Determination of Hospital Rank by Using Analytic Hierarchy Process (AHP) and Multi Objective Optimization on the Basis of Ratio Analysis (MOORA)

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***Abstract*— Hospital is a comprehensive part of a social and medical organization, which has the function of providing health services to the community both curative and preventive, where the services provided are inpatient, outpatient, and emergency units. Health is the most important thing that every human being wants to survive in doing all activities. The importance of health encourages the government and the private sector to build hospitals so that people can provide health needs. To find out which hospital has the provision of health services desired by the community, hospital ranking is conducted. Hospital ranking is done by looking at the service time for each process in the hospital. The method used by researchers is the method of Analytic Hierarchy Process (AHP) and Multi Objective Optimization with Basic Ratio Analysis (MOORA). AHP method is selected because it is able to select alternatives from several alternatives based on predetermined criteria. The results of this study are the average values of each alternative and the criteria that will be used as the best honed hospital ranking. Based on the experiment, it is found that Hospital 8 is ranked 1. Hospital 7 is ranked 2. and Hospital 2 is ranked 3.**

Keywords—Analytical Hierarchy Process, Hospital, Multi Objective Optimization on the Basis of Ratio Analysis

I. INTRODUCTION

Health is the most important thing that every human being wants to survive in doing all activities. The importance of health encourages the government and the private sector to build quality hospitals so that people can access health needs. Hospital is a comprehensive part of a social and medical organization, which has the function of providing health services to the community both curative and preventive, where the services provided are inpatient, outpatient, and emergency units [1].

Hospitals are one of the best alternatives in the health healing process. Often people feel dissatisfied and complain about the level of hospital services available. Factors that often occur community dissatisfaction in hospital services include services that are not fast, facilities that do not support, and inadequate cleanliness and security, making people confused about choosing which hospital should be used as a healing place. The quality of hospital services can be seen from the professional appearance of hospital personnel, efficiency and effectiveness of services and patient satisfaction. Patient satisfaction is determined by the overall service: admission services, doctors, nurses, food, medicine, facilities and equipment, facilities and the physical environment of the hospital and administrative services [2].

To find out which hospital has the provision of health services that the community wants, then ranking the hospital is done. Hospital ranking is done by looking at the service time for each process in the hospital. The method used by researchers is the Analytical Hierarchy Process (AHP) and Multi Objective Optimization methods on the Base of Ratio Analysis (MOORA). AHP is an appropriate approach method for dealing with complex systems that are related to the decision making of several alternatives and provide options that can be considered [3]–[7]. This AHP method helps solve complex problems by structuring a hierarchy of criteria, interested parties, results and by attracting various considerations to develop weights or priorities [8].

MOORA is a multi-objective system that optimizes two or more conflicting attributes simultaneously. This method is applied to solve problems with complex mathematical calculations [9]. The MOORA method has flexibility and convenience to be understood and separated from the subjective part of an evaluation process into decision weighting criteria with several decision maker attributes [10]. This methods is selected because it is able to select alternatives from several alternatives based on predetermined criteria. So that people can find out which hospital is suitable to be a place for healing in their health.

II. LITERATURE REVIEW

A. Analytic Hierarchy Process (AHP)

Analytic Hierarchy Process (AHP) is a method which can be used as a tool in making a decision, and solving problems through various means, such as planning, setting priorities, determining alternative, choosing policy, finding result, as well as solving conflict [4]. Analytic Hierarchy Process (AHP) is a model used to support decision making, by Thomas L. Saaty of the University of Pittsburg [11]. The stages in the Analytical Hierarchy Process (AHP) method are as follows:

1. Defining the issues, creating the possible answers, and executing the hierarchy of issues encountered.
2. Compare in pairs of criteria to determine the weighting criteria. The priority scheme is shown in Table I [12].

