Multi-criteria optimization of emergency unit allocation using COPRAS and SMART: a case study in Palembang

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ABSTRACT

Increasing living standards and instant eating patterns have improved people's demands for quality health services. Hospitals as health service facilities are actually real-time networks that expected to be able to provide effective and efficient services. This research uses the complex proportional assessment (COPRAS) and simple multi-attribute rating technique (SMART) methods to determine the hospital with the most optimal emergency unit (EU) services in each subdistrict based on predetermined criteria. The research results show that the COPRAS method is produces performance index values ranging from 0.0195 to 0.1317, while the SMART method yields scores between 0.054 and 0.122, both demonstrating consistent ranking outcomes. The three hospitals, with the most optimal EU performance are Dr. Mohammad Hoesin, RSU Pertamina, and RSJ Ernaldi Bahar, with Dr. Mohammad Hoesin achieving the highest utility value (0.1317). The novelty of this study lies in the integration of real-time spatial and operational data from Google Maps and RS Online into a hybrid set covering problem (SCP) framework, combining the strengths of COPRAS and SMART.

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1. INTRODUCTION

As the standard of living increases and the diet becomes more instant, the demand for quality health increases. The development of hospitals in Indonesia is growing rapidly from time to time. Hospitals as real-time networks [1], [2] have health facilities that have a variety of services covering various health fields. Hospitals, as a means of health care, are places that are used. With the rapid development of technology and increasingly fierce competition, hospitals must improve the quality of their services. Another factor that plays a role in influencing patient satisfaction is the facilities available at the hospital. Location facility problems, such as emergency service facilities, form an important class of location problems in optimization problems [3], [4] and waste disposal place [5]. Until now, medical and health experts have always tried to improve the quality of themselves, the profession, medical equipment, health managerial capabilities, and especially the quality of health services [6], [7], for example, with integrated health management [8] or with a high technology gadget to monitor the patient's condition [9]. One of the things that determines whether a hospital has good quality is the emergency department or emergency unit.

Therefore, hospitals are expected to be able to provide effective and efficient services to the community of health service users. The effectiveness of patient care is an important indicator in assessing the quality of health services. One of the healthcare facilities that has another very important role in providing health services to the community is the hospital [10]. Customer satisfaction can be achieved by providing quality service to its customers. Health services, according to the Ministry of Health of the Republic of Indonesia in 2009, are every effort organized individually or together in an organization to maintain and improve health. Emergency services provided must meet good service quality [11]–[14]. Services in the emergency unit will affect patient satisfaction and hospital image [15]. Services in the emergency department (ED) [16], [17] play an important role in influencing patient satisfaction and hospital reputation.

Emergency unit (EU) location optimization in Palembang City hospitals aims to minimize the average travel time from the location of customer requests to the nearest facility [18]. The best hospital criteria that can be used are service, because it is the most important thing to determine quality [19], [20]. To further improve hospital operations, an information system can be developed [9].

This study seeks to implement the complex proportional assessment (COPRAS) [21]–[23] and simple multi-attribute rating technique (SMART) [24], [25]. The COPRAS method is one method of making a decision that assumes a direct and proportional dependence on the level of significance and usefulness of alternatives. These methods can identify multiple criteria in making decisions. In addition, the COPRAS method prepares attributes to be identified, normalizes the matrix, normalizes the weighted matrix, calculates the maximum and minimum values of the index, calculates the relative weight, and calculates the quantitative utility of each alternative. The COPRAS approach is known for ranking through several stages by evaluating alternatives based on their level of significance and utility. Meanwhile, SMART is a multi-attribute decision-making technique used to support decision-makers in choosing between several alternatives. The SMART method has simple calculations and is easy to implement for handling randomness in uncertainty problems or in a group decision-making approach [26]. The weighting calculation will produce a value for each alternative to obtain the best and optimal alternative. The COPRAS method can be used to perform a ranking with the main criteria used, assuming a direct and proportional dependence of the level of significance and utility of all alternatives, including in an Industry 4.0 environment [27]. COPRAS emphasizes proportional comparison between alternatives based on the relative weight of each identified criterion.

The scarcity in discussing both methods for choosing a public health facility needs to be resolved. Therefore, the purpose of this research is to determine the most optimal alternative hospital emergency unit (EU) in each subdistrict based on predetermined criteria, based on the advantages of implementing COPRAS and SMART as real-time networks applied.

2. RESEARCH METHOD

2.1. Data source

This research uses secondary data obtained from Hospital Online Palembang City in 2024. The data consists of the number of subdistricts in Palembang City. Data were collected and verified during Quarter 1 of 2024 (January–March 2024) to ensure temporal consistency between operational hospital data and spatial travel network data. The sources of data used in this study are as follows:

1. Hospital Online Palembang City (https://sirs.kemkes.go.id/fo/) to provide hospital operational data such as the number of doctors, hospital class, and bed availability.
2. Google Maps to collect travel time and distance data from each subdistrict hospital with the EU.
3. Badan Pusat Statistik (BPS) Palembang City to supply demographic and administrative boundary information for the 18 subdistricts of Palembang City.

