A Fuzzy Approach for Prioritizing Selection Criteria

Rinki Yadav[1] ,Vincent KT Khoo[2], Shee Mooi Yee[3]

Information Systems Engineering Research Group
School of Computer Sciences,
Universiti Sains Malaysia,
Penang, MALAYSIA
[1]rinki.com08@student.usm.my
[2]vkhoo@cs.usm.my
[3]sheemooi@hotmail.com

ABSTRACT

As the jobs market becomes more competitive, more students are trying to seek admission to overseas institutions for higher education. In the design of a personalized recommendation, identifying the appropriate selection criteria and providing a structured way to prioritizing them is crucial. The objective of this paper is to use the Fuzzy Analytic Hierarchy Process to facilitate the recommendation process. In the past, rarely have the survey questions been deliberately phrased to minimize the possible vagueness in the questions. This paper proposes an enhanced way of phrasing the questions such that the respondents would find the questions more easily understandable. It is argued that better understanding of the questions will minimize the ambiguity inherent in the questions, which would then enhance the consistency and reliability of the answers.

Keywords
Fuzzy Analytic Hierarchy Process, Prioritization of criteria, Personalized recommendation.

1.0 *INTRODUCTION*

The objective of this study is to identify selection criteria and prioritize them for personalized recommendation. The goal of this paper is to reduce the difficulty encountered by the potential students by developing a structured approach to facilitate the prioritization of criteria. The main contribution of the paper is in the methodological approach proposed, which deals with identifying and prioritizing the selection criteria of potential students. Prioritizing the criteria can be considered as a multi-criteria decision making (MCDM) problem. Analytic hierarchy process, a MCDM tool, is adopted in the methodology proposed, since it has been widely and successfully adopted for prioritizing criteria (Kwong & Bai, 2002; Begiceviv, Divjak & Hunjak, 2007; Bottani & Rizzi, 2008). Fuzzy logic is also incorporated to address the vagueness of the potential students' thoughts in the criteria prioritization process.

Fuzzy Analytic hierarchy process (FAHP) requires pairwise comparisons of criteria from a decision maker. Nonetheless, potential students are not trained decision makers in answering the questions required by FAHP analysis. Questionnaires that are designed for survey usually pose many challenges to researchers in terms of accuracy in measuring respondents' perceptions (Traugott & Lavrakas, 2000). The wording of the questions is extremely important to get the true response from the respondents (Walonick, 2004). As such, FAHP questions will be reviewed and rephrased in such a way that the respondents will find them more easily understandable. It is argued that better understanding of the questions will enable the respondents to better externalize their thoughts.

2.0 LITERATURE REVIEW

2.1 Analytic Hierarchy Process (AHP)

Among various MCDM tools like AHP, TOPSIS, ELECTRE and PROMETHEE, AHP has been widely used for prioritization of criteria in several domains (Armacost, 1994). Prioritization of criteria is required to get the personalized recommendation of institutions for each interested party. The conventional AHP, proposed by (Saaty, 1980), uses pairwise comparisons to compare a number of n criteria under some given conditions and then maps the vague responses into a 9-point scale. The 9-point scale qualitatively expresses preferences among options as equally, moderately, strongly, very strongly or absolutely important. These preferences are translated into pairwise weights of 1, 3, 5, 7, 9 respectively. The Saaty's questionnaire layout allows the decision maker to evaluate the criteria from either sides of the layout as shown in Figure 1. In this way, the values entered in the comparison matrix from the decision maker's judgment are 1, 3, 5, 7, 9 or their inverse. However, a decision maker is usually uncertain about his judgment while comparing the criteria. Since each number in the pairwise comparison matrix represents the subjective opinion of the decision maker, it raises

the need for exploring the fuzzy based approaches (Fei & Yu, 2009). Fuzzy logic provides a useful tool for dealing with decisions in which the phenomena are imprecise and vague (Jamali & Tooranlo, 2009). In order to model this kind of uncertainty in human preferences, fuzzy set theory is incorporated with the pairwise comparison as an extension of AHP.