TABLE I. TABLE OF PRIORITY SCHEME

Intensity of Interest	Information	Description
1	These two elements just as important	Two elements have the same effect on a goal
3	One more little element important than others	Experience and judgment support a little more than other elements

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TABLE I. TABLE OF PRIORITY SCHEME (CONTINUANCE)

Intensity of Interest	Information	Description
5	One element is more important than the other	Experience and judgment are very strong in supporting one element above another
7	One element is clearly more important than the other elements	One of the strongest elements is maintained and dominant in practice
9	One of the most important elements of the others element	Evidence supports tasks in relation to others with the highest level of reliability
2,4,6,8	Values between two adjacent consideration values	This value is given when there are two compromises between two options
Inverse	If for activity "i" gets a number above the activity "j", then "j" has the inverse value of "i"	

3. Normalize the paired comparison matrix by summing the values of each matching matrix pair then dividing each value from the column by the appropriate number of columns to get the normalization matrix.

$$\bar{\alpha}_{jk} = \frac{\alpha_{jk}}{\sum_{l=1}^{m} \alpha_{lk}} \quad (1)$$

4. Calculate the synthesis weight by adding up each column in the same row from the results of the matrix comparison normalization.

$$\sum column = k1 + k2 + ... + kn \quad (2)$$

5. Calculate the eigenvalue by multiplying each of the matching matrix columns in the same row, then raised by the existing criteria number.

$$\lambda_1 = (k1 \times k2 \times ... \times kn)^{\frac{1}{n}} \quad (3)$$

6. Calculate the priority weights for each criterion using eigenvalues for each criterion divided by the total number of eigenvalues.
7. Calculate the importance of the criteria by dividing the synthesis weight by priority weight.
8. Calculate the maximum eigenvalue (λ max) by dividing the total number of important values by the number of criteria.
9. Measure the consistency of use to ensure that assessment for decision making has high consistency.

$$CI = \frac{(\lambda \max - n)}{n} \quad (4)$$

10. Check consistency in hierarchies provided that if the consistency ratio (CI / IR) is less than or equal to 0.1 then the calculation results are declared true [10]. IR values can be shown in Table II.

$$CR = \frac{CI}{IR} \quad (5)$$

Where :
CR = Consistency Ratio
CI = Consistency Index
IR = Index Random Consistency

TABLE II. INDEX RANDOM CONSISTENCY

Matrix	1	2	3	4	5	6	7	8	9	10	11	12
IR	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48

B. Multi Objective Optimization on the Basis of Ratio Analysis (MOORA)

Multi Objective Optimization on the Base of Ratio Analysis (MOORA) is a multi-objective decision support system which simultaneously optimizes two or more attributes or criteria despite being conflicting criteria. If a criterion generates a beneficial value or in the form of benefits, the criteria contains positive value; on the other hand, if the criterion generates cost, the criteria contains negative value.

MOORA refers to a ratio system in which each response of an alternative on certain objective is compared to the denominator, being the representation of all alternatives regarding the objective [13], [14].

Steps to solving problems using the MOORA method, among others.

a. Make a decision matrix

$$\mathbf{X} = \begin{bmatrix} X_{11} & X_{12} & \cdots & X_{mn} \\ X_{21} & X_{22} & \cdots & X_{mn} \\ \cdots & \cdots & \cdots & \cdots \\ X_{n1} & X_{n2} & \cdots & X_{mn} \end{bmatrix} \quad (6)$$

b. Normalize the x matrix

$$X*_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}^2} \quad (7)$$

c. Determine the weighted normalization matrix

$$W_j * X_{ij} \quad (8)$$

d. Determine preference results

$$Y_i = \sum_{j=1}^{g} w_j X*ij - \sum_{j=g+1}^{n} w_j X_{ij} \quad (9)$$

C. Hospital

Hospital as one of the health service facilities has a very strategic role in creating quality human resources as an effort to accelerate the improvement of health status in a comprehensive, equitable, affordable and acceptable manner to the entire community. This strategic role is obtained because the Hospital is a health service facility that is full of technology, capital, work and experts. Today the role is increasingly prominent given the emergence of changes in disease epidemiology, demographic structure, the development of science and technology, the socio-economic structure of society, which requires services that are more qualified, friendly and able to meet their expectations, desires, and needs [15].

III. RESEARCH METHOD

A. Types and Data Sources

The types of data collected and analyzed are primary data sourced from hospital simulation data in the form of Payment, Road Prone Modules, Hospital Registration, Pharmacy Model, Inpatient, and Emergency Module.

B. Analysis Steps

Analysis steps can be recorded in the flow diagram shown in Figure 1.

