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Implementation of Cheapest Insertion Heuristic Algorithm in Determining Shortest Delivery Route

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Abstract

The buying and selling transaction system that many people use today is the online buying and selling system. In this system, there is a process of goods delivery by one branch of a freight forwarder in Indonesia, namely SiCepat Express Baleendah. In the process of shipping goods, a delivery route with the shortest path is needed in order to minimize of the goods delivery process. The problem of the route of goods delivery can be solved by one of the algorithms in the Traveling Salesman Problem (TSP), namely the Cheapest Insertion Heuristic (CIH) Algorithm. This study aims to determine the shortest route and distance for goods delivery using the CIH Algorithm by the Asymmetric TSP CIH application, as well as knowing its efficiency compared to the route that used by SiCepat Express Baleendah. The result shows that the use of the CIH Algorithm is proven to produce a more efficient delivery route than the route created by SiCepat Express Baleendah. Based on the goods delivery route from SiCepat Express Baleendah, the result of the total distance is 18.55 km. On the other hand, based on the CIH Algorithm, the delivery route obtained result is 13.45 km. The efficiency of using the CIH Algorithm is 27.48% better than the result from SiCepat Express Baleendah route.

Keywords: Goods Delivery Route, Travelling Salesman Problem, Cheapest Insertion Heuristic, Algorithm, Shortest Path

1. Introduction

The process of buying and selling transactions is a common thing for the people of Indonesia and even for people around the world. One example of buying and selling transactions that exist today is online buying and selling transactions. Along with the times and increasingly sophisticated technology, people can make buying and selling transactions online through electronic media. One example is the sale and purchase of products/goods online via the internet such as Lazada, Tokopedia, Bukalapak, Blibli, Elevania, Shopee and other applications (Fitria, 2017).

Currently, many people use the online shopping system to buy the things they need. During the first 6 months of 2021, online buying and selling transactions grew 63.4 percent from IDR 114.3 trillion to IDR 186.7 trillion. Bank Indonesia (BI) also estimates that by the end of 2021 online buying and selling transactions can increase by 48.4 percent to IDR 395 trillion (Merdeka.com, 2021).

In online shopping transaction activities, there is a delivery process carried out to deliver goods from the seller to the buyer. More and more people are choosing how to shop online, this results in a high process of sending goods to buyers. This condition is quite favorable for the freight forwarder, but there are several problems including if there is an incomplete buyer's address then this can result in the slow delivery of goods and can cause the shipping route to be longer. The problem of distance and finding the shortest route is a common problem for everyone when visiting certain places, one of which is during the process of sending goods to the buyer's place (Cantona, 2020).

One of the shipping companies in Indonesia is SiCepat Express, an expedition company that was founded in 2014 (SiCepat Express, 2021). In the process of sending goods, SiCepat Express and especially SiCepat Express Baleendah do not determine the schedule for the order of delivery of goods or the route of delivery of the goods, but this is released and handed over to the delivery officers (couriers) who will deliver the goods. In practice, couriers often use less efficient routes, such as passing through several roads or the same point/location more than once.

With the increasing number of shipments of goods today, it is necessary to arrange the most efficient route in the process of sending goods. This problem can be solved through Mathematics, namely by using Graph Theory, especially by using the concept of the Travelling Salesman Problem (TSP). In TSP, the problem studied is to determine the shortest route that can be taken by a salesman who wants to visit several places without having to visit the same place more than once, and must return to the initial place of departure (Kusrini, 2007). One of the techniques used to speed up the search for solutions to the TSP problem is to use an insertion algorithm, also known as the Cheapest Insertion Heuristic (CIH) Algorithm (Yulianto, 2018).

The CIH algorithm is one of the algorithms that can help the problem of determining the shortest route. The CIH algorithm has search steps that are relatively not too difficult, but in the process of finding the route of shipping goods it takes a relatively longer time, especially if there is quite a lot of location data and it is possible that there are errors in the search process so that good accuracy is needed. Therefore, to minimize this problem, an application is needed to be able to assist the process of finding the shortest route in the goods delivery. One application that can be used is the Asymmetric TSP with CIH (ATSP CIH) application (Sayekti, 2015).

