



Implementation of the Cheapest Insertion Heuristic Algorithm for Optimizing the Shortest Route of the Semarang City Health Office to Inpatient Health Centers

Suci Permata Kusuma *, Mulyono

Department of Mathematics, Faculty of Mathematics and Natural Science,
Universitas Negeri Semarang, Semarang, 50229, Indonesia

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Abstract

Supervision visits of the Semarang City Health Office to its 10 Inpatient Community Health Centers are repeated routinely, so every extra kilometer repeats a cost in time and resources, yet the current visiting routes are not based on a distance calculation. This study determines the shortest supervision route with the Cheapest Insertion Heuristic (CIH) on the asymmetric road distances between the Office and the centers, modeled as a Travelling Salesman Problem on a complete graph, calculated manually and validated with Python. In the two supervision sessions (six and four centers), CIH gives 62.9 km against 68.5 km for the current route and 20.8 km against 25.2 km, savings of 5.6 km (8.18%) and 4.4 km (17.46%), or 10.0 km (10.7%) per round; both CIH routes equal the exact optimum found by exhaustive enumeration. If all centers are visited in one trip, CIH gives 86.6 km, 7.1 km shorter than the two current sessions together (93.7 km) but 5.0 km above the exact optimum of 81.6 km, which shows that the result depends on the initial subtour. The novelty is the application of CIH to supervisory visits with asymmetric distances, compared with the actual routes and with an exact optimum. The Office is recommended to adopt the two routes, to test several initial subtours or an exact method for a single trip, and to add travel time to the model.

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1. Introduction

Health services are a fundamental pillar in efforts to improve public welfare. This is in line with Article 34, Paragraph 3 of the 1945 Constitution of the Republic of Indonesia, which states that the government is responsible for providing adequate healthcare facilities and public infrastructure. At the regional level, the District/City Health Office is tasked with assisting the Regent/Mayor in carrying out governmental duties in the health sector that fall under regional authority, as well as delegated tasks (Kementerian Kesehatan RI, 2016). One concrete manifestation of this role is through the management of Community Health Centers.

Community Health Centers are primary-level healthcare facilities that deliver and coordinate promotive, preventive, curative, rehabilitative, and/or palliative services within their service areas (Kementerian Kesehatan RI, 2024). According to data from the Semarang City Health Office in 2025, there are 28 Non-Inpatient Community Health Centers and 10 Inpatient Community Health Centers distributed across all districts. Inpatient Community Health Centers are centers that are provided with additional healthcare resources to offer inpatient services for normal childbirth, including basic emergency obstetric and neonatal care, as well as other inpatient services (Kementerian Kesehatan RI, 2024).

To ensure that service quality is maintained and runs according to standards, the Semarang City Health Office routinely conducts supervision to all Inpatient Community Health Centers. This supervision plays an essential role in evaluating service quality, ensuring the availability of medical equipment and medicines, as well as monitoring the condition of supporting facilities and infrastructure. Based on interviews with the Semarang City Health Office, the supervision activities to the Inpatient Community Health Centers are carried out in two sessions. The first session includes six health centers: Mangkang Community Health Center, Ngaliyan Community Health Center, Karang Malang Community Health Center, Gunungpati Community Health Center, Srandol Community Health Center, and Ngesrep Community Health Center. The second session includes four other health centers: Halmahera Community Health Center, Karangdoro Community Health Center, Tlogosari Kulon Community Health Center, and Bangetayu Community Health Center.

The concrete problem addressed here is the length of the supervision routes. The Semarang City Health Office supervises its 10 Inpatient Community Health Centers in two sessions every time, and the routes now used are 68.5 km in the first session and 25.2 km in the second, 93.7 km in total, with no indication that they were derived from a distance calculation. Because the supervision is repeated routinely and is limited by time and resources, a longer route than necessary is a cost that recurs in every round. The road distances between the locations are also asymmetric, because of one-way streets and traffic directions, so that the direction in which a route is traveled matters. The urgency of this research is therefore to give the Office a calculated route that can be adopted immediately, together with a check of how good that route is.

Efficient route management is crucial to ensure that the supervision runs smoothly without disrupting the quality of healthcare services. With optimal route planning, travel time can be minimized, operational costs can be reduced, and healthcare service distribution becomes more effective. One way to obtain an efficient route is by implementing a shortest path algorithm. Shortest path search has been applied in various fields to optimize system performance, both in reducing costs and accelerating the process (Luthfita et al., 2022). One effective approach to solving this problem is through the application of graph theory.

Graph theory is a branch of mathematics and computer science that studies the characteristics and properties of graphs. A graph is a collection of objects organized in such a way that some pairs of objects are related or connected to each other (Buhaerah et al., 2022). Graphs can be used to represent discrete objects and the relationships between specific objects, one of which is in the optimization problem of finding the shortest route. By modeling this problem into a graph form, the most efficient route can be obtained through the Travelling Salesman Problem (TSP).

