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The Committees of the 5th Seminar Nasional Matematika dan Pendidikan Matematika (SENATIK) 2020

To cite this article: N D Rahmawati *et al* 2020 *J. Phys.: Conf. Ser.* **1663** 011002

Journal of Physics: Conference Series **1663** (2020) 011002 doi:10.1088/1742-6596/1663/1/011002

The Committees of the 5th Seminar Nasional Matematika dan Pendidikan Matematika (SENATIK) 2020

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The committee of the 5th Seminar Nasional Matematika dan Pendidikan Matematika (SENATIK) 2020 would like to say gratitude to all editorial board and scientific committee fo the volunteering support and contribution in the process of editing and reviewing.

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The robust counterpart open capacitated vehicle routing problem with time windows

To cite this article: E Yuliza *et al* 2020 *J. Phys.: Conf. Ser.* **1663** 012030

The robust counterpart open capacitated vehicle routing problem with time windows

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Abstract. The problem of transporting waste vehicle routes is one of the problems faced in big cities. Delay becomes a problem in the process of transporting waste. The route of garbage vehicles motivated this research. Thus, the optimization of vehicle routes is needed to minimize the distance and travel time. We investigated two robust optimization models, which are limited by vehicle capacity and time windows. Robust counterpart open capacitated vehicle routing problems with soft time windows is the first model. This model results in the arrival time of the vehicle on each TDS and FDS that may exceed the working hours. The second model is robust counterpart open capacitated vehicle routing problems with hard time windows. This model results in the arrival time of the vehicle on each TDS and FDS not to exceed the working hours. The two robust optimization models are solved using the exact approach and the heuristic approach. Complete the exact approach using the branch and bound method with LINGO software. Completion of the heuristic approach uses the Nearest Neighbour method. The two models that are solved by the branch and bound method and the Nearest Neighbour algorithm produce the optimal solution, obtained different sub tours.

1. Introduction

Robust optimization is influenced by parameters that have uncertainty. Robust optimization has experienced many developments both in the fields of transportation, economics, logistics, and the environment [1][2][3]. Robust vehicle routing problem (RVRP) is an optimization problem with vehicle route parameters that are uncertain [4]. The vehicle began moving from the depot to serve several customers who had an uncertain number of requests. Robust optimization like this is discussed in the robust capacitated vehicle routing problem (RCVRP), which is limited by the number of customer requests that are uncertain and also limited by vehicle capacity [5]. The vehicle starts moving from a point, then serves several customers and does not return at that point. This robust optimization is discussed in the robust open vehicle routing problem (ROVRP) [6]. The time interval between departure and arrival of the vehicle when serving the customer is called the time windows. Robust optimization that is affected by time window parameters is called robust vehicle routing problem with time windows (RVRPTW) [7][8][9][10]. When the vehicle serves customers is affected by uncertain travel times.

A vehicle may experience a delay when it arrives at a customer. It happens due to engine damage, broken tires, or jams. The vehicle can also arrive earlier at the customer, so the vehicle is waiting for the next trip. If the time of arrival of the vehicle in a customer exceeds the time of arrival, this is called soft time windows. However, if the vehicle's arrival time is no more than the arrival time or arrive earlier, this is called hard time windows. The optimization of robust counterpart open capacitated routing problems with time windows (RCOCVRPTW) and the deadline robust counterpart open capacitated vehicle routing problems (DR-COCVRP) have been investigated [11][12][13].

This research will discuss the model of robust counterpart open capacitated vehicle routing problem (RCOCVRP) with soft time windows and robust counterpart open capacitated vehicle routing problem (RCOCVRP) with hard time windows [7][9]. This robust optimization model is a new model that is motivated by the problem of transporting waste routes. Garbage transport vehicles start departing from a depot and then transport the garbage at each Temporary Disposal Site (TDS) and dispose of the final garbage at the Final Disposal Site (FDS). The volume of waste transported by garbage transport vehicles at each polling station has an uncertain amount. Sometimes garbage transport vehicles experience delays in the process of transporting waste.

