

Optimization Of Waste Transport Routes in West Bandung City Using The Directed Postman Problem Method with Dijkstra's Algorithm

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Abstract. Waste is one of the city's logistics problems that is still a concern. Bandung is one of the big cities, which is divided into several regions, namely West Bandung, East Bandung, South Bandung, and North Bandung. Each city must produce quite a lot of waste per day. In previous studies, it was stated that the City of Bandung produces up to 1,300 tons of waste per day, and at least 130 tons of waste is not transported (source: DLHK City of Bandung). This is a problem for the government to overcome. There are several steps to anticipate that waste transportation can be carried out optimally by determining efficient and effective waste transportation routes. An efficient and effective waste transportation route can be done by determining the minimum transportation route. Previously researched this problem. This research uses a method that is different from previous research, namely using Directed Rural Postman Problem (DRPP) with Dijkstra's Algorithm. This method determines the shortest distance from one landfill to another. Object the research that will be examined is the same as previous research, namely the West Bandung area. From the results of the study, 34 nodes were formed with a total distance to be traveled by the garbage truck which is 45.15 km. This can be compared with previous research in that using the Directed Rural Postman Problem method can get a minimum route compared to the Chinese Postman Problem (CPP) method.

Keywords: DRPP, CPP method, City Logistics, Dijkstra's Algorithm, Waste, Transportation, Route.

34. Introduction

The waste problem in the city of Bandung continues to increase from year to year. The average waste generation in the city of Bandung is 1,300 tons/day. For now, the handling of waste problems in the city of Bandung consists of sweeping the streets, transporting waste from the Temporary Disposal Site to the Final Disposal Site, as well as sorting and processing waste.

The process of transporting waste is related to cost efficiency, so waste handling needs to be considered. Therefore, it is necessary to optimize the process of transporting waste from Temporary Disposal Sites (TPS) to save time and costs as well as minimize waste accumulation.

In previous research, the minimum route for waste transportation in the West Bandung area was determined using the Chinese Postman Problem (CPP) method [1]. Meanwhile, a total of four areas in the city of Bandung produce up to 1,300 tons of waste per day, and at least 130 tons of garbage are not transported.

Referring to previous research regarding determining the route for waste transportation, can be solved with the Chinese Postman Problem (CPP), which is a problem in graph theory that discusses the problem of Chinese postmen wanting to deliver letters to addresses along the way in a wide area [2]. The CPP aims to produce a minimum total mileage provided that each point of the road segment must

be passed at least once. The results of previous studies take into account the dump truck capacity of 10 m³. The calculation results show that the truck hauling distance is 60.05 km with 34 nodes [2]. It is felt that the results of previous research still provide opportunities to be improved with other method approaches. Therefore, this study uses the Directed Rural Postman Problem (DRPP) method. The purpose of DRPP method is used as a comparison to find out whether the DRPP can obtain a more minimal or effective route or distance [3]. Based on the background of this problem, the formulation of the problem in this study is whether the optimization of waste transportation routes in the West Bandung area by paying attention to government regulations using the DPP method is better than the results of previous studies using CPP. Location and area study can be seen in **Figure 1**.

