Facility Location Problem of Dynamic Optimal Location of Hospital Emergency Department in Palembang

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Submission date: 16-Jun-2022 01:48PM (UTC+0700)
Submission ID: 1857786573
File name: sti-template.pdf (1.67M)
Word count: 3837
Character count: 18097

Science and Technology Indonesia
e-ISSN:2580-4391 p-ISSN:2580-4405
Vol. 7, No. 2, April 2022

Research Paper

Facility Location Problem of Dynamic Optimal Location of Hospital Emergency Department in Palembang

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Abstract
The Emergency Department (ED) is one part of a hospital that provides initial treatment for patients who suffer from illness and injury, which can threaten their survival. The importance of integrated care in the ED is one of the keys to successfully treating patients at an advanced level. This becomes complex because the ED works in a team consisting of various multi-disciplinary sciences and limited human resources, facilities, and infrastructure. In the City of Palembang, 23 hospitals have emergency room facilities from 18 Sub-Districts, by using the TOPSIS (Technique for Others Reference by Similarity to Ideal Solution) method to vary the distance (radius) the optimal location of the emergency department is obtained according to the number of hospitals that have emergency room facilities, namely Ilir Timur I District, Ilir Barat I District, Sukarami District, and Plaju District. Based on the formulation of the p-median model and the completion of the TOPSIS method, the order of Districts that have optimal locations from 18 Sub-Districts that have emergency department facilities in the City of Palembang is obtained.

Keywords
Optimal Location, Emergency Department, P-Median Problem, TOPSIS Method, Palembang

Received: 3 January 2022, Accepted: 14 April 2022
https://doi.org/10.26554/sti.2022.7.2.251-256

1. INTRODUCTION

The optimal location problems deal with the finding of the optimal location of the facilities (Guzmán et al., 2016), formed the set covering problem (SCP) (Doungpan, 2020; Octarina et al., 2020; Zhang and Zhang, 2015). In practical situations, it deals with the set of public facilities such as hospitals (Sitepu et al., 2019; Mohri and Haghshenas, 2021), waste bin allocation (Puspita et al., 2019), gas stations, and so on (Özceylan et al., 2017).

Some research focused on hospital or emergency unit (Ahmadi et al., 2017; Priyandari et al., 2011; Sadatasl et al., 2016), explain that ED is an emergency place in which a person needs immediate help because if he does not get immediate help, it can threaten his life or save him permanently. In these circumstances, the role of the hospital is very important (Chen and Yu, 2016; Memari et al., 2018). One of the these are hospital's supporting facilities, namely the emergency room and the availability and the closest location to reduce the risk of death due to the distance of the hospital location that can be reached. Most models of SCP only deal with the ability to set optimal facility location if the only parameter known would be the distance between facilities and distance between facilities and population (Sitepu et al., 2019).

Some approaches are available to solve SCP using exact (Sitepu et al., 2019; Sitepu et al., 2018), or heuristics methods (Yuliza et al., 2021; Avrahami and Israeli, 2013; Octarina et al., 2020; Puspita et al., 2019). Based on research that has been done previously by Sitepu et al. (2018) in optimizing the location of emergency installations at health facilities in Palembang City, this study extends the research that has been done by designing models with a criterion of unknown radius (Bashiri and Fotuhi, 2009), that never described before in dealing with ED di Palembang City of the facilities to be fulfilled by utilizing the TOPSIS method (Olugu et al., 2021; Sürmeli et al., 2015; Surya, 2018; Zhang et al., 2020), compared previously described by (Sitepu et al., 2019).

The TOPSIS method (Sürmeli et al., 2015), has an advantage with the ability to find the optimal alternative where the alternative is closest to the positive ideal solution and farthest from the negative ideal solution. TOPSIS requires an assessment of the performance of each alternative A_i on each of the normalized C_j criteria. The TOPSIS method is used to find the min-max value of the radius (Amaldi et al., 2013).