The application is implemented by creating a graph from the available data, then entering the distance data between points into the available column in the ATSP CIH application. After that, we only need to run the application and we will be able to obtain the minimum path for the delivery route. Therefore, in this article, an alternative solution will be discussed, namely applying the CIH Algorithm with the help of the ATSP CIH application to determine an efficient route for shipping goods so that SiCepat Express Baleendah can deliver goods with less distance traveled to streamline delivery times and can satisfy buyers more.

2. Literature Review

2.1. Graph Theory

This theory was introduced in the 18th century by a mathematician named Leonhard Euler (1707-1783). Euler was trying to solve a puzzle known as the Konigsberg Bridge Problem. There are seven bridges connecting two islands and a river. We will find a path that passes through each bridge exactly once (Wattimena, 2013).

Graph G is an ordered pair (V, E) where is the set of finite and non-empty vertices and E is the edge set that connects two vertices. The element is called the node and the element is called the edge, denoted as (i, j), which is the side that connects the vertex with vertex, with i,j $\in V$ (Hayu, 2017), (Harahap, 2003).

a. Cycle or Circuit

A path that starts and ends at the same node is called a cycle or circuit (Munir, 2012). In Figure 1, examples of circuits contained are 1,2,4,3,1.

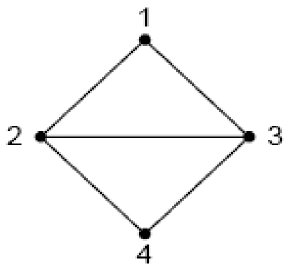


Figure 1. Cycle or Circuit

b. Connected Graph

A graph G is called a connected graph if for every pair of vertices u and v in the set V there is a path from u to v. The connection between two vertices is important in a graph. If two nodes are connected then surely the first node can be reached from the second node (Munir, 2012). An example of a connected graph is shown in Figure 2.

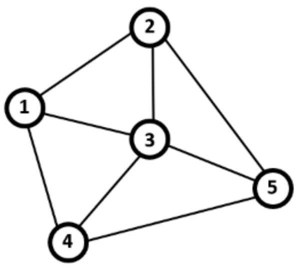


Figure 2. Connected Graph

c. Weighted Graph

A weighted graph is a graph in which each edge is assigned a value or weight. As in Figure 3, the weights on each edge can vary depending on the problem being modeled with the graph. The weight can state the distance between two places, the cost of traveling between two places, the message travel time (message) from a communication node to another communication node (in a computer network), production costs, and so on (Hayu, 2017).

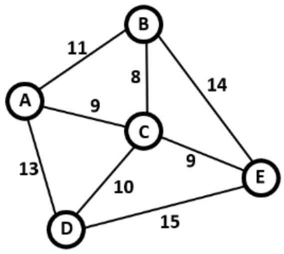


Figure 3. Weighted Graph

d. Complete Graph

A complete graph is a simple graph in which every vertex is connected (by one edge) to all the other vertices. A complete graph with n vertices is denoted by K_n, is shown in Figure 2.7. Each vertex in K_n has degree n-1 and the number of edges is $n(n-1)/2$ (Zulfa, 2021).

2.2. Travelling Salesman Problem

The Mathematical Problem of the Traveling Salesman Problem (TSP) was proposed in 1800 by Irish mathematician William Rowan Hamilton (1805-1865) and British mathematician Thomas Penington Kirkman (1806-1895).

TSP is represented by using a complete graph with weights $G = (V, E)$ where V is the set of vertices that represent the places to be visited and E is the set of edges that represent the path between vertices and edge $e = (v_i, v_j)$ has weight $c(e) = c_{ij}$, which is the side weight between points v_i and v_j which shows the distance between point i and point j. Also given $C = (c_{ij})$ as a weight matrix corresponding to E so that the TSP problem is how to find a Hamilton circuit in graph G with minimum weight.

TSP is one of the distribution problems that has been discussed for a long time in optimization studies that usually occur in everyday life. The TSP problem is about someone who has to visit all cities exactly once and return to the initial city with a minimum distance (Fadhillah, 2017).

2.3. Cheapest Insertion Heuristic Algorithm

The CIH method builds a tour from small cycles with minimal weight and successively adds new points. The selection of the new point is carried out simultaneously with the selection of the edge so that the minimum insertion value is obtained. Then the new point is inserted between the two points that make up the side that has been selected (Yulianto, 2018).

