RESEARCH ARTICLE | FEBRUARY 16 2024

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AIP Conf. Proc. 3046, 020058 (2024)
https://doi.org/10.1063/5.0194551

Fuzzy Model Set Cover Problem of Optimal Location of Emergency Departments in Palembang Based on Technique for Order Preference by Similarity to Ideal Solution Method with Some Criteria

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Abstract. This research was conducted to determine the nearest hospital that has Emergency Department (ED) facilities in each district of Palembang City. The research objective is to design the optimal location of ED facilities in Palembang with criteria involving the type of hospital and the number of general practitioners in hospitals. Gojek application to find the cost of public transportation from districts to hospitals with ED facilities. Then, this study discussed the optimal location of hospitals with ED facilities in Palembang City with the fuzzy set cover problem (SCP) models based on the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method. Fuzzy SCP models solved by the TOPSIS method solve problems in selection or ranking based on several criteria. The most optimal ED location is visited based on mileage criteria, travel time, hospital type, and public transportation costs. The results obtained at the optimal location in each district in Palembang City are different. One of the results were the order of hospitals' location that have the most optimal ED facilities visited by people from Alang-Alang Lebar District, namely RSU Muhammad Hoesin – RSU RK Charitas – RSU Palembang Bari – RSK Ernaldi Bahar – RSU Bunda.

INTRODUCTION

The concept of facility locations has been introduced in some research [1][2][3]. This study, it was discussed the problem of determining hospitals that have emergency department (ED) facilities [4][5][6] which are influenced by several criteria using a fuzzy set cover problem model [7][8][9]. The type of data used in this study is secondary data to determine the optimal ED solution in each district based on its characteristics: distance, time, type of hospital, number of doctors, and public transportation costs. The data was obtained from the Palembang BPS website, google maps, the Health Human Resources Development and Empowerment Agency (BPPSDMK) website, and the Gojek application. Website BPS Palembang City is used to find out the number of districts in Palembang City, google maps is used to find the distance and travel time from the district to the hospital that has ED facilities, the BPPSDMK website is used to find the type of hospital and the number of general practitioners in the hospital. The Gojek application is used to find the cost of public transportation from districts to hospitals with ED facilities.

Proceeding of the 7th National Conference on Mathematics and Mathematics Education (SENATIK)
AIP Conf. Proc. 3046, 020058-1–020058-11; https://doi.org/10.1063/5.0194551
Published by AIP Publishing. 978-0-7354-4834-6/$30.00

According to the official website of BPS Palembang City, in 2019, Palembang City had 18 districts with 23 hospitals with ED facilities. This study was conducted to find the nearest hospital with ED facilities in each district of Palembang City, as well as determine the optimal location using the TOPSIS method based on predetermined criteria. Thus, it can provide a hospital location [10][11][12] that has optimal ED facilities from a mathematical point of view. In addition, it is hoped that it can make it easier for the community to determine the hospital with the most optimal ED facilities to visit. This research contributes to the lack of information for society to know the nearest location to their homes for visiting ED facilities. It needs to design the formulation for choosing the best location for visiting ED facilities.

The formulation of the problem in this study is how to determine the optimal location in determining hospitals that have ED facilities based on criteria using fuzzy set cover problems [13] with the TOPSIS method [12][14][15] to get the nearest and optimal location [16][17]. The problems in this study are limited to the criteria of mileage, travel time, and cost of public transportation [18][19] from each district to hospitals with emergency room facilities, assumed to be smooth and not congested. The study aimed to determine the optimal ED location in each district in Palembang City based on predetermined criteria [14][20] by applying a fuzzy set cover problem model in the TOPSIS method. TOPSIS is the suitable method to be chosen for the problem of allocation of ED facilities if it involves some fuzzy criteria such as type of hospital and the number of general practitioners in hospitals, Gojek application to find the cost of public transportation from districts to hospitals that have ED facilities. The benefit of this study is that the Palembang City Health Office can use it to determine the optimal location of hospitals with ED facilities in each district of Palembang City.

METHOD

The data used in this study are secondary data, which include: (1) The name of the hospital that has emergency room facilities in 18 districts of Palembang City. (2) Distance from each district to the emergency room. (3) Travel time from each district to the emergency room. (4) Type of hospital that has emergency room facilities. (5) The number of doctors in hospitals that have emergency room facilities. (6) The cost of public transport.