The robust counterpart open capacitated vehicle routing problem (RCOCVRP) model with soft time windows, and the robust counterpart open capacitated vehicle routing problem (RCOCVRP) with hard time windows is solved by an exact approach and heuristic approach. Complete the exact approach using LINGO 13.0 software. LINGO can be used as an effective tool to solve the optimization problems for its high computing speed and accuracy when solving practical problems [14][15]. The RCOCVRP model with soft time windows and the RCOCVRP model with hard time windows are solved by a heuristic approach. Both of these models are limited by vehicle capacity and time windows and solved by the Nearest Neighbour method.

2. Methods

Garbage vehicle route data is obtained from the environment and cleanliness department, Palembang City. Data collection was carried out by interviewing environmental and cleaning service officers.

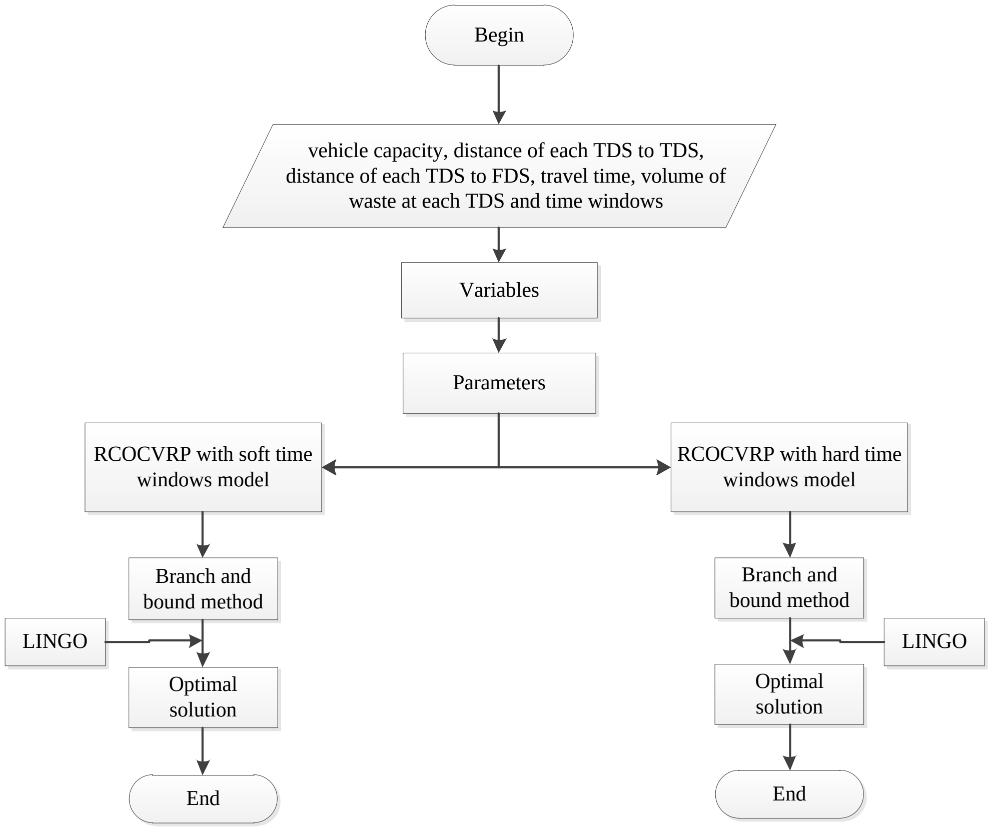

Figure 1. Procedures for mathematics formulation and solution of the RCOCVRP with soft time windows model and the RCOCVRP with hard time windows model using the exact approach.

This research data includes vehicle capacity, the distance of each TDS to TDS, the distance of each TDS to FDS, travel time, the volume of waste at each TDS, and time windows.

This research builds a robust optimization model RCOCVRP with soft time windows models and RCOCVRP with hard time windows. Both of these models were solved by the branch and bound method, which using LINGO software. The procedures for mathematics formulation and solution of those models using the exact approach can be shown in figure 1.

RCOCVRP model with soft time windows and hard time windows is a classification of RCOCVRP models with time windows. Computational calculations of the RCOCVRP with the time windows model using a heuristics approach solved by the Nearest Neighbour method. Select the shortest vertex from the origin as the current vertex. Next, find out the shortest edge connecting the current vertex. Repeat this process until all points are visited and end at the destination point and unvisited. The process stops until all vertices are visited.