2.2. Research variables and criteria

This study applies 9 evaluation criteria that represent accessibility, capacity, and service readiness of hospitals in the EU. The selection of the nine criteria in Table 1 was based on their direct relevance to both spatial accessibility and operational readiness of the EU. Each criterion represents a critical component of emergency medical service performance and aligns with national health policies and previous studies. This multidimensional structure supports decision-making under the set covering problem (SCP) framework, allowing policymakers to determine optimal emergency hospital locations that maximize coverage and accessibility for residents of Palembang City.

2.3. Methods

The research methods used in this study are as follows.

1. Determine the value of alternative linguistic weights for each subdistrict and criterion, as Table 1 explained.
2. Assign numerical weights to the 5 classifications for each subdistrict.
3. Determine the weight for each criterion in the 5 classifications. Rank the optimal hospital locations for each subdistrict using the COPRAS and SMART methods.
4. Analyze and compare the results of the two methods.

Table 1. Criteria

Code	Criterion	Definition	Unit	Type	Data source
c_1	Travel time	Average duration from the subdistrict center to EU	Minutes	Cost	Google Maps
c_2	Distance	Road network distance from the subdistrict to EU	Kilometers (km)	Cost	Google Maps
c_3	Hospital class	Classification based on service capability (A–D, where A is highest)	Ordinal (A–D)	Benefit	Website Hospital Online
c_4	Service level	Quality of emergency unit services	Scale (0–1, linguistic)	Benefit	Website Hospital Online
c_5	Number of general practitioners	Total number of general practitioners available in EU	Persons	Benefit	Website Hospital Online
c_6	Number of specialists	Total number of specialist doctors available in EU	Persons	Benefit	Website Hospital Online
c_7	Number of Class I beds	Total available inpatient beds in Class I	Units	Benefit	Website Hospital Online
c_8	Number of Class II beds	Total available inpatient beds in Class II	Units	Benefit	Website Hospital Online
c_9	Number of Class III beds	Total available inpatient beds in Class III	Units	Benefit	Website Hospital Online

Figure 1 describes the flowchart of the methods. The selection of COPRAS and SMART methods in this study is based on their simplicity, transparency, and compatibility with the nature of the data compared to other MCDM approaches such as analytic hierarchy process (AHP), technique for order of preference by similarity to ideal solution (TOPSIS), and VlseKriterijumska optimizacija I kompromisno resenje (VIKOR). Both COPRAS and SMART provide a straightforward computational process that is easy to implement and interpret, making them suitable for evaluating multiple alternatives under various criteria. COPRAS emphasizes proportional comparison based on the significance and utility levels of alternatives, while SMART applies a direct linear weighting technique to determine overall scores. These characteristics enable both methods to produce transparent and consistent results without the complex pairwise comparisons required by AHP or the iterative distance-based evaluations found in TOPSIS and VIKOR. Furthermore, COPRAS and SMART effectively accommodate mixed data types, including linguistic assessments, fast, near, good, and quantitative indicators, such as the number of doctors, number of beds, which are common in healthcare service evaluations.

