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Preface: The 6th National Conference on Mathematics and Mathematics Education (SENATIK)

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Preface: The 6th National Conference on Mathematics and Mathematics Education (SENATIK)

The 6th National Conference on Mathematics and Mathematics Education (SENATIK) was held by Mathematics Education Study Program, Universitas PGRI Semarang, Indonesia, in 11 August 2021. The seminar theme is Numerize and Digitaze of Mathematics Toward Freedom of Learning. According to the theme, this seminar aims to improve mathematics teaching, solve mathematics problems, and expand mathematics contribution to society.

Freedom of learning is a policy implemented by the Indonesian Ministry of Education and Culture. Freedom learning encourages students to master literacy, numeracy, and character. Numeration is one of the ways to make mathematics easy. At the same time, it provides opportunities for students to collaborate, has critical thinking, creative thinking, communication, good character, and face the challenges of an increasingly global world with advances in science and technology. Having numeracy skills will impact good thinking patterns and habits associated with numbers or calculations with existing problems.

Along with the freedom learning program development during the COVID-19 pandemic, it is very clear that technological developments have a high impact on the education world. This impact also occurs in the learning process, especially in accessing information as a learning resource, both online and offline learning. The availability of abundant information and easily accessible also causes learning to experience a digitization process. The era of digitalization brings challenges as well as opportunities in the world of education. There is an opportunity to integrate technology into the learning process so that learning outcomes are more effective. The integration of technology in the learning process results in digitization in the education world, especially in the learning process. The findings that were discussed in the seminar: In mathematics learning and problem-solving, teachers and students need technology. Integration of mathematics and technology is a crucial process.

There are 151 manuscripts through the peer-review and end up with 76 papers which are published in this AIP Conference Proceeding. Together with the keynote speakers and the presenters, they shared their research results on different fields in the plenary and parallel sessions attended by more than 300 participants.

We want to thank the keynote speakers; 1) Prof. Helia Jacinto, Ph. D. (University of Lisbon, Portugal); 2) Dr. Rully Charitas Indra Prahmana, S.Si., M.Pd. (Universitas Ahmad Dahlan, Indonesia), and; 3) Dr. Muhtarom, M.Pd. (Universitas PGRI Semarang, Indonesia). Many thanks go as well to the speakers in the workshop session that are Sutrisno, S.Pd., M.Pd. (Universitas PGRI Semarang, Indonesia) and Dr. Muhtarom, M.Pd (Universitas PGRI Semarang, Indonesia). We also would like to thank all the committee for arranging this conference.

The conference's success is achieved due to the support and commitment of many people, and we acknowledge their contribution, especially all the participants and presenters. For all participants and presenters, we hope they enjoy the seminar, so they are valuable, rewarding and improving their knowledge and experiences.

Thank you,

Dr. Widya Kusumaningsih, M. Pd.
Chairman The 6th National Conference on Mathematics and Mathematics Education
SENATIK
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Committee: The 6th National Conference on Mathematics and Mathematics Education (SENATIK)

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Application of the robust capacitated vehicle routing problem with time Windows model on gallon water distribution

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Application of The Robust Capacitated Vehicle Routing Problem with Time Windows Model on Gallon Water Distribution

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Abstract. This study discusses the robust capacitated vehicle routing problem with time windows which pays attention to cost. A consumer's relatively long service time will make it difficult to serve all consumers during regular working hours in the distribution of goods. It can delay the vehicle's arrival to the next customer, and additional costs are required. To overcome this incident, a robust optimization formulation that considers time windows and costs is proposed. This problem arises, for example, in the distribution of gallon water with uncertain service times. The proposed model aims to minimize costs other than vehicle routes and schedules. Completion of the robust capacitated vehicle routing problem model with time windows that pays attention to is solved with the help of LINGO 13.0 software.

INTRODUCTION

The problem of distributing goods can be viewed as a vehicle routing problem (VRP). A common problem that a company often faces in the distribution of goods is the number of requests from each customer, which is not certain, and the regular time limit for the delivery of goods. In the process of distributing goods, travel time and service time are also considered so that vehicles arrive early so there are no additional costs.

The vehicle routing problem (VRP) can be represented as a problem that designs optimal delivery routes or collections from one or several depots to serve requests from several customers with certain limitations [1][2][3]. In general, the characteristics of VRP are vehicles starting from a depot and ending at a depot, each vehicle only visits exactly one customer, each vehicle has one route, and the demand for each customer is limited by vehicle capacity [4][5]. Classical VRP is also known as capacitated vehicle routing problem (CVRP) [6]. Vehicle routing problem with time windows (VRPTW) is a variation of VRP that adds time windows called vehicle routing problem with time windows [1][2][3][4][5][6][7]. In real life, vehicle service time in meeting each customer's demands sometimes has a relatively long time so that the vehicle arrival time to the next customer experiences delays and additional costs. Pureza [8] discusses the VRPTW model, which is a variation of VRPTW, and considers the number of the crew assigned to reduce service time.

