AIP Conference Proceedings

RESEARCH ARTICLE | DECEMBER 28 2023

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AIP Conf. Proc. 2913, 030013 (2023)
https://doi.org/10.1063/5.0175708

Robust Set Cover Problem in Determining the Optimal Location of Emergency Units in Palembang City with Unknown Distance

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Abstract. Palembang comprises 18 districts, namely Alang-Alang Lebar, Bukit Kecil, Gandus, Iir Barat I, Ilir Barat II, Ilir Timur i, Ilir Tmur II, Ilir Timur III, Jakabaring, Kalidoni, Kemuning, Kertapati, Plaju, Sako, Seberang Ulu I, Seberang Ulu II, Sematang Borang and Sukarami. Where 7 Sub-districts have an Emergency Unit. This Research aims a develop a Robust Set Covering Problem in determining the optimal location of the Emergency Unit in Palembang city such as the unknown location distance or dynamic set covering problems and the community can have a hospital according to their preferences based on the optimal location placement with the urgency of research that identified that are related to the condition of the population that is growing from year to year which does not allow the allocation of health facilities to be the same every year. The distance to the location of the facility will change according to the development of the city and various types of hospitals according to the preferences of customers who are located close to the location of the facility are also a consideration in choosing the optimal location. This research formulated the ser covering problem model that includes the P-median Problem and using the Technique for Other Reference by Similarity to Ideal Solution (TOPSIS) Method. The results based on the problem of the optimal location of hospitals and clinics that have an Unit Emergency in Palembang City based on robustness such as the distance that is not known with certainty is solved by the SCP model, namely the P-median Problem model, and TOPSIS is obtained that the preference is located at Bukit Kecil Sub district which is RSU DR.AK Gani and Pulmonary Specialty Hospital, then the second in Alang-Alang Lebar Sub district which is RSIA Rika Amelia, the third namely Ilir Timur II Sub district namely Trinanda Hospital and Moulya Clinic, then Kertapati District namely PTKAI Kertapati Clinic and Ilir Barat I Sub district namely Siloam Sriwijaya Hospital.

INTRODUCTION

Optimization is a process of maximizing or minimizing the objective function with certain limiting factors. Optimization [1] aims to get the optimal value by taking into account the constraint. Set cover model attempts to serve all demand points with the fewest amount of service location points possible. The P-median problem [2,3] tries to find the facility's location in order to reduce the overall cost between the request and the facility's location [4-6].

The Set Cover Problem (SCP) model [7,8] is a model that aims to minimize the number of service points to serve all demand points. The facility allocation problem can be solved by P-median [2,3,6,9,10]. The P-median Problem aims to determine the location of the facility to minimize the total cost between the demand and the location of the facility [6]. Optimization of the shortest path [11] for example on the ambulance route [12] to the hospital which aims to optimize distance and cost. This shortest-path optimization pays attention to the closest distance to a facility with fast time [13]. In this study, it is assumed that the location of the request needs to be within

Sriwijaya International Conference on Basic and Applied Sciences 2021
AIP Conf. Proc. 2913, 030013-1–030013-6; https://doi.org/10.1063/5.0175708
Published by AIP Publishing. 978-0-7354-4775-2/$30.00

a certain range or time of the service facility, service, or being served satisfactorily [14]. Radius, quantity of service points, and placements are all essential factors in distributing demand points to facility service points so that consumers do not have to travel large distances, which might result in higher expenditures. The goal of this allocation is to keep the entire cost of allocation or transportation as low as possible [6,15-17].

In optimizing the radius problem, it can be solved using Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) [15,18,19]. This method has a simple concept, easy to understand, efficient, and able to measure the relative performance of alternative decisions. TOPSIS method is used to complete practical decision-making [20,21]. The chosen option is the one that is closest to the positive ideal solution and the furthest away from the negative ideal solution [22].

Previous research using the SCP as well as for optimizing health facilities in the form of hospitals and clinics that have Emergency Unit facilities in the city of Palembang has been carried out by Sitepu et al [23]. This study results in the number of Emergency Unit locations to serve 8 sub-districts in the city of Palembang as many as 6 locations [13]. Scarce research focusing on how to solve the robustness of SCP explored in Emergency units in a city.