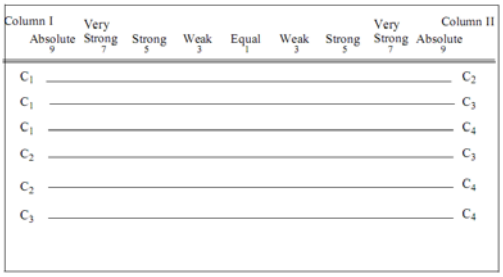


Figure 1: Saaty suggested AHP questionnaire layout (Saaty, 1980)

2.2 Fuzzy Analytic Hierarchy Process (FAHP)

The earliest work in FAHP appeared in (Laarhoven & Pedrycz, 1983) where they substituted triangular fuzzy numbers directly into the pairwise comparison matrix to deal with the ambiguity in assessing criteria. Later, (Buckley, 1985) determined the fuzzy weights with geometric mean by using trapezoidal fuzzy numbers. In the case of potential students, who are not clear about their requirements, fuzzy logic is exploited to deal with the uncertainty associated with the mapping of their perception to a number (Zadeh, 1965). FAHP is a useful approach for evaluating complex multiple criteria alternatives involving subjective and uncertain judgment (Balli & Korukoglu , 2009). In the fuzzy approach, the same numerical value may belong to two categories in different extent. The linguistic evaluations are substituted with fuzzy numbers as shown in Table 1. For calculation purposes, linguistic scale is converted into the following triangular fuzzy numbers (TFN) (Tolga, Demircan & Kahraman, 2005) as shown in Table 1.

Table 1: Triangular Fuzzy Number Values

Statement	TFN
Equally Important $(\tilde{1})$	(1, 1, 1)
Moderately Important $(\tilde{3})$	(1/2, 1, 3/2)
Strongly Important $(\tilde{5})$	(1, 3/2, 2)
Very Strongly Important $(\tilde{7})$	(3/2, 2, 5/2)
Absolutely Important $(\tilde{9})$	(2, 5/2, 3)

With the predesigned fuzzy numbers represented by a linguistic scale, potential students' actual priority of criteria can be deduced (Chen, 2009). Figure 2 shows the graph for membership function of triangular fuzzy numbers.

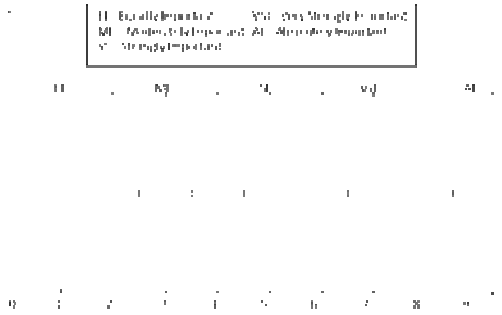


Figure 2: Fuzzy linguistic scale for the computation of weights (adapted from (Saaty, 1980))

In this study, triangular fuzzy numbers are used to represent subjective pairwise comparisons of the criteria in order to hide the vagueness. A fuzzy number is a special fuzzy subset of real number (Bellman & Zadeh, 1970).

3.0 THE PROPOSED APPROACH

A preliminary survey has been conducted to 200 international students to understand their needs and demands. A total of 70 students responded to the preliminary survey. Unstructured interviews were conducted to further understand the potential students' requirements, and problems. A questionnaire was grouped under a few categories for different purposes and statistics to get the relevant information concerning the students' pains, needs and difficulties while they are studying abroad. The categories of questions are:

a. Reasons to Study
   - Reasons for selecting a course/ institutions/ country
b. Information Collection
   - How students gather information
c. Difficulties in Collecting Data
   - Students are always confused by the different format, inconsistent and outdated data over the internet.
d. Difficulties While Studying Abroad
   - Actual pain, need, desire and difficulties
e. Accommodation Arrangement
   - Difficulties encountered
f. Students' Leisure Activities
   - Student's entertainments during free time
g. Financial Status
   - Parents' sponsorship, government scholarship, self-sponsorship, etc.

