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Robust Optimization Model and Its Solution on the Vehicle Routing Problem with Time Windows

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Abstract. The problem of the route of the garbage transporting vehicle is one of the important problems in a city. The more temporary garbage dumps and the optimization of the route of the garbage transporting vehicles, the more travel time and affect the daily work time. This paper discusses a robust optimization model on the problem of transporting garbage vehicles with time windows related to determining the optimal route for garbage trucks by taking into account the time window. The goal of this paper is to minimize the travel time of garbage collection vehicles. To solve a robust optimization model on the vehicle routing problem with a time window, LINGO software is used to solve the branch and bound method from a set of instances of waste transport vehicle routes in Ilir Barat I District, Palembang City. This research results that the more nodes will affect the arrival time of the vehicle at the next node. The occurrence of delays in waste transport vehicles from the daily time duration can be caused by the large number of temporary disposal sites and the distance from the final disposal site, while the work area is only served by one waste transport vehicle.

INTRODUCTION

Vehicle routing problem (VRP) is one of the combinatorial optimization problems and is widely applied in the fields of distribution, collection, transportation and logistics. Combinatorial optimization is an applied field of applied mathematics that combines techniques from combinatorial, linear programming and algorithm theory to solve optimization problems .

Vehicle routing problem (VRP) is a combinatorial optimization problem and is widely applied in the fields of distribution, collection, transportation and logistics. Combinatorial optimization is an applied field of applied mathematics that combines techniques from combinatorial, linear programming and algorithm theory to solve optimization problems [1]. VRP has characteristics that consist of determining routes and scheduling vehicles to meet customer needs with several constraints [2, 3]. VRP was first introduced by Dantzig and Ramser in 1959 for the Truck Dispatching Problem which minimizes the mileage of several homogeneous truck fleets that can serve the oil demand of a number of gas stations from a single center [4, 5].

The class of vehicle routing problems is the vehicle routing problem with time windows (VRPTW). VRPTW is a generalization of VRP that can be used as a model in real problems [6]. Optimization problems that have data uncertainty are discussed in robot optimization and have been widely studied in recent years [7, 9]. This research is motivated by the problem of waste transportation vehicles which are influenced by uncertain travel times and is discussed in the optimization problem class, robust vehicle routing problem with time windows (RVRPTW). Nasri et al. [10] presents an RVRPTW that takes into account the uncertainty of travel times and service times. Agra et al. [7] discusses RVRPTW which considers the uncertainty of travel time with two robust formulas of the problem.

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Problems that arise in waste transport vehicles that often experience delays at the location of temporary waste disposal sites and must be considered. Delays occur due to the increasing number of temporary garbage dumps so that travel times are not optimal. Garbage transport vehicles arrive at the temporary waste collection point beyond the arrival time, this is called the soft window of time [11]. The time window considered here is the soft time window, in other words the time window can be violated. This study aims to the robust vehicle routing problem with time window on the uncertainty of travel time to minimize travel time and obtain the optimal route from waste transport vehicles.

MATERIALS AND METHOD

The steps needed to minimize vehicle travel time are as follows:

1. Data Description
2. Defining variables and parameters
3. Formulation of the model to study robust vehicle routing problem with time windows
4. Completion of the model using the LINGO software
5. Result analysis

The completion process is as shown in Figure 1.

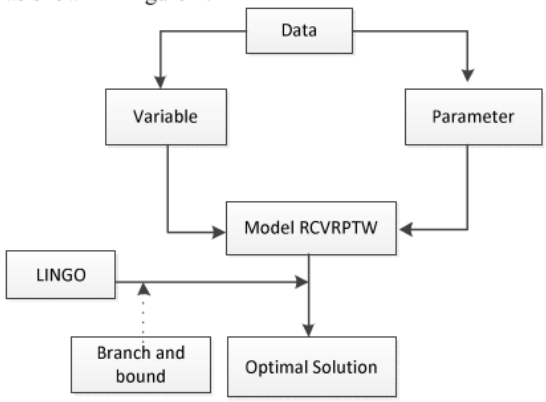

FIGURE 1. Illustration of flow chart

RESULT AND DISCUSSION

The RVRPTW model is simulated on the waste transportation route in Ilir Barat I District, Palembang to minimize the travel time of waste transport vehicles. Garbage transport vehicles carry waste to several temporary landfills and vehicles dispose of garbage at final disposal sites. Garbage transport vehicles carry out the process of transporting waste which consists of 9 work areas. Furthermore, the work area is called the area. Each work area has one garbage collection vehicle. Garbage transport vehicles have two daily working hours and each daily working time has a duration of 240 minutes. Daily working time 1: 6 am to 10 am West Indonesian Time (WIT) and daily working time 2: 4 pm to 8 pm WIT.