TSP is a combinatorial optimization problem that aims to determine the shortest route to visit all the nodes in a weighted graph and return to the starting node (Silitonga et al., 2025). TSP can be implemented on a weighted complete graph with the minimum edge weight, where the weight of the edge represents the distance. In general, TSP is divided into two types: Symmetric Travelling Salesmen Problem (STSP) and Asymmetric Travelling Salesmen Problem (ATSP). A TSP problem is categorized as Symmetric TSP (STSP) if the distance from node v_i to node v_j is equal to the distance from node v_j to node v_i ($d_{ij} = d_{ji}$ where d represents the distance). Conversely, if the distance from node v_i to node v_j is different from the distance from node v_j to node v_i ($d_{ij} \neq d_{ji}$), then the problem is classified as Asymmetric TSP (ATSP) (Tisen, 2013).

In solving the Travelling Salesman Problem (TSP), there are several basic rules that must be followed. First, the journey must start and end in the same city, which is the salesman's origin city. Second, all cities included in the route must be visited without any city being skipped. Third, during the visit process, the salesman is not allowed to return to the origin city before all cities have been visited (Wastupranata, 2022). These rules reflect the fundamental characteristics of TSP and serve as guidelines in forming the travel route. To solve it, several algorithms can be used, including *Best First Search*, *Ant Colony*, *Genetic Algorithm*, *Nearest Neighbor*, and *Cheapest Insertion Heuristic*.

The *Cheapest Insertion Heuristic* (CIH) algorithm is part of the Insertion algorithms, where each new route insertion into the subtour has the smallest weight, and the goal of this insertion is to minimize the travel distance and the time taken by the vehicle (Hanifah et al., 2020). This algorithm works by building the solution step by step, where a new point is inserted into the already formed tour based on the criterion of the smallest additional edge weight. With this approach, the CIH algorithm can generate an efficient route in a relatively short amount of time compared to exact methods.

Previous studies applied the Cheapest Insertion Heuristic to waste collection routes in Yogyakarta (Hanifah et al., 2020) and to the distribution routes of a small enterprise in Ciamis (Hilman & Sidik, 2022), heuristic solutions of the Travelling Salesman Problem to food delivery with Python (Silitonga et al., 2025), and the cheapest link method to the delivery of medicine by UAV (Wastupranata, 2022). Internationally, insertion heuristics are still being developed: Goutham and Stockar (2024) adapted the convex hull cheapest insertion heuristic to precedence constraints and compared it with the nearest neighbor heuristic on benchmark data, Gouveia et al. (2023) studied a Travelling Salesman Problem for the

scheduling of healthcare services, and Cheikhrouhou and Khoufi (2021) surveyed variants and applications of the problem. These studies concern delivery, collection, or scheduling, and, to the authors' knowledge, the supervisory visits of a municipal health office with asymmetric distances have not been analyzed, nor are heuristic routes usually compared both with the route actually used and with an exact optimum.

The novelty of this study is therefore threefold: (1) the Cheapest Insertion Heuristic is applied to the supervisory visits of a municipal health office, an administrative service and not a delivery operation; (2) the asymmetric road distances are modeled directly, and the effect of the direction of travel is analyzed; and (3) the heuristic routes are compared with the routes actually used by the Office and with the exact optimum, so that both the saving and the quality of the heuristic are known.

Based on the problem description, the objectives of this research are: (1) to determine the shortest route from the Semarang City Health Office to the Inpatient Community Health Centers using the CIH algorithm; (2) to develop a Python-based simulation to test the algorithm; (3) to analyze the comparison between the route currently used by the Office and the route generated by the CIH algorithm; and (4) to assess how close the CIH routes are to the exact optimum.

2. Method

This research uses a quantitative approach located at the Semarang City Health Office, involving Inpatient Community Health Centers (Puskesmas Ranap) as the research subjects. The selection of this location is based on its role as the central coordination hub for health service delivery at the city level in Semarang. The following steps must be undertaken to achieve the research objectives:

1. Problem Identification: Identifying issues related to optimizing the shortest route from the Semarang City Health Office to all Inpatient Health Centers.
2. Literature Study: Gathering references from books, journals, and previous research to strengthen the theoretical foundation and methods used in the study.
3. Data Collection: The process of obtaining information objectively and accurately based on facts in the field. In this study, data collection was obtained through interviews with relevant parties, indirect observation using Google Maps, and documentation of the names and addresses of the Inpatient Puskesmas obtained from official websites.
4. Graph Representation: Visually or mathematically illustrating the graph structure, with nodes as objects and edges as relationships between objects. In this research, to facilitate data analysis, the obtained location data was then represented in a complete graph.
5. Determining the Optimal Route: A calculation process to optimize the supervisory route from the Semarang City Health Office to the Inpatient Puskesmas in Semarang by implementing the Cheapest Insertion Heuristic (CIH) Algorithm. The steps of the CIH algorithm are as follows (Hilman & Sidik, 2022):
 1. The traversal begins from the starting location and is connected to the final location.
 2. A subtour is constructed between these two locations. A subtour is a journey that starts and ends at the same location by selecting the minimum total weight. For example: $(1,3) \rightarrow (3,2) \rightarrow (2,1)$, as shown in Figure 1 below:

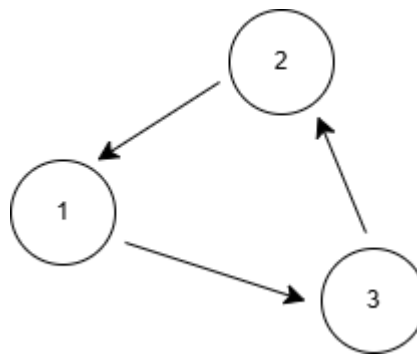


Figure 1. Subtour

3. Replace one of the arc directions between two locations with a combination of two arcs, such as arc (i, j) with arcs (i, k) and (k, j) , where i is the starting node of the arc, j is the destination node, and k is a node not yet included in the subtour, selected based on the smallest insertion cost. The insertion cost is determined by the following formula: $C_{ik} + C_{kj} - C_{ij}$, where:
 - 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 locations are included in the subtour.

The initial subtour connects the Health Office with the nearest location: Ngesrep Health Center (6.1 km) in the first session and Halmahera Health Center (3.5 km) in the second session and in the combined trip. The CIH route depends on this initial subtour, which is why its effect is examined in the results. To assess solution quality, the three problems were also solved exactly: by enumeration of all visiting orders for the two sessions and by dynamic programming (the Held-Karp algorithm) for the combined trip, and the lengths of the CIH routes were compared with these optimum values.

6. Drawing Conclusions: This is the final stage of the research method, which presents the results and discussion of the entire problem-solving process carried out previously, in accordance with the research objectives.

3. Results and Discussion

Based on the collected data, the inpatient health centers included as the subjects of this research are: Mangkang, Ngaliyan, Karang Malang, Gunungpati, Srandol, Ngesrep, Halmahera, Karangdoro, Tlogosari Kulon, and Bangetayu. In addition, the actual routes used by the Semarang City Health Office during supervision visits to the inpatient health centers were also obtained:

1. The first session route begins at the Semarang City Health Office → Mangkang Health Center → Ngaliyan Health Center → Karang Malang Health Center → Gunungpati Health Center → Srandol Health Center → Ngesrep Health Center → returns to the Semarang City Health Office.
2. The second session route also starts at the Semarang City Health Office during the supervision visit, with the route: Semarang City Health Office → Halmahera Health Center → Karangdoro Health Center → Tlogosari Kulon Health Center → Bangetayu Health Center → returns to the Semarang City Health Office.

Based on the data above, the total travel distance for the first session route is 68.5 km, while the second session route has a total distance of 25.2 km. These data were then represented in a complete graph to provide a clearer depiction of the relationships between each location. The complete graph representation can be seen in Figure 2 below:

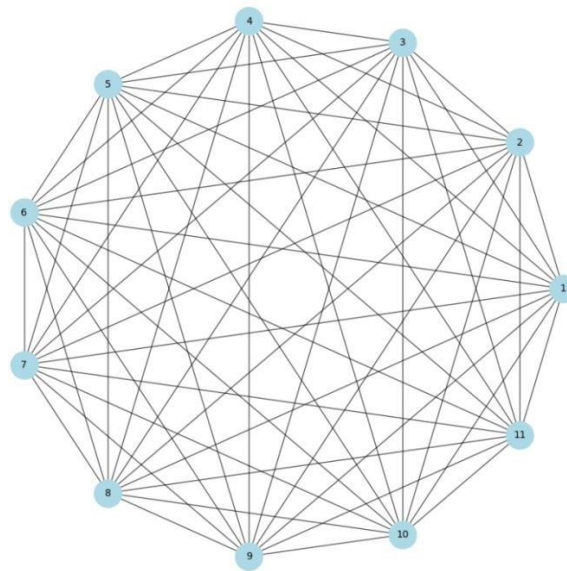


Figure 2. Complete graph representation K_{11}

Information:

1. Semarang City Health Office
2. Ngesrep Community Health Center
3. Srandol Community Health Center
4. Gunungpati Community Health Center
5. Karang Malang Community Health Center
6. Mangkang Community Health Center
7. Ngaliyan Community Health Center
8. Karangdoro Community Health Center
9. Bangetayu Community Health Center
10. Tlogosari Kulon Community Health Center
11. Halmahera Community Health Center

Figure 2 illustrates the possible travel routes from the Semarang City Health Office to the inpatient community health centers visualized in the form of a graph. The visualization represents a complete graph, K_{11} , where the number "11" refers to the total number of locations being analyzed. The nodes in the graph represent the destination locations, while the edges depict the routes connecting those locations. Each edge is assigned a weight, indicating the travel distance between locations in kilometers. Detailed information about the inter-location distances is provided in Table 1 below.