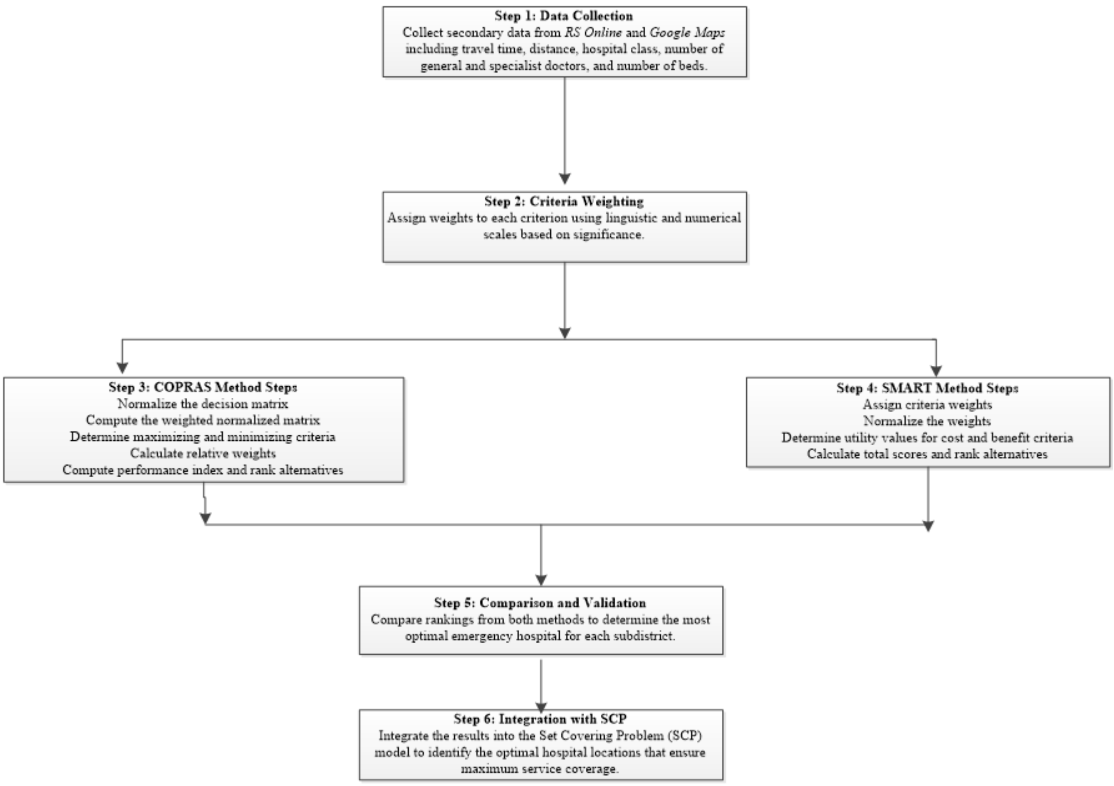

Figure 1. Flowchart of COPRAS and SMART method

Their computational efficiency also supports the integration of real-time spatial and operational data obtained from Google Maps and RS Online into the SCP framework. This integration facilitates the identification of optimal hospital locations that ensure maximum coverage and accessibility. Therefore, COPRAS and SMART are considered the most appropriate methods for this research due to their simplicity, transparency, flexibility in handling linguistic and numerical data, and strong compatibility with spatial optimization models such as SCP.

3. RESULTS AND DISCUSSION

This section discusses the steps to optimize the EU of each subdistrict in Palembang City using existing criteria by COPRAS and SMART methods. The use of these two methods is done to determine the most optimal recommendation hospital for each subdistrict.

3.1. Rank the most optimal hospitals for each district using the COPRAS method

3.1.1. Add linguistic weights for Alang-Alang Lebar Subdistrict

In the linguistic weight table for Alang-alang Lebar subdistrict, for example c_1 is the linguistic weight for the travel time criteria from the subdistrict to the hospital that has an EU facility, and so on, as presented in Table 2.

3.1.2. Add the numerical weights with Values in 5 Classification Weighting for Alang- Alang Lebar District.

Based on the weight range for each criterion, Table 3 is the numerical weight data for Alang-Alang Lebar Subdistrict.

Table 2. Linguistic weight of alternatives for Alang-Alang Lebar Subdistrict

Alternative	Criteria								
	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9
a_1	Fast	Very near	Class A	Enough	Little	Very little	Very little	Very little	Much
a_2	Medium	Medium	Class B	Enough	Very little	Very little	Very little	Very little	Very little
a_3	Fast	Near	Class B	Enough	Very little	Very little	Very little	Very little	Very little
a_4	Medium	Near	Class C	Good	Little	Little	Very little	Little	Little
a_5	Fast	Near	Class B	Enough	Much	Little	Enough	Little	Little
a_6	Medium	Near	Class C	Enough	Very little	Very little	Very little	Very little	Very little
a_7	Long	Jauh	Class C	Very good	Very little	Very little	Very little	Very little	Little
a_8	Very long	Medium	Class B	Enough	Very much	Very little	Very little	Little	Much
a_9	Very long	Medium	Class C	Good	Little	Very little	Very little	Very little	Little
a_{10}	Long	Near	Class B	Good	Very much	Enough	Enough	Much	Little
a_{11}	Long	Medium	Class C	Good	Very little	Very little	Very little	Very little	Very little
a_{12}	Medium	Near	Class C	Enough	Little	Very little	Very little	Very little	Very little
a_{13}	Long	Medium	Class C	Good	Very little	Very little	Very little	Very little	Very little
a_{14}	Very long	Jauh	Class C	Enough	Enough	Very little	Very little	Very little	Very little
a_{15}	Medium	Near	Class A	Enough	Enough	Very much	Very much	Much	Very much
a_{16}	Very long	Jauh	Class C	Enough	Much	Very little	Very little	Very little	Enough
a_{17}	Long	Medium	Class D	Very good	Little	Very little	Very little	Very little	Very little
a_{18}	Fast	Near	Class B	Good	Much	Little	Little	Very little	Very little