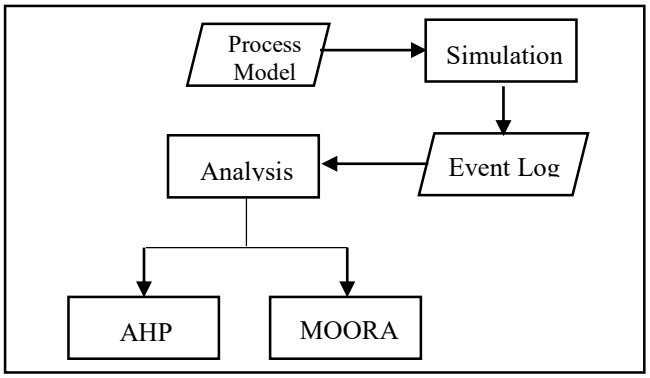

FIGURE 1. FLOW CHART

The steps of analysis in this study are (1) Model the hospital process; (2) Perform simulations; (3) Get the event log; (4) Perform analysis of event logs with two methods, namely AHP and MOORA; (5) Get hospital ranks; and (6) Conclusion.

C. Knowledge Base Management

Hospital ranking is done by looking at the service time for each process in the hospital. From the time of service, the weighting is based on criteria and alternatives. Below is a table of criteria and alternatives that will be tested in the Analytic Hierarchy Process (AHP) method so that it gets the highest alternative. The criteria and alternatives is shown in table III and IV.

TABLE III. CRITERIA

Code	Criteria	Code	Criteria
K1	Payment	K4	Pharmacy Model
K2	Road Prone Modules	K5	Inpatient
K3	Hospital Registration	K6	Emergency Module

TABLE IV. ALTERNATIVE

Code	Alternative	Code	Alternative
A1	Hospital 1	A5	Hospital 5
A2	Hospital 2	A6	Hospital 6
A3	Hospital 3	A7	Hospital 7
A4	Hospital 4	A9	Hospital 9
A8	Hospital 8	A10	Hospital 10

IV. RESULT AND ANALYSIS

In the results and discussion, the results of the best ranking will be explained using the AHP and MOORA methods as follows.

A. Analytic Hierarchy Process (AHP)

The first step is to make pair comparisons, namely comparing elements in pairs according to the given criteria shown in Table V. Pair comparisons are made according to the priority scheme table. The next step is to normalize the matrix and look for the average value for each row. From these averages, CI and CR values are calculated, each obtained a value of 0.03 and 0.02. Then do a comparison matrix of the payment criteria with the existing alternatives shown in Table VI. Comparison matrix are made according to the priority scheme table.

The next step is to normalize the matrix in Table VI and look for the average value for each row. From these averages, CI and CR values are calculated, each obtained a value of 0.11 and 0.07.

Then do a comparison matrix of the road prone modules criteria with the existing alternatives shown in table VII. Comparison matrix are made according to the priority scheme table.

The next step is to normalize the matrix in Table VII and look for the average value for each row. From these averages, CI and CR values are calculated, each obtained a value of 0.64 and 0.43.

Then do a comparison matrix of the hospital registration criteria with the existing alternatives shown in table VIII. Comparison matrix are made according to the priority scheme table.

The next step is to normalize the matrix in Table VIII and look for the average value for each row. From these averages, CI and CR values are calculated, each obtained a value of 0.61 and 0.41.

Then do a comparison matrix of the pharmacy model criteria with the existing alternatives shown in table IX. Comparison matrix are made according to the priority scheme table.

The next step is to normalize the matrix in Table IX and look for the average value for each row. From these averages, CI and CR values are calculated, each obtained a value of 0.29 and 0.2.

Then do a comparison matrix of the inpatient criteria with the existing alternatives shown in table X. Comparison matrix are made according to the priority scheme table.

TABLE V. PAIRWISE COMPARISON MATRIX

	Payment	Road Prone Modules	Hospital Registration	Pharmacy Model	Inpatient	Emergency Module
Payment	1	0.33	5	0.33	1	0.5
Road Prone Modules	3	1	7	1	3	2
Hospital Registration	0.2	0.14	1	0.14	0.2	0.17
Pharmacy Model	3	1	7	1	3	2
Inpatient	1	0.33	5	0.33	1	0.5
Emergency Module	2	0.5	6	0.5	2	1
Total	10.2	3.31	31	3.31	10.2	6.17