Table 1. Distance Between Locations

		Place of Destination										
		1	2	3	4	5	6	7	8	9	10	11
Place of Origin	1	0	6.1	9.2	16	19	15	8.5	5.3	9.7	6.4	3.5
	2	7.3	0	3.3	15	19	22	12	10	13	11	6.8
	3	11	5.5	0	12	17	26	16	14	17	14	11
	4	17	14	13	0	4.7	20	15	20	27	22	19
	5	20	19	17	4.7	0	18	13	24	30	27	24
	6	15	20	23	20	19	0	10	18	24	20	18
	7	9.4	13	16	14	13	8.8	0	12	19	14	12
	8	4.1	8.8	12	19	24	18	12	0	6.9	4.3	4
	9	9.9	15	18	25	30	24	18	5.8	0	2.8	7.6
	10	6.1	9.9	13	22	27	21	15	4.1	3	0	4.8
	11	3.1	5.6	8.8	18	22	18	12	4.5	6.6	4.4	0

From Table 1, the distance data between locations serves as the basis for the next stage, which is the data processing using the CIH algorithm. This process is carried out through two approaches: a manual implementation of the CIH algorithm and an implementation assisted by Python. The manual approach aims to provide a detailed understanding of the algorithm's step-by-step procedure, while the Python-based approach ensures computational accuracy of the results. To address this problem, the researcher applies the established steps within the CIH algorithm as a guide.

1. The route construction begins at the starting location and connects to the final location. In this study, the first location is the Semarang City Health Office, coded as 1, while the final location is Ngesrep Health Center, coded as 2.
2. Subtour is then constructed between these two locations. A subtour refers to a route that starts and ends at the same location, selecting the minimum total weight. In the context of this study, the subtour is represented as $(1,2) \rightarrow (2,1)$, indicating a trip from the Semarang City Health Office to Ngesrep Health Center and then returning to the Health Office.

Replacing one of the directed arcs between two locations with a combination of two arcs, i.e. replacing arc (i,j) with arcs (i,k) and (k,j) , where i is the starting node of the arc, j is the destination node, and k is a node not yet included in the subtour, chosen based on the smallest insertion cost. The insertion cost is calculated using the formula: $C_{ik} + C_{kj} - C_{ij}$, using this formula, in the first iteration, all nodes except nodes 1 and 2 are considered for insertion into the subtour. Next, an evaluation is performed to determine the best possible insertion by replacing either arc $(1,2)$ or $(2,1)$ with two new arcs that include the node to be inserted. The insertion costs are calculated as follows:

- Node 3: arc $(1,3)$ -(3,2); insertion value $C_{1,3} + C_{3,2} - C_{1,2} = 8.6$
- Node 4: arc $(1,4)$ -(4,2); insertion value $C_{1,4} + C_{4,2} - C_{1,2} = 23.9$
- Node 5: arc $(1,5)$ -(5,2); insertion value $C_{1,5} + C_{5,2} - C_{1,2} = 31.9$
- Node 6: arc $(1,6)$ -(6,2); insertion value $C_{1,6} + C_{6,2} - C_{1,2} = 28.9$
- Node 7: arc $(1,7)$ -(7,2); insertion value $C_{1,7} + C_{7,2} - C_{1,2} = 15.4$
- Node 3: arc $(2,3)$ -(3,1); insertion value $C_{2,3} + C_{3,1} - C_{2,1} = 7$
- Node 4: arc $(2,4)$ -(4,1); insertion value $C_{2,4} + C_{4,1} - C_{2,1} = 24.7$
- Node 5: arc $(2,5)$ -(5,1); insertion value $C_{2,5} + C_{5,1} - C_{2,1} = 31.7$
- Node 6: arc $(2,6)$ -(6,1); insertion value $C_{2,6} + C_{6,1} - C_{2,1} = 29.7$
- Node 7: arc $(2,7)$ -(7,1); insertion value $C_{2,7} + C_{7,1} - C_{2,1} = 14.1$

Based on these insertion values, node 3 is selected for insertion as it has the lowest insertion value, 7 km. Consequently, arc $(2,1)$ is replaced with two new arcs: $(2,3)$ and $(3,1)$, resulting in a new subtour: $(1,2) \rightarrow (2,3) \rightarrow (3,1)$.

