APPLICATION OF FUZZY ANALYTICAL NETWORK PROCESS IN DETERMINING THE CHOICE OF AREAS OF INTEREST

Dinda Tiara [1*]**, Evy Sulistianingsih**[2]**, Hendra Perdana**[3]**, Neva Satyahadewi**[4]**, Ray Tamtama**[5]

[1,2,3] *Statistics Study Program, Faculty of Mathematics and Natural Sciences, Tanjungpura University*
St. Prof. Dr. H. Hadari Nawawi, Pontianak, 78124, Indonesia

Corresponding author's e-mail: *dindatiara93@student.untan.ac.id

ABSTRACT

The Untan Statistics Study Program offers students a choice of areas of interest to develop competencies, attitudes, and skills. This study aims to analyze the decision to determine the choice of field of interest according to lecturers and students using the Fuzzy Analytical Network Process (FANP) method. A combination of ANP methods and Fuzzy logic, FANP is used to model and analyze complex networks of several factors determining the choice of areas of interest. The step in this study begins with the determination of the criteria and sub-criteria used for tissue formation. Then a comparison was carried out in pairs using the Fuzzy scale, so that the calculation of the global weight value of each criterion and sub-criteria was obtained. The resulting weight can be used for decision making. Data in research affects the opinions of lecturers and students. The decision obtained using the FANP method in this study is in the opinion of lecturers and students that the fields of business and finance are priority alternatives with the highest weight of 44.5%. The second priority with a weight of 37.5%, namely social and industrial interests, and the environmental and disaster sector occupies the last priority with a weight of 18%.

1. INTRODUCTION

Tanjungpura University (Untan) is one of the State Universities in West Kalimantan. One of the Study Programs offered is the Statistics Study Program. Untan Statistics Study Program has shown its existence. This can be seen from the large interest of students who want to enter the Untan Statistics Study Program, as evidenced by the results of the announcement of the Higher Education Entrance Test Institute that the interest in the Untan Statistics Study Program increases every year [1].

The Untan Statistics Study Program provides a choice of areas of interest that will later be chosen by students. A student's hesitation leads to the need for a decision support system, to help determine what area of interest should be chosen. In the mechanism of determining the field of interest, a method is needed based on considerations between criteria. The method that can be used is the Fuzzy Analytical Network process (FANP) method. FANP is a combination of Fuzzy method and Analytical Network Process (ANP) method. The ANP method can be used in the form of solving with consideration of adjusting the complexity of the problem by deciphering the synthesis along with a priority scale [2]. Fuzzy's approach is used to address incomplete data and information and accommodate the vague nature of decision makers in providing judgments that can overcome uncertainty in qualitative criteria [3]. The FANP method is a good combination because it allows good dependencies between criteria and alternatives [4].

Research using the ANP method can be applied to decision making by considering various criteria, sub-criteria and alternatives [5]. The ANP method aims to consider one criterion with another criterion or one alternative with another alternative. Then a Fuzzy approach is carried out, which aims to overcome the existence of unclear data and accommodate the vague nature of decision makers in providing assessments [6]. Therefore, a combination of the Fuzzy and Analytical Network Process (ANP) methods or known as the Fuzzy Analytical Network Process (FANP) method was carried out. The advantage of the FANP method is that it has a level of subjectivity and inaccuracies that occur can be minimized compared to using the ANP method alone [7].

The purpose of this study is to obtain three different decisions, namely based on the opinions of lecturers and students, each of which is obtained using the ANP method. Furthermore, the opinions of lecturers and students were combined which were analyzed using the FANP method. These results are obtained by considering between criteria and sub-criteria. The criteria used in this study are academic criteria, the influence of others, and individual students. Academic criteria have three sub-criteria, namely, job prospects, teaching lecturers, and courses. There are two sub-criteria of the influence of others, namely the sub-criteria of family and friends. While there are two individual sub-criteria for students, namely self-potential and self-desire of students. The alternatives used are three choices of areas of interest in the Untan Statistics Study Program, namely, the fields of business and finance, social and industrial, and environmental and disaster interests.

