SEMESTER 1 2019/2020

MSS414: TOPICS IN PURE MATHEMATICS

FUZZY SET THEORY

ASSIGNMENT 2

USING FUZZY AHP TO EVALUATE CRITERIA

FOR UNIVERSITY PERFORMANCE

GROUP MEMBERS	MATRIC NUMBER
NOR AINUN RIANI BT ROPI	134589
NUR ANATI BT MAHMUD SABRI	131898
NUR ATIQAH BT ABD MAJID	132071
NUR SYIFA BT ABDUL HALIM	134595
NURUL HUSNA BT MUHAMAD MUSTAFA AL-BAKRI	134598
RAIHANAH ADAWIYAH BT SHAHARUDDIN	134603
SITI AIZAT BT SAARI	134605
SITI NUR HAFSAH BT ADNAN	131899

LECTURER'S NAME:

DR. NORAZRIZAL ASWAD ABDUL RAHMAN

SUBMISSION DATE:

15TH DECEMBER 2019

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1.0 INTRODUCTION

Analytic Hierarchy Process (AHP) as a method of measurement with ratio scales. According to Thomas Saaty, the Analytic Hierarchy Process is a general theory of measurement in which we derive ratio scales from both discrete and continuous paired comparisons. These comparisons may be taken from actual measurements or from a fundamental scale which reflects the relative strength of preferences and feelings. In using AHP, we are concerned about the consistency, its measurement and the dependence within and between the groups of elements of its structure. More of its uses of applications came to light over the past years. It is widely used in multicriteria decision making, planning and resource allocation and in conflict resolution. (Saaty T. L., 1980) In its general form the AHP is a nonlinear framework for carrying out both deductive and inductive thinking without using the syllogism by taking several factors into consideration simultaneously and allowing for dependence and for feedback, and making numerical tradeoffs to arrive at a synthesis or conclusion. T. L. Saaty developed the AHP in 1971- 1975 while at the Wharton School (University of Pennsylvania, Philadelphia, Pa).

For a long time people have been concerned with the measurement of both physical and psychological events. By physical we mean the realm of what is fashionably known as the tangibles as it relates to some kind of objective reality outside the individual conducting the measurement. By contrast, the psychological is the realm of the intangibles as it relates to subjective ideas and beliefs of the individual about himself or herself and the world of experience. The question is whether there is a coherent theory that can deal with both these worlds of reality without compromising either. The AHP is a method that can be used to establish measures in both the physical and social domains. (Saaty R. W., 1987)

In using the AHP to model a problem, we need a hierarchic or a network structure to represent that problem and pairwise comparisons to establish relations within the structure.

Pairwise comparisons are very important in the use of the AHP. We must first establish priorities for the main criteria by judging them in pairs for their relative importance, thus generating a pairwise comparison matrix. Judgments which are represented by numbers from the fundamental scale are used to make the comparisons. The number of judgments needed for a

particular matrix of order n, the number of elements being compared, is n(n - 1)/2 because it is reciprocal and the diagonal elements are equal to unity.

Another important aspect of the AHP is the idea of consistency. If one has a scale for a property possessed by some objects and measures that property in them, then their relative weights with respect to that property are fixed. In this case there is no judgmental inconsistency (although if one has a physical scale and applies it to objects in pairs and then derives the relative standing of the objects on the scale from the pairwise comparison matrix, it is likely that inaccuracies will have occurred in the act of applying the physical scale and again there would be inconsistency). But when comparing with respect to a property for which there is no established scale or measure, we are trying to derive a scale through comparing the objects two at a time. Since the objects may be involved in more than one comparison and we have no standard scale but are assigning relative values as a matter of judgment, inconsistencies may well occur.

2.0 METHODOLOGY

A. Satty Scale

Saaty (1980) has proposed the use of ratio scale between 1 and 9. Although there has been some criticism about the use of ratio scale in measuring the relative intensity of stimuli, but the experiment reported by Saaty and experience of many users of AHP supports the view that the scale 1 to 9 presents fairly well the preference of an individual. In 2005, Saaty has suggested the relative importance scale (Saaty, 2005) which determines the relative importance of an alternative when compared to another alternative.

Scale	*Numerical Rating*	*Reciprocal*
Extremely Preferred	9	1/9
Very strong to extremely	8	1/8
Very Strongly Preferred	7	1/7
Strong to very strongly	6	1/6
Strongly Preferred	5	1/5
Moderately to strongly	4	1/4
Moderately Preferred	3	1/3
Equal to moderately	2	1/2
Equally Preferred	1	1

Table 1: The relative importance scale by Saaty

The odd number from Table 1 is commonly used to make sure there is a reasonable distinction between the measurement points. The use of even numbers should only be adopted if there is a need for negotiation between the evaluators. When a natural consensus cannot be reached, it raises the need to determine a middle point as the negotiated solution (compromise) (Saaty, 1980). Hence, based on the scale proposed by Saaty we have applied it into our analysis in evaluating the criteria and the AHP Saaty Scale used is as follows:

1- Equal Importance
3- Moderate Importance
5- Strong Importance
7- Very Strong Importance
9- Extreme Importance
(While 2, 4, 6, 8 are values in between)

B. Analytic Hierarchy Process (AHP)

1. Pairwise comparison

Level 1

For level 1 of our analysis, it consists of 7 different criteria. Let n=number of criteria, so

$$the\ number\ of\ comparisons = \frac{n(n-1)}{2}$$

Since n=7, there will be 21 pairwise comparison between the criteria. The comparison matrix corresponds to pairwise comparison between the criteria with respect to the evaluation of university performance. Hence, the resulted comparison matrix will be a 7 by 7 matrix where the diagonal element is always 1. Based on the pairwise comparison in the questionnaire, the value obtained will be used to fill up the upper part of the comparison matrix which according to the following rules:

i. *If the judgment value is on the **left** side of 1, we put the **actual judgment** value.*

ii. *If the judgment value is on the **right** side of 1, we put the **reciprocal** value*.

Next, for the lower part, let a_{ij} be an element of the comparison matrix with i row and j column, then the lower triangle matrix, a_{ji} is filled by using the formula: $a_{ji} = \frac{1}{a_{ij}}$. In the comparison matrix, all elements are positive, $a_{ij} > 0$.