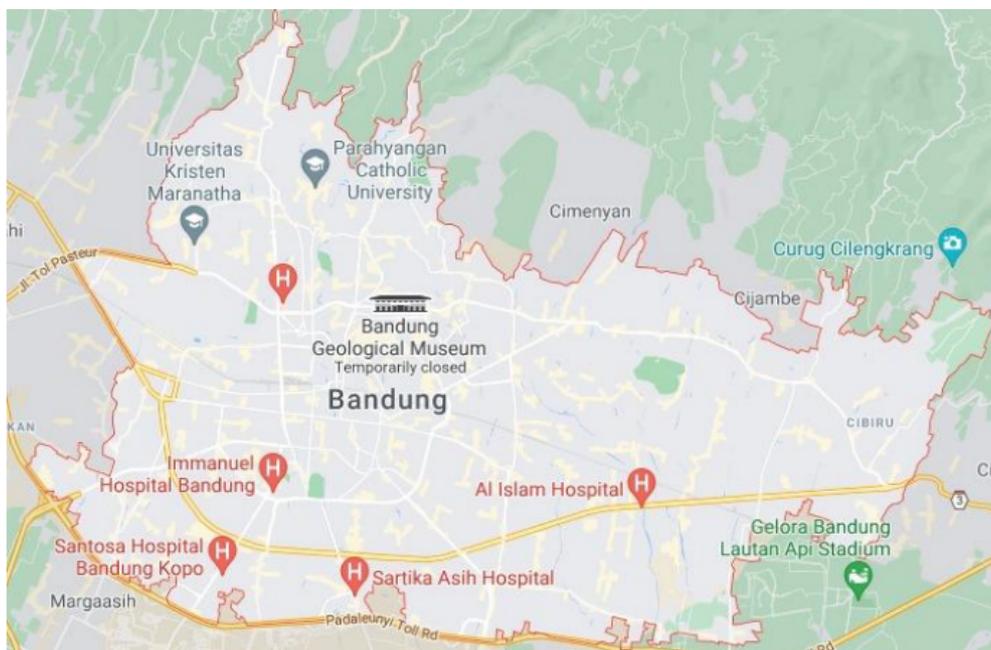


Figure 1. Map of Bandung City

35. Methods

The Rural Postman Problem (RPP) is a specific Arc Routing Problem (ARP) that consists of specifying a minimum cost circuit on a graph so that a certain subset of the required edges are traversed [4]. RPP is an NP-hard problem with significant real-life applications. RPP is a more general problem than the Chinese Postman Problem (CPP), a well-known Arc Routing Problem (ARP) whereby finding the shortest circuit that crosses each edge of the graph at least once [5]. Trapped edges may be directed, undirected, or both. Menirit Eiselt, Gendreau, and Laporte, Rural Postman Problems are divided into two, namely Directed Rural Postman Problems and Undirected Rural Postman Problems [2].

2.1 The Undirected Rural Postman Problem (URPP)

In the Undirected Rural Postman Problem, all arcs are undirected. This problem can be solved by calculating the shortest chain between vertices of odd degrees (some chains may contain edges at A/R) and continuing with a directional CPP [6]. The heuristics for URPP are:

- Step 1: Shortest Spanning Tree
- Step 2: Minimum Cost Matching
- Step 3: The Eulerian Cycle

2.2 The Directed Rural Postman Problem (DRPP)

In the Directed Rural Postman Problem defined on graph $G = (V, A)$ where A is now a set of directed arcs. The problem reduces to directional CPP whenever $G = (V, R)$ is connected [7]. The heuristic steps for Directed RPP are as follows:

Step 1: Shortest Spanning Arborescence

Step 2: Transportation Problem

Step 3: Eulerian Circuit.

In the Directed Rural Postman Problem, a solution is found by eliminating:

- a. All arcs $(i, j) \in A_s$ where $c_{ij} = c_{ik} + c_{kj}$ with some $k \in N'_R$ and
- b. Additional arc parallel to the required arc, if both arcs have the same cost

The mathematical models, variables and parameters for the Directed Rural Postman Problem can be seen in **Table 1**.

All formulations can be seen as follows.

Given a graph $G_c = (N_R, A_R \cup A_s)$, $B = [b_{ij}]$ dan $\bar{B} = [\bar{b}_{ij}]$ defined :

$$b_{ij} = 1 \text{ if } (v_i, v_j) \in R, v_i, v_j \in V', \quad 0 \text{ if not}$$

$$\bar{b}_{ij} = 1 \text{ if } (v_i, v_j) \in A' \setminus R, v_i, v_j \in V', \quad 0 \text{ if not}$$

Table 1 Parameters and mathematical model Variables

Variables and Parameters	
X_{ij}	The main decision variable that represents the number of arc times (i, j) traversed in each cycle using the vehicle starting from the node i ends at a node j .
v_i, v_j	Set all nodes in the network
G	Minimum graph result
A'	A set of directional arcs

Objective Function:

$$\text{Min} : \sum_{(v_i, v_j) \in R} (1 + x_{ij}) + \sum_{(v_i, v_j) \in A' \setminus R} x_{ij} \quad (1)$$

Subject to:

$$\sum_{(v_i, v_j) \in R} (1 + x_{ij}) b_{ij} + \sum_{(v_i, v_j) \in A' \setminus R} x_{ij} \bar{b}_{ij} = \sum_{(v_i, v_j) \in R} (1 + x_{ji}) b_{ji} + \sum_{(v_i, v_j) \in A' \setminus R} x_{ij} \quad (v_i \in V') \quad (2)$$

$$\sum_{v_i \in S, v_j \in \bar{S}} x_{ij} \geq 1 \quad (S = \cup_{k \in P} V_k, \bar{S} = (\cup_{k=1}^p V_k) \setminus S, P \subset \{1, \dots, p\}, \bar{V} \subseteq S) \quad (3)$$

$$x_{ij} \geq 0 \text{ and integer } (v_i, v_j) \in A' \quad (4)$$

The steps to solve the Directed Rural Postman Problem are as follows:

1) Shortest Spanning Arborescence (SSA)

Calculate the Shortest Spanning Arborescence using Dijkstra's Algorithm

- a. Sets k =node whose label was just made permanent

- b. Check all nodes labeled temporarily that can be connected with node k
- c. Set the label $V_{(j)} = \text{minimum} \{ v_{(j)}, v_{(k)} + v_{kj} \}$
- d. Give a permanent label to the node with the smallest $d_{(j)}$ (for example, for node k).
- e. Set the label $p_{(k)} = i$.

$$V_{(k)} = v_{(i)} + v_{ij}$$

2) *Transportation Problem*

Derive the Euler graph of G by adding the arcs with the lowest cost or distance

3) *Eulerian Circuit*

Determine the Euler circuit on the augmented graph. Where this is the conclusion of the minimum route taken from several alternatives.

Dijkstra's algorithm is used to solve the Shortest Spanning Arborescence problem.

This algorithm is a greedy algorithm for solving the shortest distance problem for a directed or undirected graph.

This algorithm will find the shortest distance from a node to all nodes in a set of nodes. Dijkstra's algorithm cannot be executed if there is a negative value on one side. However, in reality, the use of negative weights is rarely applied to solving problems. In terms of time complexity, the algorithm can be more efficient by storing the graph in the form of an adjacency list using a binary heap or Fibonacci heap as a priority queue [2],[3],[8].

The following are the steps that can be used in Dijkstra's algorithm:

- 1) Determine which point will be the initial node, then weigh the distance from the first node to the nearest node one by one, Dijkstra's Algorithm will carry out the search development from one point to another and the next point step by step.
- 2) Give a weight value (distance) for each point to another point, then set a value of 0 at the initial node and an infinite value for other (unfilled) nodes.
- 3) Set all untraversed nodes and set the initial node as the "departure node"
- 4) From the departure node, consider the untraversed neighbor nodes and calculate the distance from the departure point.
- 5) After considering each distance to the neighboring nodes, mark the nodes that have been traversed as "skipped nodes" or "permanent nodes".
- 6) Set the uncrossed vertices with the smallest distance. Then repeat Step 5.

36. Result and Discussion

The results obtained from calculating the minimum route for waste transportation in the West Bandung area using the Directed Rural Postman Problem method with Dijkstra's Algorithm obtained a total of 34 nodes that will be passed by garbage trucks whose starting point is at node/pool 1.

The total distance between nodes obtained is 54.41 km. In the Directed Rural Postman Problem method where the distance determination process is carried out by finding the shortest distance from each node or one or several Garbage Disposal Sites, the total distance that will be passed by the garbage truck is 45.15 km. This is the shortest distance obtained from data processing using the Directed Rural Postman Problem (DRPP) method.

The distance obtained is relatively minimal compared to previous studies using the Chinese Postman Problem (CPP) method, which obtained a total distance of 60.05 km with a difference saving of 14.9 km. The following is a picture of the Eulerian tour circuit can be seen in **Figure 2** and **Figure 3**.