The steps taken in this study are as follows: (1) Describe the data obtained from the BPS Palembang City website to find out the number of districts in Palembang City, google maps to find the distance and travel time from districts to hospitals that have ED facilities, the website of the Human Resources Development and Empowerment Agency (BPPSDMK) to find the type of hospital and the number of general practitioners in hospitals, Gojek application to find the cost of public transportation from districts to hospitals that have ED facilities. (2) Determine the alternative linguistic weights for each district and its criteria. (3) Determine the numerical weight of each criterion with a fuzzy value in the range [0, 1]. (4) Compiling the optimal hospital for each district using the TOPSIS method. (6) Analyze the results consisting of the chosen facilities that need to be visited, which are the closest in each district.

RESULT AND DISCUSSION

According to the Palembang City Health Office, in 2018, 23 hospitals had ED facilities from 18 districts. Table 1 explains the list of districts that have ED facilities in the city of Palembang. Based on Table 1, it is known that 23 hospitals have ED facilities in 13 districts of Palembang city, while the other five districts do not have hospitals with ED facilities. Table 2 lists all notations for the districts having the ED facilities, while Table 3 shows the determination of notation for hospitals that have er as an alternative point. Table 4 displays the determination of the notation for each criterion listed. Table 5 shows mileage data for each point of demand a_i to each alternative point of ed b_i. In Addition, Table 6 explains travel time data of demand point a to an alternative point of ed b.

TABLE 1. List of hospitals that have emergency room facilities.

Subdistrict Name	The Name of The Hospital that Has An ED Facility
Alang-alang Lebar	RSK Ernaldi Bahar
Bukit Kecil	Dr. AK Gani Hospital
	Eye Hospital
Gandus	-
Ilir Barat I	Mother's Hospital
	Siti Khodijah Hospital

Subdistrict Name	The Name of The Hospital that Has An ED Facility
	RSIA Mother Noni
	Siloam Sriwijaya Hospital
Ilir Barat II	-
Kertapati	RSIA Cadre nation
Seberang Ulu I	Palembang Bari Regional Hospital
Seberang Ulu II	Muhammadiyah Hospital
Ilir Timur I	RSIA YK Madira
	RSU RK Charitas
	Sriwijaya Hospital
Ilir Timur II	RSIA Trinanda
Ilir Timur III	-
Kalidoni	RSIA Az-zahra
	PUSRI HOSPITAL
Kemuning	Muhammad Hoesin Hospital
	Hermina Hospital
Plaju	RSU Pertamina
	RSIA Marissa
Sako	
Sematang Borang	RSU By Asih Charitas
Sukarami	RSU Ar-rasyid
	Myria Hospital
Jakabaring	-

Table 1 shows the list of hospital names is presented that have ED facilities according to the data from Health Department in Palembang. Table 2 shows the names of all districts in Palembang, where Palembang has 18 districts.

TABLE 2. Determination of notation for district names as point of demand.

Notation	District Name
a_1	Alang-alang Lebar
a_2	Bukit Kecil
a_3	Gandus
a_4	Ilir Barat I
a_5	Ilir Barat II
a_6	Kertapati
a_7	Seberang Ulu I
a_8	Seberang Ulu II
a_9	Ilir Timur I
a_{10}	Ilir Timur II
a_{11}	Ilir Timur III
a_{12}	Kalidoni
a_{13}	Kemuning
a_{14}	Plaju
a_{15}	Sako
a_{16}	Sematang Form
a_{17}	Sukarami
a_{18}	Jakabaring

Table 3 determined the notations for all Eds in Palembang hospitals. It helps to model integer linear programming problems. Furthermore, in Table 4, the criteria assigned were listed. For example, c_1 refers to the distance from the district to ED.

TABLE 3. Determination of notation for hospitals that have ED as an alternative point.

Notation	Hospital Name
b_1	RSK Ernaldi Bahar
b_2	Dr. AK Gani Hospital
b_3	Eye Hospital
b_4	Mother's Hospital
b_5	Siti Khodijah Hospital
b_6	RSIA Mother Noni
b_7	Siloam Sriwijaya Hospital
b_8	RSIA Cadre nation
b_9	Palembang Bari Regional Hospital
b_{10}	Muhammadiyah Hospital
b_{11}	RSIA Yk Madira
b_{12}	RSU RK Charitas
b_{13}	Sriwijaya Hospital
b_{14}	RSIA Trinanda
b_{15}	RSIA Az-Zahra
b_{16}	Pusri Hospital
b_{17}	Muhammad Hoesin Hospital
b_{18}	Hermina Hospital
b_{19}	RSU Pertamina
b_{20}	RSIA Marissa
b_{21}	RSU By Asih Charitas
b_{22}	Ar-Rasyid Hospital
b_{23}	Myria Hospital

TABLE 4. Determination of notation for each criterion.

