JOURNAL OF MATHEMATICS AND COMPUTING SCIENCE, 2018
Volume 4, Number 2, 1-9

DECISION-MAKING USING FUZZY ANALYTICAL HIERARCHY PROCESS IN CHOOSING POSTGRADUATE PROGRAMS

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Abstract: There are many postgraduate programs offered in public or private universities in Malaysia. Students can choose whether to further their study or not after completing their undergraduate study. If they choose to pursue their postgraduate studies, they can choose their study approach eithera coursework program or a research program. Most students who wish to pursue postgraduate studies have a problem in selecting the best program of study for them. By adopting the Fuzzy Analytical Hierarchy Process (FAHP) method, a decision-making instrument was constructed in this project to assist students to choose their postgraduate study program. In this research, seven main criteria were considered which were education, soft skills, time management, stress management, independence, teamwork and critical thinking. The weight of two main focuses which were research and coursework programs of each criteria was calculated using FAHP. The result indicates the students' tendency to choose either research or coursework programs for their postgraduate study.

Keywords: Fuzzy AHP, Main criteria, Postgraduate programs

1 Introduction

Universities are known as higher learning institutions that produce academic degrees for undergraduate and postgraduate education. Universities offer undergraduate education which is commonly known as 'first degree' or 'bachelor's degree' or simply 'degree' while postgraduate education is known as 'master's degree'and 'doctorate degree'. Postgraduate students for master's degree mostly can be classified into three major categories which are students with research, coursework orcombination of both [1].

Kaur and Sidhu [2] stated that there has been a significant increase in the number of postgraduates in many public universities since 2002 in Malaysia. Students do not stop at undergraduate level to gain more knowledge and expertise about their respective fields and learning areas. This is in accordance with the overall goal of postgraduate program which is to enhance professional practices by equipping the graduates with new knowledge and ideas for the benefit of the community and continue to develop skills in doing research [3].

A master by research is an advanced postgraduate research degree that can also be a preparation of students for doctoral research. At the master's level, the process is towards research applications and utilities in professional practices with the expectation that students carry out research projects as part of their program studies. A master by coursework is a professional qualification involving a study of a specified set of core units and a selection of eligible elective units.In this mode of master's program, students attend classes, complete assignments and sit for examinations where applicable. Majority of master coursework programs stipulate thesis writing as their final assessment [3].

Many studies have shown that there are high percentages of undergraduate students who fail to complete their studies in the given time [1]. This has led them into difficulties to pursue their studies at postgraduate level once they have graduated. Besides, being postgraduate students is not an easy

task. Most postgraduate students need to overcome challenges while studying such as family and work commitment, finance, time and so on that may affect their academic achievements [1]. Accordingly, choosing the most suitable program for their postgraduate study is one of the ways to overcome the problems. There are several important criteria and sub-criteria postgraduate students need to know particularly about their own capability before pursuing postgraduate study.The purpose of this research is to help the students determine the right postgraduate program for them which are coursework or research by using Fuzzy AHP method. Thus, students can choose the best postgraduate program that suits to their abilities and needs and at the same time minimize the problems encountered during their study.

2 Literature Review

In this section, review from the past researchis discussed. Thomas L.Saaty introduced the Analytic Hierarchy Process in 1980 as one of the methods which was widely used as a decision-making tool. However, because of its lack of ability with uncertain and imprecise values, Fuzzy AHP has been introduced as an expanded method to overcome the problem.

A Analytic Hierarchy Process (AHP)

One of the multi-criteria decision-making methods was AHP method which was widely used as a decision-making tool [4-5]. This method can help decision makers to get the solution based on the hierarchy of criteria and sub-criteriain which the goals located at the top and end of the hierarchy were potential solutions [4],[6]. A new hierarchy was to be developed depending on the changes in the structure of the hierarchy.

Pairwise comparison was the next step after developing the hierarchy in AHP. All the related elements at the end of the hierarchy were compared in pairwise comparison matrices [7]. Next, to produce an overall score for each element, each score of the elements was combined with the criterion weight [8]. Furthermore, to make the decision makers' judgments to be consistent, consistency ratio (CR) was checked.If the CR was less than 0.1, the judgments were accepted[7].

Regardless of the wide usage of AHP method, it has been criticized for its lack of ability with uncertainties and imprecision for the decision makers to get the exact number [7], [9]. Therefore, the expanded fuzzy AHP method has been developed to overcome the problem.

B Fuzzy Analytic Hierarchy Process (FAHP)

Fuzzy Analytic Hierarchy Process (FAHP) is the combination of fuzzy theory and basic Analytic Hierarchy Process. To tolerate with the problems in AHP method, fuzzy logic approach was used to improve the method [5],[10]. A new approach to deal with FAHP was introduced by Chang [11] in which the pair wise comparisons of both criteria via linguistic terms were represented by triangular numbers [12]. Besides, the triangular membership functions for the pairwise comparison were performed by Laarhoven and Pedrycz [13] as one of the first FAHP applications [5].