This study then contributes the important model in discussing the optimization of the location of hospitals [20,24,25] and clinics that have Emergency Unit facilities in Palembang city. Optimizing the location using the set covering method, namely the P-median problem which is applied using the TOPSIS method. SCP and The TOPSIS method are expected to minimize the number of facility locations points so that they can serve all demand points. The novelty of the research introduced, then will be the new way in dealing with solving SCP using the TOPSIS method.

METHOD

The names of hospitals and clinics in the city of Palembang that offer Emergency Unit facilities were gathered from the Palembang Health Office and used in this study as secondary data. The data will be presented in the form of the number of sub-districts in Palembang, the name and number of hospitals in Palembang with Emergency Unit facilities obtained from the official website of BPS Palembang City, and the distance between each sub-district and each hospital and clinic with Emergency Unit facilities obtained from Google Maps. For the P-median problem, the data obtained will be defined variables and parameters. Then, using the TOPSIS approach, determine the best option..

RESULT AND DISCUSSION

Based on the search results on the official website of Palembang City BPS, Palembang city consist of 18 sub-district namely Alang-Alang Lebar sub-district, Bukit Kecil sub-district, Gandus sub-district, Ilir Barat I sub-district, Ilir Barat II sub-district, Ilir timur I sub-district, Ilir Timur II sub-district, Ilir Timur III sub-district, Jakabaring sub-district, Kalidoni sub-district, Kemuning sub-district, Kertapati sub-district, Plaju sub-discrict, Sako sub-district, Seberang Ulu I sub-discrict, Seberang Ulu II sub-district, Sematang Borang sub-discrict and Sukarami sub-district. There are 5 hospitals and 2 clinics that have Emergency Unit in 5 sub-districts in Palembang city. It can be seen in TABLE 1 as follows:

TABLE 1. List of Hospitals and Clinics with Emergency Unit In Palembang City

No	District	Hospitals and clinics that have emergency room facilities Unit
1.	Alang-Alang Lebar	Rika Amelia Hospital
2.	Bukit Kecil	Dr AK Gani Hospital
3.	Ilir Barat 1	Pulmanory specialty Hospital
		Siloam Sriwijaya Hospital
4.	Kertapati	Kertapati PTKAI Clinic
5.	Ilir Timur II	Trinanda Hospital
		Moulya Clinic

The definition of the variable from each model used is for the name of the sub-district we will notify x_i where i=1, 2, 3,...,18. For the name of the Hospital, we denote y_j where j=1, 2,..., 7. So it can be explained that the Alang-

Alang Lebar Sub-district(x_1), Bukit Kecil Sub-District(x_2), and so on up to Sukarami Sub-district. And for Rika amelia Hospital (y_1), And so on up to Moulya's Clinic (y_7).

TABLE 2. Distance Between Demand Point *i* to Alternative Location *j* (km)

d	y_1	y_2	y_3	y_4	y_5	y_6	y_7
x_1	6.7	16	14	12	17	20	18
x_2	12	2	0.7	2.1	11	7.1	6.9
x_3	18	15	14	16	14	24	21
x_4	10	6.3	5	5.3	8.8	11	11
x_5	13	3	1.8	2.9	8.9	7.8	7.7
x_6	8.5	4.3	4.1	2.5	13	9.7	6.5
x_7	15	5.4	7	5.8	20	1.6	0.16
x_8	11	6	8.6	6.4	16	5.1	3.1
x_9	20	8.6	9.9	11	15	13	14
x_{10}	17	8	9.3	9.3	22	3.4	4.4
x_{11}	10	7.1	7.5	5.3	15	7.2	5.1
x_{12}	19	12	11	13	1	16	18
x_{13}	19	8	9.3	11	16	8.7	10
x_{14}	13	11	14	11	21	6.2	5.4
x_{15}	15	3.7	5	7	10	8	9.3
x_{16}	17	5.6	6.9	8.9	14	7	8.3
x_{17}	23	14	15	15	28	9.2	10
x_{18}	8.1	16	16	14	22	17	15

It can be seen in TABLE 2, the distance between demand points i to alternative Emergency Unit locations j in kilometers (km), for example, the distance between Alang-Alang Lebar sub-district (x_1) to Rika Amelia Hospital (y_1) is 6,7 km, and o wards to Sukarami sub-district (x_{18}) to Moulya's Clinic (y_7) is 15 km. Furthermore, to minimize the average distance between the point of request location to the point of the locationof the Emergency Units using the P-median Problem model as follows:

Min $Z_{p-median}=\sum_{i=1}^{18}\sum_{j=1}^{7} h_i d_i\, j_i$

Subject to

$$x_{i1}+x_{i2}+x_{i3}+x_{i4}+x_{i5}+x_{i6}+x_{i7}+x_{i8}+x_{i9}+x_{i10}+x_{i11}+x_{i12}+x_{i13}+x_{i14}+x_{i15}+\ x_{i16}+x_{i17} +\ x_{i18}=1$$
$$y_1+y_2+y_3+y_4+y_5+y_6+y_7=2$$
$$x_{i1}+x_{i2}+x_{i3}+x_{i4}+x_{i5}+x_{i6}+x_{i7}=y_j$$

In determining the optimal location of the ER using the P-median moel with the completion of the highest number of Emergency Units in certain sub-district, there are 2 Ilir Barat I and Ilir Timur
II sub-district. Then to find the optimal location of the hospital, the radius can be used to minimize the total allocation cost that does not depend on the distance between the points s, namely as follows:

Min $\sum_{i=1}^{18}\sum_{j=1}^{7} w_i c_{ij} x_{ij}$
Then,
Min $\sum_{j=1}^{7} x_{i1}+x_{i2}+x_{i3}+x_{i4}+x_{i5}+x_{i6}+x_{i7}$
Where is $y_j \begin{cases} 1;\ \text{if a facility is established at location } j \\ 0;\ \text{if a facility is not established at location } j \end{cases}$

Further minimizing the total number of service points such that all demand points are satisfied by at least one service point, then:

$\mathrm{Min}\left(\max\left(\sum_{i=1}^{m}\sum_{j-1}^{n} x_{ij}d_{ij}\right)\right)$

Then,

$$\mathrm{Min}(\max(\sum_{i=1}^{m}\sum_{i=1}^{n} x_{i1}+x_{i2}+x_{13}+x_{14}+x_{5}+x_{i6}+x_{i7}+x_{i8}+x_{i9}+x_{i10}+x_{i11}+x_{i12}+x_{i13}+x_{i14}+x_{i15}+x_{i16}+x_{i17}+x_{i18}+d_{ij}))$$

To determine the service point, the min-max approach is used. So that each service cannot travel too far to the point of service under consideration. Where to find the min-max value can be used TOPSIS method. In the TOPSIS method, the alternative that is closest to the positive ideal solution and farthest from the negative ideal solution is the optimal alternative. TOPSIS steps can be seen as follows:

a. Determine alternative and criteria, where alternatives are Alang-Alang Lebar Sub-district (x_1), Bukit Kecil sub-district (x_2), and so on up to Sukarami sub-district (x_{18}). For Criteria (C), namely Hospitals and Clinics that have Emergency Units facilities, namely Rika Amelia Hospital (c_1) and so on until the Moulya's clinic (c_7).
b. Create a normalized decision matrix, by squaring each distance $(y_i)^2$ on $x_1$and then adding it to $(y_1)^2$ on (x_2) to $(y_1)^2$ onx_{18}. Then y_1(entry distance) is divided by the result of the sum above. Do the same for the next.
c. Multiply each element of the normalized decision matrix by the weights listed in TABLE 3 to create a weighted normalized decision matrix.

TABLE 3. Parameter Value

Parameter	Parameter Value	Parameter	Parameter Value
a_1	1	a_{10}	0
a_2	2	a_{11}	0
a_3	0	a_{12}	1
a_4	1	a_{13}	0
a_5	0	a_{14}	0
a_6	0	a_{15}	0
a_7	2	a_{16}	0
a_8	0	a_{17}	0
a_9	0	a_{18}	0

d. Determine the positive ideal solution matrix and negative ideal solution matrix, by grouping the values of the weighted normalized decision matrix in each column which is divided into two parts, namely positive (for the largest value) and negative (for the smallest value). TABLE 4 explains the positive and negative ideal solution matrix, respectively.