2. RESEARCH METHODS

2.1 Pairwise Comparison Matrix

In this study, data collection was carried out using questionnaires addressed to students and lecturers. In the questionnaire, there is a choice of comparison of each criterion or sub-criterion on a scale of 1-9, with the results getting towards number 9, the criteria or sub-criteria are considered increasingly important. From the results of obtaining the scale, a matrix of pairwise comparison is formed. The pairwise comparison matrix is used to compare all elements in paired form for each sub-system of the hierarchy. The comparison that has been obtained is then transformed in matrix form for numerical analysis presented in **Table 1 [8]**.

Table 1. Pairwise Comparison Matrix

	C_1	C_2	C_3	…	C_h
C_1	c_{11}	c_{22}	c_{33}	…	c_{1h}
C_2	c_{21}	c_{22}	c_{23}	…	c_{2h}
C_3	c_{31}	c_{32}	c_{33}	…	c_{3h}
⋮	⋮	⋮	⋮		⋮
C_h	c_{h1}	c_{h2}	c_{h3}	…	c_{hh}

Pairwise comparison assessments are obtained using the importance levels presented in **Table 2**.

Table 2. Pairwise Comparison Assessment

Importance	Importance	Definition
1	Equally important	Both elements have the same influence
3	A little more important	Experience and judgment favor one element slightly over the other
5	More importantly	Experience and judgment strongly favor one element over their partner
7	Very important	One element is well-liked and practically its dominance is noticeable
9	Absolute importance	One element proved absolutely preferable to its counterpart
2,4,6,8	Middle value	When a compromise is needed
Opposite	$B_{ji} = 1/\ B_{ij}$	If element i has one of the numbers above When compared element j, then j has the inverse value when compared element i.

The answer to the pairwise comparison matrix using the geometric mean can be calculated using **Equation (1)**.

$$a_{ij} = (B_1 \times B_2 \times \ldots \times B_k)^{\frac{1}{N}} \tag{1}$$

with a_{ij} is the geometric mean of pairwise comparisons between i and j, B_k is the pairwise comparison value for respondents to-k, $k=1, 2, \ldots, N$, and N is the number of respondents. The geometric mean that has been obtained, the next step is mathematically normalized, it can be written as follows [9]:

$$c_{ij} = \frac{a_{ij}}{\sum_{i=1}^{N} a_{ij}} \tag{2}$$

with a_{ij} is the geometric mean of pairwise comparisons between i dan j and c_{ij} is the normalization of the geometric mean value of pairwise comparison between i and j for N respondent. Next, A weighting process is carried out for each criterion that has been determined based on the other criteria. The weighting calculation algorithm starts with paired comparison form data until the weight of each indicator of the criteria and its sub-criteria is obtainedA weighting process is carried out for each criterion that has been determined based on the other criteria. The weighting calculation algorithm starts with paired comparison form data until the weight of each indicator of the criteria and its sub-criteria is obtained [10].

2.2 Testing Consistency

Consistency tests on weight values are performed on each comparison matrix. As for some things that can be done when measuring the level of consistency as followsConsistency tests on weight values are performed on each comparison matrix. As for some things that can be done when measuring the level of consistency as follows:

a. Multiplication of the initial matrix of each criterion or subcriterion by a weight value,

$$\sum_{i=1}^{n} \sum_{j=1}^{n} a_{ij} w_{ij}, \tag{3}$$

b. Sums the values of each row on the matrix then divide by their weight values,

$$X_{ij} = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} a_{ij} w_{ij}}{w_{ij}} \tag{4}$$

c. Calculating $\lambda maks$ by using **Equation (5)**,

$$\lambda_{maks} = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} X_{ij}}{n} \tag{5}$$

d. Value λ_{maks} used for calculations Consistency Index (CI), As for the calculation of value CI presented on **Equation (6).** A matrix is generated from comparisons made randomly with a comparison scale 1-9. For some orders of the matrix, an average value is obtained Random Index (RI) presented in **Table 3 [11]**. Average rating RI can be used to determine Consistency Ratio a matrix using **Equation (7)**.

