Application of Fuzzy Algorithms and Analytical Hierarchy Process Modification in Decision Support Systems for Lazis Scholarship UNNES

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Abstract

Lazis scholarship is a scholarship given to underprivileged students and does not yet have a system that supports the decisions to be taken. AHP is one of the most popular decision making methods in solving problems. But, AHP has several weaknesses. So that it will be modified based on previous research and the addition of fuzzy algorithms to get a better decision support system method. The results of this research were A009 students with the final result priority index value of 0.004176516 getting the first position. And the addition and modification in in this research is better than the standard decision support system. Fuzzy c-means produce scores that are more variable than manual grouping. Using sorting and ranking will produce a pairwise comparison matrix that is definitely consistent and has an average faster processing time is 0.028396 seconds, whereas with the standard method is 0.284415 seconds. Modification of alternative priorities also have a relatively faster average implementation time of 0.3165 seconds than the standard calculation with 2.6003 seconds. And modifications to the FPIV, if taking the top 25 ranking in the standard FPIV produces 3 the same value while in the modified FPIV there is 1 same value.

Keywords: Decision Support System, Scholarship, Fuzzy Tsukamoto, Fuzzy CMeans, Modification AHP.

1. INTRODUCTION

Lazis UNNES scholarship is a scholarship given to underprivileged Muslim students of UNNES from semester 1 to semester 8. In 2019, Rumah Lazis UNNES as the scholarship provider opened a number of quota scholarship recipients and submitted the selection process to each department respectively. However, because the selection is done by the provisions of each department, this can allow intentional or unintentional mistakes, so that it becomes less optimal and can result in recipient selection not being objective. In 2018, actually Rumah Lazis UNNES in determining the recipients of their scholarships has conducted an open recruitment process for each student who wishes to apply for a scholarship. However, the selection process is fairly simple, namely by providing an assessment based on scoring guidelines without differentiating the importance. Of the two ways above, there are weaknesses in providing scholarships that are right on target. Terry states that one of the basics of decision making is rational,

where the resulting decision must be objective, logical, more transparent, consistent to maximize results or values within certain constraints so that it can be said to be close to the truth or according to what is desired [1]. While research conducted by Rivai

suggested one of the stages of decision making is allocating weights to the criteria to choose the best alternative [2].

Based on the opinion above, we need a decision-making system for the Lazis UNNES scholarship. Analytical Hierarchy Process or AHP is one of the most popular analytical techniques in the MCDM method for complex decision making problems. AHP has several advantages to be used as a decision-making tool including interdependence where AHP can be used on elements of a system that is mutually free, AHP considers the relative priority of factors in the system so that people are able to choose the best alternative based on their goals, and do not require a relationship linear and there is a calculation process to get priority values [3].

However, the AHP method has several weaknesses. First, in determining the priority value of criteria there is a weakness in the difficulty of determining consistency in the pairwise comparison matrix of AHP [4]. Secondly, in determining the priority value of each alternative in each criterion it is necessary to make a pairwise comparison matrix and also the criteria value matrix of a number of existing criteria, the process itself is quite long. Finally, in determining the final priority index value to determine the ranking order of each alternative often produces the same final index value, even though the parameter values of the two test data are different [5]. So that it will be modified on the AHP method based on previous research.

To maximize this decision support system, data conversion will use data grouping with the fuzzy c-means algorithm. Using a grouping with fuzzy logic is better than the classical method, because in fuzzy logic the degree of membership is known to have a range of values 0 (zero) to 1 (one), which has a value of blurring or blurring (fuzziness) between true or false [6]. In the data that will be used in this research, there are criteria data in the form of range data, this makes the data cannot be included in the fuzzy c-means clustering process, so that the data needs to be processed using fuzzy tsukamoto algorithm.

2. METHODS

This research will implement the fuzzy algorithm and modification of the analytical hierarchy process to determine the recipient of the Lazis scholarship UNNES. Fuzzy c-means algorithm is used to convert values. Fuzzy tsukamoto algorithm is used to convert range values into nominal values. While the AHP modification is done at the stage of determining criteria priorities, determining alternative priorities, and determining value of the final priority index.