Level 2

Each criteria in level 1 comprises of 2 sub-criteria. These sub-criteria generate level 2 of our analysis. There will be 14 different sub-criteria which corresponds to their respective criteria. Since every criteria is connected to each sub-criteria, hence in general there will be 7 comparison matrix where it is of the size 2 by 2 matrix. Level 1 and Level 2 differs only in their size and number of comparison matrix but the other step for determining the rank for level 2 is the same as the steps in Level 1.

2. Priority Vector (Weight)

   After the comparison matrix is obtained, then we proceed with finding the priority vector which is the normalized eigenvector of the matrix. First, to obtain the normalized relative weight, take the sum of each column in the comparison matrix and then each element of the matrix is divided by the sum of its corresponding column. Note that the total of normalized relative weight is 1 for every column. From there, the priority vector is obtained by computing the average of each row. This priority vector shows the relative weights among criteria which enable us to compare and rank the criteria.

3. Checking the Consistency

   Since the answer of questionnaire involves subjective opinions, thus this step is crucial to evaluate how consistent the judgement of respondents. The overall consistency is taken by averaging the consistency of each criteria row by row. For instance, in order to find the consistency of criteria A (first row), we multiply the first row of the comparison matrix (1 by 7 matrix) with the priority vector (7 by 1 matrix) to get a scalar. Next, this scalar is divided by the 1st element of the priority vector to obtain the value of consistency for criteria A. Continue this step for the remaining 6 criteria and take the average for the overall consistency. Prof Saaty has proposed a measure of consistency called Consistency Index, CI as deviation or degree of consistency and the formula is as follows:

$$CI = \frac{Overall\ consistency - n}{n - 1}$$

   After the overall consistency is translated in the form of CI, it is then compared with the appropriate Consistency Index also known as Random Consistency Index, RI where:

$\boldsymbol{n}$	1	2	3	4	5	6	7	8	9	10
$\boldsymbol{RI}$	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

   Then, Prof Saaty also proposed Consistency Ratio, CR as a comparison between CI and RI. Hence, the formula is:

$$CR = \frac{CI}{RI}$$

   If the value of CR is less or equal to 10%, it can be deduced that any inconsistency in the judgment is acceptable and if the value is greater that 10%, the subjective judgement is inconsistent and unacceptable, so it must be revised.

C. Fuzzy Analytic Hierarchy Process (FAHP)

	Saaty scale	*Triangular Fuzzy scale*
Equal Importance	1	(1/2, 1, 2)
Intermediate	2	(1, 2, 3)
Moderate Importance	3	(2, 3, 4)
Intermediate	4	(3, 4, 5)
Strong Importance	5	(4, 5, 6)
Intermediate	6	(5, 6, 7)
Very strong Importance	7	(6, 7, 8)
Intermediate	8	(7, 8, 9)
Extreme Importance	9	(8, 9, 9)

Table 2: Triangular Fuzzy Scale

1. Perform Fuzzy AHP scale

   In Fuzzy Analytic Hierarchy Process (FAHP), the Saaty scale that was used before in AHP will be transform into Triangular Fuzzy scale. Table 2 shows the scale that we used for our analysis. This Triangular Fuzzy scale is in the form of fuzzy number which consists of 3 values represented in equation (1). Meanwhile, equation (2) is the reciprocal value.

$$a_{ij} = (l_{ij}, m_{ij}, u_{ij}) \qquad where\ l_{ij} < m_{ij} < u_{ij} \tag{1}$$

$$a_{ij}{}^{-1} = (l_{ij}, m_{ij}, u_{ij})^{-1} = \left(\frac{1}{u_{ij}}, \frac{1}{m_{ij}}, \frac{1}{l_{ij}}\right) \qquad where\ \frac{1}{u_{ij}} < \frac{1}{m_{ij}} < \frac{1}{l_{ij}} \tag{2}$$

2. Fuzzified Pairwise Comparison Matrix

   The Comparison Matrix for FAHP will be similar as in AHP except that Triangular Fuzzy Scale will be used instead of Saaty scale. Hence, for each a_{ij} in FAHP we will be considering 3 values which are the lower, middle and upper point of the triangular fuzzy number. The judgement value will be used to fill up the upper part of the matrix:

   i. *If the judgment value is on the **left** side of 1, we put the **actual judgment** value as in the form of equation (1).*

   ii. *If the judgment value is on the **right** side of 1, we put the **reciprocal** value as in equation (2).*

   Then, the lower triangle matrix, a_{ji} is filled by using the formula: $a_{ji} = \frac{1}{a_{ij}}$.

3. Weight

First, in order to weight of each criteria we need to find the mean average for the criteria. Therefore, the Fuzzy Geometric Mean, r_i as in equation (3) is used.

$$r_i = \left[(l_{i1} * l_{i2} * \dots * l_{in})^{\frac{1}{n}}, (m_{i1} * m_{i2} * \dots * m_{in})^{\frac{1}{n}}, (u_{i1} * u_{i2} * \dots * u_{in})^{\frac{1}{n}}\right], \ i = 1,2, \dots n \qquad (3)$$

After we evaluate Fuzzy Geometric Mean, we can proceed to find the Fuzzy Weights, w_i by using equation (4)

$$w_i = r_i \otimes (r_1 \oplus r_2 \oplus \dots \oplus r_n)^{-1} \qquad (4)$$

Then, the Fuzzy Weights, w_i obtained have to go through de-fuzzification which is process of transforming it to Average Weight Criterion, M_i. The formula Centre of Area (COA) is applied in this de-fuzzification and the formula is as follows:

$$M_i = \left(\frac{l_i + m_i + u_i}{3}\right)$$

Since we want the summation of $M_i = 1$, so it is normalized to become Normalized Weight Criterion, N_i. Hence, from the N_i, the criteria can be ranked based on their priority.

3.0 CASE STUDY

This study is conducted with the aim of evaluating the performance of a university. This study requires the respondents to weight the criteria that has been identified to be important in evaluating performance of a university according to previous studies. Questionnaires have been distributed to 15 deans of each schools in Universiti Sains Malaysia and 8 lecturers in the Schools of Mathematical Sciences. 5 feedbacks from 15 questionnaires that have been distributed to the deans of the schools have been received which are School of Chemical Sciences, School of Mathematical Sciences, Schools of Computer Sciences, Schools of Management and School of Humanities. Meanwhile all 8 questionnaires that have been distributed to the lecturers in the School of Mathematical Sciences have also been received back.