3. The third step is repeated until all nodes have been inserted into the subtour. In the second iteration, the remaining unvisited nodes, namely nodes 4, 5, 6, and 7, are evaluated for possible insertion by replacing one of the three arcs in the current subtour: $(1,2)$, $(2,3)$, or $(3,1)$. The insertion values for each option are as follows:

- Node 4: arc $(1,4)$ -(4,2); insertion value $C_{1,4} + C_{4,2} - C_{1,2} = 23.9$
- Node 5: arc $(1,5)$ -(5,2); insertion value $C_{1,5} + C_{5,2} - C_{1,2} = 31.9$
- Node 6: arc $(1,6)$ -(6,2); insertion value $C_{1,6} + C_{6,2} - C_{1,2} = 28.9$
- Node 7: arc $(1,7)$ -(7,2); insertion value $C_{1,7} + C_{7,2} - C_{1,2} = 15.4$
- Node 4: arc $(2,4)$ -(4,3); insertion value $C_{2,4} + C_{4,3} - C_{2,3} = 24.7$
- Node 5: arc $(2,5)$ -(5,3); insertion value $C_{2,5} + C_{5,3} - C_{2,3} = 32.7$
- Node 6: arc $(2,6)$ -(6,3); insertion value $C_{2,6} + C_{6,3} - C_{2,3} = 41.7$
- Node 7: arc $(2,7)$ -(7,3); insertion value $C_{2,7} + C_{7,3} - C_{2,3} = 24.7$
- Node 4: arc $(3,4)$ -(4,1); insertion value $C_{3,4} + C_{4,1} - C_{3,1} = 18$
- Node 5: arc $(3,5)$ -(5,1); insertion value $C_{3,5} + C_{5,1} - C_{3,1} = 26$
- Node 6: arc $(3,6)$ -(6,1); insertion value $C_{3,6} + C_{6,1} - C_{3,1} = 30$
- Node 7: arc $(3,7)$ -(7,1); insertion value $C_{3,7} + C_{7,1} - C_{3,1} = 14.4$

From the comparison above, node 7 is selected for insertion due to its lowest insertion value of 14.4 km. Thus, arc (3,1) is replaced with two new arcs: (3,7) and (7,1), resulting in the updated subtour: (1,2) → (2,3) → (3,7) → (7,1). Since nodes 4, 5, and 6 are still unvisited, the process proceeds to the third iteration. At this stage, all remaining unvisited nodes are evaluated for possible insertion into the current route by replacing one of the four existing arcs in the subtour: (1,2), (2,3), (3,7), or (7,1). The alternatives and their respective insertion values are as follows:

- Node 4: arc (1,4)-(4,2); insertion value $C_{1,4} + C_{4,2} - C_{1,2} = 23.9$
- Node 5: arc (1,5)-(5,2); insertion value $C_{1,5} + C_{5,2} - C_{1,2} = 31.9$
- Node 6: arc (1,6)-(6,2); insertion value $C_{1,6} + C_{6,2} - C_{1,2} = 28.9$
- Node 4: arc (2,4)-(4,3); insertion value $C_{2,4} + C_{4,3} - C_{2,3} = 24.7$
- Node 5: arc (2,5)-(5,3); insertion value $C_{2,5} + C_{5,3} - C_{2,3} = 32.7$
- Node 6: arc (2,6)-(6,3); insertion value $C_{2,6} + C_{6,3} - C_{2,3} = 41.7$
- Node 4: arc (3,4)-(4,7); insertion value $C_{3,4} + C_{4,7} - C_{3,7} = 11$
- Node 5: arc (3,5)-(5,7); insertion value $C_{3,5} + C_{5,7} - C_{3,7} = 14$
- Node 6: arc (3,6)-(6,7); insertion value $C_{3,6} + C_{6,7} - C_{3,7} = 20$
- Node 4: arc (7,4)-(4,1); insertion value $C_{7,4} + C_{4,1} - C_{7,1} = 21.6$
- Node 5: arc (7,5)-(5,1); insertion value $C_{7,5} + C_{5,1} - C_{7,1} = 23.6$
- Node 6: arc (7,6)-(6,1); insertion value $C_{7,6} + C_{6,1} - C_{7,1} = 14.4$

Based on the comparison of insertion values, Node 4 is chosen to be inserted first because it provides the lowest insertion value, which is 11 km. Therefore, arc (3,7) is replaced by two new arcs, namely (3,4) and (4,7), resulting in

a new subtour: (1,2) → (2,3) → (3,4) → (4,7) → (7,1). Since Nodes 5 and 6 have not been visited yet, the process continues to the fourth iteration. In this iteration, the two remaining unvisited nodes are evaluated for possible insertion into the route by replacing one of the five arcs in the current subtour: (1,2), (2,3), (3,4), (4,7), or (7,1). The possible insertions and their values are as follows:

- Node 5: arc (1,5)-(5,2); insertion value $C_{1,5} + C_{5,2} - C_{1,2} = 31.9$
- Node 6: arc (1,6)-(6,2); insertion value $C_{1,6} + C_{6,2} - C_{1,2} = 28.9$
- Node 5: arc (2,5)-(5,3); insertion value $C_{2,5} + C_{5,3} - C_{2,3} = 32.7$
- Node 6: arc (2,6)-(6,3); insertion value $C_{2,6} + C_{6,3} - C_{2,3} = 41.7$
- Node 5: arc (3,5)-(5,4); insertion value $C_{3,5} + C_{5,4} - C_{3,4} = 9.7$
- Node 6: arc (3,6)-(6,4); insertion value $C_{3,6} + C_{6,4} - C_{3,4} = 34$
- Node 5: arc (4,5)-(5,7); insertion value $C_{4,5} + C_{5,7} - C_{4,7} = 2.7$
- Node 6: arc (4,6)-(6,7); insertion value $C_{4,6} + C_{6,7} - C_{4,7} = 15$
- Node 5: arc (7,5)-(5,1); insertion value $C_{7,5} + C_{5,1} - C_{7,1} = 23.6$
- Node 6: arc (7,6)-(6,1); insertion value $C_{7,6} + C_{6,1} - C_{7,1} = 14.4$

From the comparison above, Node 5 is chosen to be inserted first because it provides the lowest insertion value of 2.7 km. Therefore, arc (4,7) is replaced by two new arcs, namely (4,5) and (5,7), resulting in a new subtour: (1,2) → (2,3) → (3,4) → (4,5) → (5,7) → (7,1). Since Node 6 has not been visited yet, the process continues to the fifth iteration. In this step, the remaining node is evaluated for possible insertion by replacing one of the arcs from the subtour that has been formed: (1,2) → (2,3) → (3,4) → (4,5) → (5,7) → (7,1). The possible insertion for Node 6 and its insertion values are as follows:

- Node 6: arc (1,6)-(6,2); insertion value $C_{1,6} + C_{6,2} - C_{1,2} = 28.9$
- Node 6: arc (2,6)-(6,3); insertion value $C_{2,6} + C_{6,3} - C_{2,3} = 41.7$
- Node 6: arc (3,6)-(6,4); insertion value $C_{3,6} + C_{6,4} - C_{3,4} = 34$
- Node 6: arc (4,6)-(6,5); insertion value $C_{4,6} + C_{6,5} - C_{4,5} = 34.3$
- Node 6: arc (5,6)-(6,7); insertion value $C_{5,6} + C_{6,7} - C_{5,7} = 15$
- Node 6: arc (7,6)-(6,1); insertion value $C_{7,6} + C_{6,1} - C_{7,1} = 14.4$

Based on the comparison of insertion values, Node 6 is chosen to be inserted first because it provides the lowest insertion value of 14.4 km. Therefore, arc (7,1) is replaced by two new arcs, namely (7,6) and (6,1), resulting in the final subtour: (1,2) → (2,3) → (3,4) → (4,5) → (5,7) → (7,6) → (6,1). Since all nodes have been visited, the final subtour is: 1 → 2 → 3 → 4 → 5 → 7 → 6 → 1.

Thus, the shortest route in the first session, obtained through manual calculation using the CIH algorithm, is: 1 → 2 → 3 → 4 → 5 → 7 → 6 → 1, with a total travel distance of 62.9 km. Subsequently, by applying the same approach in the second session, the shortest route obtained is: 1 → 11 → 10 → 9 → 8 → 1, with a total travel distance of 20.8 km. If all health center locations are combined into a single travel session, the optimal route for visiting all locations is: 1 → 7 → 6 → 5 → 4 → 2 → 3 → 11 → 10 → 9 → 8 → 1, with a total travel distance of 86.6 km. After completing all manual calculations, the next stage is to validate the results using Python programming. This step aims to ensure the accuracy and consistency of the manual computations. The CIH algorithm is implemented systematically through a computational approach, starting from the construction of the algorithm function, inputting location codes, and building the distance matrix between points. The input of location codes and the construction of the distance matrix between points can be seen in Table 2 below.