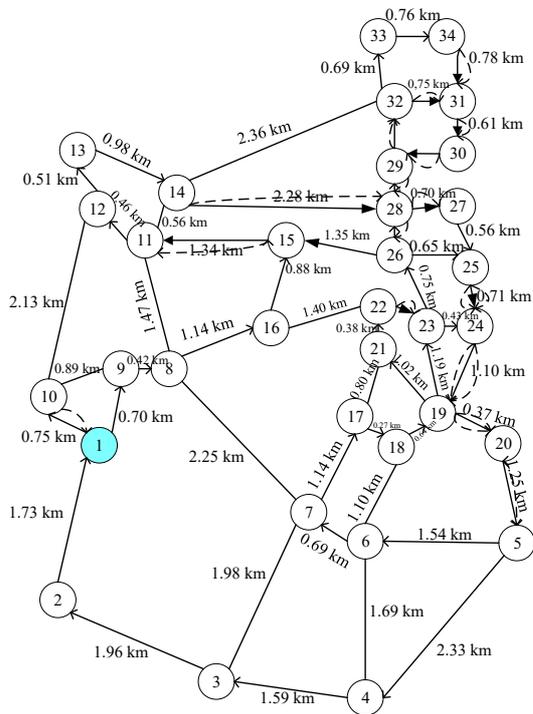


Figure 2. Eulerian Tour Result by DRPP-DA

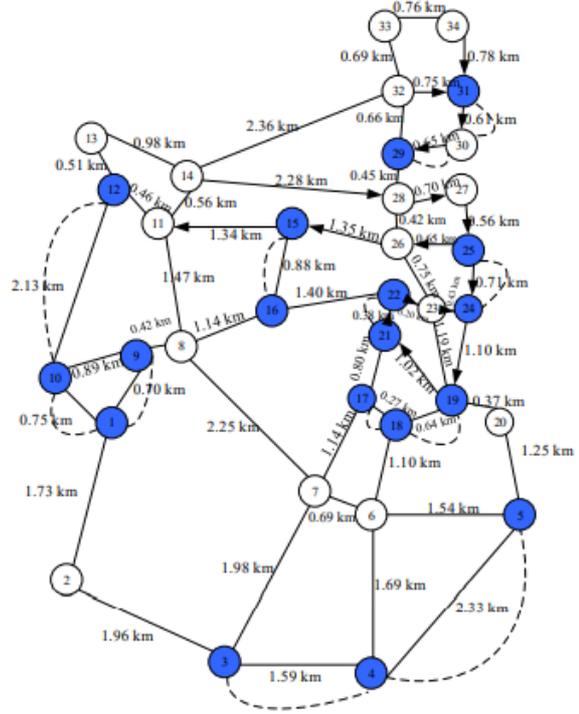


Figure 3. Eulerian Tour by CPP

In Figure 1, the Eulerian Tour selected using the Directed Rural Postman Problem is 1-9-8-16-15-11-12-13-14-28-27-25-24-19-21-22-23-24-19-23-26-28-29-32-31-30-29-32-33-34-31-30-29-28-26-25-24-19-20-5-6-7-17-18-19-20-5-4-3-2-1-10-1.

Based on the results of data processing using the Directed Rural Postman problem method which can produce a minimum route for waste transportation, it can be seen from the calculation mechanism which uses Dijkstra's Algorithm in solving Shortest Spanning Arborescence. Dijkstra's algorithm works well on directed graphs. Then the path taken is the shortest path.

From the processing results obtained as many as 52 iterations where the starting point of node 1 ends at node 1 again. If we look at previous research with the same case but using a different method, namely the Chinese Postman Problem (CPP), there is a difference, namely the route results obtained by the Directed Rural Postman Problem are minimum compared to the Chinese Postman Problem. It can be seen in the following **Figure 3** which is the result of the Eulerian tour from previous research using CPP.

The results of the study using the Directed Rural Postman Problem method with Dijkstra's Algorithm (DRPP-DA) can be seen in **Figure 2** and **Figure 3** producing 52 routes, while the Chinese Postman Problem produces 68 routes.

37. Conclusion

Based on the formulation of the problem that has been made and the results of data processing in the previous section, the minimum route results are obtained from the results of calculations using the Directed Rural Postman Problem method with Dijkstra's Algorithm with a length of 45.15 km. The total distance obtained is the distance that must be passed by a dump truck that transports waste to transport TPA in the West Bandung area.

The result of the route to be traversed is a dump truck that is 1-9-8-16-15-11-12-13-14-28-27-25-24-19-21-22-23-24- 19-23-26 -28-29-32-31-30-29-32-33-34-31-30-29-28-26-25-24-19-20-5-6-7-17- 18-19-20 -5-4-3-2-1-10-1.

Departure for transporting garbage using this dump truck starts from the pool or point 1 then traces the streets in the West Bandung area and returns to the pool. Navigate this route by taking the minimum distance to pass. The proposed route is valid for traffic conditions with the current road direction at the time of the previous study. If there is a change in the direction of traffic flow, the solution may change.

When compared with previous study with the same case on waste transportation in the West Bandung area using the Chinese Postman Problem method, the total distance traveled was 66.05 km. It can be concluded that in the same case, the Directed Rural Postman Problem method using Dijkstra's Algorithm produces a minimum total mileage compared to the Chinese Postman Problem method with a savings of 14.9 km.

38. References

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