In this method, pairwise comparison was done by using fuzzy linguistic priority scalesfrom 0 to 10 [14]. In other words, a conventional AHP approach might not fully reflect human style thinking as decision makers as they usually feel more confident to provide interval evaluation rather than expressing their judgments in the form of a single numerical value.On the other hand, FAHP can capture human estimation when complex multicriteria decision making problems were considered [7],[15]. Thus, this method has been used widely by researchers in many decision-making processes because this method can overcome the vagueness and ambiguity of the values.

3 Methodology

The postgraduate program decision-making was modelled by using FAHP method. A few factors used in the problem were weighted according to this method.

A Development of the Hierarchical Framework

This model contains 4 level of hierarchical framework starting with the goal and followed by the criteria and sub-criteria. The full forms and necessary details of the criteria and sub-criteria are shown in Table 1.

Table 1: Criteria and sub-criteria

Criteria	Sub-criteria
Education (E)	**CGPA**
	Target to graduate
Soft Skills (SS)	**Speaking**
	Writing
	Reading
Time Management (TM)	**Tracking work progress**
	Setting Priorities of work
	Quick decision making
Stress Management (SM)	**Completing the task**
	Heavy workload
	Conducting experiments
	Limited resource
Independence(I)	**Strong work ethic**
	Hardworking
	Problem solver
Teamwork (T)	**Conflict resolution**
	Leadership skills
	Cooperation skills
Critical thinking (CT)	**Evaluating**
	Analysing
	Reasoning

B Triangular Fuzzy Number

Linguistic terms were used to evaluate the importance of the criteria and to rate the alternatives with respect to various criteria. The corresponding triangular fuzzy numbers and linguistic terms are shown in Table 2. This scale is adopted from Buckley [16].

Table 2: Corresponding Triangular Fuzzy Numbers and Linguistic Terms

Saaty scale	Definition	Fuzzy Triangular Scale
1	Poor	(1,1,1)
3	Fair	(2,3,4)
5	Satisfactory	(4,5,6)
7	Good	(6,7,8)
9	Very good	(9,9,9)
2		(1,2,3)
4	The intermittent values between two	(3,4,5)
6	adjacent scale	(5,6,7)
8		(7,8,9)

C Determine the Weights of All Criteria and Sub-Criteria

There were 7 steps performed to find the normalized weights of both criteria and sub-criteria.

Step 1: Pairwise Comparison based on Linguistic Terms

The first step was to use a pairwise comparison to evaluate the weights of its elements and determine the priority. By applying the fuzzy triangular scale, the pairwise comparison for all criteria are tabulated in Table 3 and Table 4.

Table 3: Pairwise comparison of criteria for coursework

CRITERIA	SM	TM	CT	T	SS	E	I
SM	(1,1,1)	(2,3,4)	(2,3,4)	(4,5,6)	(4,5,6)	(6,7,8)	(6,7,8)
TM	(1/4, 1/3,1/2)	(1,1,1)	(2,3,4)	(2,3,4)	(4,5,6)	(4,5,6)	(6,7,8)
CT	(1/4, 1/3,1/2)	(1/4, 1/3,1/2)	(1,1,1)	(2,3,4)	(2,3,4)	(4,5,6)	(4,5,6)
T	(1/6,1/5,1/4)	(1/4, 1/3,1/2)	(1/4, 1/3,1/2)	(1,1,1)	(2,3,4)	(2,3,4)	(4,5,6)
SS	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/4, 1/3,1/2)	(1/4, 1/3,1/2)	(1,1,1)	(2,3,4)	(4,5,6)
E	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/4, 1/3,1/2)	(1/4, 1/3,1/2)	(1,1,1)	(2,3,4)
I	(1/8,1/7,1/6)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/4, 1/3,1/2)	(1,1,1)

Table 4: Pairwise comparison of criteria for research

CRITERIA	I	CT	SM	TM	SS	E	T
I	(1,1,1)	(2,3,4)	(2,3,4)	(4,5,6)	(4,5,6)	(6,7,8)	(6,7,8)
CT	(1/4, 1/3,1/2)	(1,1,1)	(2,3,4)	(2,3,4)	(4,5,6)	(4,5,6)	(6,7,8)
SM	(1/4, 1/3,1/2)	(1/4, 1/3,1/2)	(1,1,1)	(2,3,4)	(2,3,4)	(4,5,6)	(4,5,6)
TM	(1/6,1/5,1/4)	(1/4, 1/3,1/2)	(1/4, 1/3,1/2)	(1,1,1)	(2,3,4)	(2,3,4)	(4,5,6)
SS	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/4, 1/3,1/2)	(1/4, 1/3,1/2)	(1,1,1)	(2,3,4)	(4,5,6)
E	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/4, 1/3,1/2)	(1/4, 1/3,1/2)	(1,1,1)	(1,1,1)
T	(1/8,1/7,1/6)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1,1,1)	(1,1,1)

To check the consistency and validation of pair-wise comparison, the consistency test was calculated using this formula:

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

$$CR = \frac{0.097}{1.32}$$

$$= 0.07$$

where, CR is the consistency ratio, CI is the consistency index and RI is the ratio index. The result shows the data is consistent as 0.1>0.07.