Notation	Criterion
c_1	Distance from district to ED
c_2	Travel time from district to ED
c_3	Types of each hospital
c_4	Number of general practitioners in hospitals
c_5	The cost of public transport

TABLE 5. Mileage data for each point of demand a_i to each alternative point of ED b_i.

f_{ab}	Criteria (c_1)											
	b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8	b_9	b_{10}	...	b_{23}
a_1	2.8	13	7.3	8.7	10	9.5	12	18	17	16	...	6.0
a_2	14	13	6.6	3.9	3.9	2.7	2.1	9.2	7.1	6.6	...	9.8
a_3	13	16	14	12	11	9.3	13	14	13	14	...	16
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	...	⋮
a_{18}	6.9	11	4.3	7.0	8.2	9.8	9.3	17	14	14	...	3.1

TABLE 6. Travel time data of demand point a_i to alternative point of ED b_i.

f_{ab}	Criteria (c_2)											
	b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8	b_9	b_{10}	...	b_{23}
a_1	7	26	14	18	19	19	24	36	33	33	...	12
a_2	27	26	14	10	10	6	6	20	15	15	...	19
a_3	29	34	29	24	25	20	29	25	34	36	...	32
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	...	⋮
a_{18}	18	28	10	19	21	25	23	41	34	34	...	7

TABLE 7. Data on the type of each hospital that has an ED.

Alternative	Criteria (c_3)
b_1	A
b_2	C
b_3	B
⋮	⋮
b_{23}	C

TABLE 8. Data on the number of general practitioners in each hospital.

Alternative	Criteria (c_4)
b_1	17
b_2	23
b_3	0
⋮	⋮
b_{23}	11

TABLE 9. GoCar Cost (IDR) data demand point a_i to alternative point of ED b_i.

f_{ab}	Criteria (c_5)						
	b_1	b_2	b_3	b_4	b_5	...	b_{23}
a_1	18,000	55,000	32,000	84,000	42,000	...	28,000
a_2	44,000	18,000	31,000	22,000	25,000	...	47,000
a_3	54,000	18,000	34,000	45,000	43,000	...	66,000
⋮	⋮	⋮	⋮	⋮	⋮	⋯	⋮
a_{18}	28,000	43,000	21,000	29,000	31,000	...	19,000

Table 5 shows the mileage data for each point of demand a_i to each alternative point of ED b_i. Meanwhile, Table 6 shows travel time data of demand point a_i to alternative point of ED b_i. Table 7 explains data on the type of each hospital with an ED, Table 8 shows the number of general practitioners in each hospital, and Table 9 GoCar cost data demand point a_i to ED alternative point b_i.

Determination of Linguistic Weights and Alternative Numerical Weights for Each District

Mileage Criteria from Each Subdistrict to the Emergency Room

1. 24.1 – 30 km = Very Far (SJ) = 0
2. 20.1 – 24 km = Far (J) = 0.25
3. 15.1 – 20 km = Medium (S) = 0.50
4. 10.1 – 15 km = Close (D) = 0.75
5. 0.5 – 10 km = Very Close (SD) = 1

Travel Time Criteria from Each Subdistrict to the Emergency Room

1. > 40 = Very Long (SL) = 0
2. 31 – 40 = Length (L) = 0.25
3. 21 – 30 = Medium (S) = 0.50
4. 11 – 20 = Fast (C) = 0.75
5. 1 – 10 = Very Fast (SC) = 1

Type Criteria of Each Hospital

1. Undetermined = 0
2. Type D = 0.25
3. Type C = 0.50
4. Type B = 0.75
5. Type A = 1

Criteria for the Number of General Practitioners in Each Hospital

1. 0 – 10 Doctors = Very Few (SS) = 0
2. 11 – 20 Doctors = Little (S) = 0.25
3. 21 – 30 Doctors = Enough (C) = 0.50
4. 31 – 40 Doctors = Lots (B) = 0.75
5. 41 – 50 Doctors = Very Many (SB) = 1

Public Transportation Cost Criteria
1. > IDR 80,000 = Very Expensive (SMH) = 0
2. IDR 61,000 – IDR 80,000 = Expensive (MH) = 0.25
3. IDR. 41,000 – IDR 60,000 = Medium (S) = 0.50
4. IDR. 21,000 – IDR 40,000 = Cheap (M) = 0.75
5. IDR 1,000 – IDR. 20,000 = Very Cheap (SM) = 1

Then, Table 10 lists the alternative linguistic weights for Alang-Alang Lebar, Table 11 lists the alternative numerical weights for Alang-Alang Lebar, Table 12 explains the linguistic weights for each criterion, and Table 13 explains the numerical weights for each criterion.