$$CI = \left(\frac{\lambda_{maks} - n)}{n-1}\right), \qquad (6)$$

Table 3. Average rating Random Index (RI)

N	1	2	3	4	5	6	7	8	9	10	11	12
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.58

$$CR = CI/RI. \qquad (7)$$

2.3 Triagular Fuzzy Number Matrix Conversion

Before committing to FANP calculations, the hierarchical structure of the problem is solved first by calculating the ANP to find the consistency of its comparison matrix values. A comparison matrix is said to be consistent when the values CR$\leq$ 0,1 **[11]**. If eligible, the consistently converted comparison matrix values to a scale Triangular Fuzzy Number (TFN), to increase objectivity, effectiveness, and evaluate the value of trust in a criterion. The values of the ANP pairwise comparison matrix are then converted into the TFN scale, which is presented in Table 4 **[12]**.

Table 4. TFN Pairwise Importance and Comparison

Scale	Information	TFN Scale	TFN Invers Scale
	Comparison of the same elements	(1, 1, 1)	(1, 1, 1)
1	Two elements have the same importance	(1/2, 1, 3/2)	(2/3, 1, 2)
3	One element is slightly more important than the other	(1, 3/2, 2)	(1/2, 2/3, 1)
5	The element of one is strong in importance over the other	(3/2, 2, 5/2,)	(2/5, ½, 2/3)
7	The element of one is very much more powerful in importance than the other	(2, 5/2, 3)	(1/3, 2/5, 1/2)
9	The element of one is absolutely more important than the other	(5/2, 3, 7/2)	(2/7, 1/3, 2/5)

If the value has been converted into a TFN matrix, the value of fuzzy synthetic extent (*Si*) synthesis is then calculated. The purpose of obtaining the fuzzy synthetic extent value is to assess the weight of each criterion against the main purpose of the hierarchy **[13]**. The formula is given as follows:

$$Si = \sum_{j=1}^{m} M_{gi}^{j} \otimes \frac{1}{[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j}]}, \qquad (8)$$

To obtain $\frac{1}{[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j}]}$, *fuzzy* use of m value in **Equation (8)**.

$$\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} l_j \sum_{j=1}^{m} m_j \sum_{j=1}^{m} u_j\right), \qquad (9)$$

If the results obtained on the *fuzzy* matrix are M$_2 \geq$ M$_1$ where M$_1 = (l_1, m_1, u_1)$ and M$_2 = (l_2, m_2, u_2)$, then the vector value can be seen in **Equation (10) [14]**,

$$V(M_2 \geq M_1) = sup \left[min\left(\mu M_1(x), min\left(\mu M_2(y)\right)\right)\right] \qquad (10)$$

where soup is the smallest upper limit of the minimum yield, or like **Equation (9) [15]**.

$$V(M_2 \geq M_1) = \begin{cases} 1 & if \ m_2 \geq m_1 \\ 0 & if \ l_1 \geq u_2 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_2 - l_1)}; & in \ addition \ to \ the \ above \end{cases}, \qquad (11)$$

with V is a vector value, M is a fuzzy synthesis value matrix, so that an ordinate value is obtained

$$(d')d'\,(Ai)\ =\ min\,V\,(S_p \geq S_c),\qquad\qquad(12)$$

with S_p is the fuzzy synthesis value of one, S_c is another fuzzy synthesis value. Then a vector value is obtained

$$W' = (d'(A_1), d'(A_2), \ldots, d'(A_i))^T,\qquad\qquad(13)$$

with A_i *(i=1, 2, ..., n)* are *n* decision elements and *d' (A_i)* is a value that describes the relative choice of each decision attribute [15]. Normalization of vector weight values is obtained by **Equation (14)** [16].

$$d(A_n) = \frac{d'(An)}{\sum_{i=1}^{n} d'(An)},\qquad\qquad(14)$$

So that the fuzzy vector weight normalization value is obtained as follows:

$$W = (d(A_1), d(A_2), \ldots, d(A_i))^T.\qquad\qquad(15)$$

with W is a non fuzzy number. The calculation of the final weight of priority and the ranking of the final weight of priority are used to determine the order of each element [17].