TABLE 4. Positive Ideal solution Matrix and Negative Ideal Solution Matrix

Y^+	Value	Y^-	Value
${Y_1}^+$	0.475010102	${Y_1}^-$	0
${Y_2}^+$	0.396088144	${Y_2}^-$	0
${Y_3}^+$	0.333868444	${Y_3}^-$	0
${Y_4}^+$	0.313678581	${Y_4}^-$	0
${Y_5}^+$	0.578396547	${Y_5}^-$	0
${Y_6}^+$	0.456161637	${Y_6}^-$	0
${Y_7}^+$	0.466956011	${Y_7}^-$	0

e. With the positive ideal solution matrix and the negative ideal solution matrix, calculate the distance between the values of each alternative. For positive ones, subtract each column of the positive matrix with entries in rows $y_1$to y_7 and then take the root. As for negative, it subtracts each row $y_1$to y_7 to each entry in the negative matrix, like explained in TABLE 5.

TABLE 5. The Distance Between the Values of Each Hospital Alternative and The Positive Ideal Solution Matrix

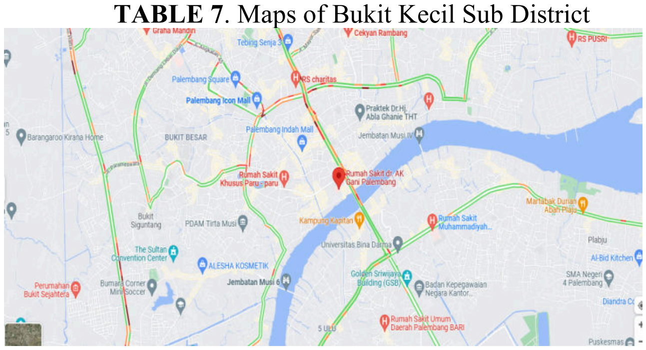
D^+	Value	D^-	Value
${D_1}^+$	0.506185252	${D_1}^-$	0.811155387
${D_2}^+$	0.599800685	${D_2}^-$	1.104305571
${D_3}^+$	1.163209665	${D_3}^-$	0
${D_4}^+$	0.742071979	${D_4}^-$	0.450211973
${D_5}^+$	1,163209665	${D_5}^-$	0
…	…	…	…
${D_7}^+$	0.466956011	${D_7}^-$	0

Then, calculate the preference value for each alternative with $\frac{D_1^-}{{D_1}^- + {D_1}^+}$. Alang-Alang Lebar Sub-district in the ideal negative solution D^- which is 0.811155837 divided by the value of Alang-Alang Lebar Sub-district in the negative solution D^- which is 0.811155837 plus the value of Alang-Alang Lebar Sub-district in the positive solution D^+ which is 0.506185252 will produce an alternative in TABLE 6 in Alang-Alang Lebar Sub-district with a preference value (v) in TABLE 6 Alang-Alang Lebar Subdistrict which is 0.615752193 and do it until Sukarami Sub-district x_{18}. We can be seen in TABLE 6 as follows:

TABLE 6. Preferences Values for Each Alternative

V	Preferences Values
V_1	0.615752193
V_2	0.648026241
V_3	0
V_4	0.377604605
V_5	0
V_6	0
V_7	0.595392375
V_8	0
V_9	0
V_{10}	0
V_{11}	0
V_{12}	0.555375382
V_{13}	0
V_{14}	0
V_{15}	0
V_{16}	0
V_{17}	0
V_{18}	0

TABLE 7. Maps of Bukit Kecil Sub District



From TABLE 6, it can be seen that the largest preference value is in Bukit Kecil Sub-district (V_2) is DR.AK Gani Hospital and Pulmonary Specialty Hospital. TABLE 7 displays the maps of one the sub-district which has the facility location.

CONCLUSION

Based on the results of research that has been carried out, the optimal location of hospitals and clinics that have Emergency Unit facilities is located in the Bukit Kecil sub-district. TOPSIS method is applied to determine the optimal location of hospitals that have Emergency Unit facilities in Palembang City. The optimal location of the emergency department in the sub-districts was obtained which was sorted by the most optimal as follows.