First of all, the hierarchical structure of the project evaluation model is constructed in line with the main criteria and then sub criteria under each main criterion in this structure are identified. These are the following criteria and sub criteria for evaluating the performance in a university.

Criteria	*Code Name*	*Sub-criteria*	*Code Name*
Culture	A	Ethics	C_1
		Working Environment	C_2
Administration	B	Problem Seeking and Problem Solving	C_3
		Sense of Vision and Mission	C_4
Knowledge Transfer	C	Learning Environment	C_5
		Quality of Teaching	C_6
Leadership	D	Autonomy	C_7
		Team Oriented	C_8
Research	E	Citation	C_9
		Publication	C_{10}
Technology Transfer	F	Patent Issued	C_{11}
		Licenses issued	C_{12}
Service	G	Quality of Lecturer	C_{13}
		Physical facilities	C_{14}

Table 3: The Criteria and Sub Criteria to Evaluate the Performance in a University

The criteria and sub criteria can also be visualized by using the Figure 1 as below and all the explanation for the sub criteria can be seen in Table 2.

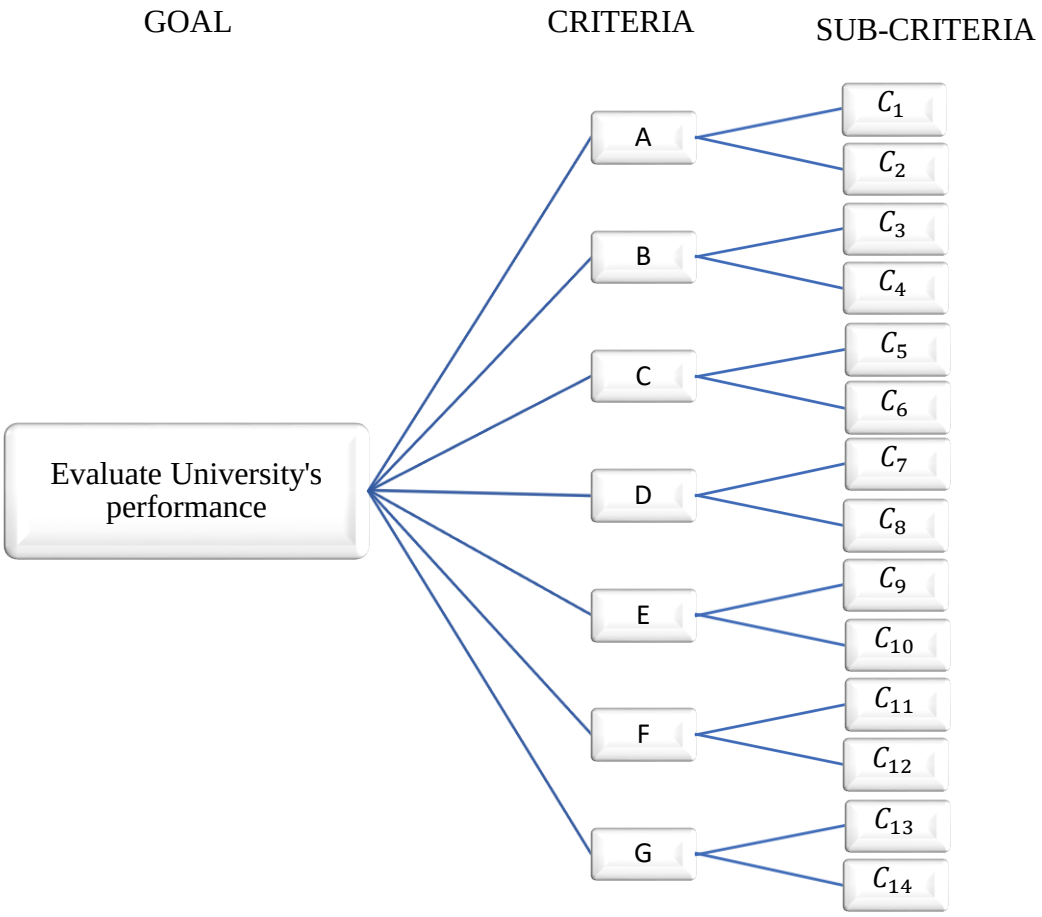

Figure 1: The Criteria and Sub Criteria to Evaluate the Performance in a University

Criteria	*Sub-criteria*	*Explanation*
Culture	Ethics	Ethics are the principles and values used by an individual to govern his or her actions and decisions. Organizational ethics is the ethics of an organization, and it is how an organization responds to an internal or external stimulus.
	Working Environment	Working environment means all your surroundings when working consists of physical working environment like tools, air, noise and psychological aspects of how work is organized and your wellbeing at workplace.
Administration	Problem Seeking and Problem Solving	The need of a culture that encourages problem seeking and solving which will encourage employees to look for problems as a way to improve the organization and to embrace the capacity to learn from failure.
	Sense of Vision and Mission	Sense of mission and vision which influences the organization by providing purpose and meaning as to why the work is important and defines the appropriate course of action for the organization and its members.
Knowledge Transfer	Learning Environment	Learning environment refers to the conduciveness of the places where learning process occurs including the quality of technologies used in teaching.
	Quality of Teaching	Quality of teaching refers to the teachers' ability to deliver the right, high quality and first class knowledge to the students.
Leadership	Autonomy	Autonomy refers to acts of a leader in individualistic, independent or has a unique characteristic that differentiate him or her from others.
	Team Oriented	Team oriented refers to inducing people to work together as a team and ensuring that communication and information-sharing contribute to a shared understanding.

Research	Citation	Citation refers to alerts the reader to a source that has informed your own writing.
	Publication	Publication refers to anything that has been published which are book, paper, news article and journal.
Technology Transfer	Patent Issued	Patent issued refers to granting of property right by a sovereign authority to an inventor.
	Licenses issued	Licenses issued refers to official permission or permit to do, use or own something.
Service	Quality of Lecturer	Being able to delivers the knowledge in a very good and good quality manner.
	Physical facilities	Provide a proper learning environment in order to enhance the learning process. Optimum technological efficiency and continuous improvement of facilities.

Table 4: The Explanation for the Sub Criteria

4.0 RESULT AND ANALYSIS

4.1 Consistency

Based on the conducted questionnaires, 9 out of the 10 questionnaires are not consistent. The inconsistency of the respondents when answering the questionnaires are shown if the consistency ratio is less than 0.1.