3. RESULTS AND DISCUSSION

The data used in this study were primary data obtained by distributing questionnaires. There were 18 respondents with details of 6 people from the class of 2019, and 7 people from the class of 2020 who had chosen the field of interest, as well as several lecturers who supervised the field of interest in the Statistics Study Program. The data obtained is then formed into a pairwise comparison matrix for each criterion and sub-criteria.

One example of a paired comparison matrix at the criterion level for the 1st respondent in lecturers can be seen in **Table 5**.

Table 5. Level Matrix of 1st Lecturer Respondent Criteria

Criterion	Academic	Influence Of Others	Individual Student
Academic	$a_{11} = 1$	$a_{12} = 7$	$a_{13} = 7$
Influence of Others	$a_{21} = 1/7$	$a_{22} = 1$	$a_{23} = 5$
Individual Student	$a_{31} = 1/7$	$a_{32} = 1/5$	$a_{33} = 1$

After obtaining a pairwise comparison matrix at the level of criteria and sub-criteria from all respondents to the lecturer, then weighting is carried out with the geometric average using **Equation (1)**.

$$a_{12} = (7 \times 9 \times 8 \times 6 \times 7)^{\frac{1}{5}} = 7{,}331$$

After weighting with the geometric average, a matrix of paired levels of lecturer respondent criteria was obtained which is presented in **Table 6**.

Table 6. Pairwise Comparison Matrix of Lecturer Criteria Level

Criterion	Academic	Influence Of Others	Individual Student
Academic	$a_{11} = 1$	$a_{12} = 7{,}331$	$a_{13} = 1{,}563$
Influence Of Others	$a_{21} = 0{,}136$	$a_{22} = 1$	$a_{23} = 0{,}296$
Individual Student	$a_{31} = 0{,}640$	$a_{32} = 3{,}380$	$a_{33} = 1$
Total	1,776	11,710	2,859

The next step is to normalize the weighting value of the lecturer respondent criteria level matrix using **Equation (2)**.

$$a_{11} = \frac{1}{1{,}776} = 0{,}563.$$

This is done on each weight value, so that the results of the normalization of the pairwise comparison matrix for the level of criteria for lecturer respondents are presented in **Table 7**.

Table 7. Normalization of Criteria Level Paired Comparison Matrix

Criterion	Academic	Influence Of Others	Individual Student	Weight
Academic	0,563	0,626	0,547	0,515
Influence Of Others	0,077	0,085	0,103	0,098
Individual Student	0,360	0,289	0,350	0,388

The calculation is carried out in the same way in the assessment results according to students, so that the normalization of paired comparison matrices at the level of criteria and sub-criteria is obtained. The results of the comparison between the weights of lecturers and students can be seen in **Table 8**.

Table 8. Comparison of Questionnaire Weights Between Lecturers and Students

Criterion	Lecturer Weight	Student Weights	Sub criteria	Lecturer Weight	Student Weights
Academic	0,515	0,352	Job Prospect	0,445	0,406
			Teaching Lecturer	0,285	0,321
			Courses	0,270	0,273
Influence Of Others	0,098	0,088	Family	0,5	0,485
			Friend	0,5	0,515
Individual Student	0,388	0,559	Self-Potential	0,597	0,5
			Self-Desire	0,403	0,5

The weighted values obtained from the normalization of paired comparison matrices, must be tested for consistency first before being set as a priority. This is done using **Equation (3)**.

$$\begin{bmatrix} 1 & 7{,}331 & 1{,}563 \\ 0{,}136 & 1 & 0{,}296 \\ 0{,}640 & 3{,}380 & 1 \end{bmatrix} \begin{bmatrix} 0{,}515 \\ 0{,}098 \\ 0{,}388 \end{bmatrix} = \begin{bmatrix} 1{,}840 \\ 0{,}283 \\ 1{,}049 \end{bmatrix}$$

The next step is to divide the consistency value for the criterion level by each of its weight values which can be done using **Equation (4).**

$$\begin{bmatrix} 1{,}840/0{,}515 \\ 0{,}283/0{,}098 \\ 1{,}049/0{,}388 \end{bmatrix} = \begin{bmatrix} 3{,}573 \\ 2{,}886 \\ 2{,}035 \end{bmatrix}$$