3.1 Analysis of survey results

Statistical Package for the Social Sciences (SPSS) was used to help in analyzing the survey results. Multiple respond sets for statistical analysis and clustering methodology had been used to analyze the students' behavior. The approach used was to first perform a hierarchical method to find out the number of clusters.

Then the k-means clustering was used to form the clusters.

In the first phase of clustering, hierarchy and k means was used to group students against reasons to study overseas, students' difficulty and financial status. The second phase of clustering used the first phase clustering results for comparison with student studying country. Students in different countries behave differently. By considering the two phases of clustering, the students' behaviors with destination country versus those pre-defined attributes had been understood. Then students were clustered into a few groups after the second phase. Students' behaviors were then analyzed and grouped in order to summarize the important features for students to find out the features that are significant and meaningful to them. From the analysis, the four (4) criteria below are major concerns among the potential students. These criteria form an input to the model for prioritization.

a. Main objective of study – Potential students always look for better job opportunities, knowledge improvement or culture learning.
b. Courses interested – Potential students look for the recognition of the institution/ school as well as the course.
c. Course Fee – The financial implication is another significant factor that potential students are concerned about.
d. Destination country – Culture and language are important for potential students. Different destination of country with different culture requires different level of adoption.

The next step involves assigning weights to the criteria. Arbitrary assignment of weights to multiple criteria is a difficult task (Parker, Chao, Ottawa & Chang, 2006). A structured approach is required to assign weights to the criteria. This weights assignment as inputs to personalized recommender is a repeated process.

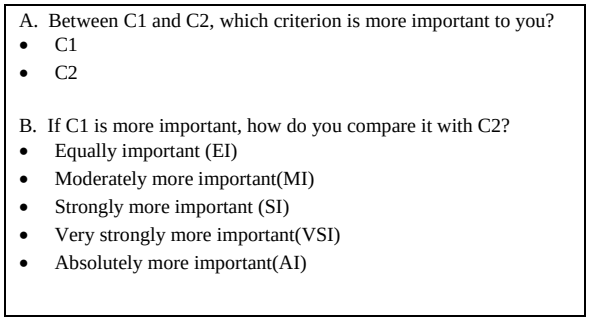
3.2 Structured prioritizing process

Based on the survey results, it was observed that there was a possible inconsistency in assigning the order of the criteria because the respondents may have assigned a higher value to criterion 1 than to criterion 2, despite the fact that they actually believe that criterion 2 is more important than criterion 1. It is felt that in order to reduce such inconsistencies, a more formalized and rigorous approach should be applied for determining the weights and priority of the criteria. In this paper, FAHP adoption is proposed for the type of analysis required in prioritizing the selection criteria. The weights of criteria calculated are required as inputs to get the personalized recommendation.

3.3 FAHP questionnaire

The questionnaire for FAHP analysis requires great efforts from the respondents because each criterion is required to be compared with every other criterion. For n selection criteria, there will be $n(n-1)/2$ pairwise comparisons. This is accomplished by asking a series of questions comparing two criteria at a time and asking the respondents to indicate their degree of preference for one criterion over the other. Survey questions should be phrased and posed in such a way that respondents can clearly understand the questions with minimal ambiguity. In the case of students, they do not have much understanding of criteria for selecting educational institution. As a result, it makes sense to make the questions more understandable to give more accurate responses. (Walonick, 2004) states that the wording of a question is extremely important to get the true response from the respondents.