Table 3. Numerical weight table of alternative in Alang-Alang Lebar Subdistrict

Alternative	Criteria								
	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9
a_1	0.75	1	1	0.50	0	0	0	0	0.75
a_2	0.50	0.50	0.75	0.50	0	0	0	0	0
a_3	0.75	0.75	0.75	0.50	0	0	0	0	0
a_4	0.50	0.75	0.50	0.75	0.25	0.25	0	0.25	0.25
a_5	0.75	0.75	0.75	0.50	0.75	0.25	0.50	0.25	0.25
a_6	0.50	0.75	0.50	0.50	0	0	0	0	0
a_7	0.25	0.25	0.50	1	0	0	0	0	0.25
a_8	0	0.50	0.75	0.50	1	0	0	0.25	0.75
a_9	0	0.50	0.50	0.75	0.25	0	0	0	0.25
a_{10}	0.25	0.75	0.75	0.75	1	0.50	0.50	0.75	0.25
a_{11}	0.25	0.50	0.50	0.75	0	0	0	0	0
a_{12}	0.50	0.75	0.50	0.50	0.25	0	0	0	0
a_{13}	0.25	0.50	0.50	0.75	0	0	0	0	0
a_{14}	0	0.25	0.50	0.50	0.50	0	0	0	0
a_{15}	0.50	0.75	1	0.50	0.50	1	1	0.75	1
a_{16}	0	0.25	0.50	0.50	0.75	0	0	0	0.50
a_{17}	0.25	0.50	0.25	1	0	0	0	0	0
a_{18}	0.75	0.75	0.75	0.75	0.75	0.25	0.25	0	0

3.1.3. Determine the decision matrix for Alang-Alang Lebar Subdistrict

The matrix is as follows.

0.75	1	1	0.5	0	0	0	0	0.75
0.5	0.5	0.75	0.5	0	0	0	0	0
0.75	0.75	0.75	0.5	0	0	0	0	0
0.5	0.75	0.5	0.75	0.25	0.25	0	0.25	0.25
0.75	0.75	0.75	0.5	0.75	0.25	0	0.25	0.25
0.5	0.75	0.5	0.5	0	0	0	0	0
0.25	0.25	0.5	1	0	0	0	0	0.25
0	0.5	0.75	0.5	1	0	0	0.25	0.75
0	0.5	0.5	0.75	0.25	0	0	0	0.25
0.25	0.75	0.75	0.75	1	0.5	0.50	0.75	0.25
0.25	0.5	0.5	0.75	0	0	0	0	0
0.5	0.75	0.5	0.5	0.25	0	0	0	0
0.25	0.5	0.5	0.75	0	0	0	0	0
0	0.25	0.5	0.5	0.5	0	0	0	0
0.5	0.75	1	0.5	0.5	1	1	0.75	1
0	0.25	0.5	0.5	0.75	0	0	0	0.5
0.25	0.5	0.25	1	0	0	0	0	0
0.75	0.75	0.75	0.75	0.75	0.25	0.25	0	0

3.1.4. Calculate the normalized matrix

$$X_{ab} = \frac{y_{ab}}{\sum_{a=1}^{r} y_{ab}}; b = 1,2,\ldots,s \qquad (1)$$

X_{ab} : Normalised decision matrix values.
y_{ab} : Decision matrix of the *a*-th alternative on the *b*-th criterion.
r : Number of alternatives.
s : Number of criteria.

The calculations are based on (1) as:

c_1 = (0.75 + 0.5 + 0.75 + 0.5 + 0.75 + 0.5 + 0.25 + 0 + 0 + 0.25 + 0.25 + 0.5 + 0.25 + 0 + 0.5 + 0 + 0.25 + 0.75) = 6.75 dan $X_{11} = \frac{0.75}{6.75}$ = 0.11, $X_{21} = \frac{0.5}{6.75}$ = 0.07, $X_{31} = \frac{0.75}{6.75}$ = 0.1

Then, the matrix is as:

0.11	0.09	0.09	0.04	0	0	0	0	0.18
0.07	0.05	0.07	0.04	0	0	0	0	0
0.11	0.07	0.07	0.04	0	0	0	0	0
0.07	0.07	0.05	0.06	0.04	0.11	0	0.11	0.06
0.11	0.07	0.07	0.04	0.125	0.11	0.22	0.11	0.06
0.07	0.07	0.05	0.04	0	0	0	0	0
0.03	0.02	0.05	0.09	0	0	0	0	0.06
0	0.05	0.07	0.04	0.17	0	0	0.11	0.18
0	0.05	0.05	0.06	0.04	0	0	0	0.06
0.03	0.07	0.07	0.06	0.17	0.22	0.22	0.33	0.06
0.03	0.05	0.05	0.06	0	0	0	0	0
0.07	0.07	0.05	0.04	0.04	0	0	0	0
0.03	0.05	0.05	0.06	0	0	0	0	0
0	0.02	0.05	0.04	0.08	0	0	0	0
0.07	0.07	0.09	0.04	0.08	0.44	0.44	0.33	1
0	0.02	0.05	0.04	0.125	0	0	0	0.12
0.03	0.05	0.02	0.08	0	0	0	0	0
0.11	0.07	0.07	0.06	0.125	0.11	0.11	0	0

3.1.5. Determine the normalized weighted decision matrix.

The normalized weighted decision matrix is as follows.

$$D' = X_{ab} W_b \qquad (2)$$

Where;
D' : Weighted normalised matrix value.
X_{ab} : Normalised decision matrix values.
W_b : Numerical weighting of the classification on each b-th criterion.