TABLE VI. COMPARATIVE MATRIX PAIRED WITH PAYMENT CRITERIA

Payment	Hospital 1	Hospital 2	Hospital 3	Hospital 4	Hospital 5	Hospital 6	Hospital 7	Hospital 8	Hospital 9	Hospital 10
Hospital 1	1	0.333	7	5	2	7	0.200	0.500	3	5
Hospital 2	3	1	5	3	5	7	0.500	2	5	7
Hospital 3	0.143	0.200	1	0.500	0.200	0.500	0.143	0.200	0.333	0.333
Hospital 4	0.200	0.333	2	1	0.333	1	0.143	0.200	0.500	0.500
Hospital 5	0.500	0.200	5	3	1	3	0.200	0.333	2	2
Hospital 6	0.143	0.143	2	1	0.333	1	0.143	0.200	0.500	0.500
Hospital 7	5	2	7	7	5	7	1	3	5	5
Hospital 8	2	0.500	5	5	3	5	0.333	1	3	3
Hospital 9	0.333	0.200	3	2	0.500	2	0.200	0.333	1	1
Hospital 10	0.200	0.143	3	2	0.500	2	0.200	0.333	1	1
Total	12.519	5.052	40	29.500	17.867	35.500	3.062	8.100	21.333	25.333

TABLE VII. COMPARATIVE MATRIX PAIRED WITH ROAD PRONE MODULES CRITERIA

Road Prone Modules	Hospital 1	Hospital 2	Hospital 3	Hospital 4	Hospital 5	Hospital 6	Hospital 7	Hospital 8	Hospital 9	Hospital 10
Hospital 1	1	0.33	7	5	3	0.14	0.2	0.14	0.33	0.2
Hospital 2	3	1	5	0.33	2	7	0.2	0.14	1	0.5
Hospital 3	0.14	0.2	1	5	7	2	3	0.5	5	5
Hospital 4	0.2	3	0.2	1	3	0.33	0.5	0.14	2	1
Hospital 5	0.33	0.5	0.14	0.33	1	0.14	0.2	0.14	0.33	0.33
Hospital 6	7	0.14	0.5	3	7	1	3	0.33	5	5
Hospital 7	5	5	0.33	2	5	0.33	1	0.2	3	2
Hospital 8	7	7	2	7	7	3	5	1	7	5
Hospital 9	3	1	0.2	0.5	3	0.2	0.33	0.14	1	0.5
Hospital 10	5	2	0.2	1	3	0.2	0.5	0.2	2	1
Total	31.68	20.18	16.58	25.17	41	14.35	13.93	2.95	26.67	20.53

TABLE VIII. COMPARATIVE MATRIX PAIRED WITH HOSPITAL REGISTRATION CRITERIA

Hospital Registration	Hospital 1	Hospital 2	Hospital 3	Hospital 4	Hospital 5	Hospital 6	Hospital 7	Hospital 8	Hospital 9	Hospital 10
Hospital 1	1	0.33	5	3	3	5	0.2	0.14	0.5	3
Hospital 2	3	1	7	5	5	7	0.33	0.2	3	5
Hospital 3	0.2	0.14	1	0.33	0.5	2	0.2	0.14	0.2	1
Hospital 4	0.33	0.2	3	1	2	3	0.2	0.14	0.33	2
Hospital 5	0.33	0.2	2	0.5	1	2	0.14	0.14	5	1
Hospital 6	0.2	0.14	0.5	0.33	0.5	1	0.14	0.14	0.2	0.5
Hospital 7	5	3	5	5	7	7	1	0.33	5	7
Hospital 8	7	5	7	7	7	7	3	1	0.2	0.14
Hospital 9	2	0.33	5	3	0.2	5	0.2	5	1	5
Hospital 10	0.33	0.2	1	0.5	1	2	0.14	7	0.2	1
Total	19.4	10.55	36.5	25.67	27.2	41	5.56	14.25	15.63	25.64

TABLE IX. COMPARATIVE MATRIX PAIRED WITH PHARMACY MODEL CRITERIA

Pharmacy Model	Hospital 1	Hospital 2	Hospital 3	Hospital 4	Hospital 5	Hospital 6	Hospital 7	Hospital 8	Hospital 9	Hospital 10
Hospital 1	1	0.33	5	5	2	3	2	0.5	5	0.33
Hospital 2	3	1	5	5	3	5	5	2	7	0.5
Hospital 3	0.2	0.2	1	0.5	0.2	0.33	0.33	0.2	1	0.2
Hospital 4	0.2	0.2	2	1	0.2	0.33	0.33	0.2	1	0.2
Hospital 5	0.5	0.33	5	5	1	3	2	0.33	3	0.33
Hospital 6	0.33	0.2	3	3	0.33	1	0.33	0.2	2	0.14
Hospital 7	0.5	0.2	3	3	0.5	3	1	0.33	5	0.2
Hospital 8	2	0.5	5	5	3	5	3	1	0.2	2
Hospital 9	0.2	0.14	1	1	0.33	0.5	0.2	5	1	0.2
Hospital 10	3	2	5	5	3	7	5	0.5	5	1
Total	10.93	5.11	35	33.5	13.57	28.17	19.2	10.27	30.2	5.11