Then, the research is intended to seek the possible new parameter concerning the unknown radius of the population involved closest to the facilities that have never been discussed

Table 1. List of Names of Sub-Districts and Hospitals That Have ED

Sub-Districts	ED Facilities of Hospital
Alang-Alang Lebar	Ernaldi Bahar Psychiatric Hospital
Bukit Kecil	RSU Dr. AK Gani Public Hospital
	Mata Public Hospital
Gandus	-
Ilir Barat I	Bunda Public Hospital
	Siti Khodijah Public Hospital
	Bunda Noni Mother and Child Hospital
	Siloam Sriwijaya Public Hospital
Ilir Barat II	-
Kertapati	RSIA Kader Bangsa Mother and Child Hospital
Seberang Ulu I	Palembang Bari Regional Public Hospital
Seberang Ulu II	Muhammadiyah Public Hospital
Ilir Timur I	RSIA YK Madira Mother and Child Hospital
	RK Charitas Public Hospital
	Sriwijaya Public Hospital
Ilir Timur II	Trinanda Mother and Child Hospital
Ilir Timur III	-
Kalidoni	Az-zahra Mother and Child Hospital
	PUSRI Public Hospital
Kemuning	Muhammmad Hoesin Public Hospital
	Hermina Public Hospital
Plaju	Pertamina Public Hospital
	Marissa Mother and Child Hospital
Sako	-
Sematang Borang	Karya Asih Charitas Public Hospital
Sukarami	Ar-Rasyid Public Hospital
	Myria Public Hospital
Jakabaring	-

Source : CBS in Palembang, year 2019

before in any research dealing with SCP of ED in Palembang City. Lastly, the contribution of the research is to extend the research which involves the new parameter of unknown radius to be considered in solving the optimal location of ED, so enable the population that are closest to the facilities to have direct access immediately.

2. EXPERIMENTAL SECTION

2.1 Method

In this research, the type of data is secondary data from google maps in August 2021, to find the distance (in km) between hospitals in each Sub-District (center of the Sub-District) in the City of Palembang which has emergency facilities. While the method used is a descriptive model with data collection method approach that is using the document study method.

The steps taken in conducting the research are following:
(1) Describe the data used which is the distance between the center point of the District and the ED location.
(2) Measure the mileage from each request location to the facility location using the help of google maps.
(3) Define the p-median variables and parameters.
(4) Define variables and parameters for Location Set Covering Problem (LSCP), Maximal Covering Location Problem (MCLP), and p-median.
(5) Modeling using TOPSIS method.
(6) Finding a solution from the covering-based model.
(7) Analyzing the results of the covering-based model.
(8) Interpret the results obtained.

3. RESULTS AND DISCUSSION

Based on Palembang City Health Office in 2018, from 18 Sub-Districts, there are 23 hospitals that have ED facilities as in CBS (Central Bureau of Statistics) website list.

Then, assumed that: $\tilde{x}_i$ = District name, $\tilde{y}_i$ = hospital name, $\tilde{h}_i$ = number of hospitals in each District.

Then it can be seen from Table 1, the notations of each Sub-District are for example, Alang-Alang Lebar Sub-District ($\tilde{x}_1$), Bukit Kecil Sub-District ($\tilde{x}_2$), and so on until Jakabaring Sub-District ($\tilde{x}_{18}$). Then, the notations continue for RSK Ernaldi Bahar ($\tilde{y}_1$), RSU Dr. AK Gani ($\tilde{y}_2$), and so on until RSK Myria