Respondents	Consistency Ratio
R1	0.106
R2	0.137
R3	0.203
R4	0.158
R5	0.185
R6	0.492
R7	0.276
R8	0.769
R9	1.094
R10	0.000

Table 1.1 Consistency Ratio

Based on Table 1.1, notice that R10 is the only respondent that shows consistency in answering the questionnaire because the consistency ratio of R10 is less than 0.1. It is hard to get the consistency ratio less than 0.1, since the value is depending on the respondents. When the number of criteria increase, it will be harder for a person to answer the survey consistently because there is no big difference between which criteria is more important. For example, if we are required to choose only two criteria, it will be easier to be consistent, but if we are considering ten criteria, it will be harder.

Moreover, we are conducting survey to compare seven criteria, and it is hard to get the consistent data. Therefore, the only way to get survey with consistency ratio less than 0.1 is by increasing the number of respondents. If there are many data having consistency ratio greater than

0.1, then we can find the average of criteria weightage and we will get the ranking but not the accurate result.

4.2 AHP and Fuzzy AHP

CRITERIA	**Weight of criterion**						
	A	B	C	D	E	F	G
Average weight	0.055	0.101	0.197	0.188	0.132	0.203	0.125
Normalized average weight	0.055	0.101	0.197	0.188	0.132	0.203	0.125
Preliminary ranking	7.000	6.000	2.000	3.000	4.000	1.000	5.000

Table 2.1 AHP

CRITERIA	**Weight of criterion**						
	A	B	C	D	E	F	G
Average weight	0.063	0.120	0.130	0.213	0.163	0.252	0.140
Normalized average weight	0.058	0.112	0.120	0.197	0.151	0.233	0.130
Preliminary ranking	7	6	5	2	3	1	4

Table 2.2 Fuzzy AHP

In this discussion we consider both AHP and fuzzy AHP. We will compare both result and consider why the result there exist differences in result. AHP are used to measure the weight of criteria in making decision. In addition to that, fuzzy AHP is used to check the uncertainty respondents' answer. We calculated the weight of fuzzy AHP using geometric mean and defuzzify the triangular fuzzy number by calculating the average.

We know that from Table 2.1 for AHP that the rankings are technology transfer, knowledge transfer, leadership, research, service, administration and cultural. On the other hand, for the fuzzy AHP the ranking is technology transfer, leadership research, service, knowledge transfer, administration and cultural. We can see that there is a slight difference between both results.

Based on the Table 2.1 and Table 2.2, the average weight of technology transfer is the highest which is 0.203 in AHP and 0.233 in fuzzy AHP. This shows that technology transfer is the most important criteria in evaluating university performance. Technology transfer is being utilized as one motive power for enhancing university competitiveness of small and medium venture enterprise in their efforts towards globalization. Technology transfer also gives credits to the university since the new technology that invented by the student shows that they have potential to succeed in the future. So, the graduated students from that university have more quality than students from other universities. If there are more adoption of technology from the university, the easier to see how well the performance of the university is.

Notice that, from Table 2.1 and Table 2.2, the preliminary rank of knowledge transfer are second in AHP but fifth in fuzzy AHP. The results show there is uncertainness that knowledge transfer will affect the university performance since the fuzzy weight for knowledge transfer is quite low which is 0.102 compared to other four criteria. Thus, we can conclude that the respondents lack of confidence in their answer whether knowledge transfer play an important role in evaluating university performance.

Next, we can see in Table 2.1 and Table 2.2 that leadership is one of the criteria that can influence the university performance since leadership rank third in AHP but second in fuzzy AHP. This shows that the certainty is high since there is not much difference in classical AHP and fuzzy AHP. The leader of the organization in university plays important role in assuring every task for university is done systematically. Thus, jobs with other department or outside organization will not delayed. This will give a great image to a university.

In addition, research is rank fourth in AHP to analyze university performance. Based on Table 2.2, the fuzzy weight of research is rank third. We can see that certainty is considerably high in fuzzy AHP. The respondents consists of lecturers therefore it is obvious for them to think research is one of the important criteria. If there are more quality research are conducted, then the university will improve their performance. Besides that, articles that are release will be cited by other researcher indirectly give credits to university. This shows that the university have a lot of lecturers that being authoritative and expert in knowledge and skills.

Service is quite important on assessing university performances since the lecturers and students more prefer on conducting research in university that have necessary facilities. After that,

administration is ranked second last criteria. Most of the respondents consider organization among university departments do not give higher impact on university ranking. Administration only gives internal support for university performance but not rising the university image on global view.

After that, considerably least significance criteria in evaluating university performance are cultural because it is in the rank seventh in both AHP and fuzzy AHP. Meaning that, they are quite certain that cultural do not give a great impact in evaluating university performance. Cultural maybe is in the lowest rank because university is focusing more on knowledge and research because the respondents are among lecturers.

In conclusion, we know that technology transfer give great effect in evaluating university performance rather than other criteria. The ranking is almost similar in AHP and fuzzy AHP except for knowledge transfer. This can help the university achieve better performance based on the criteria above.

4.3 Sub-criteria AHP and Fuzzy AHP

AHP

	C1	**C2**
Average weight	0.66	0.34
Normalized average weight	0.66	0.34
Ranking	1	2

Table 3.1

	C3	**C4**
Average weight	0.62	0.38
Normalized average weight	0.62	0.38
Ranking	1	2

Table 3.2

	C5	**C6**
Average weight	0.32	0.68
Normalized average weight	0.32	0.68
Ranking	2	1

Table 3.3

	C7	**C8**
Average weight	0.32	0.68
Normalized average weight	0.32	0.68
Ranking	2	1

Table 3.4

	C9	**C10**
Average weight	0.69	0.31
Normalized average weight	0.69	0.31
Ranking	1	2

Table 3.5

	C11	**C12**
Average weight	0.53	0.47
Normalized average weight	0.53	0.47
Ranking	1	2

Table 3.6

	C13	C14
Average weight	0.75	0.25
Normalized average weight	0.75	0.25
Ranking	1	2

Table 3.7

Fuzzy AHP

	C1	C2
Average weight	0.64	0.63
Normalized average weight	0.50	0.49
Ranking	1	2

Table 3.8

	C3	C4
Average weight	0.59	0.62
Normalized average weight	0.49	0.51
Ranking	2	1

Table 3.9

	C5	C6
Average weight	0.20	1.02
Normalized average weight	0.16	0.84
Ranking	2	1

Table 3.10

	C7	C8
Average weight	0.33	0.84
Normalized average weight	0.28	0.72
Ranking	2	1

Table 3.11

	C9	C10
Average weight	0.64	0.51
Normalized average weight	0.56	0.44
Ranking	1	2

Table 3.12

	C11	C12
Average weight	0.48	0.87
Normalized average weight	0.36	0.64
Ranking	2	1

Table 3.13

	C11	C12
Average weight	0.84	0.42
Normalize average weight	0.67	0.33
Ranking	1	2

Table 3.14

Ethics and working environment are the sub criteria for the cultural. Cultural is the least important criteria. Based on Table 3.1, we can see that ethics is more important than working environment because working environment is only external factor and do not involved people communication while ethics consists of organization to make actions and decision for better university performance.