TABLE X. COMPARATIVE MATRIX PAIRED WITH INPATIENT CRITERIA

Inpatient	Hospital 1	Hospital 2	Hospital 3	Hospital 4	Hospital 5	Hospital 6	Hospital 7	Hospital 8	Hospital 9	Hospital 10
Hospital 1	1	3	5	3	2	3	5	1	3	2
Hospital 2	0.33	1	3	2	0.5	1	3	0.33	2	0.5
Hospital 3	0.2	0.33	1	0.33	0.2	0.33	1	0.14	0.5	0.2
Hospital 4	0.33	0.5	3	1	0.5	1	3	0.33	2	0.5
Hospital 5	0.5	2	5	2	1	2	5	0.5	3	1
Hospital 6	0.33	1	3	1	0.5	1	3	0.33	2	0.5
Hospital 7	0.2	0.33	1	0.33	0.2	0.33	1	0.14	0.5	0.2
Hospital 8	1	3	7	3	2	3	7	1	5	2
Hospital 9	0.33	0.5	2	0.5	0.33	0.5	2	0.2	1	0.33
Hospital 10	0.5	2	5	2	1	2	5	0.5	3	1
Total	4.73	13.67	35	15.17	8.23	14.17	35	4.49	22	8.23

TABLE XI. COMPARATIVE MATRIX PAIRED WITH EMERGENCY MODULE CRITERIA

Emergency Module	Hospital 1	Hospital 2	Hospital 3	Hospital 4	Hospital 5	Hospital 6	Hospital 7	Hospital 8	Hospital 9	Hospital 10
Hospital 1	1	0.5	7	7	3	7	0.33	3	7	7
Hospital 2	2	1	7	7	3	7	0.33	3	7	7
Hospital 3	0.14	0.14	1	0.5	0.14	1	0.14	0.14	0.5	0.5
Hospital 4	0.14	0.14	2	1	0.14	3	0.14	0.14	1	1
Hospital 5	0.33	0.33	7	7	1	7	0.2	0.5	7	7
Hospital 6	0.14	0.14	1	0.33	0.14	1	0.14	0.14	0.33	0.33
Hospital 7	3	3	7	7	5	7	1	5	7	7
Hospital 8	0.33	0.33	7	7	2	7	0.2	1	7	7
Hospital 9	0.14	0.14	2	1	0.14	3	0.14	0.14	1	1
Hospital 10	0.14	0.14	2	1	0.14	3	0.14	0.14	1	1
Total	7.38	5.88	43	38.83	14.71	46	2.78	13.21	38.83	38.83

The next step is to normalize the matrix in Table X and look for the average value for each row. From these averages. CI and CR values are calculated. each obtained a value of 0.02 and 0.01. Then do a comparison matrix of the emergency module criteria with the existing alternatives shown in table XI. Comparison matrix are made according to the priority scheme table. The next step is to normalize the matrix in Table XI and look for the average value for each row. From these averages. CI and CR values are calculated. each obtained a value of 0.18 and 0.12. From all the stages above. then the ranking process is shown in the Table XII.

TABLE XII. ALTERNATIVE RANKING OF AHP

Alternative	Value	Ranking
Hospital 1	0.6	4
Hospital 2	1.11	3
Hospital 3	0.11	10
Hospital 4	0.15	9
Hospital 5	0.27	8
Hospital 6	0.36	6
Hospital 7	1.31	1
Hospital 8	1.18	2
Hospital 9	0.33	7
Hospital 10	0.59	5

Table XII shows that the ranking using AHP it is found that Hospital 7 is ranked 1. Hospital 8 is ranked 2. and Hospital 2 is ranked 3.

B. Multi Objective Optimization on the Basis of Ratio Analysis (MOORA)

The first step in MOORA is to normalize the decision matrix. The calculation results can be seen in Table XIII.