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Table 2. Distance between Request Point *i* to Alternative ED Location *j*

d	$\tilde{y}_1$	$\tilde{y}_2$	$\tilde{y}_3$	$\tilde{y}_4$	$\tilde{y}_5$	...	$\tilde{y}_{23}$
$\tilde{x}_1$	1.7	13	8.6	10	11	...	8
$\tilde{x}_2$	14	3	4.9	2.7	3.2	...	7.6
$\tilde{x}_3$	18	12	14	12	11	...	17
$\tilde{x}_4$	12	3.7	6.5	4.3	3.8	...	7.2
$\tilde{x}_5$	14	3.2	7.1	4.9	6.2	...	8.3
$\tilde{x}_6$	19	12	14	12	11	...	15
$\tilde{x}_7$	13	3.6	3.9	2.4	2.9	...	5.4
$\tilde{x}_8$	12	5.6	3.3	3.4	3.8	...	4
$\tilde{x}_9$	5.9	11	6.2	7.7	8.1	...	9.7
$\tilde{x}_{10}$	23	4.1	8.9	8	8.5	...	10
$\tilde{x}_{11}$	17	3.8	8.7	7.8	8.3	...	13
$\tilde{x}_{12}$	16	5.5	7.7	6.8	7.3	...	9.1
$\tilde{x}_{13}$	14	6.5	5.1	5.1	5.6	...	5,4
$\tilde{x}_{14}$	18	8.4	8.9	9	9.4	...	12
$\tilde{x}_{15}$	22	8.2	13	12	13	...	14
$\tilde{x}_{16}$	16	9.7	8.3	8.3	8.8	...	9
$\tilde{x}_{17}$	19	11	10	10	11	...	18
$\tilde{x}_{18}$	25	8.9	14	13	13	...	15

Source : Google maps, taken in August 2021

Table 3. Determination The Notation for Alternatives and The Weight of The Criterion

Alternative	Weight
$\tilde{h}_1$	1
$\tilde{h}_2$	2
$\tilde{h}_3$	0
$\tilde{h}_4$	4
$\tilde{h}_5$	0
$\tilde{h}_6$	1
$\tilde{h}_7$	1
$\tilde{h}_8$	1
$\tilde{h}_9$	3
$\tilde{h}_{10}$	1
$\tilde{h}_{11}$	0
$\tilde{h}_{12}$	2
$\tilde{h}_{13}$	2
$\tilde{h}_{14}$	2
$\tilde{h}_{15}$	0
$\tilde{h}_{16}$	1
$\tilde{h}_{17}$	2
$\tilde{h}_{18}$	0

($\tilde{y}_{23}$). Furthermore, for the number of hospitals in each Sub-District will be defined as ($\tilde{h}_i$), for example, Alang-Alang Lebar Sub-District has 1 hospital ($\tilde{h}_1$), Bukit Kecil Sub-District has 2 hospitals ($\tilde{h}_2$), and so on until the Jakabaring Sub-District has 0 hospitals ($\tilde{h}_{18}$) as stated in Table 1.

Table 2 displays the distance between the request point and ED location with a distance unit of kilometers (km), it can be seen in the distance between Alang-Alang Lebar ($\tilde{x}_1$) to RSK Ernaldi Bahar ($\tilde{y}_1$) is 1.7 km, and so on until Jakabaring ($\tilde{x}_{18}$), (Myria Hospital) ($\tilde{y}_{23}$) is 15 km. To reduce the average distance between the point of request and the point of ED location, the p-median problem model is used, namely:

$$Z_{\text{p-median}} = \max \sum_{i=1}^{18} \sum_{j=1}^{32} \tilde{h}_i \tilde{d}_{ij} \tilde{x}_{ij} \quad (1)$$

Subject to

$$\tilde{x}_{1,1} + \tilde{x}_{1,2} + \tilde{x}_{1,3} + \tilde{x}_{1,4} + \tilde{x}_{1,5} + \cdots + \tilde{x}_{18,23} = 1 \quad (2)$$

$$\tilde{y}_1 + \tilde{y}_2 + \cdots + \tilde{y}_{23} = 4 \quad (3)$$

$$\tilde{x}_{i1} + \tilde{x}_{i2} + \tilde{x}_{i3} + \cdots + \tilde{x}_{i21} + \tilde{x}_{i22} + \tilde{x}_{i23} \leq \tilde{y}_j \quad (4)$$