2.1. Fuzzy C-Means Algorithm

Fuzzy c-means is data grouping technique (fuzzy clustering) in which the existence of each data point in a cluster is determined by the level of membership. Fuzzy c-means is a supervised grouping algorithm, because in the fuzzy c-means algorithm the number of clusters to be formed needs to be known first [7].

Fuzzy c-means (FCM) algorithm steps [8] as follows:
1) Determine the data to be grouped on cluster X_{ij} in the form of a matrix measuring n x m.
   Where:
   n   = Number of sample data
   m   = Attribute of each data
   X_{ij} = Sample data
2) Determine the initial value.
   Number of clusters   = c
   Weight of rank   = w (w > 1)
   Maximum iteration   = MaxIter
   The smallest expected error   = ε
   The initial objective function   = P0 = 0
   Initial Interaction   = t = 1
3) Generating random numbers μ_{ik} as elements of the initial partition matrix U.
   Where:
   μ_{ik} = Degree of membership

4) Count the number of each column.
$$Q_i = \sum_{k=1}^{c} \mu_{ik} \tag{1}$$
$$\mu_{ik} = \frac{\mu_{ik}}{Q_i} \tag{2}$$
   Where:
         Q_i = Number of each column
5) Calculate the center of the cluster.
$$V_{kj} = \frac{\sum_{i=1}^{n}((\mu_{ik})^{w} * X_{ij})}{\sum_{i=1}^{n}((\mu_{ik})^{w})} \tag{3}$$
   Where:
   V_{kj} = Center of the cluster
6) Calculate the objective function on iteration:
$$P_t = \sum_{i=1}^{n} \sum_{k}^{c} ([\sum_{j=1}^{m}(X_{ij} - V_{kj})^2](\mu_{ij})^{w}) \tag{4}$$
   Where:
   P_t = Objective function
   t   = Number of iterations
7) Calculate changes to the partition matrix.
$$\mu_{ik} = \frac{[\sum_{j=1}^{m}(X_{ij}-V_{kj})^2]^{\frac{-1}{w-1}}}{\sum_{k}^{c}[\sum_{j=1}^{m}(X_{ij}-V_{kj})^2]^{\frac{-1}{w-1}}} \tag{5}$$
8) Check whether the condition is less than the smallest expected error, if not iterated again.
$$P_t - P_{t-1} < \varepsilon \tag{6}$$
Where:
        ε   = Limit of error

2.2. Fuzzy Tsukamoto Algorithm

Fuzzy tsukamoto is an extension of a monotonous reasoning, which has the characteristic that every result of the IF-THEN form must be represented by a fuzzy set with a monotonous membership function. So as a result, the output of inference results from each rule is given explicitly (crisp) based on α-predicate [9].

Fuzzy tsukamoto algorithm is used to get nominal data from the father's income and mother's income criteria data which were originally in the form of range data, where the steps are as follows:

1) Determine the minimum and maximum values of related data.
2) Determine the applicable fuzzy rules. Where:
   Rule 1 = if UKT is big then income is big
   Rule 2 = if UKT is small then income is small
3) Calculates membership value from UKT data.

$$\mu UKT_{small} = \frac{Max - x}{Max - Min} \tag{7}$$

$$\mu UKT_{big} = \frac{x - Min}{Max - Min} \tag{8}$$

Where:
x = Alternative data from known data
Max = Maximum data
Min = Minimum data

4) Make the implication function of income data for each group.
   a. Very high (<Rp 500,000).

$$\mu VH_{down} = \frac{500.000 - z}{500.000 - 0} \tag{9}$$

   b. High (Rp 500.000 - Rp 1.500.000).

$$\mu H_{up} = \frac{z - 0}{500.000 - 0} \tag{10}$$

$$\mu H_{down} = \frac{2.500.000 - z}{2.500.000 - 1.500.000} \tag{11}$$

   c. Pretty high (1.500.000 - Rp 2.500.000).