Table 2. Location Distance

```

places = [
    "1", "2", "3", "4", "5", "6", "7"
]
distance_matrix = np.array ( [
    [0, 6.1, 9.2, 16, 19, 15, 8.5],
    [7.3, 0, 3.3, 15, 19, 22, 12],
    [11, 5.5, 0, 12, 17, 26, 16],
    [17, 14, 13, 0, 4.7, 20, 15],
    [20, 19, 17, 4.7, 0, 18, 13],
    [15, 20, 23, 20, 19, 0, 10],
    [9.4, 13, 16, 14, 13, 8.8 0],
])

```

From Table 2, the involved locations are represented in the form of a list named `places`, which contains the codes for each travel point. This representation serves as the foundation for processing the distance data between locations. Subsequently, the inter-location distance data is entered into a NumPy matrix named `distance_matrix`, which represents the asymmetric distances from one point to another, reflecting the actual conditions in the field. This matrix functions as the core component in calculating insertion values during each iteration of the CIH algorithm. After all algorithmic processes are systematically executed through Python programming, the final result can be obtained by running the commands shown in Table 3 below.

Table 3. Shortest Route Results

```

print ("Route: ", " → ".join (route_names))
print (f "Total jarak: {total_distance: .2f} km")

```

Thus, the shortest route for the first session is: 1 → 2 → 3 → 4 → 5 → 7 → 6 → 1 with a total travel distance of 62.9 km. Next, by applying the same approach in the second session, the shortest route obtained is: 1 → 11 → 10 → 9 → 8 → 1 with a total distance of 20.8 km. When all health center locations are combined into a single travel session, the optimal route for visiting all locations is: 1 → 7 → 6 → 5 → 4 → 2 → 3 → 11 → 10 → 9 → 8 → 1, with a total travel distance of 86.6 km. The results of this study show that both approaches yield identical routes and total travel distances. This consistency indicates that the CIH algorithm can be reliably applied both manually and through Python-based computation. The shortest routes obtained from both approaches are presented in Table 4 below.

Table 4. Research Result

Inpatient Community Health Centers	Route	Total Distance Traveled
First Session	1 → 2 → 3 → 4 → 5 → 7 → 6 → 1	62.9
Second Session	1 → 11 → 10 → 9 → 8 → 1	20.8
All Health Centers	1 → 7 → 6 → 5 → 4 → 2 → 3 → 11 → 10 → 9 → 8 → 1	86.6

Table 4 presents the route results from the implementation of the CIH algorithm in supervisory activities conducted by the Health Office of Semarang City. In the first session, which covers six Inpatient Community Health Centers, the shortest route obtained has a total travel distance of 62.9 km. Meanwhile, in the second session, which includes four inpatient health centers, the total travel distance obtained is 20.8 km. If all inpatient health centers are combined into a single supervisory route without session division, the total travel distance reaches 86.6 km.

Based on interviews conducted prior to this study, the Semarang City Health Office had already been using a supervisory route in its operational activities. In the first session, the previously used route was: Semarang City Health Office → Mangkang Community Health Center → Ngaliyan Community Health Center → Karang Malang Community Health Center → Gunungpati Community Health Center → Srandol Community Health Center → Ngesrep Community Health Center → Semarang City Health Office, with a total travel distance of 68.5 km. After applying the CIH algorithm, a more efficient supervisory route was obtained, namely: Semarang City Health Office → Ngesrep Community Health Center → Srandol Community Health Center → Gunungpati Community Health Center → Karang Malang Community Health Center → Ngaliyan Community Health Center → Mangkang Community Health Center → Semarang City Health Office, with a reduced travel distance of 62.9 km. Thus, there is a reduction in travel distance of 5.6 km, or approximately 8.18% compared to the previously used route.

In the second session, the previously used route was: Semarang City Health Office → Halmahera Community Health Center → Karangdoro Community Health Center → Tlogosari Kulon Community Health Center → Bangetayu Community Health Center → Semarang City Health Office, with a total travel distance of 25.2 km. After applying the CIH algorithm, a more optimal route was obtained: Semarang City Health Office → Community Health Center Halmahera → Community Health Center Tlogosari Kulon → Community Health Center Bangetayu → Community Health Center Karangdoro → Semarang City Health Office, which reduced the travel distance to 20.8 km. This change resulted in a distance reduction of 4.4 km, or approximately 17.46% compared to the original route.

This result indicates that the CIH algorithm not only produces more efficient supervisory routes but also significantly reduces travel distances compared to those previously used by the Semarang City Health Office. The efficiency gains in

travel distance for both the first and second sessions demonstrate that this algorithm can offer a more optimal solution for route planning in supervisory activities, thereby saving both time and resources.

The routes currently used are 68.5 km in the first session and 25.2 km in the second, 93.7 km in total. With the CIH routes (62.9 km and 20.8 km, 83.7 km in total), the total distance per round falls by 10.0 km, or 10.7%. If all centers are visited in one trip, the CIH route of 86.6 km is 7.1 km (7.6%) shorter than the two current sessions together. The route of 86.6 km is the best route found by CIH from the initial subtour used here; it is not necessarily the optimal route.