P.T. Indotirta Sriwijaya Perkasa is a company that distributes gallon water. The demand from each customer per day is uncertain, and the vehicle's travel time is also uncertain. Optimization problems that have data uncertainty are called robust optimization. Robust optimization addresses problems that have data uncertainty [9][10]. Robust optimization that has data uncertainty on the number of requests is called the robust capacitated vehicle routing

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problem (RCVRP) [11][12]. Gounaris [13] and Bernardo [14] discuss the solution approach of the robust capacitated vehicle routing problem (RCVRP) with demand uncertainty. Eufinger *et al.* [15] discuss the RCVRP approach with cost uncertainty. RCVRP Robust capacitated vehicle routing problem with time windows (RCVRPTW) is a robust optimization problem that considers vehicle capacity and time windows.

This study will discuss the robust capacitated vehicle routing problem with the time windows model with a definite cost which is applied to the distribution of gallon water. The purpose of this study is to minimize operational costs in order to obtain optimal vehicle routes and schedules.

METHOD

The RCVRPTW model was completed using LINGO 13.0 software. LINGO is an effective tool for solving optimization problems [16]. LINGO has high computational speed and accuracy [17][18]. The method of solving this model with LINGO software uses the branch and bound algorithm. This algorithm can be used to solve optimization problems. In this algorithm, the set of all possible solutions is enumerated systematically using a rooted tree [19]. The following are the steps for completing the RCVRPTW model in the distribution of gallon water:

1. Data description includes distance matrix, travel time matrix, service time, number of demand.
2. Definition of variables and parameters
3. RCVRPTW model formulation
4. Completion of the RCVRPTW model using the LINGO 13.0 software

The gallon water distribution problem can be represented as a complete graph directed $G = (V, E)$. The set $V = \{1, 2, 3,\ldots, n\}$ represents the set of nodes of each customer, and the set $E = \{(i, j)|\ i \in V, j \in V, i \neq j\}$ represents the arc of the trip vehicle from customer i to customer j.

RESULT AND DISCUSSION

The data of this research were obtained from P.T. Indotirta Sriwijaya Perkasa (depot) is a company engaged in the field of Bottled Drinking Water (BDW) located in Prabumulih City. There is one driver and one crew serving each customer. The depot (denoted by 0) serves 6 customers (denoted by 1, 2, 3, 4, 5, 6). Details of the operational costs of the gallon water distribution vehicle for work area A per day are as follows: the average vehicle maintenance cost (C_1) is IDR 6,944.00 per day, the average travel cost (C_2) is IDR 33,333.00 per day, and the average cost for the driver and crew (C_3) is IDR 135,000.00 per day. It is assumed that the distance matrix (km) and travel time matrix (minute) are s symmetric with $i = 0, 1, 2, 3, 4, 5, 6$ and $j = 0, 1, 2, 3, 4, 5, 6$. The distance matrix $[d_{ij}]$ represents the distance from the depot to each customer and the distance from customer i to customer j. The travel time matrix $[tv_{ij}]$ represents the travel time from the depot to each customer and the travel time from customer i to customer j. It is assumed that the average speed of the vehicle is 40 km/hour. Data for service time and the number of requests for each customer are as shown in Table 1.

$$\left[d_{ij}\right]=\begin{bmatrix} 0 & 3.5 & 6.4 & 3.1 & 4 & 6.2 & 6.1 \\ 3.5 & 0 & 4.1 & 0.8 & 1 & 1.7 & 5.6 \\ 6.4 & 4.1 & 0 & 4.5 & 4.6 & 2.8 & 6.8 \\ 3.1 & 0.8 & 4.5 & 0 & 0.9 & 2.2 & 5.2 \\ 4 & 1 & 4.6 & 0.9 & 0 & 2.2 & 6.2 \\ 6.2 & 1.7 & 2.8 & 2.2 & 2.2 & 0 & 7.8 \\ 6.1 & 5.6 & 6.8 & 5.2 & 6.1 & 7.8 & 0 \end{bmatrix}$$

and

$$
\left[tv_{ij}\right]=\begin{bmatrix} 0 & 9 & 15 & 8 & 11 & 11 & 16 \\ 9 & 0 & 10 & 4 & 2 & 5 & 13 \\ 15 & 10 & 0 & 12 & 12 & 7 & 16 \\ 8 & 4 & 12 & 0 & 3 & 6 & 11 \\ 11 & 2 & 12 & 3 & 0 & 7 & 14 \\ 11 & 5 & 7 & 6 & 7 & 0 & 16 \\ 6 & 13 & 16 & 11 & 14 & 16 & 0 \end{bmatrix}
$$

TABLE 1. Service times and demands.