Then, based on (2), A_{11} = (0.11) (0.17) = 0.02, A_{21} = (0.11) (0.17) = 0.02, …, A_{198} = (0) (0.08). Then, the matrix generated is as follows:

0.02	0.02	0.01	0	0	0	0	0	0.01
0.01	0.01	0.01	0	0	0	0	0	0
0.02	0.01	0.01	0	0	0	0	0	0
0.01	0.01	0	0.01	0.01	0.1	0	0.01	0
0.02	0.01	0.01	0	0.01	0.1	0.02	0.01	0
0.01	0.01	0	0	0	0	0	0	0
0.01	0	0	0.01	0	0	0	0	0
0	0.01	0.01	0	0.02	0	0	0.01	0.01
0	0.01	0	0.01	0.01	0	0	0	0
0.01	0.01	0.01	0.01	0.02	0.03	0.02	0.03	0
0.01	0.01	0	0.01	0	0	0	0	0
0.01	0.01	0	0	0.01	0	0	0	0
0.01	0.01	0	0.01	0	0	0	0	0
0	0	0	0	0.01	0	0	0	0
0.01	0.01	0.01	0	0.01	0.06	0.04	0.03	0.02
0	0	0	0	0.02	0	0	0	0.01
0.01	0.01	0	0.01	0	0	0	0	0
0.02	0.01	0.01	0.01	0.02	0.1	0.1	0	0

3.1.6. Calculate of maximizing and minimizing *i*-index for each criterion

$$S_{+a} = \sum_{b=1}^{s} d_{ab}\,, a = 1,2,\ldots r; S_{-a} = \sum_{b=1}^{s} d_{ab}\,, a = k+1, k+2, \ldots, r \quad (3)$$

Were,
S_{+a}: The maximum value of the index for each criterion.
S_{-a}: The minimum value of the index on each criterion.
d_{ab}: Weighted normalised matrix.

c_1, c_2, c_3, c_7, c_8, and c_9 are cost criteria while c_4, c_5, and c_6 are the benefit criteria.

Using (3), then:

S_{-i} = c_1+ c_2 + c_3 + c_7 + c_8 + c_9, A_1 = 0.02 + 0.02 + 0.01 + 0 + 0 + 0.01 = 0.06, A_2 = 0.01 + 0.01 + 0.01 + 0 + 0 + 0 = 0.03, …. Total cost or the minimum value is 0.06.

S_{+i} = c_4+ c_5 + c_6 , A_1 = 0 + 0 + 0 = 0, A_2 = 0 + 0 + 0 = 0 …, A_{18} = 0.01 + 0.02 + 0.01 = 0.04. The total benefit or the maximal value is 0.04. To calculate the relative weight using (4):

$$Q_a = S_{+a} + \frac{\sum_{a=1}^{r} S_{-a}}{S_{-a}\sum_{a=1}^{r}\frac{1}{S_{-a}}} \quad (4)$$

where:
Q_a : Relative weight value of each alternative.
r : Number of alternatives. For computing the value of $\frac{1}{S_{-a}}$ then,

$$\frac{1}{0.06} = 16.67, \frac{1}{0.07} = 14.624, \frac{1}{0.03} = 33.33, \frac{1}{0.02} = 50, \frac{1}{0.04} = 25, \frac{1}{0.03} = 33.33 \text{ so } \sum\frac{1}{S_{-a}} = 654.238$$

Then, Table 4 is obtained to show the alternative priority of Alang-Alang Lebar Subdistrict by applying (4).

3.1.7. Calculate the performance index value of each alternative

The performance index value of each alternative is stated in (5), as follows:

$$P_a = \frac{Q_a}{Q_{max}}(100) \quad (5)$$

where:
P_a : Performance index value of each alternative.

