

OPTIMIZATION OF GOODS DISTRIBUTION ROUTE ASSISTED BY GOOGLE MAP WITH CHEAPEST INSERTION HEURISTIC ALGORITHM (CIH)

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Abstract -- In the distribution of goods, the efficiency of goods delivery one of which was determined by the path that passed to deliver the goods. The problem of choosing the shortest route was known as the Traveling Salesman Problem (TSP). To solve the problem of choosing the shortest route in the distribution of goods, the algorithm to be used was Cheapest Insertion Heuristic (CIH). This study aims to determine the minimum distance traveled by using the CIH algorithm. Researchers determine the route and distance of each place visited by using google map. The concept in the CIH algorithm was to insert an unexpired city with an additional minimum distance until all cities are passed to get the solution of the problem. The step completion problem with CIH algorithm was: 1) search, 2) making sub tour; 3) change the direction of the relationship, 4) repeat the steps so that all places are included in the sub tour. Theoretically, the total distance calculated using the CIH algorithm is 20.2 km, while the total distance calculated previously traveled with the ordered route is 25.2 km. There was a difference of 5 km with the application of CIH algorithm. The difference between the distance certainly has an impact on the optimal distribution of goods to the destination. Therefore, CIH algorithm application can provide a solution for determining the shortest route from the distribution of goods delivery.

Keywords: Optimization; Route; Sub tour; Algorithm; Graph

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INTRODUCTION

In this global era, almost every activity is based on an online system. The activities of sale and purchase transactions, education, entertainment, social and others can all be accessed online. Especially in the field of trade, the goods result of sale and purchase transactions sent to the buyer by using delivery services. Therefore, various delivery services now become a trend in big cities. With the digital era is, of course, this resulted in freight forwarding services company overgrowing (Bodyanskiy et al., 2017).

In the scope of goods delivery services, many factors that significantly affect the service. One of them is the high mobility activities in the public streets will significantly change the distribution of goods delivery. Especially if located in big cities, congestion is one factor that can affect the level of service delivery. Therefore, every company is always looking for ways to minimize the cost and time of distribution of goods to maintain the price and quality of service to consumers (Demirgüç-Kunt et al., 2017).

In the distribution of goods using delivery service, special attention is given by the management of related companies on efficiency,

effectiveness, and productivity by considering resources owned. To achieve the expected target required policy, one of which is how the arrangement of the delivery route of goods optimally to consumers. The distribution of a goods must consider several factors. As for some of these factors include: time and mileage, fuel costs, and how many fleets are in need. According to Achmad Rozy, an effective distribution strategy and can work optimally has three critical factors. The first factor is the area factor, which means that knowledge is needed about the area of the distribution area so that the distributor can work in the distribution area optimally. The second factor is the inventory factor, which means that there is a need for consideration in making decisions about how much inventory is for each delivery. The third factor is the transportation factor, which means that the necessary process was governing the planning of the scheduling (Febriantono et al., 2012).

In addition to the problem of means of transportation, the efficiency of delivery of goods is also determined by the path taken to deliver the goods. Lane selection affects the effectiveness of the delivery of goods. Like the

problems faced by Cahaya Bintang Printing and Advertising. The focus of this company is to prioritize the results and service, to the consumer, where goods that have been completed in the process will soon be distributed to consumers. Distribution of goods and purchases of raw materials made by employees of these companies have made the route systematically. However, the predetermined route does not guarantee that the delivery of goods will take place efficiently. Based on the observation, that in a day the employees of the starlight will visit seven sites that are located far apart. Every day employees will start distributing goods at 10:00 pm and will return at 14.00. The distance traveled by employees is calculated manually from the average vehicle kilometer is 28 km. From the point that the company wants a solution to reduce the distance traveled. Because the reduction in mileage will also reduce fuel costs and time.

The problem of choosing the shortest route is known as the Traveling Salesman Problem (TSP). TSP is a classic problem that tries to find the shortest route that can be passed by salesmen who want to visit several cities without having to visit the same city more than once (Kusriani and Istiyanto, 2007). TSP is an application of Graph Theory. TSP consists of Symmetric TSP (STSP) and Asymmetric TSP (ATSP). STSP is a TSP where the paths go, and the return path between the two cities is always the same. While ATSP is TSP where the go path and the return path are not still the same (Lancia and Serafini, 2018; Caturiyati, 2008).

