

## **Implementation of AHP and SAW Methods for Optimization of Decision Recommendations**

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### **ABSTRACT**

Differences in interest in decision making are one of the things that must be facilitated in decision support applications. The most basic difference of interest in decision making is the difference in the weight of the importance of each criterion used. Each decision maker has their own interest in the criteria used. If these differences can be facilitated properly, the resulting decision recommendations can be optimal, in this case more in line with the interests of the users. The model is designed using the Analytical Hierarchy Process (AHP) and Simple Additive Weight (SAW) methods, using 5 criteria. The final result of the AHP method is in the form of criteria weights that are in accordance with the interests of decision makers and in accordance with the consistency of the comparisons that have been given. The resulting weight will be used in the final calculation of SAW, namely in the calculation of alternative weights. By using AHP, the weight of the criteria becomes more subjective according to the interests of decision makers. Thus, the resulting alternative recommendations become more optimal because they are in accordance with the needs of decision makers.

**Keywords:** Analytical Hierarchy Process (AHP), Criterion Weight, Simple Additive Weight (SAW)

**JEL Classification Codes:** D80, D81, D89

### **INTRODUCTION**

Determining the weight of the importance of the criteria in the decision support application becomes something important because it will affect the alternative that will be suggested as the best solution. The determination of the weight of the interest must have an argument that is logically acceptable. With various interests, the weight of the criteria for each decision maker may differ according to the conditions of each decision maker. But on the other hand, decision makers also experience difficulties if they have to state the importance weight (percentage) of the criteria directly, especially for cases that are not/semi-structured.

Decision Support System (DSS) is a form of computer-based information system (CBIS), which is interactive and flexible. This system was developed specifically to support unstructured problem solving and improve the quality of decision making. Decision support systems take data as input, and carry out the process to produce the desired output in the form of information that will help decision makers (Turban et al., 2005). The quality of the information produced is very important in a decision support system. This is because the information will be used as the basis for making decisions, and decisions will determine actions (Machmud et al., 2018). This can be supported by the application of information technology. Information technology supports humans to create, change, store, and communicate/distribute information (Mgunda, 2019).

The number of alternatives available in the case of decision making demands the need for a simple method of calculation. The simplicity of the method can be seen from the form of data that can be managed and the calculation process carried out. The multi-

criteria decision analysis method is widely used to select the best solution or to sort a series of problems. In most cases, the focus of solving a multi-criteria decision-making problem is finding a solution to a particular set of alternatives. Problems arise when the attribute values of one or more decision variants change, or when new evaluation alternatives emerge (Rymaszewska, et al, 2020). Some of the methods that are still widely used are the AHP and SAW methods.

The AHP method can be used to evaluate variants of transportation routes (Wolnowska & Konicki, 2018), or it can be collaborated with Geographic Information Systems (GIS) to detect flood prone areas (Matori et al., 2014), even AHP can be used for criteria selection and prioritization (Benmoussa et al., 2019). Mapping of flood-prone areas can also be done using the SAW method (Setyani & Saputra, 2015). SAW can also be used to determine alternative housing choices (Adianto et al., 2017).