3. Result and discussion

The research data was obtained from the Agency of Cleanliness and the Environment (ACE) in the form of waste transportation in the district of Sako, Palembang, in September 2019.

Types of garbage transport vehicles are dump trucks with a capacity of 8 tons. Travel time for garbage transport vehicles is assumed 4 hours. Garbage transport vehicles depart from 06:00 to 10:00 and 16:00 to 20:00. Service time is the time to put the garbage into the vehicle and remove it from the vehicle.

The time to put garbage into the vehicle and remove it from the vehicle is assumed the same. It is about 15 minutes. Waste transported from each TDS is disposed of at FDS Sukawinatan. The speed of the garbage transport vehicle is assumed to be 40 km/ hour. Several waste collection vehicles serve TDS in the three work areas, as shown in table 1.

Table 1. Data for waste transportation route problems.

Working area	TDS	The Volume of Waste (ton)	Time windows
1	1	4.5	[07:00, 07:30]
	2	2	[07:30, 08:30]
	3	4	[08:30, 09:00]
	4	2	[09:00, 09:30]
	5	1.5	[09:30, 10:00]
	6	3	[10:00, 10:30]
2	1	2.2	[07:00, 07:50]
	2	1.5	[07:50, 08:40]
	3	1.6	[08:40, 09:20]
	4	2	[09:20, 10:10]
3	1	2	[07:00, 07:20]
	2	1.5	[07:20, 07:40]
	3	1	[07:40, 08:00]
	4	2	[08:00, 08:20]
	5	2	[08:20, 08:40]
	6	1.5	[08:40, 09:00]
	7	3	[09:00, 09:20]
	8	1.7	[09:20, 09:40]
	9	5	[09:40, 10:00]
	10	4	[10:00, 10:20]
	11	1.5	[10:20, 10:40]

Table 2 and table 3 give variables and parameters of the RCOCVRP model with soft time windows and RCOCVRP with hard time windows.

Table 2. Table of variables.

Variable	Description
x_{ij}	Traveling from TDS *i* to TDS *j*
y_{ij}	Routing from TPS *i* to TDS *j*
y_i	Vehicle load when leaving TDS to *i*
y_j	Vehicle load when leaving TDS to *j*
t_i	The time arrived of the vehicle when serving TDS to *i*
t_j	The time arrived of the vehicle when serving TDS to *j*

Table 3. Table of parameters.

Parameter	Description
c_{ij}	Distance from TDS *i* to TPD *j*
Q	Vehicle capacity
q_i	The volume of waste transported at TDS to *i*
t_{ij}	Travel time from TDS to *i* to TDS to *j*
a_i	When a vehicle leaves the TDS to *i* when transporting garbage at TDS to *i*
b_j	When a vehicle leaves the TDS to *j* when transporting garbage at TDS to *j*
s_{ij}	Service time on the TDS *i*

The following is the mathematical formulation of RCOCVRP with soft time windows at working area 1 for sub route 1.

Minimize:

$$0.4x_{12}+0.35x_{13}+2.3x_{17}+0.4x_{21}+0.55x_{23}+2.3x_{27}+0.35x_{31}+0.55x_{32}+2.2x_{37}+2.3x_{71}+2.3x_{72}+2.2x_{73}$$

Subject to:

$$x_{12}+x_{13}+x_{17}=1,$$

$$x_{21}+x_{23}+x_{27}=1,$$

$$x_{31}+x_{32}+x_{37}=1,$$

$$x_{71}+x_{72}+x_{73}=1,$$

$$x_{12}+x_{32}+x_{72}-x_{21}-x_{23}-x_{27}=0,$$

$$x_{21}+x_{31}+x_{71}-x_{12}-x_{13}-x_{17}=-1,$$

$$x_{13}+x_{23}+x_{73}-x_{31}-x_{32}-x_{37}=0,$$

$$x_{17}+x_{27}+x_{37}-x_{71}-x_{72}-x_{73}=1,$$

$$800\le y_1\le 8000,$$

$$500\le y_2\le 8000,$$

$$600\le y_3\le 8000,$$

$$0\le y_7\le 8000,$$

$$y_1 - y_2+8000x_{12}\le 45,$$

$$y_3-y_7+8000x_{37}\le 0,$$

$$7\le t_1\le 7.5,$$

$$7.5\le t_2\le 8,$$

$$8\le t_3\le 8.5,$$

$$10.5\le t_7\le 11,$$

$$t_1 - t_2 + 0.01x_{12} \le 0,$$
$$t_2 - t_3 + 0.01375x_{23} \le 0,$$
$$t_3 - t_7 - 2x_{37} + 0.055x_{37} \le -2$$