$$\mu PH_{up} = \frac{x - 500.000}{1.500.000 - 500.000} \tag{12}$$

$$\mu PH_{down} = \frac{3.500.000 - z}{3.500.000 - 2.500.000} \tag{13}$$

   d. Low (Rp 2.500.000 - Rp 3.500.000).

$$\mu L_{iup} = \frac{z - 1.500.000}{2.500.000 - 1.500.000} \tag{14}$$

$$\mu L_{down} = \frac{10.000.000 - z}{10.000.000 - 3.500.000} \tag{15}$$

   e. Very Low (>Rp 3.500.000).

$$\mu VL_{up} = \frac{z - 3.500.000}{10.000.000 - 3.500.000} \tag{16}$$

Where:

z = Alternative data from sought data in rule

5) Find the z value for each rule.
    a. Rule 1.
$$\alpha\text{-}predicate_1 = \ min\ (\mu UKT_{small})$$ (17)
    b. Rule 2.
$$\alpha\text{-}predicate_2 = \ min\ (\mu UKT_{big})$$ (18)
    Where: $\alpha\text{-}predicate$ = Function implications from the rules

6) Find the overall z value.
$$Z = \frac{\sum_1^n(\alpha-predicate*z)}{\sum_1^n(\alpha-predicate)}$$ (19)

Where:

Z = Alternative data from sought data

2.3. Determining Criteria Priorities

The modification stage is done by changing the pairing matrix with a scale of importance being a method of sorting and ranking, where the steps are as follows:

1) Sort criteria based on the importance of each criteria, then give values based on Table 1 [4].

Table 1. Assigning Sorted Element Values

Number of Elements	Grouping						
	1	2	3	4	5	6	7
3	10	6	1				
4	10	7	4	1			
5	10	8	6	3	1		
6	10	8	6	5	3	1	
7	10	9	7	6	4	3	1

2) Make a pairwise comparison matrix using the formula below.
$$If\ U_i \geq U_j, then\ a_{ij} = max(U_i - U_j\ ; 1)$$ (20)
$$If\ U_i < U_j, then\ a_{ij} = 1/(U_j - U_i)$$ (21)

Where:

a_{ij} = Unit of pairwise comparison matrix
U_i = Element value comparator
U_j = Element value compared

3) Considerations of the pairwise comparisons were synthesized to obtain overall priorities with a criterion value matrix.

2.4. Determining Alternative Priorities

In generating alternative priority values, where initially using the pairwise comparison matrix and the alternative value matrix was changed using the priority formula in Eq. 22.

$$P_i = \frac{\dfrac{N_i}{Max(N_1:N_n)}}{\sum \dfrac{N_i}{Max(N_1:N_n)}} \tag{22}$$

Where:
P_i = Priority value
N_i = Element value to-i

2.5. Determining Final Priority Index Value

Modification at this stage is to change the formula slightly in the calculation of the Final Priority Index Value (FPIV), with the aim of minimizing the same NIPA value even though the parameter values of the two test data are different [5].

$$FPIV(t) = (EV_{s-t} * N_s) EV_{u-t} + ((EV_{s-1})EV_{u-1} \ldots + (EV_{s-n})EV_{u-n} \tag{23}$$

Where:
P_i = Priority value
N_i = Element value to-i

EVs-t	= Eigenvector sub criteria (in sub criteria with the largest eigenvector)
EVs-n	= Eigenvector sub criteria 1 ... n
EVu-t	= Eigenvector main criteria (in criteria with the largest eigenvector)
EVu-n	= Eigenvector main criteria 1 ... n
Ns	= Sub Criteria Value (in sub criteria with the largest eigenvector)
FPIV(t)	= Modified Final Priority Index Value

3. RESULT AND DISCUSSION

Based on 810 student data that has been entered into the system with the criteria used are father's work, mother's work, father's income, father's income, UKT, GPA and student condition (orphan or not), resulting in 10 Lazis scholarship recipients based on this decision support system, can seen in Table 2.