## **RESEARCH METHOD**

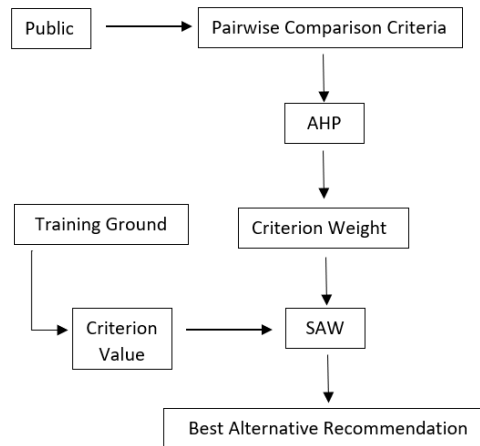
This research uses 2 methods, namely Analytical Hierarchy Process (AHP) and Simple Additive Weighting (SAW). These two methods are used to provide recommendations for the best alternative for choosing a taekwondo practice site. AHP and SAW methods are methods that can be used to solve multi-criteria problems. Multi-criteria decision analysis (MCDA) provides a means to assess complex issues to support decision making (Abrahamsen-Mills et al., 2021) and policy making (Karimi et al., 2021). Multi-Criteria Decision Analysis (MCDA) is widely used for prioritization problems. The basis of MCDA is to determine the relevant criteria for existing decisions and determine their relative importance, usually represented in weights (De Nardo et al., 2020). Multi-criteria analysis (MCA) is applied in cases where it is necessary to rank different options or make choices among a limited set of alternatives in a transparent and objective manner, taking into account several criteria (Pérez-Hoyos & Rembold, 2020).

The MCDA approach can assist in complex decisions to select alternatives taking into account the different nature of the criteria and perceptions. from various stakeholder groups (Banach et al., 2021). The MCDA method helps decision makers to choose alternatives in complex problems, without ignoring the nature of standards and differences in perceptions. for various stakeholder groups multi-criteria decision making is one of the important decision support tools that deal with uncertainty and deviations from the decision-making process undertaken. This tool helps to deal with problems especially for selecting the best option from a set of alternatives involving two or more attributes (Nsafon et al., 2020).

### **Decision Model**

The decision model to be used can be seen in Fig 1. Users/decision makers determine pairwise comparisons of the importance of the criteria which will then be processed using the AHP method to produce the weight of each criterion. The weight of the criteria will be stored and will be used in the calculation of SAW. From the calculation of SAW will be obtained alternative that is recommended as the best solution.

**Figure. 1 Decision model**



The criteria used in this study were the level of the trainer, the cost of training, the distance from the training ground to the city center, the training facilities, and the achievements of the members. The level of the coach and the performance of the members were chosen as the criteria because it is one of the indicators/values of the performance of the training ground. Performance value is the easiest indicator to use to measure the work performance that has been achieved. If the manager can increase the performance value, it can be said that the manager has been able to show good performance (Tumiwa et al., 2020). The cost of training is used as a criterion. For prospective participants who want quality, price is an important consideration in making decisions. The more unfair the perception of the prospective participant on the price, the more delayed his decision to join. The magnitude of the price perception will be in line with the size of the potential participants/consumers. In other words, the better the perception of the price, the greater the opportunity for solo participants to decide to join the training. Price perception becomes a psychological factor that has an important role in decision making (Mukaromah et al., 2019). The criteria used are static criteria. The alternative assessment for each criterion uses a Linkert scale, where each criterion has a different assessment parameter. Especially for the criteria for the level of trainers and members' achievements, the final score is obtained from the calculation of the average value of each alternative, in this case the training ground. Table 1 is the assessment parameter used for each criterion.

**Table 1. Assessment parameters used**

Criteria\ weight	Coach level	Cost (thousands of rupiahs)	Distance (km)	facilities	Member achievements
1	The red belt doesn't have a coach's license yet	<= 50	<= 5	Field	District Level
2	Black belt no trainer license	<=.100	<=10	Building	Area Level
3	Regional coach license black belt	<=150	<= 30	Field, Equipment	Regional Level
4	National coach license black belt	<=.200	<= 50	Field, Equipment	National level
5	International coach license black belt	> 200	> 50	Field, Building, Equipment	International Level

### Analytic Hierarchy Process (AHP)

Analytic Hierarchy Process is a decision-making method that can be used for several criteria. Its basic function is to compare the importance of the criteria used in solving decision-making problems (Fentanu, 2021). In general, the analytical hierarchy process consists of three main processes (Chen et al, 2021), (1) creating a hierarchical structure; (2) compiling an evaluation matrix (comparison of pairs); (3) hierarchical sorting and consistency checking, where the level of consistency can be carried out in two main calculation steps (Kabo-bah et al., 2021).