The following is the mathematical formulation of RCOCVRP with hard time windows at working area 1 for sub route 1.

Minimize:

$$0.4x_{12} + 0.35x_{13} + 1.3x_{15} + +2.3x_{17} + 0.4x_{21} + 0.55x_{23} + 1.3x_{25} + 2.3x_{27} + 0.35x_{31} + 0.55x_{32} + 1.4x_{35} + 2.2x_{37}$$
$$+1.3x_{51} + 1.3x_{52} + 1.4x_{53} + 1.2x_{57} + 2.3x_{71} + 2.3x_{72} + 2.2x_{73} + 1.2x_{75}$$

Subject to:

$$x_{12} + x_{13} + x_{15} + x_{17} = 1,$$
$$x_{21} + x_{23} + x_{25} + x_{27} = 1,$$
$$x_{31} + x_{32} + x_{35} + x_{37} = 1,$$
$$x_{51} + x_{52} + x_{53} + x_{57} = 1,$$
$$x_{71} + x_{72} + x_{73} + x_{75} = 1,$$
$$y_{21} + y_{31} + y_{51} + y_{71} - y_{12} - y_{13} - y_{15} - y_{17} = -1,$$
$$y_{17} + y_{27} + y_{37} + y_{57} - y_{71} - y_{72} - y_{73} - y_{75} = 1,$$
$$y_{12} + y_{32} + y_{52} + y_{72} - y_{21} - y_{23} - y_{25} - y_{27} = 0,$$
$$y_{13} + y_{23} + y_{53} + y_{73} - y_{31} - y_{32} - y_{35} - y_{37} = 0;$$
$$y_{15} + y_{25} + y_{35} + y_{75} - y_{51} - y_{52} - y_{53} - y_{57} = 0,$$
$$y_{12} - x_{12} = 0, \quad y_{13} - x_{13} = 0,$$
$$y_{15} - x_{15} = 0, \quad y_{17} - x_{17} = 0,$$
$$y_{21} - x_{21} = 0, \quad y_{23} - x_{23} = 0,$$
$$y_{25} - x_{25} = 0, \quad y_{27} - x_{27} = 0,$$
$$y_{31} - x_{31} = 0, \quad y_{32} - x_{32} = 0,$$
$$y_{35} - x_{35} = 0, \quad y_{37} - x_{37} = 0,$$
$$y_{51} - x_{51} = 0, \quad y_{52} - x_{52} = 0,$$
$$y_{53} - x_{53} = 0, \quad y_{57} - x_{57} = 0,$$
$$y_{71} - x_{71} = 0, \quad y_{72} - x_{72} = 0,$$
$$y_{73} - x_{73} = 0, \quad y_{75} - x_{75} = 0,$$
$$800 \le y_1 \le 8000,$$
$$1500 \le y_2 \le 8000,$$
$$600 \le y_3 \le 8000,$$
$$700 \le y_5 \le 8000,$$
$$0 \le y_7 \le 8000,$$
$$y_1 - y_2 + 8000x_{12} \le 4500,$$
$$y_2 - y_3 + 8000x_{23} \le 5400,$$

$$y_3 - y_5 + 8000x_{35} \le 5300,$$
$$y_5 - y_7 + 8000x_{57} \le 0,$$
$$-0.59y_{12} \le 0, \quad -1.09125y_{13} \le 0,$$
$$-2.0675y_{15} \le 0, \quad -3.5425y_{17} \le 0,$$
$$-0.58625y_{23} \le 0, \quad -1.5675y_{25} \le 0,$$
$$-3.0425y_{27} \le 0, \quad -1.065y_{35} \le 0,$$
$$-2.545y_{37} \le 0; \quad -1.57y_{57} \le 0$$

Table 4. The solution of the model uses the branch and bound method.