Based on the p-median model in determining the optimal location of the emergency department with the highest number of emergency installations completed in 4 Districts. Furthermore, to find the optimal location of the hospital by using a radius to minimize the total allocation cost that does not depend on the distance between the points, namely:

$$\min \max \sum_{i=1}^{18} \sum_{j=1}^{32} \tilde{h}_i \tilde{d}_{ij} \tilde{x}_{ij} \quad (5)$$

So:

$$\min\left(\max\left(\sum_{i=1}^{m} \sum_{j=1}^{n} (\tilde{x}_{1,1} + \tilde{x}_{1,2} + \tilde{x}_{1,3} + \ldots + \tilde{x}_{2,1} + \tilde{x}_{2,2} + \tilde{x}_{2,3} + \ldots + \tilde{x}_{23}) \tilde{d}_{ij}\right)\right) \quad (6)$$

Using the min-max approach to assign service points so that each customer should not travel too far to the service point under consideration to find the value of min-max using the TOPSIS method. The optimal alternative solution in the TOPSIS method will be the one that is closest to the positive ideal solution and farthest away from the negative ideal solution. TOPSIS requires a performance rating of each alternative A_i on each normalized C_j criterion, the steps of the TOPSIS method:

a. Determine alternatives and criteria and their weights, where alternatives ($\tilde{x}_i$) Sub-District, namely Alang-Alang Lebar Sub-District (x_1), Bukit Kecil Sub-District ($\tilde{x}_2$), and so on until Jakabaring Sub-District ($\tilde{x}_{18}$). For weight namely the number of each hospital in each Sub-District, and for criterion (C)

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Table 4. Determination The Normalized Decision Matrix

d	$\tilde{C}_1$	$\tilde{C}_2$	$\tilde{C}_3$	...	$\tilde{C}_{23}$
$\tilde{x}_1$	0.101025071	0.376677119	0.222016265	...	0.168778249
$\tilde{x}_2$	0.199204365	0.086925489	0.12649764	...	0.160339337
$\tilde{x}_3$	0.256119898	0.347701956	0.361421827	...	0.35865378
$\tilde{x}_4$	0.170746598	0.107208103	0.167802991	...	0.151900424
$\tilde{x}_5$	0.199204365	0.092720522	0.183292498	...	0.175107434
$\tilde{x}_6$	0.270348781	0.347701956	0.361421827	...	0.175107434
$\tilde{x}_7$	0.184975482	0.104310587	0.100681795	...	0.316459218
$\vdots$	$\vdots$	$\vdots$	$\vdots$	...	$\vdots$
$\tilde{x}_8$	0.35572208	0.257878951	0.100681795	...	0.316459218

Table 5. Weighted Normalized Matrix

d	$\tilde{C}_1$	$\tilde{C}_2$	$\tilde{C}_3$	...	$\tilde{C}_{23}$
$\tilde{x}_1$	0.101025071	0.376677119	0.222016265	...	0.236403463
$\tilde{x}_2$	0.39840873	0.173850978	0.252995279	...	0.270175387
$\tilde{x}_3$	0	0	0	...	0
$\tilde{x}_4$	0.682986392	0.428832412	0.671211965	...	0.154385935
$\tilde{x}_5$	0	0	0	...	0
$\tilde{x}_6$	0.184975482	0.347701956	0.361421827	...	0.221929782
$\tilde{x}_7$	0.170746598	0.104310587	0.100681795	...	0.127850853
$\vdots$	$\vdots$	$\vdots$	$\vdots$	...	$\vdots$
$\tilde{x}_8$	0	0	0	...	0

where C is the same as the hospital ($y_i = C_j$), as stated in Table 2.