Table 2. Data of Lazis Scholarship Recipient Students

No	Name	Score	Ranking
1	A009	0.004176516	1
2	A248	0.004167576	2
3	A479	0.003853168	3
4	A368	0.002536608	4
5	A262	0.002521991	5
6	A747	0.002518631	6
7	A059	0.002510377	7
8	A350	0.002482678	8

| 9 | A438 | 0.002482678 | 8 |
| 10 | A236 | 0.002479923 | 10 |

3.1. Fuzzy C-Means Algorithm

In the system in this research, fuzzy c-means is used to convert the initial data into data that will be processed by the decision-making method. If taken in a range of adjacent values, a comparison of scores with a manual process is shown in Table 3 and Figure 1.

Table 3. Data of Lazis Scholarship Recipient Students

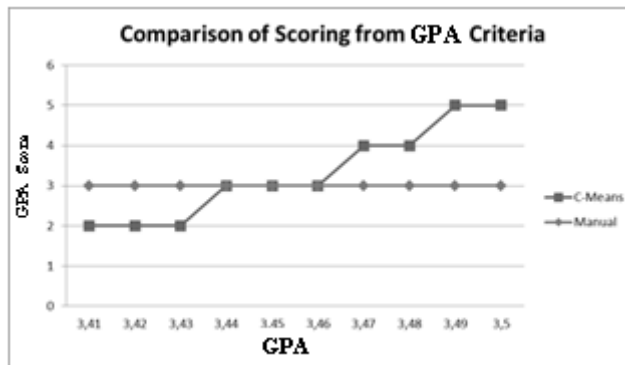| No | Name | GPA | Score | |
			Manual	C-Means
1	A005	3.45	3	3
2	A009	3.41	3	2
3	A030	3.44	3	3
4	A044	3.50	3	5
5	A051	3.47	3	4
6	A053	3.43	3	2
7	A083	3.46	3	3
8	A103	3.48	3	4
9	A166	3.42	3	2
10	A206	3.49	3	5

Figure 1. Charts Scoring with C-Means and Manuals

Based on the graph above it can be seen that manual calculations for GPA of 3.41 to 3.5 produce the same score of 3, while the fuzzy c-means calculation produces scores that vary more between 2 to 5, although the initial data is not too much different.

3.2. Fuzzy Tsukamoto Algorithm

Fuzzy tsukamoto algorithm in this research can be used to get unit data from the initial income criteria in the form of a range data, father's income can be seen in Table 4.

Table 4. Data of Lazis Scholarship Recipient Students (Indonesian Format)

No	Name	Father's Income (Range Data)	Father's Income (Unit Data)
1	A001	< Rp. 500.000	Rp 145.161,2903
2	A002	Rp. 500.000 - 1.500.000	Rp 893.340,2706
3	A003	Rp. 500.000 - 1.500.000	Rp 976.670,1353
4	A004	Rp. 500.000 - 1.500.000	Rp 1.312.695,1093
5	A005	Rp. 500.000 - 1.500.000	Rp 1.102.164,4121
6	A006	Rp. 500.000 - 1.500.000	Rp 837.689,9063
7	A007	Rp. 2.500.000 - 3.500.000	Rp 4.342.872,0083
8	A008	< Rp. 500.000	Rp 283.870,9677
9	A009	< Rp. 500.000	Rp 354.838,7097
10	A010	Rp. 500.000 - 1.500.000	Rp 594.693,0281
11	A011	Rp. 1.500.000 - 2.500.000	Rp 2.067.741,9355
12	A012	Rp. 500.000 - 1.500.000	Rp 1.312.695,1093
13	A013	< Rp. 500.000	Rp 354.838,7097
14	A014	< Rp. 500.000	Rp 216.129,0323
15	A015	Rp. 500.000 - 1.500.000	Rp 594.693,0281
16	A016	Rp. 500.000 - 1.500.000	Rp 1.190.447,4506
17	A017	< Rp. 500.000	Rp 377.419,3548
18	A018	Rp. 1.500.000 - 2.500.000	Rp 1.564.516,1290
19	A019	Rp. 500.000 - 1.500.000	Rp 594.693,0281
20	A020	Rp. 500.000 - 1.500.000	Rp 594.693,0281
21	A021	Rp. 2.500.000 - 3.500.000	Rp 4.417.502,6015
22	A022	Rp. 1.500.000 - 2.500.000	Rp 2.067.741,9355
23	A023	Rp. 500.000 - 1.500.000	Rp 1.054.963,5796
24	A024	Rp. 500.000 - 1.500.000	Rp 1.190.447,4506
25	A025	Rp. 1.500.000 - 2.500.000	Rp 1.932.258,0645
26	A026	< Rp. 500.000	Rp 370.967,7419
27	A027	< Rp. 500.000	Rp 145.161,2903
⋮	⋮	⋮	⋮
809	A809	Rp. 500.000 - 1.500.000	Rp 1.259.625,39
810	A810	Rp. 500.000 - 1.500.000	Rp 1.075.442,248