The result of dividing the consistency value by the weight value of each criterion so that the average value obtained is the maximum eigenvalue.

$$\lambda_{maks} = \frac{(3{,}573 + 2{,}886 + 2{,}035)}{3} = 3{,}054$$

After getting the grade λ_{maks}, The next step is to calculate the consistency index value

$$CI = \left(\frac{\lambda_{maks} - n}{n-1}\right) = \frac{3{,}054 - 3}{3 - 1} = 0{,}027$$

If $n = 3$, in Table 3 obtained the value of RI = 0.58, Then the consistency ratio value is obtained as follows:

$$CR = \frac{CI}{RI} = \frac{0{,}027}{0{,}58} = 0{,}046$$

Value CR 0,046 ≤0,1000, with a CR value of 4.6%. Since the value is less than 10%, it can be said that respondents' assessment of the questionnaire is consistent and the weight obtained can be used for prioritization. **Table 9** presents a comparison of CI and CR scores for lecturer and student questionnaires as follows:

Table 9. Comparison of CI and CR Values Between Lecturers and Students

	Consistency Index	*Consistency Ratio*	Information
Lecturer	0,027	0,046	Consistent
Student	0,021	0,036	Consistent

After obtaining the local weighting value on each criterion or sub-criterion, then an overall comparison is carried out to obtain the global weight value. Criteria and alternatives that are taken into consideration in determining the field of interest. Calculations with the help of *Support Decision software* obtained the results given in **Table 10.**

Table 10. Global Weight Comparison Between Lecturers and Students

Criterion	Sub Kriteria	Global Weights	Rank	Global Weights	Rank
Academic	Job Prospect	0,229	2	0,143	3
	Teaching Lecturer	0,147	4	0,113	4
	Courses	0,139	5	0,096	5
Influence Of Others	Family	0,049	6	0,043	7
	Friend	0,049	6	0,045	6
Individual Student	Self-Potential	0,232	1	0,280	1
	Self-Desire	0,156	3	0,280	1

After comparison of alternative choices of areas of interest by taking into account the relationship between sub criteria and criteria, overall results were obtained in **Table 11**.

Table 11. Weighting of Alternative Assessments Determination of Areas of Interest

Alternative	Student Weights	Rank	Lecturer Weight	Rank
Business and Finance	0,416	2	0,449	1
Social and Industrial	0,441	1	0,397	2
Environment and Disaster	0,143	3	0,154	3

Based on **Table 11**, it was found that the field of industrial social interest is the best alternative for students because it has the highest weight of 44.1%, while lecturers in the field of business and finance interest are the best alternative with the highest weight value of 44.9%.

The data used for the measurement of priority interests were obtained by combining student and lecturer questionnaires. The data obtained is then formed into a pairwise comparison matrix for each criterion. One example of a pairwise comparison matrix at the criterion level can be seen in **Table 12**.

Table 12. Pairwise Comparison Matrix with Geometric Mean

Criterion	Academic	Influence Of Others	Individual Student
Academic	$a_{11} = 1$	$a_{12} = 5{,}745$	$a_{13} = 0{,}745$
Influence Of Others	$a_{21} = 0{,}174$	$a_{22} = 1$	$a_{23} = 0{,}217$
Individual Student	$a_{31} = 1{,}343$	$a_{32} = 4{,}608$	$a_{33} = 1$

The determination of paired comparison matrix elements in Table 12 was carried out by means of geometric averages from the combination of student and lecturer questionnaires with the ANP method. The CR value in the combined lecturer and student questionnaire was obtained at -0.189 which means less than 0.1000. Thus, it can be said that respondents' assessment of the questionnaire is consistent.

A consistent comparison matrix can be used for conversion to *a Triangular Fuzzy Number* (TFN) matrix. The matrix values in **Table 12** are converted to TFN matrices which can be seen in **Table 13**.