TABLE 10. Alternative linguistic weights for Alang-Alang Lebar District.

Alternative	Criterion				
	c_1	c_2	c_3	c_4	c_5
b_1	SD	SC	A	S	BC
b_2	D	S	C	C	S
b_3	SD.	C	B	SS.	M
⋮	⋮	⋮	⋮	⋮	⋮
b_{23}	SD.	C	C	S	M

TABLE 11. Alternative numerical weights for Alang-Alang Lebar District.

Alternative	Criterion				
	c_1	c_2	c_3	c_4	c_5
b_1	1	1	1	0.25	1
b_2	0.75	0.50	0.50	0.50	0.50
b_3	1	0.75	0.75	0	0.75
⋮	⋮	⋮	⋮	⋮	⋮
b_{23}	1	0.75	0.50	0.25	0.75

TABLE 12. Linguistic weights for each criterion.

Criterion	Weight
Distance from district to Ed	Very Important
Travel time from district to ED.	Very Important
Types of each hospital	Important Enough
Number of general practitioners in hospitals	Important
The cost of public transport	Important Enough

TABLE 13. Numerical weights for each criterion.

Criterion	Weight
Distance from district to ED	1
Travel time from district to ED	1
Types of each hospital	0.50
Number of general practitioners in hospitals	0.75
The cost of public transport	0.50

Then, proceed with the search for the most optimal hospital ranking for each district using the TOPSIS Method as follows.
1. Create a Normalized Decision Matrix in Each District, as stated in the formulation.

$$t = \frac{a_{11}}{\sqrt{a_{11}^2 a_{21}^2 a_{31}^2 \dots a_{231}^2}} = \frac{1}{3.7416} = 0.2673$$

Then, Table 14 shows all the calculations created.

TABLE 14. Normalized matrix for Alang-Alang Lebar District.

Alternative	Criterion				
	c_1	c_2	c_3	c_4	c_5
b_1	0.2673	0.3564	0.3522	0.1474	0.4083
b_2	0.2004	0.1782	0.1761	0.2949	0.2041
b_3	0.2673	0.2673	0.2641	0	0.3062
⋮	⋮	⋮	⋮	⋮	⋮
b_{23}	0.2673	0.2673	0.1761	0.1747	0.3062

2. Create a Weighty Normalized Decision Matrix for Each District

   Table 15 shows the weight values created. Meanwhile, Table 16 displays the weighted normalized matrix calculation for one district.

TABLE 15. Weight values of each *fuzzy criterion* in the range [0, 1].

c_1	c_2	c_3	c_4	c_5
1	1	0.5	0.75	0.5

$$b_{11} = w_1 t_{11} = 1(0.2673) = 0.2673$$

TABLE 16. Weighted normalized matrix for Alang-Alang Lebar District.

Alternative	Criterion				
	c_1	c_2	c_3	c_4	c_5
b_1	0.2673	0.3564	0.1761	0.1106	0.2041
b_2	0.2004	0.1782	0.0880	0.2212	0.1021
b_3	0.2673	0.2673	0.1321	0	0.1531
⋮	⋮	⋮	⋮	⋮	⋮
b_{23}	0.2673	0.2673	0.0881	0.1310	0.1531

3. Determination of Positive Ideal Solution Matrix and Negative Ideal Solution Matrix Based on TOPSIS Method for Each District

   Based on the calculation of the positive ideal solution to determine the most optimal hospital for each sub-district, namely, includes criteria with maximum conditions or attributes of profit. It includes the cost attribute criteria, i.e., each criterion's selected value is the minimum value. The calculation of the negative ideal solution to determine the most optimal hospital for each district includes criteria that have minimal requirements or are attributes of profit. Includes the cost attribute criteria; the selected value is the maximum value of each criterion. Positive Ideal Solution Matrix and Negative Ideal Solution Matrix for Alang-Alang Lebar District.