Problem seeking and problem solving and sense of vision and mission are the sub criteria for administration. From the Table 3.2, problem seeking and problem solving is more vital than sense of vision and mission because it is needed in order to achieve the aims of a university.

From Table 3.3, quality of teaching is significant than learning environment under criteria of knowledge transfer. This is because quality teaching can enhance student performance even though the university do not have better learning environment.

Moreover, autonomy and team oriented are sub criteria for leadership. Autonomy refers to acts of a leader in individualistic, independent or has a unique characteristic that differentiate him or her from others while team oriented refers to inducing people to work together as stem and ensuring that communication and information-sharing contribute to a shared understanding. As we can see in Table 3.4, team oriented is more essential compared to autonomy because team communication and cooperation between team members achieve high impact rather than individual quality in a team.

Citation and publication are sub criteria of research. Citation refers to a quotation from or reference to a book, paper, or author, especially in a scholarly work while publication refers to anything that has been issued to a public sale. From Table 4.8, citation is more significant than publication since high citation counts show which papers are the most important in their field and made the largest advances and rising the university image in worldwide.

Other than that, from Table 4.9, patent issued is giving more impact in university performance compared to license issued in technology transfer. This is because patent issued give more authority to a university to transfer any research using technology to a public rather than licenses issued.

Lastly, quality of lecturer is more important than physical facilities under the criteria of service because quality of lecturer can enhance student understanding even though there have less physical facilities.

Sub-criteria for fuzzy AHP same result with non-fuzzy AHP in all sub-criteria except for sub-criteria for technology transfer and administration. This is because for fuzzy AHP, we take the left and right values from respondents' choices to consider the uncertainties. These will give high impact on the average weightage for fuzzy AHP and non-fuzzy AHP. Fuzzy AHP consider the fuzziness in the respondents answer therefore it leads to different results.

5.0 CONCLUSION

We have conducted the AHP and fuzzy AHP to know which criteria is the best fit to evaluate the university performance regardless the consistency of the data. This research are conducted to ten people consists of high education background. There are inconsistency from the methodology Saaty scale is used in order to evaluate the criteria. For the fuzzy AHP we used method of geometric mean to get the result. In case of study we explained about the criteria and sub-criteria that are consider in evaluating university performance. For this case a lot of data do not have enough consistency when calculated using AHP. We can see there are difference between AHP and fuzzy AHP result regardless of the inconsistency of questionnaire's answer. But, we still get the same result for the most significance criteria in evaluating the university performance. We can conclude that a university can used this AHP or geometric mean of fuzzy AHP to analyze the data collected from each of the respondents that evaluate each criterion. This will help the university to accomplish higher achievement for university evaluation.

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7.0 ATTACHMENT

Questionnaire

Part 1: Relative Importance between the Criteria

CRITERIA 1	FACTOR WEIGHING SCALE																	CRITERIA 2
	EXTERMELY		VERY STRONGLY		STRONGLY		MODERATELY		EQUALLY		MODERATELY		STRONGLY		VERY STRONGLY		EXTERMELY	
Cultural	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Administration
Cultural	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Knowledge transfer
Cultural	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Leadership
Cultural	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Technology transfer
Cultural	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Research
Cultural	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Service
Administration	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Knowledge transfer
Administration	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Leadership
Administration	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Technology transfer
Administration	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Research
Administration	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Service

Knowledge transfer	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Leadership
Knowledge transfer	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Technology transfer
Knowledge transfer	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Research
Knowledge transfer	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Service
Leadership	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Technology transfer
Leadership	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Research
Leadership	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Service
Technology transfer	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Research
Technology transfer	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Service
Research	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Service

Part 2: Relative Importance between Sub criteria of Culture

CRITERIA 1	FACTOR WEIGHING SCALE																	CRITERIA 2
	EXTERMELY		VERY STRONGLY		STRONGLY		MODERATELY		EQUALLY		MODERATELY		STRONGLY		VERY STRONGLY		EXTERMELY	
Ethics	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Working Environment

Part 3: Relative Importance between Sub criteria of Administration

CRITERIA 1	FACTOR WEIGHING SCALE																	CRITERIA 2
	EXTERMELY		VERY STRONGLY		STRONGLY		MODERATELY		EQUALLY		MODERATELY		STRONGLY		VERY STRONGLY		EXTERMELY	
Problem Seeking and Problem Solving	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Sense of vision and mission

Part 4: Relative Importance between Sub criteria of Knowledge Transfer

CRITERIA 1	FACTOR WEIGHING SCALE																	CRITERIA 2
	EXTERMELY		VERY STRONGLY		STRONGLY		MODERATELY		EQUALLY		MODERATELY		STRONGLY		VERY STRONGLY		EXTERMELY	
Learning Environment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Quality of Teaching

Part 5: Relative Importance between Sub criteria of Leadership

CRITERIA 1	FACTOR WEIGHING SCALE																	CRITERIA 2
	EXTERMELY		VERY STRONGLY		STRONGLY		MODERATELY		EQUALLY		MODERATELY		STRONGLY		VERY STRONGLY		EXTERMELY	
Autonomy	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Team Oriented

Part 6: Relative Importance between Sub criteria of Research

CRITERIA 1	FACTOR WEIGHING SCALE																	CRITERIA 2
	EXTERMELY		VERY STRONGLY		STRONGLY		MODERATELY		EQUALLY		MODERATELY		STRONGLY		VERY STRONGLY		EXTERMELY	
Citation	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Publication