Q_a : Relative value or weight given to alternatives.
Q_{max} : Alternative value with the highest number of relative weights.
Then, the calculations using (5) are as follows:

$$P_1 = \frac{0.0195}{0.1317}(100) = 14.814, P_2 = \frac{0.0384}{0.1317}(100) = 29.147, P_3 = \frac{0.0286}{0.1317}(100) = 21.718, \ldots$$

From the results of the calculation process using the COPRAS method, the result is that the order of P_i from the first to the last rank can be seen from the largest P_i value to the smallest, namely P_{14} is RSU Pusri, P_{15} is RSUP Dr. Mohammad Hoesin, P_{16} is RSU Pertamina, P_{10} is RSU RK Charitas, P_9 is RSU Muhammadiyah, P_{17} is RSU Karya Charitas, P_{13} is RSIA Tiara Fatrin, P_{11} is RSIA Az-Zahra, P_7 is RSIA Kader Bangsa, P_{18} is RSUD Siti Fatimah, P_8 is RSUD Palembang Bari, P_5 is RSI Siti Khodijah, P_4 is Bunda General Hospital, P_{12} is Sriwijaya General Hospital, P_2 is Palembang Lung Hospital, P_6 is RSIA Bunda Noni, P_3 is Eye Hospital, and the last order is P_1 is RSJ Ernaldi Bahar.

Therefore, the order of hospitals that have EU facilities that can be visited by the community in Alang-Alang Lebar Subdistrict is RSU Pusri, RSUP Dr. Mohammad Hoesin, RSU Pertamina, RSU RK Charitas, RSU Muhammadiyah, RSU Karya Charitas, RSIA Tiara Fatrin, RSIA Az-Zahra, RSIA Kader Bangsa, RSUD Siti Fatimah, RSUD Palembang Bari, RSI Siti Khodijah, RSU Bunda, RSU Sriwijaya, RSK Paru Palembang, RSIA Bunda Noni, RSK Mata, and the last is RSJ Ernaldi Bahar. Do the same calculation as Alang-Alang Lebar subdistrict, with complete stages for Bukit Kecil, Ilir Barat I, Kertapati, Seberang Ulu I, Seberang Ulu II, Ilir Timur I, Ilir Timur II, Kalidoni, Kemuning, Plaju, Sematang Borang, and Sukarami subdistricts.

Table 4. Alternative priority of Alang-Alang Lebar Subdistrict

Alternative	S_+	S_-	$\frac{1}{S_{-a}}$	Q_a
a_1	0	0.06	16.67	0.0195
a_2	0	0.03	33.33	0.0384
a_3	0	0.04	25	0.0286
a_4	0.02	0.04	25	0.0458
a_5	0.03	0.07	14.624	0.0462
a_6	0	0.03	33.33	0.0358
a_7	0.01	0.02	50	0.055
a_8	0.02	0.04	25	0.0484
a_9	0.01	0.02	50	0.0651
a_{10}	0.05	0.07	14.62	0.066
a_{11}	0.01	0.02	50	0.056
a_{12}	0.01	0.03	33.33	0.041
a_{13}	0.01	0.02	50	0.056
a_{14}	0.01	0.01	100	0.1317
a_{15}	0.07	0.12	8.33	0.0773
a_{16}	0.02	0.02	50	0.0705
a_{17}	0.01	0.02	50	0.0638
a_{18}	0.03	0.04	25	0.0548

3.2. Ranking the most optimal hospitals for Alang-Alang Lebar Subdistrict applying SMART method

3.2.1. Determine criteria

In this study, there are 9 criteria used in ranking the most optimal hospitals, namely distance traveled, travel time, level of service, number of specialists, and number of general practitioners from each hospital that has an EU. Determine the criteria weight as Table 5 shows:

Table 5. Criteria weight for EU

Criteria	Weight
Travel time from the subdistrict to EU	1
Distance from subdistrict to EU	1
Class of the hospital	0.50
Service level of the hospital	0.50
Number of general practitioners in each hospital	0.75
Number of specialist doctors in each hospital	0.75
Availability of class I beds	0.50
Availability of class II beds	0.50
Availability of class III beds	0.50

3.2.2. Determine the normalization of criteria weights

$$\text{Normalization} = \frac{w_j}{\sum_{j=1}^{r} w_j} \tag{6}$$

Were,
w_j : Weight value of the *j*-th criterion.
$\sum w_j$: Total sum of all criteria weights.

c_1 = (0.75 + 0.5 + 0.75 + 0.5 + 0.75 + 0.5 + 0.25 + 0 + 0 + 0.25 + 0.25 + 0.5 + 0.25 + 0 + 0.5 + 0 + 0.25 + 0.75) = 6.75 then $X_{11} = \frac{0.75}{6.75}$ = 0.11, $X_{21} = \frac{0.5}{6.75}$ = 0.07, $X_{31} = \frac{0.75}{6.75}$ = 0.11, …, $X_{181} = \frac{0.75}{6.75}$ = 0,11, …,
c_9 = (0.75 + 0 + 0 + 0.25 + 0.25 + 0 + 0.25 + 0.75 + 0.25 + 0.25 + 0 + 0 + 0 + 0 + 1+ 0.5 + 0 + 0) = 4.25, $X_{19} = \frac{0.75}{4.25}$ = 0.18, $X_{29} = \frac{0}{4.25}$ = 0, $X_{39} = \frac{0}{4.25}$ = 0, …, $X_{189} = \frac{0}{4.25}$ = 0