3.3. Determining Criteria Priorities

The modification phase is done by changing the pairing comparison matrix with a scale of importance that is considered difficult in determining consistency, so consistency checking must be done using a consistency index calculation, with the sorting and ranking method so that it is not necessary to check the consistency of the paired comparison matrix made. Assessment process with sorting and ranking as in Table 5.

Table 5. Assessment Every Criteria

No	Criteria	Ranking	Score
1	Father's occupation	3	6
2	Mother's job	3	6
3	Father's income	2	8
4	Mother's income	2	8
5	Number of families	5	3
6	Tuition fee	4	5
7	GPA	6	1
8	Condition	1	10

Determining the importance of each criterion on a scale of importance is more difficult when compared to ranking. And it is not yet known also that the importance scale can make a consistent pairwise comparison matrix or not, so there is a need to check consistency with the consistency index calculation. In contrast to determining interests

by using rating, where there is no need to check for consistency because the resulting pairwise comparison matrix is definitely consistent, this has been confirmed in previous research.

If you take Faisol's research that discusses the comparison of FAHP and AHP [10], the time needed for weighting the criteria to have a faster execution time is shown in Table 6 and Figure 2. This is because in the priority criteria process in the modified AHP there is no need to check the consistency of the pairwise comparison matrix.

Table 6. Comparison of Execution Time from Criteria Priority

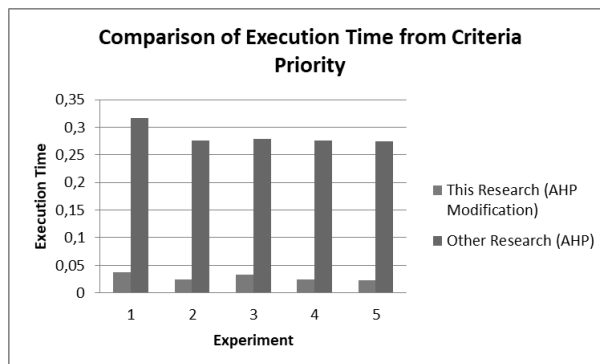| | Execution Time from Criteria Priority (second) | | | |
	Other Research		This Research	
	12 Criteria	1 Criteria	8 Criteria	1 Criteria
1	3.7992	0.3166	0.302891731	0.037861466
2	3.309	0.27575	0.19097662	0.023872077
3	3.3537	0.279475	0.259442091	0.032430261
4	3.3041	0.275341667	0.195183754	0.024397969
5	3.2989	0.274908333	0.187356949	0.023419619

Figure 2. Charts Comparison of Execution Time from Criteria Priority

3.4. Determining Alternative Priorities
Modification to the alternative priority calculation process. just using a simpler calculation formula but the calculation process that is executed is basically not too changed. this can be seen from Figure 3 where the results obtained are exactly the same as the calculation alternative priority standard process.
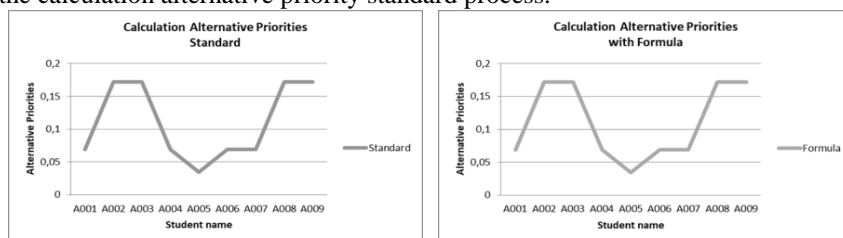