The optimal solution of this TSP problem will significantly assist freight companies to streamline the delivery process of goods, both regarding time and funds. There are many algorithms for performing the shortest route search. Selection of the most optimum algorithm is always a problem in the search for the shortest route, where each algorithm has its advantages and disadvantages respectively. The algorithm is a computational procedure that transforms some inputs into some outputs (Wibowo and Wicaksono, 2012). An algorithm is said to be true if for every input it produces the correct output as well. In this case, the algorithm can be used as a method to know the steps to achieve the goal.

The algorithm to be used in this research is Cheapest Insertion Heuristic (CIH). The CIH algorithm is an algorithm that builds a tour of a small particle with minimum weight and is successively added with a new point until all the points are successfully passed. In determining the shortest route of the TSP, the basic concept that becomes the reference for finding the

solution is the graph theory. The graph is the set of vertices and the set of edges. The points in a graph are connected to each other through the segment. G graph consists of a non-empty set of elements called vertices and an unordered list of node pairs called edges. The set of vertices of a graph G is denoted by $V(G)$ while the set list of edges of graph G is denoted by $E(G)$. Furthermore, a graph G can be denoted by $G = (V, E)$ which means that graph G has V vertices and E edges (Tanjung et al., 2017).

Some research results mention that the CIH algorithm can be used for determining the shortest route such as Febriantono et al., (2010) which uses CIH algorithm in web-based distribution application. The use of CIH algorithm in the program is proven to provide optimal mileage. In addition, the use of CIH algorithm is also discussed in Saleh and Prihandono (2015) research, which states that the application of CIH algorithm able to provide the shortest route from the distribution of goods in the company under study. When compared to several algorithms, of course, each algorithm has advantages and weaknesses of each. According to Efendi and Maulinda (2010) research results, that for the calculation of minimum distances in less than 20 cities, the CIH algorithm shows relatively fast processing times compared to other algorithms.

Based on the background, while the formulation of the problem in this research is how the application of CIH algorithm to determine the shortest route on the distribution of goods delivery in Cahaya Bintang Printing and Advertising. The purpose of this study is to find out how the application of CIH algorithm in determining the shortest route on the distribution of goods delivery.

METHOD

This research is qualitative research designed using case study method. This study aims to determine the minimum distance traveled by using the CIH algorithm. Based on the objective, then the variables that become the focus of this research is the minimum distance that can be reached by the subject. External variables such as vehicle speed and congestion levels in the course of an issue are assumed to be constant so that it will not affect the subject's distance.

In this study, researchers took the route from the employee of Cahaya Bintang Printing and Advertising. Cahaya Bintang is a business entity that works in the field of advertising. For every day Cahaya Bintang employees will visit several places in the area to buy raw materials such as paper, ink, etc. as well as distributing

goods produced. To determine the location and route of travel Cahaya Bintang employee will be assisted by using google map application. With the google map application, the distance of each place can be determined.

The steps undertaken in this research are problem identification, literature study, data collection, representation in a graph and optimal route determination. In problem identification, the problem discussed in determining the optimal route of goods distribution with CIH algorithm. The distribution route will be determined using google map. Calculating the distance of each place from the place of origin is also determined by using google map. Data obtained using google map then analyzed using CIH algorithm to determine the minimum distance that can be taken by the subject. After the route is set using the CIH algorithm, then the route will be represented in a graph and calculated the shortest distance that can be passed.

RESULTS AND DISCUSSION

The CIH algorithm is one of the algorithms that can be used to solve TSP problems. The CIH algorithm has the time complexity of $O(n^3)$. This algorithm has the concept of inserting an unexpired city with an additional minimum distance until all the cities are passed to get the solution of the problem (Rotlauff, 2011). A trip The CIH algorithm starts from an initial node (1) to all vertices (2,3, ..., n) and returns to the initial node (1) without any node being visited more than once by taking into account the additional minimum distance when one node is inserted into the current partial tour.