1. Bukit Kecil sub district
2. Alang-Alang Lebar sub district
3. Ilir Timur II sub district
4. Kertapati sub district
5. Ilir Barat I sub district

ACKNOWLEDGMENT

On November 23, 2020, DIPA of the Public Service Agency of Universitas Sriwijaya 2021, SP DIPA-023.17.2.677515 /2021, supported the publishing of this article. On April 28, 2021, the Rector's Decree Number: 0010/ UN9/ SK.LP2M.PT/2021 was issued.

REFERENCES

[1] P.H. Kumar and R. Mageshvaran, Int. J. Sci. Technol. Res. **9**, 1872 (2020).
[2] E. Özceylan, S. Mete, and Z.A. Çil, Proc. 14th Int. Symp. Oper. Res. SOR 2017 **2017-Septe**, 141 (2017).
[3] J. Bendík, in *2015 IEEE 13th Int. Sci. Conf. Informatics, INFORMATICS 2015 - Proc.* (2016), pp. 47–51.
[4] R. Sitepu, F.M. Puspita, and S. Romelda, Annu. Res. Semin. 2018 (2018).
[5] A.K. Vatsa and S. Jayaswal, Eur. J. Oper. Res. **289**, 1107 (2021).
[6] S. Dantrakul, C. Likasiri, and R. Pongvuthithum, Expert Syst. Appl. **41**, 3596 (2014).
[7] F.J. Vasko, Y. Lu, and K. Zyma, Oper. Res. Lett. **44**, 366 (2016).
[8] S. Octarina, D.G. Juita, N. Eliyati, and P.B.J. Bangun, Sci. Technol. Indones. **5**, 121 (2020).
[9] M. Basti and M. Sevkli, Int. J. Metaheuristics **4**, 91 (2015).
[10] M. Dzator and J. Dzator, in *Data Decis. Sci. Action, Lect. Notes Manag. Ind. Eng.*, edited by S. Dunstall and L. Young (Springer International Publishing AG 2018, 2017).
[11] P. Kirci, Sadhana - Acad. Proc. Eng. Sci. **41**, 519 (2016).
[12] S.S. Mohri and H. Haghshenas, Comput. Ind. Eng. **151**, 106937 (2021).
[13] R. Sitepu, F.M. Puspita, S. Romelda, A. Fikri, B. Susanto, and H. Kaban, J. Phys. Conf. Ser. **1282**, (2019).
[14] A. Ahmadi-Javid, P. Seyedi, and S.S. Syam, Comput. Oper. Res. **79**, 223 (2017).
[15] M. Bashiri and F. Fotuhi, in *IEEM 2009 - IEEE Int. Conf. Ind. Eng. Eng. Manag.* (2009), pp. 1979–1983.
[16] D. Juliandri, H. Mawengkang, and F. Bu'Ulolo, in *IOP Conf. Ser. Mater. Sci. Eng.* (2018).
[17] A. Ardiansyah and Mardlijah, J. Phys. Conf. Ser. **1373**, 337 (2019).
[18] G. Sürmeli, I. Kaya, and M. Erdoɫan, in *6th Int. Conf. Model. Simulation, Appl. Optim. ICMSAO 2015 - Dedic. to Mem. Late Ibrahim El-Sadek* (2015).
[19] Z.I. Mohamadabadi, R. Azari, and E. Shadkam, Int. J. Adv. Robot. Expert Syst. **1**, 19 (2019).
[20] A.Y. Chen and T.Y. Yu, Transp. Res. Part B Methodol. **91**, 408 (2016).
[21] J. Men, P. Jiang, S. Zheng, Y. Kong, Y. Zhao, G. Sheng, N. Su, and S. Zheng, IEEE Trans. Intell. Transp. Syst. **21**, 4749 (2020).
[22] C. Surya, J. RESTI (Rekayasa Sist. Dan Teknol. Informasi) **2**, 322 (2018).
[23] R. Sitepu, F.M. Puspita, S. Romelda, A. Fikri, B. Susanto, and H. Kaban, in *J. Phys. Conf. Ser.* (2019).
[24] W. Pettersson, M. Delorme, S. García, J. Gondzio, J. Kalcsics, and D. Manlove, Comput. Oper. Res. **128**, 105128 (2021).
[25] J.P. Messina, A.M. Shortridge, R.E. Groop, P. Varnakovida, and M.J. Finn, Int. J. Health Geogr. **5**, 1 (2006).