Then, the matrix is as follows.

$$\begin{vmatrix}
0.11 & 0.09 & 0.09 & 0.04 & 0 & 0 & 0 & 0 & 0.18 \\
0.07 & 0.05 & 0.07 & 0.04 & 0 & 0 & 0 & 0 & 0 \\
0.11 & 0.07 & 0.07 & 0.04 & 0 & 0 & 0 & 0 & 0 \\
0.07 & 0.07 & 0.05 & 0.06 & 0.04 & 0.11 & 0 & 0.11 & 0.06 \\
0.11 & 0.07 & 0.07 & 0.04 & 0.125 & 0.11 & 0.22 & 0.11 & 0.06 \\
0.07 & 0.07 & 0.05 & 0.04 & 0 & 0 & 0 & 0 & 0 \\
0.03 & 0.02 & 0.05 & 0.09 & 0 & 0 & 0 & 0 & 0.06 \\
0 & 0.05 & 0.07 & 0.04 & 0.17 & 0 & 0 & 0.11 & 0.18 \\
0 & 0.05 & 0.05 & 0.06 & 0.04 & 0 & 0 & 0 & 0.06 \\
0.03 & 0.07 & 0.07 & 0.06 & 0.17 & 0.22 & 0.22 & 0.33 & 0.06 \\
0.03 & 0.05 & 0.05 & 0.06 & 0 & 0 & 0 & 0 & 0 \\
0.07 & 0.07 & 0.05 & 0.04 & 0.04 & 0 & 0 & 0 & 0 \\
0.03 & 0.05 & 0.05 & 0.06 & 0 & 0 & 0 & 0 & 0 \\
0 & 0.02 & 0.05 & 0.04 & 0.08 & 0 & 0 & 0 & 0 \\
0.07 & 0.07 & 0.09 & 0.04 & 0.08 & 0.44 & 0.44 & 0.33 & 1 \\
0 & 0.02 & 0.05 & 0.04 & 0.125 & 0 & 0 & 0 & 0.12 \\
0.03 & 0.05 & 0.02 & 0.08 & 0 & 0 & 0 & 0 & 0 \\
0.11 & 0.07 & 0.07 & 0.06 & 0.125 & 0.11 & 0.11 & 0 & 0
\end{vmatrix}$$

3.2.3. Determine the parameter values for each criterion

Parameter values for each criterion are described in Table 3.
Determine utility value,

a. For criteria with the cost category, it can be calculated with (7) as follows:

$$u_j(a_i) = \frac{C_{out} - C_{min}}{C_{max} - C_{min}} \tag{7}$$

b. For favourable criteria (benefit), it is calculated with (8) as follows:

$$u_j(a_i) = \frac{C_{max} - C_{out}}{C_{max} - C_{min}} \tag{8}$$

Were,
$u_j(a_i)$: *j*-th criterion utility value for *i*-th alternative.
C_{max} : Maximum criterion score.
C_{min} : Minimum criterion score.
C_{out} : *j*-th criterion value.

Cost criteria ($c_1, c_2, c_3, c_7, c_8 c_9$) is calculated by using (7) as follows:

$$c_1(a_1) = 100\ \frac{(0.75 - 0.75)}{(0.75 - 0)} = 0,\ c_1(a_2) = 100\ \frac{(0.75 - 0{,}5)}{(0.75 - 0)} = 0.33, \ldots, c_1(a_{18}) = 100\ \frac{(0.75 - 0.75)}{(0.75 - 0)} = 0$$

For benefit criteria (c_4, c_5, dan c_6), the calculations by using (8) are as follows:

$$c_4(a_1) = 100\ \frac{(0.5 - 0.5)}{(1 - 0.5)} = 0,\ c_4(a_2) = 100\ \frac{(0.5 - 0.5)}{(1 - 0.5)} = 0, \ldots, c_4(a_{18}) = 100\ \frac{(0.75 - 0.5)}{(1 - 0.5)} = 0.5$$

3.2.4. Rank

From the results of the above calculations, the number of each criterion is obtained as follows:

$a_1 = 0.19, a_2 = 0.44, a_3 = 0.33, a_4 = 0.47, a_5 = 0.37, a_6 = 0.42, a_7 = 0.65, a_8 = 0.59, a_9 = 0.64, a_{10} = 0.53, a_{11} = 0.57, a_{12} = 0.45, a_{13} = 0.57, a_{14} = 0.7, a_{15} = 0.3, a_{16} = 0.69, a_{17} = 0.64, a_{18} = 0.48.$