The CIH algorithm according to Kusrini and Istiyanto (2007) is as follows:

1. Search

It starts with the first place connected to the last place.

2. Created sub tour relationship

A sub tour relationship is created between the 2 places. The sub tour means a journey from the first city and ends in the first city, for example $(1,3) \rightarrow (3,2) \rightarrow (2,1)$ as illustrated in Fig. 1.

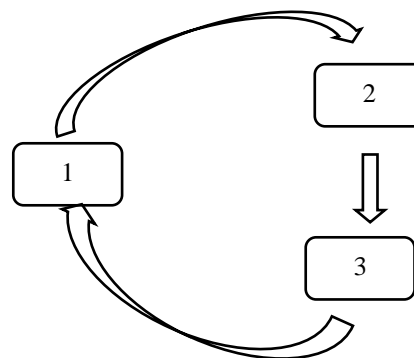


Figure 1. Sub tour

3. Changing the direction of the relationship

One direction of the relationship (arc) of two cities is replaced by a combination of two arcs, it is arc (i, j) with arc (i, k) and arc (k, j), with k taken from a city that has not entered the sub tour, and with extra smallest distance. Distance is obtained from Equ. (1):

$$c_{ik} + c_{kj} - c_{ij} \tag{1}$$

Information:

c_{ik} is the distance from city i to city k

c_{kj} is the distance from city k to city j

c_{ij} is the distance from city i to city j

4. Repeat step 3 until the entire city enters the sub tour.

In this study, it took the route of the employee journey from Cahaya Bintang Setting and Advertising. For every day Cahaya Bintang employees will visit several places in the area to buy raw materials such as paper, ink and distribute the products. Data obtained from observation and interview will be analyzed by using CIH algorithm. To determine the place and route of the distribution of goods from Cahaya Bintang will be assisted by using google map application. To determine the distance and route in the google map application is to enter the name of the place or address in the search field. Google map will automatically show you the shortest distance from multiple route options between places with one another. Here is the look of the places that the Starlight employees will see in Fig. 2.

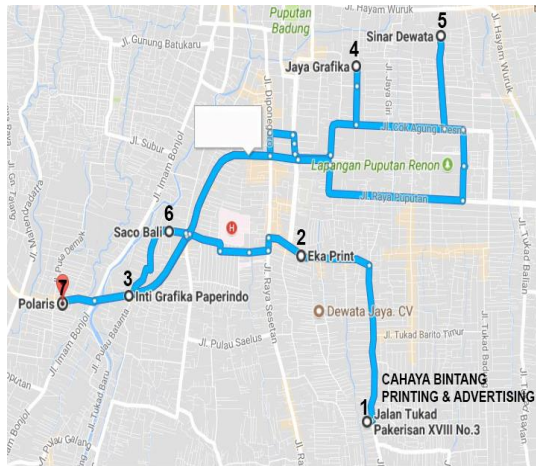


Figure 2. Distribution Line Route by Google Map App

After determining the place to be visited, the next step is to calculate the distance of each place from the point of origin presented in Table 1.

Table 1. Distributions Place Distance from The Origin Poin

Place	Distance
Cahaya Bintang (1)	0 km
Eka Print (2)	2,3 km
Inti Grafika (3)	4,8 km
Jaya Grafika (4)	4,9 km
Sinar Dewata (5)	6,2 km
Saco Bali (6)	4,2 km
Polaris (7)	5,6 km

The list of distribution points will be converted to the numbers shown in Table 2.

Table 2. Distance Conversion of Distribution Place from Origin Point

Place	Distance
1	0 km
2	2,3 km
3	4,8 km
4	4,9 km
5	6,2 km
6	4,2 km
7	5,6 km

The next step is to determine the distance from each place presented in Table 3.

To find the shortest distance from place 1 to place 7, as for the steps are as follows:

1. Take the journey from 1st to 7th place
2. Create sub tour (1,7) → (7,1)
3. Create a table that stores a place that can be inserted in the sub tour along with the additional distance, as shown in Table 4.