   Positive Ideal Solution Matrix:

$$M^+ = \left[b_1^+, b_2^+, b_3^+, b_4^+, b_5^+ \right]$$

   = [0.2673 0.3564 0.1761 0.4423 0]

   Negative Ideal Solution Matrix:

$$M^- = \left[b_1^-, b_2^-, b_3^-, b_4^-, b_5^- \right]$$

   = [0.0668 0 0 0 0.2041]

4. Determination of the Distance between the Value of Each Alternative with the Positive Ideal Solution Matrix and the Negative Ideal Solution Matrix Based on the TOPSIS Method for Each District

   Positive Ideal Solution:

$$A_1^+ = \sqrt{\left(b_{11} - b_1^+\right)^2 + \left(b_{12} - b_2^+\right)^2 + \cdots \left(b_{15} - b_5^+\right)^2}$$

$$A_1^+ = \sqrt{(0.2673 - 0.2673)^2 + (0.3564 - 0.3564)^2 + \cdots (0.2041 - 0)^2} = 0.3895$$

Negative Ideal Solution:

$$A_1^- = \sqrt{\left(b_{11} - b_1^-\right)^2 + \left(b_{12} - b_2^-\right)^2 + \cdots \left(b_{15} - b_5^-\right)^2}$$

$$A_1^- = \sqrt{\left(0.2673 - 0.0668\right)^2 + \left(0.3564 - 0\right)^2 + \cdots \left(0.2041 - 0.2041\right)^2} = 0.4587$$

Then, all calculations were displayed in Table 17 regarding the distance between the value of each alternative with the positive ideal solution matrix and the negative ideal solution matrix for the Alang Alang Lebar.

TABLE 17. Distance between the value of each alternative with the positive ideal solution matrix and the negative ideal solution matrix for the Alang Alang Lebar.

A^+	Value	A^-	Value
A_1^+	0.3895	A_1^-	0.4587
A_2^+	0.3214	A_2^-	0.3416
A_3^+	0.4785	A_3^-	0.3629
⋮	⋮	⋮	⋮
A_{23}^+	0.3688	A_{23}^-	0.3731

5. Determination of Preference Value for Each Alternative Based on the TOPSIS Method in Each Subdistrict.

$$p_1 = \frac{A_1^-}{A_1^+ + A_1^-} = \frac{0.4587}{0.3895 + 0.4587} = 0.5408$$

Calculate all preference values, then list them in Table 18.

TABLE 18. Preference values of each alternative for Alang-Alang Lebar District.

	Preference Value
p_1	0.5408
p_2	0.5153
p_3	0.4313
p_4	0.5400
p_5	0.5190
p_6	0.4335
p_7	0.4109
p_8	0.2775
p_9	0.5537
p_{10}	0.3403
p_{11}	0.4080
p_{12}	0.7034
p_{13}	0.4189
p_{14}	0.2511
p_{15}	0.3661
p_{16}	0.3403
p_{17}	0.7076
p_{18}	0.4284
p_{19}	0.2675
p_{20}	0.2675
p_{21}	0.3252
p_{22}	0.4189
p_{23}	0.5029

Based on Table 18, five hospital sequences were obtained from the most optimally visited for the people of Alang-Alang Lebar District, namely Muhammad Hoesin Hospital, RK Charitas Hospital, Palembang Bari Hospital, Ernaldi Bahar Hospital, and Bunda Hospital as stated in Table 19. Figure 1 shows the position of all ED facility locations in Palembang.

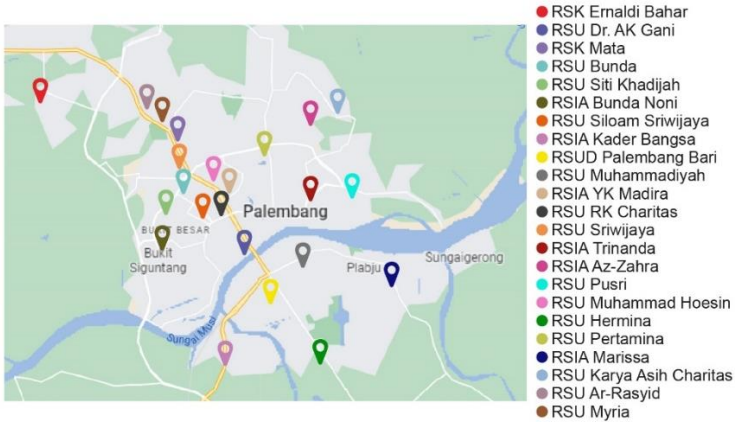

FIGURE 1. Optimal location of ED facilities in Palembang.

TABLE 19. Most optimal ED for each district.