Node i	**ts_i (Minutes)**	**q_i (Gallon)**
0	-	-
1	127	111
2	57	56
3	43	39
4	64	102
5	25	23
6	12	14

The parameters used in the RVRPTW model with regard to costs in the distribution of gallon water at PT. Indotirta Sriwijaya Perkasa is defined as follows:

n : number of customers
C_1 : vehicle maintenance costs
C_2 : travel expenses
C_3 : daily crew wage (driver and courier fee)
Q : vehicle capacity (150 gallons)
T : distribution time to customers in each work area
V : average vehicle speed
d_{ij} : distance between customer i to customer j ($i, j = 1,\dots, n$, $i \neq j$)
tv_{ij} : average travel time between customer i to customer j
ts_i : service time at node i
q_i : number of customers demand i
$[a_i, b_i]$: time windows for customer i
a_i : fastest arrival time at customer i
b_i : late arrival time at customer i

The variables used in the RVRPTW model in this study are defined as follows:

z : cost of optimization
y_{ij} : travel from i to j
h_i : vehicle arrival time when serving customers i
x_i : vehicle load when serving customers i

The mathematical formulation of the RCVRPTW model is as follows

Minimize:

$$
z = 6{,}944\, y_{12} + 6{,}944\, y_{13} + 6{,}944\, y_{14} + 6{,}944\, y_{15} + 6{,}944\, y_{16} + 6{,}944\, y_{17} + 116{,}665.5\, y_{21} + 136{,}665.3\, y_{23} + 26{,}666.4\, x_{24} + 33{,}333\, y_{25} + 56{,}666{,}1\, y_{26} + 186{,}664.8\, y_{27} + 213{,}331.2\, y_{31} + 136{,}665.3\, y_{32} + 149{,}998.5\, y_{34} + 153{,}331{,}8\, y_{35} + 93{,}332.4\, y_{36} + 226{,}664.4\, y_{37} + 103{,}332.3\, y_{41} + 26{,}666.4\, y_{42} + 149{,}998.5\, y_{43} + 29{,}999.7\, y_{45} + 73{,}332.6\, y_{46} + 173{,}331.6\, y_{47} + 133{,}332\, y_{51} + 33{,}333\, y_{52} + 153{,}331.8\, y_{53} + 29{,}999.7\, y_{54} + 73{,}332.6\, y_{56} + 203{,}331.3\, y_{57} + 206{,}664.6\, y_{61} + 56{,}666.1\, y_{62} + 93{,}332.4\, y_{63} + 73{,}332.6\, y_{64} + 73{,}332.6\, y_{65} + 259{,}997.4\, y_{67} + 203{,}331.3\, y_{71} + 186{,}664.8\, y_{72} + 226{,}664.4\, y_{73} + 173{,}331.6\, y_{74} + 203{,}331.3\, y_{75} + 259{,}997.4\, y_{76} + 135{,}000\, y_{12} + 135{,}000\, y_{13} + 135{,}000\, y_{14} + 135{,}000\, y_{15} + 135{,}000\, y_{16} + 135{,}000\, y_{17} \quad (1)
$$

Subject to:

$$y_{12} + y_{13} + y_{14} + y_{15} + y_{16} + y_{17} = 1 \quad (2)$$

$$y_{12} + y_{32} + y_{42} + y_{52} + y_{62} + y_{72} = 1 \quad (3)$$

$$y_{13} + y_{23} + y_{43} + y_{53} + y_{63} + y_{73} = 1 \quad (4)$$

$$y_{14} + y_{24} + y_{34} + y_{54} + y_{64} + y_{74} = 1 \quad (5)$$

$$y_{15} + y_{25} + y_{35} + y_{45} + y_{65} + y_{75} = 1 \quad (6)$$

$$y_{16} + y_{26} + y_{36} + y_{46} + y_{56} + y_{76} = 1 \quad (7)$$

$$y_{17} + y_{27} + y_{37} + y_{47} + y_{57} + y_{67} = 1 \quad (8)$$

$$y_{21} + y_{23} + y_{24} + y_{25} + y_{26} + y_{27} = 1 \quad (9)$$

$$y_{31} + y_{32} + y_{34} + y_{35} + y_{36} + y_{37} = 1 \quad (10)$$

$$y_{41} + y_{42} + y_{43} + y_{45} + y_{46} + y_{47} = 1 \quad (11)$$

$$y_{51} + y_{52} + y_{53} + y_{54} + y_{56} + y_{57} = 1 \quad (12)$$

$$y_{61} + y_{62} + y_{63} + y_{64} + y_{65} + y_{67} = 1 \quad (13)$$

$$y_{71} + y_{72} + y_{73} + y_{74} + y_{75} + y_{76} = 1 \quad (14)$$

$$y_{12} + y_{32} + y_{42} + y_{52} + y_{62} + y_{72} - y_{12} - y_{32} - y_{42} - y_{52} - y_{62} - y_{72} = 0 \quad (15)$$

$$y_{13} + y_{23} + y_{43} + y_{53} + y_{63} + y_{73} - y_{13} - y_{23} - y_{43} - y_{53} - y_{63} - y_{73} = 0 \quad (16)$$

$$y_{14} + y_{24} + y_{34} + y_{54} + y_{64} + y_{74} - y_{14} - y_{24} - y_{34} - y_{54} - y_{64} - y_{74} = 0 \quad (17)$$

$$y_{15} + y_{25} + y_{35} + y_{45} + y_{65} + y_{75} - y_{15} - y_{25} - y_{35} - y_{45} - y_{65} - y_{75} = 0 \quad (18)$$

$$y_{16} + y_{26} + y_{36} + y_{46} + y_{56} + y_{76} - y_{16} - y_{26} - y_{36} - y_{46} - y_{56} - y_{76} = 0 \quad (19)$$

$$y_{17} + y_{27} + y_{37} + y_{47} + y_{57} + y_{67} - y_{17} - y_{27} - y_{37} - y_{47} - y_{57} - y_{67} = 0 \quad (20)$$

$$-h_1 + h_2 + 9.11 y_{21} \leq 7 \quad (21)$$

$$-h_2 + h_3 + 9.75 y_{32} \leq 7 \quad (22)$$

$$-h_3 + h_4 + 7.71 y_{43} \leq 7 \quad (23)$$

$$-h_4 + h_5 + 8.06 y_{54} \leq 7 \quad (24)$$

$$-h_5 + h_6 + 7.42 y_{65} \leq 7 \quad (25)$$

$$-h_6 + h_7 + 7.2 y_{76} \leq 7 \quad (26)$$

$$-x_2 + x_1 + 261 y_{12} \leq 150 \quad (27)$$

$$-x_3 + x_2 + 206 y_{23} \leq 150 \quad (28)$$

$$-x_4 + x_5 + 189 y_{34} \leq 150 \quad (29)$$

$$-x_5 + x_6 + 252 y_{45} \leq 150 \quad (30)$$

$$-x_6 + x_5 + 173 y_{56} \leq 150 \quad (31)$$

$$-x_7 + x_6 + 164 y_{67} \leq 150 \quad (32)$$

$$8 \leq h_1 \leq 8.5 \quad (33)$$

$$8.5 \leq h_2 \leq 11 \quad (34)$$

$$11 \leq h_3 \leq 12 \quad (35)$$

$$13 \leq h_4 \leq 14 \quad (36)$$

$$14 \leq h_5 \leq 15 \quad (37)$$

$$15 \leq h_6 \leq 16 \quad (38)$$

$$16 \leq h_7 \leq 17 \quad (39)$$

$$0 \leq x_1 \leq 150 \quad (40)$$

$$111 \leq x_2 \leq 150 \quad (41)$$

$$56 \leq x_3 \leq 150 \quad (42)$$

$$39 \leq x_4 \leq 150 \quad (43)$$

$$102 \leq x_5 \leq 150 \quad (44)$$

$$23 \leq x_6 \leq 150 \quad (45)$$

$$14 \leq x_7 \leq 150 \quad (46)$$

The objective function (1) aims to minimize operational costs. Constraints (2) to (14) indicate that the vehicle only visits the customer exactly once. Constraints (15) to (20) indicate that the path from the vehicle serving customer i to customer j. Constraints (21) to (26) indicate that the vehicle's arrival time at customer i is limited by travel time and service time. Constraints (27) to (32) state that the vehicle load when serving customer i is limited by the number of requests and vehicle capacity. Constraints (33) to (39) indicate time windows on customers i. Constraints (40) to (46) indicate that the vehicle load when serving customer i is limited by the number of demands. RCVRPTW model represented by objective functions (1), Equations (2) until (20), inequalities (21) until (26), inequalities (27) until (32), inequalities (33) until (39), and inequalities (40) until (46) are solved by LINGO. Solver LINGO is a branch and bound algorithm. The result of the solution of RCVRPTW model using LINGO is given by Table 2.