For the purposes of pairwise comparisons, Saaty assigns values that can be used, from 1 to 9 of equal to the extreme importance of one criterion against another as can be seen in Table 2 (Castanon-Jano et al., 2021).

**Table 2. Pairwise comparison rating scale (Saaty)**

Level of importance	Linguistik term
1	Equal
3	Moderate
5	Strong
7	Very strong
9	Extreme
2, 4, 6, 8	Intermediate values

Basically, the mathematical formulation of the AHP model is done by using a matrix. For example, the operating elements in the operating subsystem are operating elements A1, A2, ..., An, then the pairwise comparison results from these elements will form a comparison matrix. Pairwise comparisons will be applied to all existing criteria, starting from the highest level of the hierarchy. The criteria are the basis for pairwise comparisons to be carried out (Saaty, 1991). Next, pay attention to the elements to be compared, which can be seen in Figure 2.

**Figure 2. Pairwise Comparison Matrix**

	$C_1$	$C_2$	....	$C_n$
$A_1$	$A_{11}$	$A_{12}$	....	$A_{1n}$
$A_2$	$A_{21}$	$A_{22}$	....	$A_{2n}$
.	.	.	.	.
.	.	.	.	.
$A_n$	$A_{n1}$	$A_{n2}$	...	$A_{nn}$

After the pairwise comparison matrix is formed, normalization of the values of the i-row matrix of criteria j and the j-th column  $A_i, j$  criteria j. The end of this normalization process will produce the value of the weight vector which is called the priority vector or the principle of normalization of the Eigenvector. The eigenvectors are calculated based on the normalized score matrix. However, when multiple pairwise comparisons are performed, inconsistencies may occur (Aoun et al, 2021). To overcome this, a consistency calculation will be carried out. To calculate the consistency index (CI), equation (1) can be used.

$$CI = \frac{(\max \lambda - n)}{n} \quad (1)$$

Explanation CI : Consistency Index  
 $\max \lambda$  : maximum eigen

n : Number of criteria.

To be able to calculate the CR consistency ratio, equation (2) can be used.

$$CR = \frac{CI}{IR} \quad (2)$$

Explanation: CR : Consistency Ratio,  
 CI : Consistency Index  
 IR : Index Random Consistency  
 Consistent ratio is acceptable if the value is less than or equal to 0.1

### Simple Additive Weight

Simple Additive Weighting (SAW) is one method that can be used for multi-criteria cases, with the concept of adding weights (Setyani & Saputra, 2016). The SAW method will produce a final value in the form of a total weighted performance rating of each alternative based on all the attributes used (Eshra et al., 2021). Broadly speaking, the steps taken in this method are (Kusumadewi et al., 2006):

1. Determine an alternative, call it  $A_i$ .
2. Determine the criteria used in decision making called  $C_i$ .
3. Determine the weight of the criteria ( $W$ ) which shows the importance of the criteria in making this decision.  $W = [W_1, W_2, \dots, W_n]$
4. Make a table of suitability ratings and decision matrix ( $X$ ) for each alternative on each criterion.

$$X = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1j} \\ x_{i1} & x_{i2} & \dots & x_{ij} \end{bmatrix}$$

5. Perform normalization on the conformity matrix that is formed. The type of criteria (profit attribute or cost attribute) will determine the equation used. This step will produce a normalized matrix  $R$ . Equation (3) is used to perform normalization.

$$r_{ij} = \begin{cases} \frac{x_{ij}}{\max_{ij}}, & \text{if } x \text{ is the benefit criteria} \\ \frac{\min_{ij}}{x_{ij}}, & \text{if } x \text{ is the cost criteria} \end{cases} \quad (3)$$

Information :