From the results of the calculation process with the SMART method, the results show that the order of a from the first rank to the last rank, which can be seen from the largest to the smallest value, namely a_{14} is RSU Pusri, a_{16} is RSU Pertamina, a_7 is RSIA Kader Bangsa, a_{17} is RSU Karya Charitas, a_9 is RSU Muhammadiyah, a_8 is RSUD Palembang Bari, a_{11} is RSIA Tiara Fatrin, a_{13} is RSIA Az-Zahra, a_{10} is RSU RK Charitas, a_{18} is RSUD Siti Fatimah, a_4 is RSU Bunda, a_{12} is RSU Sriwijaya, a_2 is Palembang Lung Hospital, a_6 is RSIA Bunda Noni, a_5 is RSI Siti Khodijah, a_3 is RSK Mata, a_{15} is RSUP Dr. Mohammad Hoesin, and a_1 is RSJ Ernaldi Bahar. By doing the same calculation as the Alang-Alang Lebar subdistrict, with complete stages for the subdistricts of Bukit Kecil, Ilir Barat I, Kertapati, Seberang Ulu I, Seberang Ulu II, Ilir Timur I, Ilir Timur II, Kalidoni, Kemuning, Plaju, Sematang Borang, and Sukarami, as stated in Figure 2.

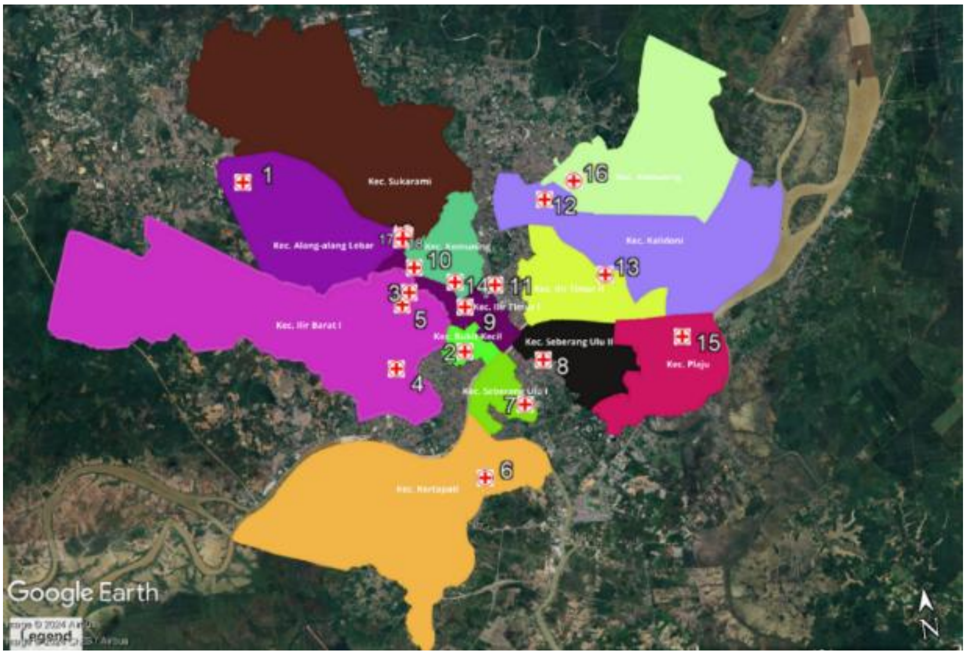

Figure 2. Optimal location of emergency unit in Palembang

4. CONCLUSION

Based on the results and discussion, when applying COPRAS method, the optimal sequence of hospitals that can be visited from each subdistrict is RSU Karya Charitas - RSUP Dr. Mohammad Hoesin - RSU Pusri - RSU Pertamina - RSU RK Charitas - RSIA Az-Zahra - RSUD Siti Fatimah - RSI Siti Khadijah - RSU Muhammadiyah - RSU Bunda - RSU Sriwijaya - RSUD Palembang Bari - RSIA Kader Bangsa - RSIA Tiara Fatrin - RSK Mata - RSIA Bunda Noni - RSJ Ernaldi Bahar - RSK Paru Palembang. Meanwhile, by applying the SMART method, the optimal sequence of hospitals that can be visited from each subdistrict is obtained- RSU Pertamina - RSU Pusri - RSIA Az-Zahra - Siti Fatimah Hospital - RSU Muhammadiyah - RSIA Kader Bangsa - RSU RK Charitas - RSUD Palembang Bari - RSIA Tiara Fatrin - RSU Sriwijaya - RSK Mata - RSU Bunda - RSI Siti Khodijah - RSJ Ernaldi Bahar - RSUP Dr. Mohammad Hoesin - RSK Paru Palembang - RSIA Bunda Noni. From the method used, the optimal hospital recommendation is to use the COPRAS method because this method is easy to implement in the faithful calculation steps. Lastly, future research is recommended to use other methods such as multi-objective optimization based on ratio analysis (MOORA). In addition, several criteria can also be added such as the capacity of the ER unit, availability of medical personnel, and availability of ambulance cars.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
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O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

The data supporting the findings of this study are available from RS Online (https://sirs.kemkes.go.id/fo/).

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