	RCOCVRP with soft time windows		RCOCVRP with hard time windows	
	Distance (km)	Route	Distance (km)	Route
Working Area 1	7.35	TDS 1 – FDS – TDS 3 – TDS 2 – FDS	7.35	TDS 1 – TDS 3 – FDS – TDS 5 – TDS 2 – FDS
	14.9	TDS 4 – FDS – TDS 6 – TDS 5 – FDS	13.5	TDS 4 – FDS – TDS 6 – FDS
Working Area 2	14.8	TDS 1 – FDS – TDS 3 – TDS 2 – FDS	17.2	TDS 1 – FDS – TDS 4 – FDS
	6.2	TDS 4 – FDS	14.3	TDS 2 – FDS – TDS 3 – FDS
Working Area 3	6.5	TDS 1 – TDS 5 – TDS 2 – FDS	6.9	TDS 1 – FDS – TDS 2 – FDS
	15.6	TDS 4 – FPS – TDS 7 – TDS 6 – FPS	12.4	TDS 3 – FDS – TDS 4 – FDS
	15	TDS 3 – FDS – TDS 9 – FDS	13.5	TDS 5 – FDS – TDS 6 – FDS
	17.8	TDS 8 – FDS – TDS 11 – TDS 10 – FDS	16.98	TDS 7 – TDS 8 – FDS – TDS 9 – FDS
			17.4	TDS 10 – FDS – TDS 11 – FDS

Table 4 shown RCOCVRP with soft time windows models and RCOCVRP with hard time windows are related to window time. Garbage transport vehicles in the garbage transport process are influenced by travel time so that the garbage transport vehicles arriving at the FDS do not exceed the window time. RCOCVRP model with time windows is solved using the Nearest Neighbour method, as shown in table 5.

Table 5. The solution of RCOCVRP with the time windows model using the Nearest Neighbour method.

	Distance (km)	Route
Working Area 1	3.2	TDS 1 – TDS 3 – TDS 2 – FDS
	2.9	TDS 4 – TDS 5 – FDS
	5.6	TDS 6 – FDS
Working Area 2	5.8	TDS 1 – TDS 2 – TDS 3 – FDS
	6.2	TDS 4 – FDS
Working Area 3	5.86	TDS 1 – TDS 2 – TDS 3 – FDS
	5.75	TDS 4 – TDS 5 – TDS 6 – FDS
	6.18	TDS 7 – TDS 8 – FDS
	6.4	TDS 9 – TDS 11 – FDS
	6.4	TDS 10 – FDS

4. Conclusion

The solution of the robust counterpart model open capacitated vehicle routing problem with soft time windows and the robust counterpart model open capacitated vehicle routing problem with hard time windows with the exact approach and heuristic approach produce an optimal solution to minimize the travel distance and time. However, the two models have different sub-routes. The robust counterpart open capacitated vehicle routing problems with soft time windows models result in the arrival time of the vehicle on each TDS and FDS that may exceed the working hours. The robust counterpart open capacitated vehicle routing problems with hard time windows. The two robust optimization models are solved using the exact approach and the heuristic approach. This model results in the arrival time of the vehicle on each TDS and FDS not to exceed the working hours. This model results in the arrival time of the vehicle on each TDS and FDS not to exceed the working hours. Both models produce an optimal solution if the volume of waste at each TDS transported by the vehicle does not exceed the vehicle's capacity, and the travel time does not exceed the vehicle's arrival time.

Acknowledgments

The Faculty of Mathematics and Natural Sciences, Universitas Sriwijaya through the Sciences and Technology Research Grant Scheme 2020 support this research.

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SERTIFIKAT

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Evi Yuliza, M.Si

sebagai

PEMAKALAH

dalam kegiatan Seminar Nasional Matematika dan Pendidikan Matematika Tahun 2020 dengan tema "Merdeka Belajar: Integrasi Teknologi dalam Pembelajaran Matematika" pada tanggal 12 - 13 Agustus 2020 yang diselenggarakan oleh Program Studi Pendidikan Matematika FPMIPATI Universitas PGRI Semarang.

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