Variables :

x_{ij} the vehicle travels from node i to node j

P_i arrival time at node i

Parameters :

t_{ij} travel time from node i ke node j

a_i vehicle departure from node i

b_i vehicle arrival time at node i

TABLE 1. Data

Region	The number of temporary dumps	Number of node
Region 1	1	2
Region 2	7	8
Region 3	2	3
Region 4	5	6
Region 5	6	7
Region 6	3	4
Region 7	7	8
Region 8	3	4
Region 9	6	7

Defined the set of all nodes $N = \{1,2,3, \dots n, m\}$ and the set of all vehicles $V = \{1,2,3, \dots, k\}$ with node 1 representing the starting node, n representing the number of nodes and $m = n + 1$ represents the destination node (d). A set $N/\{m\}$ represents of the number of temporary dumps and m represents the final dumps. The number of temporary waste disposal sites for each area in Ilir Barat I District, Palembang is as shown in Table 1.

The formulation of the RVRPTW Model for the problem of transporting waste is given as follows:

Minimize

$$Z = \sum_{(i,j)\in A} t_{ij}\, x_{ij} \tag{1}$$

Subject to:

$$\sum_{j\in N} x_{ij} = 1, \forall (i \in N) \tag{2}$$

$$\sum_{j\in N;(j,i)\in A^k} x_{ji} - \sum_{j\in N;(i,j)\in A^k} x_{ij} = \begin{cases} -1\ ; \text{ for } i = 1 \\ 1\ ; \text{ for } i = d \\ 0\ ; \text{ the others} \end{cases} \tag{3}$$

$$a_i \le P_i \le b_i, \forall (i \in N) \tag{4}$$

$$P_i + t_{ij} - P_j \le M\left(1 - x_{ij}\right), \forall (i \in N), (j \in N/\{m\}) \tag{5}$$

$$P_i \ge 0, \forall (i \in N) \tag{6}$$

$$x_{ij} \in \{0,1\} \tag{7}$$

TABLE 2. Result is obtained by solving with LINGO daily working time 1

Region	Travel time (minute)	Route
Region 1	14.4	1 – 2
Region 2	39.6	1 – 8 – 7 – 8
	44.4	2 – 3 – 4 – 5 – 8 – 6 – 8
Region 3	38.4	1 – 3 – 2 – 3
Region 4	37.2	1 – 2 – 6 – 3 – 6
	39.6	4 – 6 – 5 – 6
Total travel time	213.6	

TABLE 3. Result is obtained by solving with LINGO daily working time 2

Region	Travel time (minute)	Route
Region 5	42.6	6 – 7 – 1 – 7
	33.6	2 – 4 – 3 – 7 – 5 – 7
Region 6	51.6	1 – 4 – 3 – 2 – 4
Region 7	39.6	1 – 2 – 3 – 6 – 8 – 7 – 8
	31.2	4 – 8 – 5 – 8
Region 8	49.8	1 – 2 – 4 – 3 – 4
Region 9	49.2	1 – 5 – 7 – 6 – 4 – 7

	40.2	2 – 7 – 3 – 7
Total travel time	337.8	

During daily work time 1, waste transport vehicles carry out waste transportation in work area 1, work area 2, work area 3 and work area 4 with a total daily work time of 213.6 minutes as shown in Table 2. so that the vehicle has a waiting time of about 26.4 minutes to carry out the waste transportation process again for the daily working time 2.

At 4 am, the garbage transporting vehicle returns to the garbage collection process. The calculation results from the RVRPTW model for other work areas are as shown in Table 3. During daily work 2, the waste transport vehicle transports waste in work area 5, work area 6, work area 7, work area 8 and work area 9 with a total daily work time of 337.8 minutes. This shows that the garbage collection vehicle arrives later than the daily working time duration of 97.8 minutes.

CONCLUSION

The more nodes will affect the arrival time of the vehicle at the next node. For the case of the waste transportation route in Ilir Barat I District, Palembang, the arrival time of vehicles at a temporary dump site was delayed. Even though it has 2 daily working hours per day, the total travel time of the garbage transport vehicle is delayed from the daily working time. This is not good because it can affect operational costs. The occurrence of delays in waste transport vehicles from the daily time duration can be caused by the large number of temporary disposal sites and the distance from the final disposal site, while the work area is only served by one waste transport vehicle.

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