b. Create a normalized decision matrix, by doubling each distance $(\tilde{y}_1)^2$ on $(\tilde{x}_1)$ then adding up to $(\tilde{y}_1)^2$ on $(\tilde{x}_2)$ until $(\tilde{y}_1)^2$ on $(\tilde{x}_{18})$ then each entry distance $(\tilde{y}_1)$ is divided by the result summation above. Do the same for $(\tilde{y}_{23})$ to $(\tilde{x}_{18})$ as explained in Table 3.

c. Create a weighted normalized decision matrix, by multiplying each entry of the decision matrix is normalized with each weight as Table 4 explained.

d. Determine the positive and negative ideal solution matrices, by grouping the values of the normalized decision matrix weighted in each column into two parts, namely positive (for the value of largest) and negative (for the smallest value) as Table 5 explained.

e. Determine the distance between the value of each alternative and the ideal solution matrix positive and the ideal solution matrix is negative. For the positive in a way subtract each column of a positive matrix with entries in row $(\tilde{y}_1)$ to $(\tilde{y}_{23})$, then rooted. While for negative subtract each row $(\tilde{y}_1)$ to $(\tilde{y}_{23})$ to each entry in the negative matrix, as stated in Table 6.

f. Calculates the preference value for each alternative. With do $\frac{\tilde{x}_1^-}{\tilde{x}_1^- + \tilde{x}_1^+}$ it up to $\tilde{x}_{18}$. Then sort from the most optimal to the least optimal value, so that the most optimal location is obtained to the non-optimal location. Then we get $\tilde{x}_9$ as the most optimal location where $(\tilde{x}_9)$ Ilir Timur I District as stated in Table 7.

Table 6. Matrix of Positive Ideal Solution and Negative Ideal Solution

Criteria	Positive	Negative
$\tilde{C}_1$	0.682986392	0
$\tilde{C}_2$	0.956390379	0
$\tilde{C}_3$	0.671211965	0
$\tilde{C}_4$	0.647086749	0
$\tilde{C}_5$	0.657677381	0
$\tilde{C}_6$	0.796052478	0
$\tilde{C}_7$	0.706258955	0
$\tilde{C}_8$	1.031308491	0
$\tilde{C}_9$	1.206837006	0
$\tilde{C}_{10}$	1.205411197	0
$\vdots$	$\vdots$	$\vdots$
$\tilde{C}_{23}$	0.75950212	0

From Table 8, it can be seen that the largest preference value is located in $(\tilde{x}_9)$, so $(\tilde{x}_9)$ as the most optimal location where $(\tilde{x}_9)$ Ilir Timur I Sub-District, namely RSIA YK Madira,

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Table 7. The Difference in Values Between Each Hospital Option and The Positive and Negative Ideal Solution Matrix

D^+	Value	D^-	Value
$\tilde{x}_1$	2.953477	$\tilde{x}_1$	1.550049
$\tilde{x}_2$	3.207706	$\tilde{x}_2$	1.364829
$\tilde{x}_3$	4.381804	$\tilde{x}_3$	0
$\tilde{x}_4$	1.765836	$\tilde{x}_4$	3.306415
$\tilde{x}_5$	4.381804	$\tilde{x}_5$	0
$\tilde{x}_6$	3.028842	$\tilde{x}_6$	1.515281
$\tilde{x}_7$	3.892671	$\tilde{x}_7$	0.557388
$\tilde{x}_8$	3.763845	$\tilde{x}_8$	0.667304
$\tilde{x}_9$	0.761096	$\tilde{x}_9$	4.229952
$\tilde{x}_{10}$	3.686918	$\tilde{x}_{10}$	0.902231
$\tilde{x}_{11}$	4.381804	$\tilde{x}_{11}$	0
$\tilde{x}_{12}$	3.064979	$\tilde{x}_{12}$	1.593795
$\tilde{x}_{13}$	3.321605	$\tilde{x}_{13}$	1.395468
$\tilde{x}_{14}$	2.621008	$\tilde{x}_{14}$	2.171972
$\tilde{x}_{15}$	4.381804	$\tilde{x}_{15}$	0
$\tilde{x}_{16}$	3.386626	$\tilde{x}_{16}$	1.116394
$\tilde{x}_{17}$	1.824748	$\tilde{x}_{17}$	3.008616
$\tilde{x}_{18}$	4.381804	$\tilde{x}_{18}$	0

