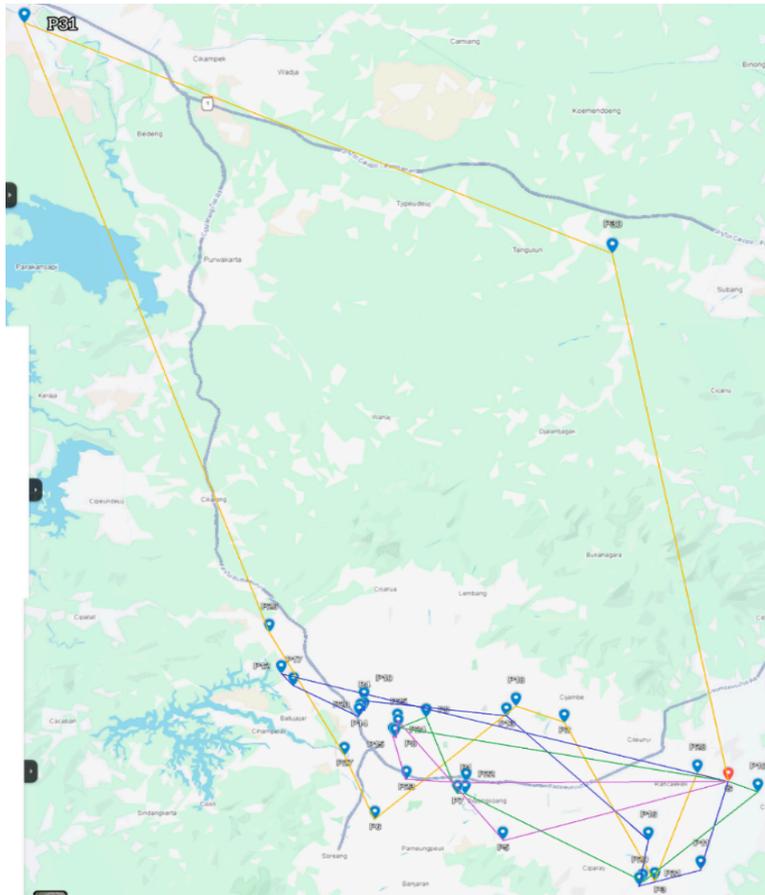

Fig. 3. Routes Obtained by 1-Insertion Intra-Route

4   Conclusions

The distribution route of a company is solved by using the Clarke and Wright Savings algorithm, Nearest Neighbour Search and 1 insertion intra-route Algorithm. The proposed algorithm can produce a solution that can improve the current distribution route by 18,2%. It means the company can reduce transportation costs for distributing its product. The solution quality of the proposed method can be improved by applying an algorithm that can move or swap customers between routes or apply a metaheuristic algorithm such as Adaptive Large Neighborhood Search, Tabu search, and Variable Neighborhood Search. Those algorithms are considered the best algorithms to solve the vehicle routing problem and its variants

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