No.	District	Hospitals That Have the Most Optimal Emergency Room Facilities				
		First Order	Second Order	Third Order	Fourth Order	Fifth Order
1.	Alang-Alang Lebar	Muhammad Hoesin Hospital	RSU RK Charitas	Palembang Bari Hospital	RSK Ernaldi Bahar	Mother's Hospital
2.	Bukit Kecil	RSU RK Charitas	Muhammad Hoesin Hospital	Palembang Bari Hospital	Dr. AK Gani Hospital	Siti Khodijah Hospital
3.	Gandus	RSU RK Charitas	Muhammad Hoesin Hospital	Palembang Bari Hospital	RSK Ernaldi Bahar	RSIA Mother Noni
4.	Ilir Barat I	RSU RK Charitas	Muhammad Hoesin Hospital	Palembang Bari Hospital	Dr. AK Gani Hospital	Siti Khodijah Hospital
5.	Ilir Barat II	RSU RK Charitas	Muhammad Hoesin Hospital	Palembang Bari Hospital	Dr. AK Gani Hospital	Siloam Sriwijaya Hospital
6.	Ilir Timur I	RSU RK Charitas	Muhammad Hoesin Hospital	Palembang Bari Hospital	Dr. AK Gani Hospital	RSK Ernaldi Bahar
7.	Ilir Timur II	RSU RK Charitas	Muhammad Hoesin Hospital	Palembang Bari Hospital	Dr. AK Gani Hospital	RSK Ernaldi Bahar
8.	Ilir Timur III	RSU RK Charitas	Muhammad Hoesin Hospital	Palembang Bari Hospital	Dr. AK Gani Hospital	RSK Ernaldi Bahar
9.	Jakabaring	RSU RK Charitas	Palembang Bari Hospital	Muhammad Hoesin Hospital	Dr. AK Gani Hospital	Muhammadiyah Hospital
10.	Kalidoni	Muhammad Hoesin Hospital	RSU RK Charitas	Palembang Bari Hospital	Dr. AK Gani Hospital	Pusri Hospital
11.	Kemuning	RSU RK Charitas	Muhammad Hoesin Hospital	Palembang Bari Hospital	Dr. AK Gani Hospital	Hermina Hospital
12.	Kertapati	RSU RK Charitas	RSU Palembang Bari	RSU Dr. AK Gani	RSU Muhammad Hoesin	RSIA Kader Bangsa
13.	Plaju	RSU RK Charitas	RSU Palembang Bari	RSU Muhammad Hoesin	RSU Dr. AK Gani	RSU Muhammadiyah

14.	Sako	RSU Muhammad Hoesin	RSU RK Charitas	RSU Palembang Bari	RSU Dr. AK Gani	RSU Siti Khodijah
15.	Seberang Ulu I	RSU RK Charitas	RSU Muhammad Hoesin	RSU Palembang Bari	RSU Dr. AK Gani	RSU Muhammadiyah
16.	Seberang Ulu II	RSU RK Charitas	RSU Muhammad Hoesin	RSU Palembang Bari	RSU Dr. AK Gani	RSU Muhammadiyah
17.	Sematang Borang	RSU RK Charitas	RSU Muhammad Hoesin	RSU Palembang Bari	RSU Pusri	RSU Dr. AK Gani
18.	Sukarami	RSU Muhammad Hoesin	RSU RK Charitas	RSU Palembang Bari	RSU Myria	RSU Dr. AK Gani

In Table 19, the summary of steps for the TOPSIS method for each district is obtained, the calculations for TOPSIS steps are listed from steps 1-4 of TOPSIS, and the repetition steps to obtain Table 14-Table 18 are also conducted again.

CONCLUSION

Based on the results and discussion using a fuzzy set cover problem model with the TOPSIS method in determining the optimal location of hospitals that have emergency department facilities from each district, the order of hospitals with the most optimal emergency ED facilities is visited according to the criteria for mileage, travel time, type of each hospital, the number of general practitioners in each hospital and the cost of public transportation as suggested in Fig 1 and Table 19. The people in each area can choose the ED facilities according to their nearest location from home to facilities. For further research, the fuzzy SCP model with the TOPSIS method can be used to determine the optimal location in several selected criteria, for example, the location of schools, restaurants, bus stops, lodging, and garbage disposal locations.

ACKNOWLEDGMENTS

DIPA of Public Service Agency of Universitas Sriwijaya 2022 funded the research/publication of this article. SP DIPA-023.17.2.677515/2022 on December 13, 2021. In accordance with the Rector's Decree Number:0109/UN9.3/SK/2022, on April 28, 2022

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