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Research Article

Utilizing the Vehicle Routing Problem Model to Determine Restaurant Outlet Waste Transport Routes

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Abstract.
The capital's traffic density affects the way waste is transported as well. The utilization of the vehicle routing problem (VRP) approach for determining the optimal route for the transportation of food waste from PT. ABC restaurants are covered in this study. PT. ABC owns a number of restaurants that are located on routes with traffic regulations that restrict the number of vehicles on the road. As a result, PT. ABC's waste delivery vehicles must find new routes in order to continue moving waste. The transportation trucks return to the waste collecting place later than expected since they picked another route. It is anticipated that by streamlining the waste transportation route, the total time and distance required will be reduced. The VRP method is utilized to make the existing waste pickup route more effective and efficient. The suggested route was derived from the data processing procedure under two different scenarios: normal traffic conditions and vehicle restrictions. In the suggested route, 111 minutes would be needed to travel 36.3 km in normal conditions. In the meantime, the suggested trip took 126 minutes to complete and covered 46.8 km when vehicle restrictions were in place.

Keywords: distance, time, vehicle routing problem

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1. Introduction

The problem with waste transportation in the capital city is the presence of traffic congestion on multiple roadways. In addition, the capital city government has established several traffic determines to minimize the number of vehicles on the streets. PT ABC encountered this issue while hauling food waste from its 11 outlets. Traffic congestion and the introduction of vehicle limitations on multiple roads led PT ABC's waste transportation vehicles to use alternative routes. The ineffectiveness of the routes utilized caused trash transportation vehicles to arrive late at their respective waste collecting places. Steps to improve and optimize trash transportation routes are urgently required to address this issue. Where the time given for the waste transportation process ranges from 07:00 to 12:00 WIB a (300 minutes). However, the total arrival time of the transport vehicle at the waste collection was recorded at 317 minutes and the average distance traveled was 47.2 km

Lau et al., used the Vehicle Routing Problem with Time Windows method to solve the problem of shipping products with few cars by modifying the proposed route [1]. Zhong and Cole solved the problem of late delivery of products by optimizing current routes and reduced the overall distance traveled by 10-19% [2]. According to Kritikos et al., employing the Vehicle Routing Problem not only reduces the distance traveled, but it also reduces the requirement for vehicles by spreading the burden on each vehicle employed evenly [3]. Xiao et al., enhanced the delivery route of commodities to reduce fuel consumption, hence lowering transportation expenses [4]. I. W. Saputra et al., proposed route modifications to eliminate delays in the delivery of newspapers to subscribers [5]. Prasetyo et al., were successful in lowering the overall distribution cost of delivering soft drinks to clients by modifying the suggested delivery route [6]. Nurprihatin et al., employed the Capacitated Vehicle Routing Problem (CVRP) approach to improve rice distribution routes throughout Indonesia, thereby resolving previous food import concerns [7]. To maximize urban transportation trip time, route optimization was performed [8].

Jayarathna et al., improved the planned route for distributing natural rubber to each client exactly and in accordance with the quota based on regional clustering [9]. Oliveira et al., used the Vehicle Routing Problem with Time Windows (VRPTW) technique to identify potential routes for increasing COVID-19 vaccine delivery [10]. The proposed approach was successful in reducing CO2 emissions while also lowering distribution-related operational costs. Other studies, such as Latiffianti et al., which improved the planned route, were able to minimize the number of bus fleets utilized for the company's employee pick-up process, resulting in operational cost savings of up to 9% [11]. Repoussis et al., improved the proposed route in order to speed up the delivery of items from the warehouse to clients, hence increasing customer satisfaction [12]. Ba nos et al. adjusted the planned route to avoid logistics delays and impacts from economic, environmental, and industrial activity [13]. Shen et al., stated that the proposed route enhancements have an impact on discarded carbon emissions, allowing logistics organizations to forecast cargo losses [14]. Restuaji and Madelan improved the projected package delivery route to reduce operational costs linked to fuel use and delivery delays [15].

Manuel et al., also stated that the suggested route improvements effect the amount of weight that the vehicle would carry, ensuring that the vehicle's total volume is met [16]. Kim et al., proposed a more ideal route for garbage transportation, with the goal of minimizing the distance traveled by vehicles in the waste transportation process [17]. This can improve the efficiency of the transportation process several times in the surrounding area, allowing the work to be completed before the break time arrives. Buhrkal et al., found that route optimization can reduce completion time by 30-45% in the rather complex urban garbage transportation process [18]. Tirkolaee et al., recommended route changes for multi-trip trash delivery, resulting in a 13.3% reduction in operational expenses [19]. Puspita et al., enhanced the intended garbage transportation route, resulting in faster transit and lower operational expenses. After reviewing various previously explained research, it is clear that the Vehicle Routing Problem (VRP) method is the best method for optimizing routes or proposing new routes in order to reduce distance traveled or vehicle travel time [20].