The concept of CIH has the following algorithm (Wiyanti, 2013):

1. Search, starting from a first place that is linked to the nearest place.
2. Creation of subtour relationships; a subtour link is created between 2 places. A subtour is a journey from the first place and ends at the first place, for example (1,3) → (3,2) → (2,1) as shown in Figure 4.

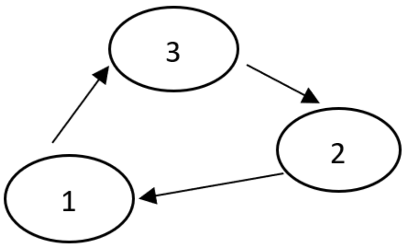


Figure 4. Subtour

3. Change the direction of the relationship. One of the direction of the relationship (arc) of two places with a combination of two arcs, namely arc (i,j) is changed to arc (i,k) and arc (k,j), where k is the insertion place with the smallest additional distance, which is obtained from $C_{ik} + C_{kj} - C_{ij}$ with the caption:
   C_{ik} is the distance from location i to location k
   C_{kj} is the distance from location k to location j
   C_{ij} is the distance from location i to location j
4. Repeat step 3 until all places fit into the subtour. The addition of this subtour can be done up to the nth node until the subtour with the smallest total distance is obtained.

2.4. Google Maps

Google Maps is an online map application service provided by Google. Google Maps map service can officially be accessed through the site http://maps.google.com. Google Maps has many facilities that can be used for example location search by entering keywords, in the form of place names, cities, roads, or other keywords. Route search between points/places is also one of the other facilities that can be searched using Google Maps (Sunaryono, 2016).

3. Materials and Methods

3.1. Materials

This study uses address data and the order of delivery of goods obtained from interviews with one of the Baleendah SiCepat Express couriers. Address data (delivery location) is used to map the path (graph) of the delivery of goods. In this study, there were 40 addresses/locations used to search for shipping routes.

3.2. Methods

In this study, the first step is to collect address data for which the route of delivery of the goods will be searched. The second step is to create a graph representation of the data that has been obtained. After that, calculate the total distance for shipping goods from the route used by SiCepat Express Baleendah. The next step is to find the route and total distance for shipping goods using the ATSP CIH application. The results obtained are then compared with the route used by SiCepat Express Baleendah to determine the efficiency of using the CIH Algorithm in the ATSP CIH application.

4. Results and Discussion

Based on the known address data, it will then be searched or determined one by one the position/point of delivery location using the Google Maps application. The application can be accessed through the playstore/appstore or the http://maps.google.com site. Determination of the location is determined by assuming that the position shown first by Google Maps is the most suitable position. In addition to determining the location points, the weights of the sides that connect each of these points are also determined. The process of searching for side weights or distances between points is done by entering each address distance to be searched into Google Maps. As in determining the location, determining the distance between locations is also obtained by taking the results that are first displayed by Google Maps.

The next process is graph making, this is done so that all points can be displayed simultaneously in one view. The type of graph created is a complete graph, so that each location point has the same degree, namely n-1 = 40-1 = 39. In Figure 5, the following is a graph representation of the results that have been obtained from Google Maps.

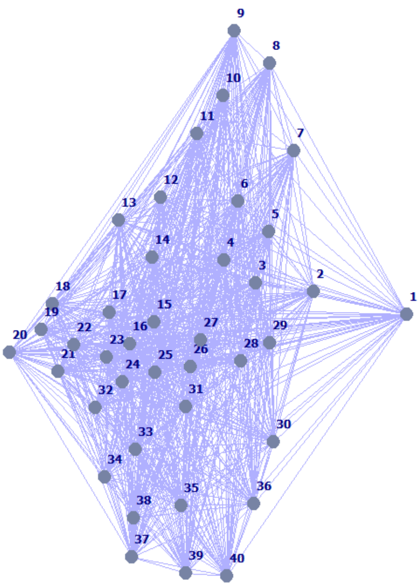


Figure 5. Complete Graph of Goods Delivery Locations

4.1. Route and Total Distance of Goods Delivery by SiCepat Express Baleendah

In the process of shipping goods, SiCepat Express Baleendah does not determine the schedule for the order of delivery of goods or the route of delivery of the goods in advance. This is released and handed over to the delivery officers (couriers) who will deliver the goods.