$r_{ij}$  = normalized performance rating value  
 $x_{ij}$  = attribute value owned by each criterion.  
 $\text{Maxi}(x_{ij})$  = the largest value of each criterion  
 $\text{Mini}(x_{ij})$  = the smallest value of each criterion

6. The sum of the results of the normalized matrix  $\textcircled{R}$  with the preference weight ( $W$ ) will be used as the basis for the process. The alternative ( $A_i$ ) which has the greatest value is chosen as the best alternative ( $A_i$ ) which is the solution to the problem. The preference value for each alternative ( $V_i$ ) is given as a formula in Equation (4).

$$V_i = \sum_{j=1}^n W_j R_{ij} \quad (4)$$

Information :

$V_i$  = rank for each alternative  
 $W_j$  = weight value of each criterion

$R_{ij}$  = normalized performance rating value

A larger  $V_i$  value indicates that alternative  $A_i$  is preferred.

## RESULTS AND DISCUSSION

As shown in Figure 1, the first step is to perform a pairwise comparison of the criteria used. This step is used to obtain the weight of each of the criteria used. The final outcome of this step is to get the weight of the interests of each criteria. For testing, 2 weights of importance will be used. The pairwise comparison matrix for test 1 can be seen in Table 3.

**Table 3. Pairwise Comparison Matrix of cases 1**

Criteria	Coach level	Cost	Distance	Facilities	Member achievements
Coach level	1.0	3.0	3.0	3.0	1.0
Cost	0.3	1.0	2.0	0.3	0.3
Distance	0.3	0.5	1.0	0.5	0.5
Facilities	0.3	3.0	2.0	1.0	0.3
Member achievements	1.0	3.0	2.0	3.0	1.0

The table display matrix comparison of criteria for case 2 can be seen in Table 4.

**Table 4. Pairwise Comparison Matrix of cases 2**

Criteria	Coach level	Cost	Distance	Facilities	Member achievements
Coach level	1.0	2.0	0.5	0.5	2.0
Cost	0.5	1.0	0.5	0.3	0.5
Distance	2.0	2.0	1.0	2.0	2.0
Facilities	2.0	3.0	0.5	1.0	1.0
Member achievements	0.5	2.0	0.5	1.0	1.0

The differences seen in cases 1 and 2 are as follows,

### 1. Trainer level criteria

In case 1, the trainer level has the same importance as the member's achievements. This can be seen from the comparison value listed, which is 1. On the other hand, the trainer level criteria are considered to be slightly more important than cost, distance, and facilities. This can be seen from the comparison value given, which is 3.

In case 2, the trainer level criteria are very slightly more important than the coach level criteria and member achievements. This can be seen from the comparison value given, which is 2. For other criteria, namely the distance criteria and the facility criteria, the level of importance is inversely proportional to the level of importance between the distance criteria and the coach level criteria, and between the facility criteria and the coach level criteria. This can be seen from the value at the intersection of the coach level row and the cost column, and the facility column is 0.5.

### 2. Cost criteria

In case 1, the cost criterion is only slightly more important than the distance criteria. This can be seen from the comparison figures listed in the cost and distance column, namely 2. The importance of the cost criteria compared to other criteria, namely the level of trainers, facilities, and member achievements can be said to be not too important. This can be seen from the existing importance value of 0.3, which is an inverse comparison of the importance of these criteria to the cost criteria.

In case 2, the cost criterion becomes less important than the other criteria. This can be seen from the comparison figures in the cost criteria row in table 4 which are

smaller or equal to 1. This indicates that other criteria are more important than the cost criteria.

### 3. Distance criteria

In case 1, the distance criteria become a criterion that is not too important compared to the other criteria. This can be seen from the comparison of the numbers in the distance criteria row in table 3 which are smaller or equal to 1. This means that other criteria are more important than the distance criteria.

In case 2, the cost criterion becomes very little more important than the other criteria. This can be seen from the comparison of the numbers in the distance criteria row in all columns (except the distance column) in table 4 which has a value of 2.