Step 2: The geometric means of fuzzy comparison values

According to Buckley [16], the geometric means of fuzzy comparison values of all criteria was calculated using this formula:

$$\widehat{r_i} = \left(\prod_{j=1}^{n} \widehat{d_{ij}}\right)^{1/n}, i = 1,2,\ldots,n$$

Where $\widehat{r_1}$ = triangular values, n = total number of main criteria, $\widehat{d_{ij}}$ = k^{th} of main criteria's preference of i^{th} criterion over j^{th} criterion via fuzzy triangular numbers. The geometric means of fuzzy comparison values of criteria for research is shown in Table 5.

Table 5: Geometric means of criteria for research

Criteria	$\tilde{r}_1$		
I	3.022419	3.77992	4.491297
CT	1.919471	2.446776	3.022419
SM	1.219014	1.58382	2.033937

TM	0.774169	1	1.291708
SS	0.542834	0.679183	0.869255
E	0.299668	0.349338	0.427376
T	0.256142	0.28773	0.330861
Total	8.033716	10.12677	12.46685
Reverse	0.124475	0.098748	0.080213
Increasing Order	0.080213	0.098748	0.124475

Step 3: The fuzzy weight

To find the fuzzy weight of criterion ($\widetilde{W\imath}$), multipy each $\check{r}i$ with reverse vector. The equation and the relative fuzzy weights of all criteria for research are shown in Table 6.

Table 6: Fuzzy weight of criteria for research

Criteria	$\widetilde{W\imath}$		
I	0.24243639	0.373260342	0.559055952
CT	0.15396598	0.241614714	0.376216757
SM	0.09778038	0.156399337	0.253175103
TM	0.06209816	0.098748201	0.1607859
SS	0.04354216	0.067068123	0.108200887
E	0.02403722	0.034496484	0.053197757
T	0.02054585	0.0284128	0.041184031

Step 4: Defuzzification and normalization

The relative non-fuzzy weight of all criteria (Mi)was calculated by taking the average of fuzzy numbers for all criteria.

Table 7: Averaged and normalized relative weights of criteria for research

Criteria	Mi	Ni
I	0.39158423	0.367544085
CT	0.25726582	0.241471752
SM	0.16911827	0.158735764
TM	0.10721075	0.100628869
SS	0.07293706	0.068459304

E	0.03724382	0.034957347
T	0.03004756	0.02820288
Total	1.0654075	1

The weights for all criteria areshown in Table 7.

Table 8: Weights for research

Criteria	Weights
I	0.367544085
CT	0.241471752
SM	0.158735764
TM	0.100628869
SS	0.068459304
E	0.034957347
T	0.02820288

Table 9: Weights for coursework

Criteria	Weights
SM	0.367544085
TM	0.241471752
CT	0.158735764
T	0.100628869
SS	0.068459304
E	0.034957347
I	0.367544085

4 Result and Discussion

This research was conducted to propose a method to evaluate the capability of students to further their study at master's level either in research or coursework program. The weights were calculated based on the survey done to students who were furthering their study in master's level in both programs. The evaluation is measured based on 5 categories from 'poor' to 'very good' according to one's preference. Prior to the survey, a preliminary survey was administered to test the method which was based on the proposed Fuzzy AHP method.The respondents who were final year degree students were asked to complete the survey and rank each criterion. The calculation using the Fuzzy AHP methods reveals the following result of each respondent.

Table 10: Result of respondent for research and coursework programs.

Respondent	I	CT	SM	TM	SS	E	T	Research	Coursework
1	4	3	4	3	3	4	3	3.5612372	3.430704312
2	2.33	3	2	2.67	3	3	2.67	2.55249522	2.500666781
3	2.33	2	2	2.67	3	4	2.67	2.34598082	2.376888364
4	3.33	3	2.5	2.67	2.67	3	3.67	3.0050185	2.790679002
5	3.33	4	4	4	3	5	4	3.72024351	3.947602114

Table 10 shows the aggregated results of respondents for research and coursework programs. The results show the level of preference for the respondents to further study in master's level are 'fair' to 'very good'.The first respondent has the largest value for criteria 'I' and 'SM'which are the most important criteria ranked in research programs.The last respondent has the largest value for the criteria 'CT', 'SM', 'TM' and'T'which are the most important criteria ranked in coursework program. Therefore, it is suggested to respondents 1, 2 and 4 to choose the research program while for respondents 3 and 5 to choose the coursework program.

5 Conclusion

In conclusion, the aim of this paper is accomplished that is to develop a model based on Fuzzy AHP method to facilitate students with the decision-making process whether to pursue in research program or coursework program in their master'sstudy. The criteria involved in this paper are'Independent', 'Critical Thinking', 'Stress Management', 'Time Management', 'Soft Skills', 'Education' and 'Teamwork'. For future works, researchers are suggested to combine other multi-criteria decision-making methods such as Fuzzy TOPSIS-Fuzzy AHP to solve the problem.

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