Based on the data, the order of delivery of goods is : 1 – 5 – 32 – 23 – 22 – 21 – 20 – 19 – 18 – 14 – 13 – 8 – 9 – 10 – 6 – 26 – 12 – 11 – 3 – 15 – 24 – 16 – 33 – 34 – 38 – 36 – 37 – 35 – 40 – 39 – 25 – 31 – 27 – 17 – 28 – 29 – 30 – 2 – 4 – 7 – 1.

In Figure 6, the following is the form of the delivery route used by SiCepat Express Baleendah in graph form.

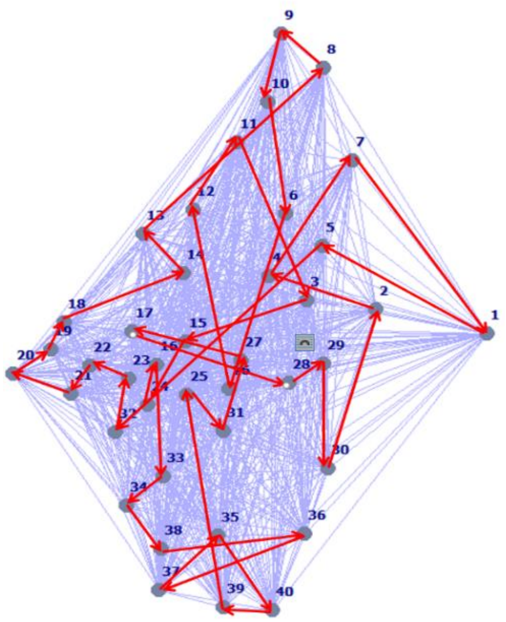


Figure 6. Goods Delivery Route Graph by SiCepat Express Baleendah

The process that will be carried out this time is to calculate the total distance traveled for the delivery route used by SiCepat Express Baleendah. Based on the distance data between locations that have been obtained, in Table 1 the following is a table of distance data that corresponds to the order in which the goods are delivered by SiCepat Express Baleendah.

Table 1. Data for Each Distance of Goods Delivery by SiCepat Express Baleendah

Trip	Edge	Distance (m)	Trip	Edge	Distance (m)
1	(0.4)	750	22	(15.32)	900
2	(4.31)	1500	23	(32.33)	500
3	(31.22)	240	24	(33.37)	270
4	(22.21)	250	25	(37.35)	400
5	(21.20)	30	26	(35.36)	450
6	(20.19)	350	27	(36.34)	230
7	(19.18)	130	28	(34.39)	500
8	(18.17)	51	29	(39.38)	110
9	(17.13)	600	30	(38.24)	950
10	(13.12)	650	31	(24.30)	220
11	(12.7)	850	32	(30.26)	120
12	(7.8)	300	33	(26.16)	300
13	(8.9)	280	34	(16.27)	450
14	(9.5)	450	35	(27.28)	150
15	(5.25)	700	36	(28.29)	450
16	(25.11)	600	37	(29.1)	700
17	(11.10)	350	38	(1.3)	250
18	(10.2)	650	39	(3.6)	550
19	(2.14)	700	40	(6.0)	1000
20	(14.23)	550	**Total Distance**		**18,549**

Trip	Edge	Distance (m)	Trip	Edge	Distance (m)
21	(23.15)	68			

So, the total distance traveled from the goods delivery route used by SiCepat Express Baleendah is 18,549 meters or 18.549 km.

4.2. Route and Total Distance of Goods Delivery with ATSP CIH Application

In the process of finding the route and total mileage using the Asymmetric TSP CIH application, it is not too difficult to do, the first is to create a graph of the problem to be searched in the available places and enter the distance data between locations into the available table. After that, the running process can be carried out on the application by pressing the Run button which is already available or by pressing the F12 key on the keyboard. For more details, here are the steps.