Table 8. Preference and Rank Values for Each Alternative

Alternative	Preference	Rank
$\tilde{x}_1$	0.344186	6
$\tilde{x}_2$	0.298484	8
$\tilde{x}_3$	0	14
$\tilde{x}_4$	0.651863	2
$\tilde{x}_5$	0	16
$\tilde{x}_6$	0.33346	7
$\tilde{x}_7$	0.125254	13
$\tilde{x}_8$	0.150594	12
$\tilde{x}_9$	0.847508	1
$\tilde{x}_{10}$	0.196601	11
$\tilde{x}_{11}$	0	16
$\tilde{x}_{12}$	0.342106	5
$\tilde{x}_{13}$	0.295833	9
$\tilde{x}_{14}$	0.453157	4
$\tilde{x}_{15}$	0	17
$\tilde{x}_{16}$	0.247921	10
$\tilde{x}_{17}$	0.622468	3
$\tilde{x}_{18}$	0	18

RSU RK Charitas, and RSU Srivijaya. Figure 1 explains the locations of the facilities obtained.

By applying the TOPSIS method in determining the location of the hospital that has ER facilities in the City of Palembang, it is obtained that the location of the ER in the Sub-District are listed as follows: Ilir Timur I, Ilir Barat I, Sukarami, Plaju, Kalidoni, Alang-Alang Lebar, Kertapati, Bukit kecil, Kemuning, Sematang Borang, Ilir Timur II, Sebrang Ulu II, Sebrang Ulu I, Gandus, Ilir Barat II, Ilir Timur III, Sako, and Jakabaring Sub-District.

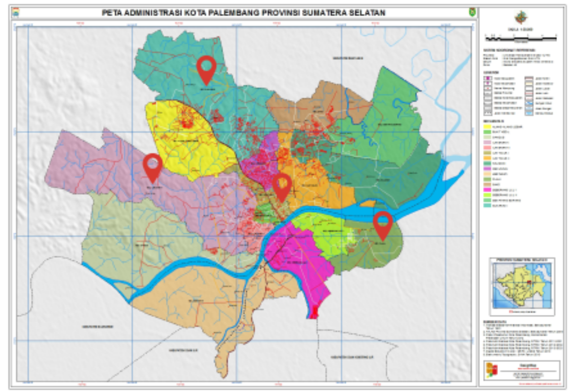

Figure 1. Map of Palembang and Sub-Districts

Source: Palembang Government, 2022

Based on Figure 1, there are 4 Sub-Districts have hospitals with the most optimal emergency facilities in the City of Palembang, namely Ilir Timur I Sub-District, Ilir Barat I Sub-District, Sukarami Sub-District, and Plaju Sub-District.

4. CONCLUSION

Based on the research, the optimal location of the hospital that has emergency facilities in the City of Palembang is located in the Ilir Timur I Sub-District. The setting up of the location of the facilities enable population closest to the ED to reach the facilities as soon as possible. The reduction the risk of death that often occurs due to the distance from the location of hospitals that have emergency facilities can be achieved.

For further research, it is suggested to also include some new parameters involved in designing the model of SCP in ED in Palembang to also include the possibility of recent conditions occurring in practical conditions. Such as how to reach the facilities, the number of doctors involved in the hospital, or possibilities of transportation means existed.

5. ACKNOWLEDGEMENT

On November 23, 2020, DIPA of the Public Service Agency of Sriwijaya University 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.

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