### 4. Facility criteria

In case 1, the facility criteria have varying degrees of importance. The facility criteria are considered to be slightly more important than the cost criteria, and less important than the distance criteria. Compared to the level of the coach and the achievements of the members, the facility criteria are not very important criteria. This can be seen from the comparison numbers in the criteria row for the coach level column and the member achievement column in table 3, which are 0.3, or 1.

In case 2, the facility criteria become slightly more important than the cost criteria, and less important than the coach level criteria. This can be seen from the importance values in Table 4 in the facility criteria row, namely 3 for the cost column and 2 for the coach level column. On the other side, the facility criteria is a criteria that has half the importance of the distance criteria, which is 0.5, and is an equally important criteria with the member's achievement criteria.

### 5. Member achievement criteria

In case 1, this criterion is considered to be slightly more important than the cost criterion and the facility criterion. It can be seen that the importance value for each criterion is 3. The member achievement criteria are considered to have the same importance as the coach level criteria, and are very slightly more important than the distance criteria. It can be concluded in case 1 that the member's achievement criteria become criteria that have a higher level of importance compared to other criteria.

In case 2, the member achievement criteria have the same importance as the facility criteria, and are slightly more important than the cost criteria. Compared to the coach level criteria and the distance criteria, the member achievement criteria have very little importance.

After the pairwise comparison values were processed using the AHP method, the consistency ratio value for case 1 was 0.068, and for case 2 0.082. This means that the pairwise comparison can be accepted and the weight of importance obtained can be used. The importance of each criterion for case 1 and case 2 can be seen in Table 5.

**Table 5. Criteria's weight**

Criteria	Cases 1	Cases 2
Coach level	0.32	0.19
Cost	0.11	0.10
Distance	0.10	0.32
Facilities	0.17	0.23
Member achievements	0.30	0.16

The next step is to calculate the alternative weights using the SAW metode. For the discussion, sample data will be used as shown in Table 6. The data used are:

1. Alternative data. the alternative used is a place to practice taekwondo
2. Data for each criterion in each alternative.

For the sake of normalization in the SAW method, the criteria used must be categorized as profit criteria or cost criteria. in this case. the coach level criteria, facilities, and member achievements are considered as profit criteria. Cost and distance criteria are grouped into cost criteria.

Before normalizing the SAW method, the value of the coach level criteria and member achievements in Table 6 will be processed first. The value at each level (column) will be multiplied by the weight that has been determined in the assessment parameters (Table 1), then the average will be calculated for each criterion.

**Table 6. Sample data for taekwondo practice**

Alternative\ Criteria	Coach Level					Cost	Distan- ce	Facili- ties	Member achievements				
	A	B	C	D	E				F	G	H	I	J
HISTORY	9	3	2	0	0	2	2	2	20	17	15	15	0
PTC	15	6	4	1	1	1	3	5	35	25	25	10	8
AKAKOM	6	2	4	1	0	1	3	4	15	15	10	5	0
ELTC	14	4	4	1	0	2	1	4	29	17	13	6	0
SMPN 1	0	0	2	1	0	1	1	2	18	14	0	0	0
MERCUBUANA	1	2	1	1	0	1	3	4	25	15	10	0	0
MELIA	3	1	2	0	0	2	3	2	15	15	5	0	0
STTA	5	2	2	1	0	1	3	5	25	25	19	10	0
GOLDEN STAR	0	0	2	1	0	2	2	2	15	10	0	0	0
CANDEN	0	0	2	0	0	1	2	2	15	15	6	0	0
BANYAKAN	0	0	2	1	0	1	3	2	10	10	7	0	0
BANTUL KOTA	9	3	5	1	0	1	3	2	15	15	10	0	0
BNTA	9	3	5	1	0	1	1	2	20	15	12	3	0
BAWURAN	0	2	2	0	0	1	3	2	15	15	10	0	0
TAMANAN	6	3	3	0	0	1	3	2	18	18	13	0	0