Figure 3. Chart Calculation Alternative Priorities Standard and

Alternative Priorities with Formulas

If taking the execution time needed in an alternative weighting in Faisol's research [10]. Although there is no difference in the final result. which is somewhat faster. can be seen in Figure 4. This is because. the alternative priority process in the AHP modification uses a simpler formula.
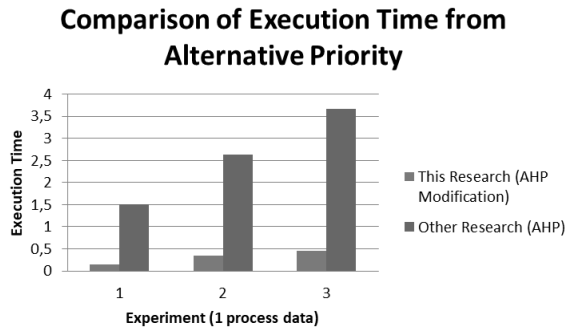

Figure 4. Charts Comparison of Execution Time from Alternative Priority

3.5. Determining Final Priority Index Value

Comparison of calculation results using the initial FPIV formula and the modified NIPA formula. if we take from the top 25 can be seen in Table 7.

Based on Figure 5. it can be known that the initial FPIV calculation process contains 3 equal value data. namely rank 6. 18. and 23. While the calculation of FPIV modification is 1. namely in rank 8.

This modification only affects if the parameter values in two different test data are still within the same criteria range. not if the parameter values are the same. And in the modified FPIV formula there is an alternative initial value variable. so this FPIV modification will be more maximal if it is used in a system that uses data with all initial data in the form of numbers such as income. IPK. and UKT data.

Table 7. Comparison of Calculation from Initial FPIV and Modified FPIV

No	Other Initial FPIV			Modified FPIV		
	Name	Score	Rank	Name	Score	Rank
1	A009	0.002055512	1	A009	0.004176516	1
2	A248	0.002046572	2	A248	0.004167576	2
3	A368	0.001829606	3	A479	0.003853168	3
4	A747	0.00181163	4	A368	0.002536608	4
5	A384	0.001782135	5	A262	0.002521991	5
6	A350	0.001775676	6	A747	0.002518631	6
7	A438	0.001775676	6	A059	0.002510377	7
8	A392	0.001757796	8	A350	0.002482678	8
9	A658	0.001748856	9	A438	0.002482678	8

|						
10	A174	0.001745988	10	A237	0.002479923	10
11	A458	0.001742548	11	A295	0.002477248	11
12	A214	0.001739916	12	A106	0.002474423	12
13	A479	0.001732163	13	A185	0.002473808	13
14	A770	0.001712419	14	A072	0.002473746	14
15	A619	0.00170942	15	A392	0.002464798	15
16	A206	0.001695703	16	A683	0.002459941	16
17	A483	0.001693071	17	A658	0.002455858	17
18	A312	0.001692878	18	A174	0.00245299	18
19	A539	0.001692878	18	A568	0.002451001	19
20	A189	0.001667405	20	A458	0.002449549	20
21	A796	0.001665574	21	A214	0.002446918	21
22	A187	0.001659846	22	A267	0.00244412	22
23	A123	0.001656925	23	A257	0.002437855	23
24	A357	0.001656925	23	A770	0.002419421	24
25	A099	0.001647217	25	A398	0.002417872	25
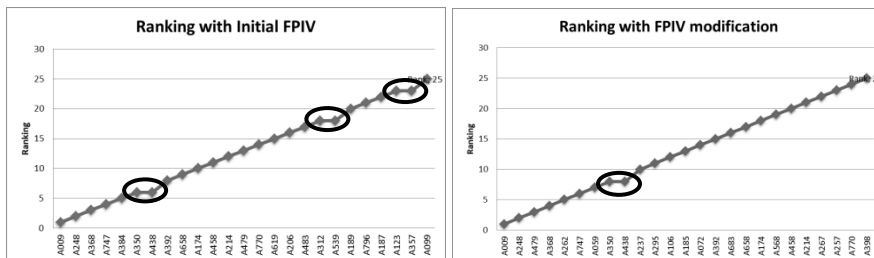
Figure 5. Chart Ranking with Initial FPIV and FPIV modification