1. Create a graph.

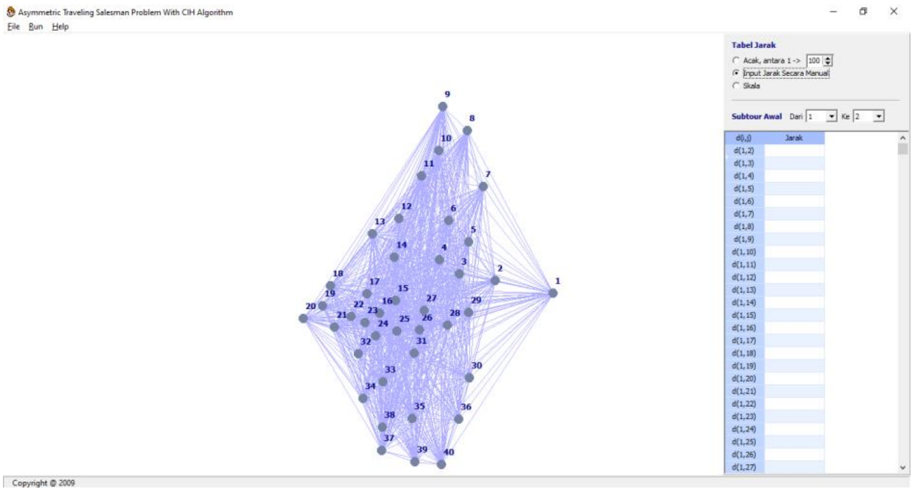
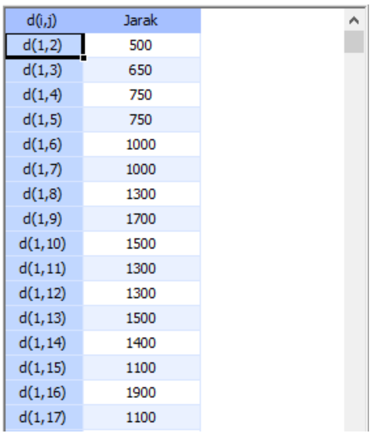


Figure 7. Making Graphs on the ATSP CIH Application

2. In the "*Tabel Jarak*" section select "*Input Jarak Secara Manual*" and in the "*Subtour Awal*" section select from point 1 to point 2. This initial subtour selection is selected from the smallest weight connected to the starting point of delivery as shown in Figure 8.

Figure 8. Initial Distance and Subtour Input Selection

3. Entering distance data between locations into the table provided as shown in Figure 9.



d(i,j)	Jarak
d(1,2)	500
d(1,3)	650
d(1,4)	750
d(1,5)	750
d(1,6)	1000
d(1,7)	1000
d(1,8)	1300
d(1,9)	1700
d(1,10)	1500
d(1,11)	1300
d(1,12)	1300
d(1,13)	1500
d(1,14)	1400
d(1,15)	1100
d(1,16)	1900
d(1,17)	1100

Figure 9. Input Distance Between Locations

4. Run the program which is located on the top left of the application display as shown in Figure 10, or it can be done by pressing the F12 key on the keyboard.

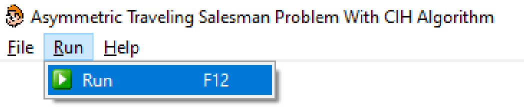


Figure 10. How to Run the Program

5. In Figure 11, the results of the route and the total distance traveled for goods delivery are shown.

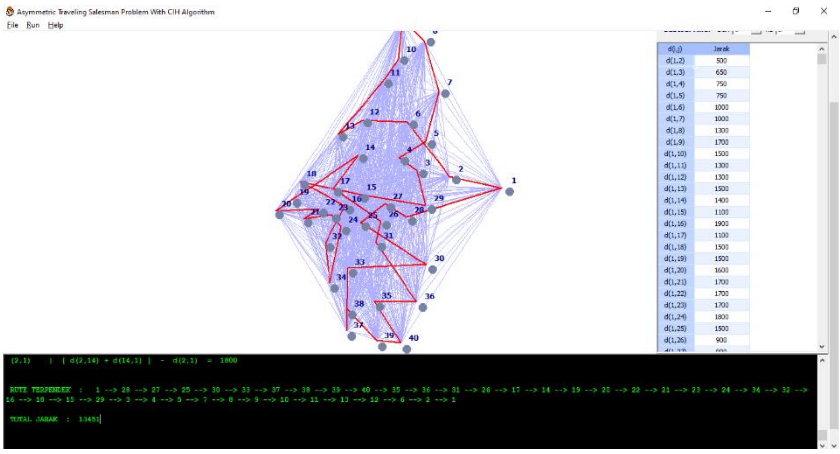


Figure 11. Output Display on ATSP CIH Application

Based on Figure 11, so the route of delivery of the goods is as follows: 1 - 28 - 27 - 25 - 30 - 33 - 37 - 38 - 39 - 40 - 35 - 36 - 31 - 26 - 17 - 14 - 19 - 20 - 22 - 21 - 23 - 24 - 34 - 32 - 16 - 18 - 15 - 29 - 3 - 4 - 5 - 7 - 8 - 9 - 10 - 11 - 13 - 12 - 6 - 2 – 1.