Table 6 explanation:

- For the cost criteria, distance and facilities, the existing data is conversion data according to the assessment parameters used (Table 1).
- For the trainer level criteria, the input data is the number of trainers according to the level owned by the practice, as well as the member achievement criteria
- Column explanation
  - Column A : The red belt doesn't have a coach's license yet
  - Column B : Black belt no trainer license
  - Column C : Regional coach license black belt
  - Column D : National coach license black belt
  - Column E : International coach license black belt
  - Column F : District level
  - Column G : Area level
  - Column H : Regional level
  - Column I : National level
  - Column J : International level

After the data in table 6 was normalized using the SAW method, the results obtained can be seen in Table 7.

**Table 7. Results of data normalization using the SAW method**

Alternative / Criteria	Coach level	Cost	Distance	Facilities	Member achievements
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HISTORY	0.50	0.50	0.50	0.40	0.67
PTC	1.00	1.00	0.33	1.00	1.00
AKAKOM	0.60	1.00	0.33	0.80	0.40
ELTC	0.80	0.50	1.00	0.80	0.54
SMP N 1	0.20	1.00	1.00	0.40	0.21
MERCUBUANA	0.30	1.00	0.33	0.80	0.35
MELIA	0.30	0.50	0.33	0.40	0.25
STTA	0.40	1.00	0.33	1.00	0.73
GOLDEN STAR	0.20	0.50	0.50	0.40	0.15
CANDEN	0.20	1.00	0.50	0.40	0.27
BANYAKAN	0.20	1.00	0.33	0.40	0.23
BANTUL KOTA	0.70	1.00	0.33	0.40	0.31
BNTA	0.70	1.00	1.00	0.40	0.42
BAWURAN	0.20	1.00	0.33	0.40	0.31
TAMANAN	0.50	1.00	0.33	0.40	0.40

The alternative solution is obtained by multiplying the weight of each criterion generated from the AHP calculation and the normalized data obtained by the SAW method. The results can be seen in Table 8.

The results obtained in table 8 show a change in ranking between the results of case 1 and case 2. There are practice places whose ranking changes by 1 level, or 2 levels, even 3 levels. There is also a practice that does not have a different ranking, namely Melia.

A significant change in ranking occurred in SMP N 1. In case 1 SMP N 1 was ranked 9, and in case 2 SMP N 1 was ranked 6. When viewed from the normalized data (Table 7), SMP N 1 had a value of 0.21 for coach level criteria, 1 for cost and distance criteria, 0.4 for facilities criteria, and 0.4 for member achievement criteria. A very significant difference in ranking occurs because of the difference in the weight of the criteria in each case. SMP N has a maximum normalization value on the criteria of cost and distance. In case 1 the weight and distance criteria are very small, namely 0.111 and 0.096. In case 2, although the weight of the cost criteria is less than that of case 1, which is 0.099, the weight of the distance criterion is much higher than the weight of the distance criterion in case 1 of 0.318.

**Table 8. Alternative ranking results**

Rank	Alternative Case 1	Alternative Case 2
1	PTC	ELTC
2	ELTC	PTC
3	STTA	BNTA
4	AKAKOM	STTA
5	BNTA	AKAKOM
6	MERCUBUANA	SMP N 1
7	BANTUL KOTA	MERCUBUANA
8	TAMANAN	BANTUL KOTA
9	SMP N 1	HISTORY
10	HISTORY	TAMANAN
11	BANYAKAN	CANDEN
12	BAWURAN	GOLDEN STAR
13	CANDEN	BANYAKAN
14	GOLDEN STAR	BAWURAN
15	MELIA	MELIA

The alternative that has the same rank in case 1 and case 2 is Melia. When viewed from the normalization results in table 7, Melia does not have any maximum values. However, this is not the reason the ranking does not change, because it also happened to Golden Star and History. Melia, Golden Star and History both do not have the maximum value

in the normalization results. However, when viewed from the normalization value of each criterion, Melia has 4 criteria whose value is the lowest value for the relevant criteria as a whole. In other words, Melia only has 1 criterion whose value is above the overall minimum criterion value, while Golden Star and History have 2 criteria whose value is above the overall minimum criterion value.