4. CONCLUSION

The application of the fuzzy algorithm and the modification of the AHP method to the recipients of the SPK Lazis scholarship in 2018 at UNNES. which involved the use of 810 student registrant data obtained results in which the first position was occupied by A009 students with a final priority index value of 0.004176516 and ten ratings Top recipients of Lazis scholarships are shown in Table 2. Using the calculation process in the decision support system in this research is better than the standard decision support system. this was shown in the previous discussion. Such as the use of fuzzy Tsukamoto can be used to change the value of the range into unit values. Fuzzy c-means produce a more variable score. but the more data and the more varied the spread of data. The better if the number of clusters is determined too. In modifying the determination of the importance of each criterion. Using sorting and ranking will produce a pairwise comparison matrix that is certainly consistent and has a faster processing time than using an interesting scale. But is less suitable for solving unstructured problems. In the alternative priority. modification has a relatively faster execution time than standard calculations. But it is also not suitable to solve unstructured problems. And modifications to the FPIV can be minimized to produce the same final value. But more leverage if used on a system that uses data with all initial data in the form of all numbers.

5. REFERENCES

[1] Triantaphyllou. E.. & Mann. S. H. (1995). Using The Analytic Hierarchy Process for Decision Making in Engineering Applications: Some Challenges. *Inter'l Journal of Industrial Engineering: Applications and Practice*. *2*(1). 35-44.

[2] Rivai. V. (2009). *Education Management Analisis Teori dan Praktik.* Jakarta: Rajawali Pers.

[3] Munthafa. A. E.. & Mubarok. H. (2017). Penerapan Metode Analytical Hierarchy Process dalam Sistem Pendukung Keputusan Penentuan Mahasiswa Berprestasi. *Jurnal Siliwangi. 3*(2). 192-201.

[4] Li. F.. Phoon. K. K.. Du. X.. & Zhang. M. (2013). Improved AHP Method and Its Application in Risk Identification. *Journal of Construction Engineering And Management*. 312-320.

[5] Rosmawanti. N.. & Bahar. (2014). Penentuan Skala Prioritas Berbasis Algoritma AHP Termodifikasi. *Jurnal PROGRESIF*. *10*(1). 961-970.

[6] Mahmudin. D.. Dharma. A. S.. Susanto. E.. & Wahyu. Y. (2014). Perancangan dan Implementasi Pengontrol Arah Pancaran Radar Pengawas Pantai Terhadap Sudut Tertentu. *Jurnal Elektronika dan Telekomunikasi. 14*(1). 29-35.

[7] Sediyono. E.. Widiasari. I. R.. & Milasari. (2006). Penentuan Lokasi Fasilitas Gudang Menggunakan Fuzzy C–Means (FCM). *Jurnal Informatika. 2*(2). 155-166.

[8] Muhardi. & Nisar. (2015). Penentuan Penerima Beasiswa dengan Algorima Fuzzy C-Means di Universitas Megow Pak Tulang Bawang. *Jurnal TIM Darmajaya. 1*(2). 158-174.

[9] Sugianti. (2016). Menentukan Penerima KPS Menggunakan Fuzzy Inference System Metode Tsukamoto. *Jurnal Ilmiah Multitek Indonesia. 10*(1). 48-56.

[10] Faisol. A.. Muslim. M. A.. & Suyono. H. (2014). Komparasi Fuzzy AHP dengan AHP pada Sistem Pendukung Keputusan Investasi Properti. *Jurnal EECCIS. 8*(2). 123-128.