Next do the weighted normalization matrix. Normalization of the weighted matrix is obtained by multiplying the weight of the criteria that have been obtained by the normalization matrix shown in table XIV.

TABLE XIII. NORMALIZING MOORA DECISION MATRICS

	Payment	Road Prone Modules	Hospital Registration	Pharmacy Model	Inpatient	Emergency Module
Hospital 1	0.37	0.18	0.3	0.36	0.37	0.48
Hospital 2	0.48	0.23	0.38	0.47	0.28	0.48
Hospital 3	0.12	0.43	0.18	0.12	0.18	0.12
Hospital 4	0.15	0.27	0.24	0.16	0.26	0.15
Hospital 5	0.16	0.18	0.26	0.19	0.51	0.15
Hospital 6	0.12	0.4	0.17	0.19	0.3	0.12
Hospital 7	0.55	0.33	0.44	0.28	0.19	0.5
Hospital 8	0.42	0.48	0.49	0.42	0.39	0.43
Hospital 9	0.21	0.24	0.33	0.14	0.23	0.15
Hospital 10	0.18	0.28	0.19	0.52	0.31	0.15

TABLE XIV. NORMALIZING MOORA BREAKED NORMALIZATION MATRICES

	Payment	Road Prone Modules	Hospital Registration	Pharmacy Model	Inpatient	Emergency Module
Hospital 1	-0.48	-0.32	-0.4	-0.62	-0.64	-1.03
Hospital 2	-0.63	-0.39	-0.49	-0.81	-0.48	-1.04
Hospital 3	-0.15	-0.75	-0.24	-0.21	-0.31	-0.26
Hospital 4	-0.2	-0.47	-0.31	-0.27	-0.45	-0.32
Hospital 5	-0.21	-0.32	-0.34	-0.33	-0.89	-0.32
Hospital 6	-0.16	-0.69	-0.22	-0.33	-0.51	-0.25
Hospital 7	-0.72	-0.57	-0.58	-0.48	-0.33	-1.08
Hospital 8	-0.54	-0.83	-0.64	-0.72	-0.68	-0.94
Hospital 9	-0.27	-0.42	-0.43	-0.24	-0.4	-0.33
Hospital 10	-0.23	-0.48	-0.25	-0.91	-0.54	-0.32

TABEL XV. MOORA ALTERNATIVE RANKING

Alternative	Value	Ranking	Alternative	Value	Ranking
Hospital 1	3.49	4	Hospital 6	2.17	7
Hospital 2	3.84	2	Hospital 7	3.77	3
Hospital 3	1.93	10	Hospital 8	4.35	1
Hospital 4	2.1	9	Hospital 9	2.09	8
Hospital 5	2.41	6	Hospital 10	2.73	5

From all the stages above. then the ranking process is shown in the Table XV. Table XV shows that the ranking using AHP it is found that Hospital 8 is ranked 1. Hospital 2 is ranked 2. and Hospital 7 is ranked 3.

C. Combined Rank between AHP and MOORA

The combined rating is obtained by looking for the average value between the values of AHP and MOORA. The combined rank between AHP and MOORA is shown in Table XVI. Table XVI shows that the ranking using AHP it is found that Hospital 8 is ranked 1. Hospital 7 is ranked 2. and Hospital 2 is ranked 3.

TABEL XVI. COMBINED ALTERNATIVE RANKING

Alternative	Value	Ranking	Alternative	Value	Ranking
Hospital 1	2.04	4	Hospital 6	1.27	7
Hospital 2	2.47	3	Hospital 7	2.54	2
Hospital 3	1.02	10	Hospital 8	2.77	1
Hospital 4	1.07	9	Hospital 9	1.21	8
Hospital 5	1.34	6	Hospital 10	1.66	5

V. CONCLUSION

This research determines the ranking of hospitals with the aim of providing recommendations to the community. The method used in this study is Analytic Hierarchy Process (AHP) and Multi Objective Optimization on the Base of Ratio Analysis (MOORA). There are three steps in this study. First. ranking hospitals using the AHP method. Then. rank the hospital using MOORA. Finally. combining the two results of the method to determine hospital rankings. From the experimental results. it is found that Hospital 8 is ranked 1. Hospital 7 is ranked 2. and Hospital 2 is ranked 3. For further research. the addition of other ranking methods needs to be done in order to obtain maximum results in determining the best hospital.

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