TABLE 2. Computational results of LINGO 13.0.

Route	***z***
0-6-0	182606.6
0-2-5-0	463272.2
0-4-1-3-0	318607.7
Total of Oprational Cost	964486.5

The total operational cost for the gallon water distribution problem is IDR 964486.5 with sub-routes of 0-6-0, 0-2-5-0, and 0-4-1-3-0. The RCVRPTW model has a vehicle arrival time at customer i if it satisfies the feasible region of the set of all time windows for each customer. The total travel time of vehicles distributing gallons of water does not exceed regular working hours. The load of the vehicle when serving customer i satisfies the feasible area if it does not exceed the vehicle capacity and the number of demands. The RVRPTW model with a definite cost applied to the distribution of gallon water at P.T. Indotirta Sriwijaya Perkasa obtained optimal vehicle routes and vehicle arrival times to minimize operational costs.

CONCLUSION

This paper presents the RCVRPTW model, which aims to minimize operational costs with a LINGO-based optimization approach. The RCVRPTW model can be implemented in optimizing operational costs for gallon water distribution problems. This model has the optimal solution when considering the vehicle capacity and time windows. If not, then the solution is not feasible. This model is solved using linear programming in LINGO with branch and bound algorithm solver for optimization calculations. The results showed that the RCVRPTW model, which was solved using the branch and bound algorithm, could minimize operational costs.

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REFERENCES

1. A. K. Ariyani, W. F. Mahmudy, and Y. P. Anggodo, Int. J. Electron. Comput. Eng. **8**, 4713 (2018).
2. T. Azad and M. A. A. Hasin, Int. J. Logist. Syst. Manag. **32**, 132 (2019).
3. A. A. Ibrahim, N. Lo, R. O. Abdulaziz, and J. A. Ishaya, Int. J. Res. **7**, 310 (2019).
4. R. Atefi, M. Salari, L. C. Coelho, and J. Renaud, Eur. J. Oper. Res. **265**, 316 (2018).
5. Z. Borcinova, Croat. Oper. Res. Rev. **8**, 463 (2017).
6. K. Braekers, K. Ramaekers, and I. Van Nieuwenhuyse, Comput. Ind. Eng. **99**, 300 (2016).
7. N. A. El-sherbeny, J. King Saud Univ. **22**, 123 (2010).
8. V. Pureza, R. Morabito, and M. Reimann, Eur. J. Oper. Res. **218**, 636 (2012).
9. E. Yuliza, F. M. Puspita, S. S. Supadi, and S. Octarina, J. Phys. Conf. Ser. **1663**, 1 (2020).
10. E. Yuliza, F. M. Puspita, and S. S. Supadi, Sci. Technol. Indones. **6**, 53 (2021).
11. I. Sungur, F. Ordóñez, and M. Dessouky, IIE Trans. **40**, 1 (2008).
12. L. Sun and B. Wang, Math. Probl. Eng. **2015**, 1 (2015).
13. C. E. Gounaris, W. Wiesemann, and C.A. Floudas, Oper. Res. **61**, 677 (2013).
14. M. Bernardo, B. Du, and J. Pannek, Transp. Lett. **7867**, (2020).
15. L. Eufinger, J. Kurtz, C. Buchheim, and U. Clausen, INFORMS J. Optim. **2**, 79 (2020).
16. E. Yuliza, F. M. Puspita, S. Yahdin, and R. Emiliya, J. Phys. Conf. Ser. 1663, 012027 (2020).
17. B. Liu and N. Jin, "An application of lingo software to solve dynamic programming problem in the field of environmental protection," in 2015 IEEE Advanced Information Technology, Electronic and Automation Control Conference (IAEAC 2015), (IEEE, New York, 2015), pp. 577-580.
18. Z. Yao-Zhong and X. Song-Yan, "Multi-UAV cooperative reconnaissance decision-making based on Lingo," in *2nd Asia-Pacific Conference on Intelligent Robot Systems (ACIRS) 1017*, pp. 210-213 (2017).
19. K. Sharma, V. Pratap, and D. Chakraborty, Authorea **1,** 1 (2020) available at https://www.authorea.com/users/373415/articles/495809-a-branch-and-bound-based-solution-method-for-solving-vehicle-routing-problem-with-fuzzy-stochastic-demands?commit=0d813c5413484524fce3f175b82fc60812d15953

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