Table 3. Distance from Each Place

Origin Palce	Destination	Distance
1	2	2,3 km
1	3	4,8 km
1	4	4,9 km
1	5	6,2 km
1	6	4,2 km
1	7	5,6 km
2	3	2,5 km
2	4	2,5 km
2	5	3,9 km
2	6	1,8 km
2	7	3,3 km
3	4	4,5 km
3	5	6,5 km
3	6	1,1 km
3	7	0,8 km
4	5	2,4 km
4	6	4,1 km
4	7	5,5 km
5	6	5,9 km
5	7	7,4 km
6	7	2,0 km

Table 4. Arc Addition of First Subtour

Arc be replaced	to Arc to be added to Subtour	Additional Distance
(1,7)	(1,2) → (2,7)	$c_{12} + c_{27} - c_{17} = 0$
(1,7)	(1,3) → (3,7)	$c_{13} + c_{37} - c_{17} = 0$
(1,7)	(1,4) → (4,7)	$c_{14} + c_{47} - c_{17} = 4,8$
(1,7)	(1,5) → (5,7)	$c_{15} + c_{57} - c_{17} = 8$
(1,7)	(1,6) → (6,7)	$c_{16} + c_{67} - c_{17} = 6$
(7,1)	(7,2) → (2,1)	$c_{72} + c_{21} - c_{71} = 0$
(7,1)	(7,3) → (3,1)	$c_{73} + c_{31} - c_{71} = 0$
(7,1)	(7,4) → (4,1)	$c_{74} + c_{41} - c_{71} = 4,8$
(7,1)	(7,5) → (5,1)	$c_{75} + c_{51} - c_{71} = 8$
(7,1)	(7,6) → (6,1)	$c_{76} + c_{61} - c_{71} = 6$

From Table 4, two sub tours have the shortest distance. Because the distance is the same therefore can be selected as one of the two. So, it is chosen for arc (1,7) replaced with arc (1,2) and arc (2,7) or arc (7,1) replaced by arc (7,2) and arc (2,1). From the substitution sub tour, the new sub tour is obtained (1,2) → (2,7) → (7,1).

Then repeat the steps above to insert a new subtitle on the new route. The addition of new sub tours is presented in Table 5.

From Table 5, the smallest distance is 0 by substituting arc (2,7) with arc (2,3) and arc (3,7), so that the new sub tour generated is (1,2) → (2,3) → (3,7) → (7,1).

Do the steps above to get all the places traversed. The new sub tour search will be presented in Table 6.

Table 5. Arc Addition of Second Subtour

Arc to be replaced	Arc to be added to Subtour	Additional Distance
(1,2)	(1,3) → (3,2)	$c_{13} + c_{32} - c_{12} = 5$
(1,2)	(1,4) → (4,2)	$c_{14} + c_{42} - c_{12} = 5,1$
(1,2)	(1,5) → (5,2)	$c_{15} + c_{52} - c_{12} = 7,8$
(1,2)	(1,6) → (6,2)	$c_{16} + c_{62} - c_{12} = 3,7$
(2,7)	(2,3) → (3,7)	$c_{23} + c_{37} - c_{27} = 0$
(2,7)	(2,4) → (4,7)	$c_{24} + c_{47} - c_{27} = 3$
(2,7)	(2,5) → (5,7)	$c_{25} + c_{57} - c_{27} = 8$
(2,7)	(2,6) → (6,7)	$c_{26} + c_{67} - c_{27} = 0,5$
(7,1)	(7,4) → (4,1)	$c_{74} + c_{41} - c_{71} = 4,8$
(7,1)	(7,5) → (5,1)	$c_{75} + c_{51} - c_{71} = 8$
(7,1)	(7,6) → (6,1)	$c_{76} + c_{61} - c_{71} = 6$