Solution quality. The exact solutions show that for both sessions the CIH route is the optimum (62.9 km and 20.8 km). For the combined trip the exact optimum is 81.6 km ($1 \rightarrow 10 \rightarrow 9 \rightarrow 8 \rightarrow 11 \rightarrow 2 \rightarrow 3 \rightarrow 4 \rightarrow 5 \rightarrow 7 \rightarrow 6 \rightarrow 1$), so the CIH route of 86.6 km is 5.0 km, or 6.1%, above the optimum. Starting CIH from other initial subtours gives routes of 82.2 to 86.9 km, which shows that the choice of the initial subtour matters for the larger problem, and that trying every initial subtour is a cheap way to improve the result.

Interpretation. In the first session the CIH route ($1 \rightarrow 2 \rightarrow 3 \rightarrow 4 \rightarrow 5 \rightarrow 7 \rightarrow 6 \rightarrow 1$) is the current route traveled in the opposite direction. The whole saving of 5.6 km therefore comes from the asymmetry of the road distances: the arcs 1–2, 2–3, 3–4, and 7–6 are 1.2, 2.2, 1.0, and 1.2 km shorter in the direction of the CIH route, and the other arcs have the same distance in both directions. In the second session the CIH route changes the order of the visits (Halmahera, Tlogosari Kulon, Bangetayu, Karangdoro instead of Halmahera, Karangdoro, Tlogosari Kulon, Bangetayu) and saves 4.4 km mainly because it ends at Karangdoro, which is only 4.1 km from the Office, whereas the current route ends at Bangetayu, 9.9 km from the Office. This shows that both the order and the direction of the visits matter when the distances are asymmetric.

The results agree with the earlier applications of the Cheapest Insertion Heuristic in Indonesia (Hanifah et al., 2020; Hilman & Sidik, 2022) in that the heuristic gives routes that are shorter than those used in practice, and they extend these studies in three ways. First, the application is a supervisory service with asymmetric distances, and the analysis shows that direction alone can account for the saving. Second, the heuristic routes are compared with the exact optimum: CIH is optimal for the two small sessions of seven and five nodes but not for the combined trip of 11 nodes, so the quality of a heuristic should be checked when the problem grows. Third, the saving is compared both for each session and for the whole round. Because the studies differ in the type of problem and in the data, the comparison is limited to the direction of the findings.

The novelty of the findings is that the saving in the first session comes entirely from the direction of travel, that CIH reaches the optimum for the sessions but is 6.1% above it for the single trip, and that the result for the single trip depends on the initial subtour (82.2 to 86.9 km). These findings lead to the following recommendations for the Semarang City Health Office. (1) Adopt the route $1 \rightarrow 2 \rightarrow 3 \rightarrow 4 \rightarrow 5 \rightarrow 7 \rightarrow 6 \rightarrow 1$ for the first session and the route $1 \rightarrow 11 \rightarrow 10 \rightarrow 9 \rightarrow 8 \rightarrow 1$ for the second session, which are optimal and save 10.0 km per round. (2) If a single trip is considered, use the exact route of 81.6 km or test every initial subtour, and note that a single trip (81.6 km) is 2.1 km shorter than the two optimal sessions together (83.7 km) but may not suit the time available. (3) Re-measure the distance matrix periodically and add travel time and traffic, because the shortest distance is not always the shortest time. (4) Use the same procedure for the supervision of other services.

Several limitations should be noted. The distances were taken from map data at one time, the objective is distance and not time or cost, the two sessions are fixed as in the current practice, no time windows or service times are included, and CIH is a heuristic. Future research should include travel time, compare other heuristics such as nearest neighbor and 2-opt improvement, and use exact methods for the sizes of problem that allow it.

4. Conclusion

The four objectives are met as follows. First, the CIH algorithm gives the shortest routes $1 \rightarrow 2 \rightarrow 3 \rightarrow 4 \rightarrow 5 \rightarrow 7 \rightarrow 6 \rightarrow 1$ (62.9 km, six health centers) for the first session and $1 \rightarrow 11 \rightarrow 10 \rightarrow 9 \rightarrow 8 \rightarrow 1$ (20.8 km, four health centers) for the second session, and 86.6 km for a combined trip. Second, the Python simulation reproduced the manual calculation, which supports the validity of the procedure and reduces the risk of human error. Third, compared with the current routes (68.5 km and 25.2 km), the CIH routes save 5.6 km (8.18%) in the first session and 4.4 km (17.46%) in the second, 10.0 km (10.7%) per round; for the combined trip the saving against the two current sessions is 7.1 km (7.6%). Fourth, the CIH routes of the two sessions equal the exact optimum, whereas the combined route is 5.0 km (6.1%) above the exact optimum of 81.6 km and depends on the initial subtour.

The Office is recommended to adopt the two session routes, to test every initial subtour or use an exact method if a single trip is planned, and to add travel time and traffic to the model in further research.

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