The total distance of the goods delivery route obtained is 13,451 meters or 13,451 km. For details of the data for each distance between locations for delivery of goods, see Table 2 below.

Table 2. Data for Each Distance of Goods Delivery using the ATSP CIH Application

Trip	Edge	Distance (m)	Trip	Edge	Distance (m)
1	(0.27)	750	22	(23.33)	400
2	(27.26)	180	23	(33.31)	300
3	(26.24)	180	24	(31.15)	160
4	(24.29)	500	25	(15.17)	280
5	(29.32)	800	26	(17.14)	350
6	(32.36)	450	27	(14.28)	500
7	(36.37)	84	28	(28.2)	350
8	(37.38)	230	29	(2.3)	87
9	(38.39)	110	30	(3.4)	350
10	(39.34)	500	31	(4.6)	400
11	(34.35)	240	32	(6.7)	400
12	(35.30)	400	33	(7.8)	300
13	(30.25)	110	34	(8.9)	280
14	(25.16)	300	35	(9.10)	160
15	(16.13)	700	36	(10.12)	450
16	(13.18)	650	37	(12.11)	170
17	(18.19)	130	38	(11.5)	400
18	(19.21)	350	39	(5.1)	500
19	(21.20)	30	40	(1.0)	500
20	(20.22)	280	**Total Distance**		**13,451**

Trip	Edge	Distance (m)	Trip	Edge	Distance (m)
21	(22.23)	140			

Based on Table 2, the total distance traveled from the delivery route obtained using the ATSP CIH application is smaller than the shipping route used by SiCepat Express Baleendah.

Based on the results of previous calculations, the route used by SiCepat Express Baleendah is different from the route obtained using the ATSP CIH Application. Total distance for the delivery route used by SiCepat is longer than that obtained using the ATSP CIH application. In Table 3 the following is a comparison of the results that have been obtained.

Table 3. Comparison of Goods Delivery Routes

No.	Results	Route	Total Distance
1	SiCepat Express Baleendah	0 – 4 – 31 – 22 – 21 – 20 – 19 – 18 – 17 – 13 – 12 – 7 – 8 – 9 – 5 – 25 – 11 – 10 – 2 – 14 – 23 – 15 – 32 – 33 – 37 – 35 – 36 – 34 – 39 – 38 – 24 – 30 – 26 – 16 – 27 – 28 – 29 – 1 – 3 – 6 – 0	18.549 km
2	Aplikasi ATSP CIH	0 – 27 – 26 – 24 – 29 – 32 – 36 – 37 – 38 – 39 – 34 – 35 – 30 – 25 – 16 – 13 – 18 – 19 – 21 – 20 – 22 – 23 – 33 – 31 – 15 – 17 – 14 – 28 – 2 – 3 – 4 – 6 – 7 – 8 – 9 – 10 – 12 – 11 – 5 – 1 – 0	13.451 km

In Table 3, total distance of the delivery route obtained using the CIH Algorithm with the ATSP CIH application is smaller than the other results. The percentage of efficiency obtained is $(13{,}451 - 18{,}549)/18{,}549\ x\ 100\% = -27.48\%$. These results indicate that there is a significant decrease in total distance, which is 27.48%, thus proving that the use of the CIH Algorithm is proven to help streamline the process of shipping goods carried out by SiCepat Express Baleendah.

5. Conclussion

Based on the results obtained in the discussion session above, the delivery route used by SiCepat Express Baleendah is different from the route obtained using the CIH Algorithm. The total distance for delivery of goods used by SiCepat Express Baleendah is 18.55 km, while the results obtained using the ATSP CIH application are 13.45 km. So, it can be concluded that the use of the ATSP CIH application is proven to have more efficient results, with a percentage decrease in total mileage of 27.48%.

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