When compared to alternative ranking positions in case 1 and ranking in case 2, there is 1 alternative that does not change in ranking, there are 2 alternatives that have increased by 1 level of ranking, 2 alternatives have increased by 2 levels of ranking, 1 alternative has increased by 3 levels of ranking, 5 alternatives has decreased 1 ranking level, and 3 alternatives have decreased 2 ranking level.

## CONCLUSIONS

The use of the AHP method in applications that are built can facilitate the differences in the interests of decision makers on each of the criteria used. Changes in the importance of criteria can change the ranking of alternatives. By using the SAW method, the number of alternatives used is not a problem because the normalization process will be recalculated based on the number of existing alternatives. The addition of alternative data will result in a change in the normalization value, and result in the final ranking results. Automatic conversion of data to assessment parameters creates value standards. By using the AHP and SAW methods, in this case the optimal decision recommendations are obtained, which means that they are in accordance with the interests of the user.

## REFERENCES

- Abrahamsen-Mills, L., Wareing, A., Fowler, L., Jarvis, R., Norris, S., & Banford. (2021). Development of a multi criteria decision analysis framework for the assessment of integrated waste management options for irradiated graphite. *Nuclear Engineering and Technology*, 53(4), 1224-1235.
- Adianto T. R., Arifin Z., & Khairina, D. M. (2017). Sistem pendukung keputusan pemilihan rumah tinggal di perumahan menggunakan metode *Simple Additive Weighting* (SAW) (Studi kasus: Kota Samarinda). *Proceedings of Seminar Ilmu Komputer dan Teknologi Informasi*, Vol. 2, No. 1.
- Aoun J., Quaglietta, E., Goverde, R. M. P., Scheidt, M., Blumenfeld, M., Jack, A., & Redfern, B. (2021). A hybrid Delphi-AHP multi-criteria analysis of moving block and virtual coupling railway signalling. *Transportation Research Part C: Emerging Technologies*, 129, 1-22.
- Banach, J. L., Zwietering, M. H., & van der Fels-Klerx, H. J. (2021). Multi-criteria decision analysis to evaluate control strategies for preventing cross-contamination during fresh-cut lettuce washing. *Food Control*, 128, 108-136
- Benmoussa, K., Laaziri, M., Khouilji, S., Kerkeb, M. L., & Yamami, A. E. (2019). AHP-based ApZproach foe Evaluating Ergonomic Criteria. *Procedia Manufacturing*, 32, 856-863.
- Castanon-Jano, L., Castro-Fresno, D., Blanco-Fernandez, E., & Carpio-Garcia, J. (2021). Selection of membranes and linking method in slope stabilization systems or the reduction on the installation time using multi-criteria decision analysis. *Ain Shams Engineering Journal*, 1-14.
- De Nardo, P., Gentilotti, E., Mazzaferri, F., Cremonini, E., Hansen, P., Goossens, H., & Tacconelli, E. (2020). Multi-Criteria decision analysis to prioritize hospital