2. Literature Review

In general, the Vehicle Routing Problem (VRP) can be defined as solving problems linked to product distribution to consumers by managing or picking the distribution route. VRP is an element of the NP-Hard Problem program, which is integer programming capable of solving complicated problems as their scope increases. The core concept of implementing the Vehicle Routing Problem (VRP) focuses on delivery or pick-up actions, which cannot be done simultaneously [15]. Vehicle Routing Problem with Time Windows (VRPTW) is a subset of the Capacitated Vehicle Routing Problem (CVRP) that offers services to consumers within a defined deadline/time frame [21]. Vehicle Routing Problem with Time Windows (VRPTW) is a method of distribution to customers spread across several locations with limited cargo owned by the vehicle and customer reception time.

VRPTW modeling in the waste transportation process can be defined as a graph $G = (V, A)$. Where the set V is the set of depot locations (Central Kitchen) and all store outlets that transport waste, $V = \{0, 1, \ldots ,12\}$. All routes start and end at 0, and the vehicles used in transportation are denoted by k. Vehicle k is a vehicle used with a capacity of Q. Each store $i \in V$ has an amount of waste transported that does not exceed the vehicle capacity.

The mathematical formula of VRPTW for waste transportation route optimization is:

Minimize

$$\sum_{i,j\,\in\,V} c_k b_k x_{ijk}$$

Constraints,

Vehicles used for the waste transportation process depart from the depot (Central Kitchen) and must return to the depot:

$$\sum_{j\,\in\,V} x_{ijk} = k$$

Each outlet store is only visited once by a waste transportation vehicle:

$$\sum_{i\,\in\,V} x_{ijk} = 1, \qquad j\,\in V.$$

$$\sum_{j\,\in\,V} x_{jik} = 1, \qquad i\,\in V.$$

The number of waste outlet stores transported in a route does not exceed the vehicle capacity:

$$\sum_{j\in\,V} d_j \sum_{i\,\in\,V} x_{ijk}\ \leq Q$$

Preventing the occurrence of unfeasible subtours:

$$a_{ik} - \ a_{jk} + V x_{ijk}\ \leq V - 1$$

Vehicles move from one consumer to another:

$$\sum_{j\,\in\,V} x_{ik} - \sum_{i\,\in\,V} x_{jk}\ = 0, \quad i,\ j\ \in V$$

No repeated visits to one outlet store:

$$x_{ijk} = 0, \ \ i = j, \qquad i, j \in V$$

Travel time constraints are the result of the distance between outlet stores and vehicle speed:

$$t_{ijk} = \frac{b_{ij}}{v} \text{ , } \quad i \neq j$$

Travel time from outlet store i to j using vehicle k plus transportation time at outlet store i must be less than or equal to the transportation time of vehicle k at outlet store j. It can be formulated as:

$$l_{ik} + s_i + t_{ij} \leq l_{jk}, \quad \forall i, j \in V$$

Variable x_{ijk} is a binary variable:

x_{ijk} 1, if the trip from i to j uses vehicle k

0, if using other

3. Research Methodology

This descriptive quantitative research focuses on the detailed, methodical, and structured use of numbers. Because quantitative research is focused on the processing and analysis of graphical data, it can help to draw conclusions more easily. The goal of this study is to assess the effectiveness of present garbage transportation routes and to propose new, more appropriate routes. The study phase begins by observing the causes of slowness in waste pickups in the field. Furthermore, research was carried out to develop corrective measures to ensure that trucks hauling waste are spared from delays when returning from the store. This study utilizes secondary data. The data acquired is based on a vehicle use form document possessed by the Department of Logistics and Distribution. The data utilized for observation is waste transportation data from October to December 2023. Other data used include journey time and distance information acquired from the Google Maps program. The Vehicle Routing Problem with Time Window (VRPTW) consider is used to process and analyze data in order to provide an overview of the study object and potential solutions to these obstacles.

4. Results and Discussion

Data processing using Lingo.18 software is divided into two types of conditions: transportation in normal situations and transportation when traffic regulations limit the number of cars on the road conditions. Data is processed based on each of these variables to determine the distance and lowest transportation time for waste transportation. The input data is taken from the Google Maps application during the working hours of garbage transfer.

4.1. Mileage simulation

Table 1: Mileage simulation (normal conditions).

Objective Value	36,3	
Objective Bound	36,3	
Variable	**Value**	**Reduce Cost**
X (CK, TA)	1.000000	5,5
X (TA, KS)	1.000000	3,1
X (KS, SAM)	1.000000	1,6
X (MTG, RDS)	1.000000	3,1
X (SAM, MTG)	1.000000	1,5
X (RDS, SLB)	1.000000	2,1
X (SLB, TEB)	1.000000	4,7
X (TEB, PSM)	1.000000	2,3
X (PSM, WIN)	1.000000	5,5
X (KMG, CK)	1.000000	0
X (WIN, PB)	1.000000	3,8
X (PB, KMG)	1.000000	3,1

Table 1 shows the results of data processing to determine the proposed route based on the distance traveled under normal traffic conditions. It can be seen that the interaction between nodes produces the shortest distance of 36.3 km. In this situation, it is assumed that the vehicle transporting food waste can pass through a route that is not subject to vehicle restrictions. The recommended route is the shortest route back to the waste collection point.