Part 7: Relative Importance between Sub criteria of Technology Transfer

CRITERIA 1	FACTOR WEIGHING SCALE																	CRITERIA 2
	EXTERMELY		VERY STRONGLY		STRONGLY		MODERATELY		EQUALLY		MODERATELY		STRONGLY		VERY STRONGLY		EXTERMELY	
Patent issued	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	License issued

Part 8: Relative Importance between Sub criteria of Service

CRITERIA 1	FACTOR WEIGHING SCALE																	CRITERIA 2
	EXTERMELY		VERY STRONGLY		STRONGLY		MODERATELY		EQUALLY		MODERATELY		STRONGLY		VERY STRONGLY		EXTERMELY	
Quality of Lecturer	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Physical Facilities

RESPONDENTS' NORMALIZED WEIGHT AND RESULTS

CRITERIA AHP

R1:

Criteria	A	B	C	D	E	F	G	Weight
A	0.040	0.011	0.061	0.018	0.034	0.038	0.067	0.038
B	0.200	0.057	0.061	0.055	0.034	0.038	0.200	0.092
C	0.200	0.285	0.306	0.273	0.169	0.570	0.200	0.286
D	0.120	0.057	0.061	0.055	0.034	0.038	0.067	0.062
E	0.200	0.285	0.306	0.273	0.169	0.063	0.200	0.214
F	0.200	0.285	0.102	0.273	0.506	0.190	0.200	0.251
G	0.040	0.019	0.102	0.055	0.056	0.063	0.067	0.057
Sum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

R2:

Criteria	A	B	C	D	E	F	G	Weight
A	0.065	0.150	0.045	0.031	0.181	0.134	0.187	0.113
B	0.011	0.025	0.053	0.022	0.006	0.027	0.027	0.024
C	0.454	0.150	0.318	0.306	0.136	0.268	0.374	0.287
D	0.324	0.175	0.159	0.153	0.226	0.134	0.094	0.181
E	0.016	0.200	0.106	0.031	0.045	0.034	0.037	0.067
F	0.065	0.125	0.159	0.153	0.181	0.134	0.094	0.130
G	0.065	0.175	0.159	0.306	0.226	0.268	0.187	0.198
Sum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

R3:

Criteria	A	B	C	D	E	F	G	Weight
A	0.035	0.154	0.030	0.021	0.122	0.050	0.008	0.060
B	0.012	0.051	0.050	0.038	0.082	0.076	0.025	0.048
C	0.174	0.154	0.149	0.150	0.245	0.151	0.051	0.154
D	0.244	0.205	0.149	0.150	0.286	0.113	0.407	0.222
E	0.012	0.026	0.025	0.021	0.041	0.091	0.102	0.045
F	0.314	0.308	0.448	0.601	0.204	0.454	0.356	0.383
G	0.209	0.103	0.149	0.019	0.020	0.065	0.051	0.088
Sum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

R4:

Criteria	A	B	C	D	E	F	G	Weight
A	0.027	0.007	0.023	0.052	0.013	0.027	0.012	0.023
B	0.135	0.035	0.017	0.052	0.013	0.027	0.082	0.052
C	0.135	0.248	0.117	0.072	0.325	0.189	0.082	0.167
D	0.189	0.248	0.585	0.361	0.455	0.189	0.576	0.372
E	0.135	0.177	0.023	0.052	0.065	0.189	0.082	0.103
F	0.189	0.248	0.117	0.361	0.065	0.189	0.082	0.179
G	0.189	0.035	0.117	0.052	0.065	0.189	0.082	0.104
Sum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

R5:

Criteria	A	B	C	D	E	F	G	Weight
A	0.032	0.016	0.009	0.074	0.018	0.011	0.036	0.028
B	0.226	0.115	0.425	0.074	0.255	0.452	0.250	0.257
C	0.226	0.016	0.061	0.074	0.218	0.065	0.214	0.125
D	0.226	0.803	0.425	0.519	0.218	0.387	0.214	0.399
E	0.065	0.016	0.010	0.086	0.036	0.011	0.036	0.037
F	0.194	0.016	0.061	0.086	0.218	0.065	0.214	0.122
G	0.032	0.016	0.010	0.086	0.036	0.011	0.036	0.033
Sum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

R6:

Criteria	A	B	C	D	E	F	G	Weight
A	0.031	0.026	0.008	0.009	0.032	0.029	0.081	0.031
B	0.031	0.026	0.011	0.006	0.036	0.025	0.012	0.021
C	0.219	0.132	0.055	0.005	0.287	0.228	0.012	0.134
D	0.156	0.184	0.436	0.043	0.041	0.033	0.010	0.129
E	0.281	0.211	0.055	0.298	0.287	0.228	0.725	0.298
F	0.250	0.237	0.055	0.298	0.287	0.228	0.081	0.205
G	0.031	0.184	0.382	0.341	0.032	0.228	0.081	0.183
Sum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

R7:

Criteria	A	B	C	D	E	F	G	Weight
A	0.032	0.029	0.091	0.009	0.008	0.012	0.017	0.028
B	0.161	0.143	0.091	0.234	0.191	0.301	0.424	0.221
C	0.161	0.714	0.455	0.234	0.191	0.301	0.424	0.354
D	0.161	0.029	0.091	0.047	0.191	0.012	0.017	0.078
E	0.161	0.029	0.091	0.009	0.038	0.012	0.017	0.051
F	0.161	0.029	0.091	0.234	0.191	0.060	0.017	0.112
G	0.161	0.029	0.091	0.234	0.191	0.301	0.085	0.156
Sum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

R8:

Criteria	A	B	C	D	E	F	G	Weight
A	0.040	0.024	0.008	0.069	0.010	0.368	0.005	0.075
B	0.120	0.072	0.162	0.347	0.012	0.053	0.033	0.114
C	0.280	0.024	0.054	0.010	0.243	0.053	0.232	0.128
D	0.040	0.014	0.379	0.069	0.340	0.053	0.232	0.161
E	0.200	0.288	0.011	0.010	0.049	0.053	0.232	0.120
F	0.040	0.505	0.379	0.485	0.340	0.368	0.232	0.336
G	0.280	0.072	0.008	0.010	0.007	0.053	0.033	0.066
Sum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

R9:

Criteria	A	B	C	D	E	F	G	Weight
A	0.021	0.003	0.006	0.005	0.015	0.007	0.009	0.010
B	0.167	0.026	0.007	0.005	0.013	0.008	0.009	0.034
C	0.167	0.179	0.051	0.005	0.012	0.456	0.450	0.188
D	0.188	0.230	0.461	0.045	0.015	0.008	0.009	0.136
E	0.146	0.204	0.461	0.313	0.104	0.456	0.008	0.242
F	0.167	0.179	0.006	0.313	0.013	0.057	0.450	0.169
G	0.146	0.179	0.007	0.313	0.829	0.008	0.064	0.221
Sum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

R10:

Criteria	A	B	C	D	E	F	G	Weight
A	0.143	0.143	0.143	0.143	0.143	0.143	0.143	0.143
B	0.143	0.143	0.143	0.143	0.143	0.143	0.143	0.143
C	0.143	0.143	0.143	0.143	0.143	0.143	0.143	0.143
D	0.143	0.143	0.143	0.143	0.143	0.143	0.143	0.143
E	0.143	0.143	0.143	0.143	0.143	0.143	0.143	0.143
F	0.143	0.143	0.143	0.143	0.143	0.143	0.143	0.143
G	0.143	0.143	0.143	0.143	0.143	0.143	0.143	0.143
Sum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

CRITERIA FUZZY AHP

R1:

CRI	*Wi*		
A	0.029	0.040	0.065
B	0.061	0.086	0.139
C	0.216	0.318	0.000
D	0.045	0.068	0.119
E	0.161	0.232	0.380
F	0.196	0.272	0.419
G	0.040	0.062	0.119

Fuzzy Weight

CRI	Mi	Ni	Rank
A	0.045	**0.044**	**7.000**
B	0.095	**0.093**	**4.000**
C	0.178	**0.174**	**3.000**
D	0.077	**0.076**	**5.000**
E	0.257	**0.252**	**2.000**
F	0.296	**0.289**	**1.000**
G	0.074	**0.072**	**6.000**
TOTAL	1.022		

Mi: Average weight
Ni: Normalized Weight

R2:

CRI	*Wi*		
A	0.075	0.104	0.200
B	0.019	0.022	0.037
C	0.195	0.294	0.000
D	0.138	0.188	0.386
E	0.044	0.054	0.095
F	0.093	0.138	0.309
G	0.132	0.201	0.409

Fuzzy Weight

CRI	Mi	Ni	Rank
A	0.126	**0.121**	**5.000**
B	0.026	**0.025**	**7.000**
C	0.163	**0.156**	**4.000**
D	0.237	**0.227**	**2.000**
E	0.064	**0.062**	**6.000**
F	0.180	**0.172**	**3.000**
G	0.247	**0.237**	**1.000**
TOTAL	1.044		

Mi: Average weight
Ni: Normalized Weight

R3:

CRI	*Wi*		
A	0.037	0.045	0.068
B	0.040	0.045	0.080
C	0.108	0.158	0.000
D	0.175	0.228	0.362
E	0.034	0.047	0.077
F	0.325	0.407	0.592
G	0.050	0.071	0.123

Fuzzy Weight

CRI	Mi	Ni	Rank
A	0.050	**0.049**	**7.000**
B	0.055	**0.054**	**5.000**
C	0.088	**0.086**	**3.000**
D	0.255	**0.249**	**2.000**
E	0.053	**0.051**	**6.000**
F	0.441	**0.431**	**1.000**
G	0.081	**0.079**	**4.000**
TOTAL	1.023		

Mi: Average weight
Ni: Normalized Weight

R4:

CRI	*Wi*		
A	0.017	0.022	0.035
B	0.031	0.044	0.074
C	0.108	0.167	0.000
D	0.272	0.384	0.634
E	0.069	0.109	0.213
F	0.099	0.175	0.365
G	0.057	0.100	0.210

Fuzzy Weight

CRI	Mi	Ni	Rank
A	0.024	**0.023**	**7.000**
B	0.049	**0.047**	**6.000**
C	0.092	**0.086**	**5.000**
D	0.430	**0.405**	**1.000**
E	0.130	**0.123**	**3.000**
F	0.213	**0.201**	**2.000**
G	0.122	**0.115**	**4.000**
TOTAL	1.061		

Mi: Average weight
Ni: Normalized Weight

R5:

CRI	*Wi*		
A	0.020	0.026	0.042
B	0.223	0.263	0.349
C	0.085	0.109	0.000
D	0.359	0.429	0.573
E	0.024	0.034	0.051
F	0.085	0.109	0.160
G	0.022	0.030	0.048

Fuzzy Weight

CRI	Mi	Ni	Rank
A	0.029	**0.029**	**7.000**
B	0.278	**0.274**	**2.000**
C	0.065	**0.064**	**4.000**
D	0.453	**0.447**	**1.000**
E	0.036	**0.036**	**5.000**
F	0.118	**0.116**	**3.000**
G	0.034	**0.033**	**6.000**
TOTAL	1.013		

Mi: Average weight
Ni: Normalized Weight

R6:

CRI	*Wi*		
A	0.022	0.033	0.058
B	0.018	0.025	0.040
C	0.060	0.094	0.000
D	0.072	0.096	0.143
E	0.217	0.335	0.557
F	0.146	0.245	0.449
G	0.113	0.173	0.297

Fuzzy Weight

CRI	Mi	Ni	Rank
A	0.037	**0.035**	**6.000**
B	0.028	**0.026**	**7.000**
C	0.051	**0.048**	**5.000**
D	0.104	**0.097**	**4.000**
E	0.370	**0.347**	**1.000**
F	0.280	**0.263**	**2.000**
G	0.194	**0.183**	**3.000**
TOTAL	1.064		

Mi: Average weight
Ni: Normalized Weight

R7:

CRI	*Wi*		
A	0.021	0.029	0.040
B	0.201	0.291	0.391
C	0.317	0.461	0.000
D	0.052	0.073	0.100
E	0.033	0.046	0.064
F	0.081	0.116	0.158
G	0.128	0.184	0.248

Fuzzy Weight

CRI	Mi	Ni	Rank
A	0.030	**0.030**	**7.000**
B	0.294	**0.291**	**1.000**
C	0.259	**0.257**	**2.000**
D	0.075	**0.074**	**5.000**
E	0.048	**0.047**	**6.000**
F	0.118	**0.117**	**4.000**
G	0.187	**0.185**	**3.000**
TOTAL	1.011		