Table 6. Arc Addition of Third Subtour

Arc to be replaced	Arc to be added to Subtour	Additional Distance
(1,2)	(1,4) → (4,2)	$c_{14} + c_{42} - c_{12} = 5,1$
(1,2)	(1,5) → (5,2)	$c_{15} + c_{52} - c_{12} = 7,8$
(1,2)	(1,6) → (6,2)	$c_{16} + c_{62} - c_{12} = 3,7$
(2,3)	(2,4) → (4,3)	$c_{24} + c_{43} - c_{23} = 4,5$
(2,3)	(2,5) → (5,3)	$c_{25} + c_{53} - c_{23} = 7,9$
(2,3)	(2,6) → (6,3)	$c_{26} + c_{63} - c_{23} = 0,4$
(3,7)	(3,4) → (4,7)	$c_{34} + c_{47} - c_{37} = 9,2$
(3,7)	(3,5) → (5,7)	$c_{35} + c_{57} - c_{37} = 13,1$
(3,7)	(3,6) → (6,7)	$c_{36} + c_{67} - c_{37} = 2,3$
(7,1)	(7,4) → (4,1)	$c_{74} + c_{41} - c_{71} = 4,8$
(7,1)	(7,5) → (5,1)	$c_{75} + c_{51} - c_{71} = 8$
(7,1)	(7,6) → (6,1)	$c_{76} + c_{61} - c_{71} = 6$

From Table 6, the smallest distance is 0,4 by substituting arc (2,3) with arc (3,6) and arc (6,7), so the newly generated sub tour is:

$$(1,2) \rightarrow (2,6) \rightarrow (6,3) \rightarrow (3,7) \rightarrow (7,1)$$

Do the steps above to get all the places traversed. The new sub tour search will be presented in Table 7.

From Table 7, it is obtained that the smallest distance is 4,8. Because there are two sub tours with the shortest distance can be selected as one of them. On this occasion, the arc (2,6) will be replaced by arc (2,4) and arc (4,6), so the newly generated sub tours are:

$$(1,2) \rightarrow (2,4) \rightarrow (4,6) \rightarrow (6,3) \rightarrow (3,7) \rightarrow (7,1)$$

Take a similar step to get all the places traversed. The new sub tour will be presented in Table 8.

Table 7. Arc Addition of Fourth Subtour

Arc to be replaced	Arc to be added to Subtour	Additional Distance
(1,2)	(1,4) → (4,2)	$c_{14} + c_{42} - c_{12} = 5,1$
(1,2)	(1,5) → (5,2)	$c_{15} + c_{52} - c_{12} = 7,8$
(2,6)	(2,4) → (4,6)	$c_{24} + c_{46} - c_{26} = 4,8$
(2,6)	(2,5) → (5,6)	$c_{25} + c_{56} - c_{26} = 8$
(6,3)	(6,4) → (4,3)	$c_{64} + c_{43} - c_{63} = 7,5$
(6,3)	(6,5) → (5,3)	$c_{65} + c_{53} - c_{63} = 11,3$
(3,7)	(3,4) → (4,7)	$c_{34} + c_{47} - c_{37} = 9,2$
(3,7)	(3,5) → (5,7)	$c_{35} + c_{57} - c_{37} = 13,1$
(7,1)	(7,4) → (4,1)	$c_{74} + c_{41} - c_{71} = 4,8$
(7,1)	(7,5) → (5,1)	$c_{75} + c_{51} - c_{71} = 8$

Table 8. Arc Addition of Fifth Subtour

Arc to be replaced	Arc to be Added to Subtour	Additional Distance
(1,2)	(1,5) → (5,2)	$c_{15} + c_{52} - c_{12} = 7,8$
(2,4)	(2,5) → (5,4)	$c_{25} + c_{54} - c_{24} = 3,8$
(4,6)	(4,5) → (5,6)	$c_{45} + c_{56} - c_{46} = 4,2$
(6,3)	(6,5) → (5,3)	$c_{65} + c_{53} - c_{63} = 11,3$
(3,7)	(3,5) → (5,7)	$c_{35} + c_{57} - c_{37} = 13,1$
(7,1)	(7,5) → (5,1)	$c_{75} + c_{51} - c_{71} = 8$

From Table 8, the smallest distance is 3,8 by substituting arc (2,4) with arc (2,5) and arc (5,4), so the newly generated sub tour is:

$$(1,2) \rightarrow (2,5) \rightarrow (5,4) \rightarrow (4,6) \rightarrow (6,3) \rightarrow (3,7) \rightarrow (7,1)$$

Here is the shortest path representation in graph form shown in Fig. 3.