- admission of patients affected by COVID-19 in low-resource settings with hospital-bed shortage. *International Journal of Infectious Diseases*, 98, 494-500.
- Eshra N. M., Ahmed, F. Z., Shady H. E., & Aleem, A. (2021). Assessment of mini and micro hydropower potential in Egypt: Multi-criteria analysis. *Energy Reports*, 7, 81-94.
- Fentanu, T. M., Bagyaraj, M., Melesse M.A., & Korme, T. (2021). Seismic hazard sensitivity assessment in the Ethiopian Rift, using an integrated approach of AHP and DInSAR methods. *The Egyptian Journal of Remote Sensing and Space Sciences*,
- Jinyue Chen, Shuisen Chen, Rao Fu, Chongyang Wang, Dan Li, Hao Jiang, Jing Zhao, Li Wang, Yongshi Peng, Yan Me, 2021, Simulation of water hyacinth growth area based on multi-source geographic information data: An integrated method of WOE and AHP. *Ecological Indicator*, 125, 1-17.
- Kabo-bah, K. J., Guoan, T., Yang, X., Na, J., & Xiong, L. (2021). Erosion potential mapping using analytical hierarchy process (AHP) and fractal dimension. *Heliyon*, 7(6), 1-7.
- Karimi, M., der Zwaan, L., Islam, K., Genabeek, J., & Rutten-vanMölken, M. (2021). Evaluating complex health and social care program using multi-criteria decision analysis: A case study of “Better Together in Amsterdam North”. *Health Policy Analysis*, 24(7), 966-975.
- Kusumadewi, S., Hartati, S., Harjoko, A., & Wardoyo, R., (2006). *Fuzzy Multy Attribute Decision Making (FUZZY MADM)*. Graha Ilmu
- Machmud, R., Saerang, D. P. E., Soegoto A. S., & Wenas R. S. (2018). E-Marketing and information system through university image on student decision selecting Teacher Training Institute (LPTK) in Eastern Indonesia. *Asia Pacific Journal of Management and Education*, 1(1), 20-29.
- Matori, A. N., Dano, U. L., Yusof, K. W., & Hashin, A. M. (2014). Spatial analytic hierarchy process model for flood forecasting: An integrated approach. *IOP Conference Series Earth and Environmental Science*, Vol. 20, No. 1.
- Mgunda, M. I. (2019). The impacts information technology on business. *Journal of International Conference Proceedings (JICP)*, 2(3), 149-156.
- Mukaromah, A. L., Kusuma, I. G. N. A. E. T., & Anggraini, N. P. N. (2019). The effect of green marketing, brand awareness and price perception on purchase decision. *International Journal of Applied Business and International Management*, 4(3), 75-83.
- Nsafon, B. E. K. N., Butu, H. M., Owolabi, A. B., Roh, J. W., Suh, D., & Huh, J. S. (2020). Integrating multi-criteria analysis with PDCA cycle for sustainable energy planning in Africa: Application to hybrid mini-grid system in Cameroon. *Sustainable Energy Technologies and Assessments*, 37, 1-12.
- Pérez-Hoyos, A., & Rembold, A. U. F. (2020). Integrating multiple land cover maps through a multi-criteria analysis to improve agricultural monitoring in Africa, *International Journal of Applied Earth Observation and Geoinformation*, Volume 88, 1-15.
- Rymaszewska, S., Watróbskia, J., & Karczmarczyk, A. (2020). Identification of reference multi criteria domain model - Productionline optimization case study. *Procedia Computer Science*, 176, 3794–3801.
- Saaty, T. L. (1991). *Pengambilan keputusan bagi para pemimpin*. PT. Dharma Aksara Perkasa.
- Setyani, R. E., & Saputra, R. (2016). Flood-prone areas mapping at Semarang City by using simple additive weighting method. *Procedia - Social and Behavioral Sciences*, 227, 378-386.
- Tumiwa R. A. F., Apituley J. R. M., & Lasut, S. A. (2020). Is the value of the company affected by company investment decisions and financing decisions?. *Journal of International Conference Proceedings*, 3(2), 100-110.
- Turban, E., Aronson, E. J., & Liang, T. P. (2005). *Decision support system and intelligence system* (D. Prabantini (Trans) (7th ed.). Andi.

Wolnowska, A. E., & Konicki, W. (2018). Multi-criterial analysis of oversize cargo transport through the city using the AHP method. *Transportation Research Procedia*, 39, 614-623.