Mi: Average weight
Ni: Normalized Weight

R8:

CRI	*Wi*		
A	0.028	0.042	0.072
B	0.078	0.115	0.186
C	0.091	0.116	0.000
D	0.111	0.149	0.227
E	0.078	0.099	0.143
F	0.321	0.432	0.648
G	0.035	0.047	0.071

Fuzzy Weight

CRI	Mi	Ni	Rank
A	0.047	**0.046**	**7.000**
B	0.127	**0.123**	**3.000**
C	0.069	**0.067**	**5.000**
D	0.162	**0.158**	**2.000**
E	0.107	**0.104**	**4.000**
F	0.467	**0.453**	**1.000**
G	0.051	**0.049**	**6.000**
TOTAL	1.030		

Mi: Average weight
Ni: Normalized Weight

R9:

CRI	*Wi*		
A	0.016	0.019	0.022
B	0.029	0.035	0.040
C	0.155	0.184	0.000
D	0.100	0.121	0.133
E	0.286	0.350	0.393
F	0.152	0.187	0.214
G	0.157	0.194	0.223

Fuzzy Weight

CRI	Mi	Ni	Rank
A	0.019	**0.019**	**7.000**
B	0.034	**0.034**	**6.000**
C	0.113	**0.113**	**5.000**
D	0.118	**0.118**	**4.000**
E	0.343	**0.342**	**1.000**
F	0.184	**0.184**	**3.000**
G	0.192	**0.191**	**2.000**
TOTAL	1.003		

Mi: Average weight
Ni: Normalized Weight

R10:

CRI	*Wi*		
A	0.044	0.143	0.469
B	0.044	0.143	0.469
C	0.044	0.143	0.469
D	0.044	0.143	0.469
E	0.044	0.143	0.469
F	0.044	0.143	0.469
G	0.044	0.143	0.469

Fuzzy Weight

CRI	Mi	Ni	Rank
A	0.218	**0.143**	**1.000**
B	0.218	**0.143**	**1.000**
C	0.218	**0.143**	**1.000**
D	0.218	**0.143**	**1.000**
E	0.218	**0.143**	**1.000**
F	0.218	**0.143**	**1.000**
G	0.218	**0.143**	**1.000**
TOTAL	1.529		

Mi: Average weight
Ni: Normalized Weight

SUB-CRITERIA AHP

CRITERIA	Weight of criterion													
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**	**C113**	**C14**
R1	0.750	0.250	0.250	0.750	0.250	0.750	0.500	0.500	0.333	0.667	0.500	0.500	0.833	0.167
R2	0.500	0.500	0.750	0.250	0.250	0.750	0.143	0.857	0.500	0.500	0.500	0.500	0.800	0.200
R3	0.750	0.250	0.333	0.667	0.500	0.500	0.200	0.800	0.750	0.250	0.833	0.167	0.875	0.125
R4	0.500	0.500	0.833	0.167	0.500	0.500	0.500	0.500	0.875	0.125	0.500	0.500	0.500	0.500
R5	0.833	0.167	0.500	0.500	0.250	0.750	0.125	0.875	0.875	0.125	0.500	0.500	0.875	0.125
R6	0.500	0.500	0.500	0.500	0.500	0.500	0.100	0.900	0.500	0.500	0.500	0.500	0.500	0.500
R7	0.500	0.500	0.833	0.167	0.167	0.833	0.167	0.833	0.833	0.167	0.500	0.500	0.833	0.167
R8	0.889	0.111	0.875	0.125	0.125	0.875	0.875	0.125	0.875	0.125	0.125	0.875	0.875	0.125
R9	0.900	0.100	0.875	0.125	0.125	0.875	0.125	0.875	0.900	0.100	0.875	0.125	0.900	0.100
R10	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500
Average weight	0.662	0.338	0.625	0.375	0.317	0.683	0.324	0.677	0.694	0.306	0.533	0.467	0.749	0.251
Normalized average weight	0.095	0.053	0.104	0.070	0.063	0.146	0.081	0.184	0.231	0.133	0.267	0.318	0.749	1.000
Preliminary ranking	10.000	14.000	9.000	12.000	13.000	7.000	11.000	6.000	5.000	8.000	4.000	3.000	2.000	1.000

SUB-CRITERIA FUZZY AHP

CRITERIA	**Weight of criterion**													
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**	**C113**	**C14**
R1	0.75	0.32	0.10	1.05	0.07	0.99	0.43	1.07	0.21	1.15	0.43	1.07	0.86	0.16
R2	0.43	1.07	0.75	0.32	0.07	0.99	0.03	1.00	0.03	1.00	0.43	1.07	0.76	0.28
R3	0.75	0.32	0.21	1.15	0.43	1.07	0.06	1.02	0.75	0.32	0.86	0.16	0.93	0.10
R4	0.43	1.07	0.86	0.16	0.43	1.07	0.43	1.07	0.91	0.10	0.43	1.07	0.43	1.07
R5	0.86	0.16	0.43	1.07	0.07	0.99	0.03	1.00	0.93	0.10	0.43	1.07	0.91	0.10
R6	0.43	1.07	0.43	1.07	0.43	1.07	0.02	0.99	0.43	1.07	0.43	1.07	0.43	1.07
R7	0.43	1.07	0.86	0.16	0.05	1.01	0.05	1.01	0.86	0.16	0.43	1.07	0.86	0.16
R8	0.92	0.08	0.91	0.10	0.03	1.00	0.91	0.10	0.91	0.10	0.03	1.00	1.91	0.10
R9	0.93	0.07	0.91	0.10	0.03	1.00	0.91	0.10	0.93	0.07	0.91	0.10	0.93	0.07
R10	0.43	1.07	0.43	1.07	0.43	1.07	0.43	1.07	0.43	1.07	0.43	1.07	0.43	1.07
Average weight	0.64	0.63	0.59	0.62	0.20	1.02	0.33	0.84	0.64	0.51	0.48	0.87	0.84	0.42
Normalized average weight	0.07	0.05	0.05	0.06	0.02	0.09	0.03	0.08	0.06	0.05	0.05	0.09	0.10	0.04
Preliminary ranking	5.00	8.00	9.00	7.00	14.00	3.00	13.00	4.00	6.00	10.00	11.00	2.00	1.00	12.00