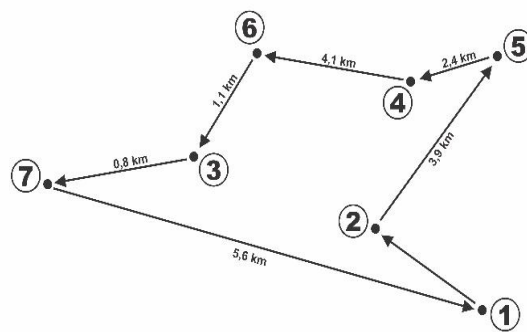


Figure 3. Shortest Trajectory of Goods Distribution

Based on the calculation of CIH algorithm can be determined that the shortest distance of an employee of Cahaya Bintang to distribute the goods are:

$$\begin{aligned}
 s &= s((1,2) + (2,5) + (5,4) + (4,6) + (6,3) + (3,7) + (7,1)) \\
 &= 2,3 + 3,9 + 2,4 + 4,1 + 1,1 + 0,8 + 5,6 \\
 &= 20,2 \text{ km}
 \end{aligned}$$

The shortest travel route is starting from the starting point to number 2, then the next number 5, then number 6, then number 3, and the last is number 7 before returning to the starting point. If we calculate the distance from route from point 1 to point 7 with normally route then the distance obtained is:

$$\begin{aligned} s &= s((1,2) + (2,3) + (3,4) + (4,5) + (5,6) + \\ &\quad (6,7) + (7,1)) \\ &= 2,3 + 2,5 + 4,5 + 2,4 + 5,9 + 2,0 + 5,6 \\ &= 25,2 \text{ km} \end{aligned}$$

CIH algorithm is one algorithm that can solve TSP. CIH algorithm is an algorithm with a heuristic method which means this method is applied will give a varied result and shorter calculation time. Based on the results of research from Kusriani and Istiyanto (2007) mentioned that the use of CIH algorithm in the trial of TSP completion program could be reached with a relatively short time. If viewed the results of trials, for the determination of the distance of 5 cities the process time is 1 second, ten cities 3 seconds (Kusriani and Istiyanto, 2007). It shows that CIH implementation can make the time to calculate the minimum distance that can be taken.

Based on the observations, if the vehicle speed and the congestion rate are assumed to be constant, the subject can travel from one to seven and return to one of approximately 25.2 km. The distance is derived from the calculation by using google map from one place to the seventh place and back again the starting point.

It can be seen that the comparison of the distance with the normal route and route using the CIH algorithm yields a difference of 5 km. Where the route using the CIH algorithm is shorter 5 km than the regular route. Of course, with a difference of 5 km will be able to save fuel and time, so that the delivery of goods more effective and efficient. This route is supported from Caturiyati (2008) which states that CIH algorithm is one algorithm that can be used to solve the Traveling Salesman Problem (TSP) especially the problem of travel route optimization. In addition to Saleh and Prihandono (2015) research also mentions that the shortest route can be determined optimally using the CIH algorithm. Theoretically, CIH algorithm can provide a solution to the problem of finding the shortest route experienced by the subject. When compared to the previous conditions, where the route through either selected in sequence or random may not necessarily produce minimum travel distance.

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With the completion of the CIH algorithm, of course, the distribution of goods will be more effective and efficient both regarding cost and time.

CONCLUSION

The Cheapest Insertion Heuristics (CIH) algorithm is one of the algorithms that can be used to solve TSP problems. This algorithm has the concept of inserting an unexpired city with the addition of the minimum distance until all the cities are passed to get the solution of the problem. Theoretically, the total distance calculated using the CIH algorithm is 20.2 km, while the total distance calculated previously traveled with the ordered route is 25.2 km. There is a difference of 5 km with the application of CIH algorithm. The difference between the distance certainly has an impact on the optimal distribution of goods to the destination. Therefore, CIH algorithm application can provide a solution for determining the shortest route from the distribution of goods delivery in Cahaya Bintang Printing and Advertising.

As for suggestions that can be submitted is, it is advisable for further researchers to

compare the algorithm Cheapest Insertion Heuristics (CIH) with another algorithm to find out which algorithm is more useful to solve the traveling salesman problem.

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