Table 13. Triangular Fuzzy Number Matrix Conversion

Criterion	C1			C2			C3			$\sum_{j=1}^{m} M_{gi}^{j}$ number of rows		
	l_1	m_1	u_1	l_2	m_2	u_2	l_3	m_3	u_3	l	m	u
C1	1	1	1	3/2	2	5/2	1/2	1	3/2	3	4	5
C2	2/5	1/2	2/3	1	1	1	1/2	1	3/2	1,9	2,5	3,17
C3	2/3	1	2	2/3	1	2	1	1	1	2,33	3	5
$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}$ or the number of columns										7,23	9,50	13,17

The predefined Triangular Fuzzy Number *matrix value* is used to find the fuzzy synthesis value *(Si)* on each criterion (S_{ci}) based on **Equation (8)** as follows:

$$S_{c1} = (3;\ 4;\ 5) \otimes (\frac{1}{13,17}, \frac{1}{9,50}, \frac{1}{7,23})$$

$$= 0,228;\ 0,421;\ 0,691.$$

After obtaining the value of fuzzy synthesis in the first criterion, namely academic criteria, then it is carried out as well as other criteria. The calculation of the fuzzy synthesis value obtained is given in **Table 14**.

Table 14. Fuzzy Synthesis Value Criteria

Criterion	*(Si)*		
	l	*m*	*u*
C1	0,228	0,421	0,691
C2	0,144	0,263	0,438
C3	0,177	0,316	0,691

After obtaining the fuzzy synthesis value, the minimum defuzzification ordinate value (*d'*) is then calculated. Based on **Equation (11)**, the vector value of the Academic criterion (*C1*) is obtained, with the vector value being as follows:

Table 15. Defuzzification Ordinate Value

Fuzzy Synthesis Criteria	Ordinate Value
$V(S_{c1} \geq S_{c2})$	1
$V(S_{c1} \geq S_{c3})$	1
$V(S_{c2} \geq S_{c1})$	0,571
$V(S_{c2} \geq S_{c3})$	0,832
$V(S_{c3} \geq S_{c1})$	0,815
$V(S_{c3} \geq S_{c2})$	1

Based on the ordinate value there is a minimum value of each $VS_{c1}, VS_{c2},\ dan\ VS_{c3}$, fuzzy synthesis criterion, so that the vector weight value can be determined as follows:

$$W' = (1;\ 0,571;\ dan\ 0,815)^T$$

The normalized vector weight value will be 1, with the normalized value as follows:

$$W_{lokal} = \underbrace{(0,419;\ 0,239, 0,342)^T}_{\sum W_{lokal}=1}$$

Thus, the weight of the (local) criteria obtained is 0.419; 0.239 and 0.342. Thus, it can be concluded that the top priority with the highest weight is found in academic criteria with a score of 41.9%, with the second highest priority being individual student criteria at 34.2%, and 23.9% for other people's influence criteria.

The ranking of each alternative is obtained by taking into account the relationship between sub-criteria and criteria. The calculation process is carried out using the help of Support Decision software. The results obtained can be seen in **Table 16**.

Table 16. Alternative Assessment Weights

Alternatif	Weight	Rank
Business and Finance	**0,445**	**1**
Social and Industrial	0,375	2
Environment and Disaster	0,180	3

Source: data processing in Super Decision software

Based on the use of FANP in determining the selection of areas of interest according to the opinions of students and lecturers who have been combined, it was found that the fields of business and finance became the first priority in the selection of areas of interest with the highest weight of 44.5%. The second priority is the social industry sector with a weight of 37.5% and the environment and disaster sector occupies the last position with the lowest weight value of 18%.

4. CONCLUSIONS

This study has discussed the use of Fuzzy Analytical Network Process in determining areas of interest in the Statistics study program FMIPA Tanjungpura University. Based on the results and discussions that have been explained, the decision was obtained, namely, the merger of lecturers and students' opinions obtained a global value weight in the fields of business and finance with the highest weight value of 44.5%, the social and industrial sector with a weight of 37.5%, and the field of interest in the disaster environment occupied the last position with the lowest weight of 18%. So that a decision was obtained that the field of business and financial interest is the main priority alternative in determining the choice of field of interest in the UNTAN Statistics Study Program.

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