Table 2 shows the proposed route based on the distance traveled when the vehicle restriction policy is enforced. This route allows food waste transport vehicles to continue

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Table 2: Mileage simulation (limiting cars conditions).

Objective Value	46,8	
Objective Bound	46,8	
Variable	**Value**	**Reduce Cost**
X (CK, PB)	1.000000	5,6
X (TA, CK)	1.000000	0
X (KS, TA)	1.000000	3,1
X (MTG, SAM)	1.000000	1,5
X (SAM, KS)	1.000000	1,6
X (RDS, MTG)	1.000000	3,1
X (SLB, TEB)	1.000000	4,7
X (TEB, RDS)	1.000000	6,8
X (PSM, SLB)	1.000000	7,0
X (WIN, KMG)	1.000000	4,8
X (KMG, PSM)	1.000000	5,5
X (PB, WIN)	1.000000	3,1

transporting waste even though they use alternative roads that were not used on the previous route. This is what caused the large distance traveled to increase by 46.8 km

4.2. Travel time simulation

Table 3 shows the results of the interaction between nodes on the variable travel time of the transport vehicle. It can be seen that under normal conditions, the transport vehicle only needs 111 minutes to arrive at the waste collection point and complete the transportation process.

Whereas in Table 4 it can be seen that the vehicle travel time is longer compared to normal conditions because in this condition the transport vehicle uses an alternative route as previously explained in Table 2. The waste transport vehicle only needs to travel 126 minutes to complete the transport process and arrive at the waste collection point.

5. Conclusion

(1) The results of data processing that have been carried out by researchers on two conditions of waste transportation (normal conditions & odd-even conditions) can be

TABLE 3: Travel time simulation (normal conditions).

Objective Value	111,0	
Objective Bound	111,0	
Variable	**Value**	**Reduce Cost**
X (CK, TA)	1.000000	12
X (TA, KS)	1.000000	15
X (KS, SAM)	1.000000	6
X (SAM, MTG)	1.000000	5
X (MTG, RDS)	1.000000	9
X (RDS, SLB)	1.000000	4
X (SLB, CK)	1.000000	0
X (CK, TEB)	1.000000	13
X (TEB, PSM)	1.000000	15
X (PSM, CK)	1.000000	0
X (CK, PB)	1.000000	12
X (PB, KMG)	1.000000	8
X (KMG, WIN)	1.000000	12
X (WIN, CK)	1.000000	0

concluded as follows. The waste transportation route generated by Lingo software data processing for each condition based on the distance traveled is.

a. Normal Conditions, CK – TA – KS – SAM – MTG – RDS – SLB – TEB – PSM – KMG – PB – WIN – CK.

b. Odd-Even Conditions, CK – PB – WIN – KMG – PSM – SLB – TEB – RDS – MTG – SAM – KS – TA – CK.

(2) The waste transportation route generated by Lingo software data processing for each condition based on travel time is.

a. Normal conditions are divided into three routes,

1. First route, CK – TA – KS – SAM – MTG – RDS – SLB – CK,

2. Second route, CK – TEB – PSM – CK,

3. Third route, CK – PB – WIN – KMG – CK.

b. Odd-even conditions are divided into three routes,

1. First route, CK – TEB – SLB – KS – SAM – MTG – RDS – TA – CK.

2. Second route, CK – PSM – CK.

3. Third route, CK – PB – WIN – KMG – CK.

TABLE 4: Travel time simulation (limit the number of cars conditions).

Objective Value	126,0	
Objective Bound	126,0	
Variable	**Value**	**Reduce Cost**
X (CK, TEB)	1.000000	13
X (CK, PSM)	1.000000	17
X (CK, PB)	1.000000	12
X (TA, CK)	1.000000	0
X (KS, SAM)	1.000000	6
X (MTG, RDS)	1.000000	9
X (SAM, MTG)	1.000000	5
X (RDS, TA)	1.000000	19
X (SLB, KS)	1.000000	10
X (TEB, SLB)	1.000000	15
X (PSM, CK)	1.000000	0
X (WIN, KMG)	1.000000	12
X (KMG, CK)	1.000000	0
X (PB, WIN)	1.000000	8

(3) Under normal conditions, the variable distance traveled from the recommended route is 36.3 kilometers, which is 22.8% less than the current route in use. Meanwhile, the total distance traveled by the suggested route under odd-even conditions is 46.8 kilometers. Despite the fact that the distance is nearly identical, the proposed route is more efficient than the present route. The travel time variable for the recommended route under normal conditions is 111 minutes, which reduces 63% of the time offered. Meanwhile, the overall travel time for the route in odd-even conditions is 126 minutes, reducing 58% of the total time available for transferring waste.

Referring to previous research Puspita et al., which proposed improvements to waste transportation routes in urban areas. the results of this study can also be used as an alternative method to solve waste transportation problems in urban areas that have similar conditions (congestion or restrictions on the number of vehicles) [20]. the researcher would like to thank all parties who have contributed so that this research can be carried out. The results of this study also need to be developed in order to be able to describe the solution to more complex problems.

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