In order to increase the objectivity of the FAHP questions, each question has been expanded into two parts. The original question from Saaty's questionnaire layout is how important is criterion 1 when compared to criterion 2. In the enhanced approach, this question is split into two questions for better understanding of the questions and thus increases the objectivity of the answering process. The first question establishes the preferred criterion between two compared criteria. Once the preferred criterion is known, it is kept on the left and the second criterion on the right. The second question establishes how much the preferred criterion is more important than the other. A sample of the spilt questions is shown in Figure 3. In this way, each respondent has to compare two criteria only in one direction. Since, the preferred criterion is known to a respondent before being asked to indicate his degree of preference over the other. Thus, it increases the consistency in his judgment. In a normal question, criteria appear randomly on both sides of the linguistic scale as shown in Figure 1.


A. Between C1 and C2, which criterion is more important to you?
- C1
- C2

B. If C1 is more important, how do you compare it with C2?
- Equally important (EI)
- Moderately more important(MI)
- Strongly more important (SI)
- Very strongly more important(VSI)
- Absolutely more important(AI)

Figure 3: Proposed FAHP questionnaire layout

Following the proposed approach shown in Figure 3, the entire questionnaire can be formed by considering all the pairwise comparisons as required inputs to the FAHP comparison matrix.

4.0 FAHP MODEL FOR PRIORITISING SELECTION CRITERIA

AHP model has been used in the past for prioritization of criteria. But AHP model only works well when a decision maker is certain about his requirements and clearly understands the relative importance of the criteria. The users of this recommendation system are however students, who more often than not are uncertain of their needs and are easily confused by misleading questions. As such, a more formalized FAHP model is adopted to prioritize the selection criteria, based on the criteria identified in section 3.1. These criteria serve as input to the FAHP model with the proposed steps in the following sections:

4.1 Construction of the hierarchical framework

In the FAHP model, the criteria prioritization process is divided into three (3) levels of hierarchy. The first level is goal, the second level shows the criteria, and the third level shows the sub criteria. The purpose of this hierarchy is to systematize the complex prioritization of process. The hierarchy tree and criteria are shown in Figure 4.

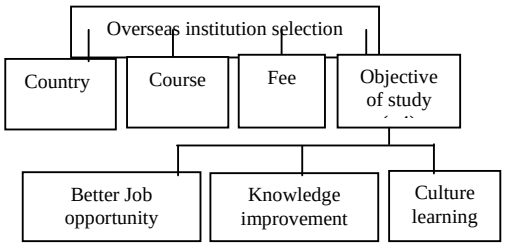


Figure 4: A hierarchical representation of students' criteria for prioritization

4.2 Construction of the fuzzy pairwise matrix

The pairwise comparisons matrix is generated for each request for recommendation to evaluate the criteria. Triangular fuzzy numbers are used to express the preferences in the pairwise comparisons. The proposed Fuzzy AHP questionnaire is used to get the pairwise comparison matrix.

4.3 Determination of the weights of criteria

The normalized fuzzy weights are determined by the fuzzy Eigenvalue method. The fuzzy operations are performed to get the fuzzy weights. From the defuzzification methods, the mean of maxima method is chosen (Nurcahyo, 2003) which calculates the crisp value as $(l + m + u)/ 3$, where l is the lower value, m is the middle value, and u is the upper value of a triangle.

The proposed model should help to resolve the subjectivity of the prioritization process. Utilizing a structured approach formalizes the prioritizing process for personalized recommendation. In addition, the design and explanation of the proposed FAHP questionnaire would help the respondents to evaluate the criteria in a more understandable manner and thus enhance the consistency and reliability of the answers.

5.0 DISCUSSION

In a basic preliminary survey, it was found that some respondents had given a higher rating to "destination country" than "courses interested". However, when it was specifically asked about the relative importance between the two criteria, the respondents involved actually specified the answers in a reverse manner. To reduce such inconsistencies, the FAHP method was used to re-evaluate the criteria. An additional series of pairwise comparisons was introduced to prioritize the criteria.

In Saaty's layout, as shown in Figure 1, the respondents have to use either one of two sides to access the corresponding criteria. On the other hand, in the proposed approach, the respondents first select the more important criterion between two given criteria, and then state how much the selected criterion is more important than the other. The additional step of splitting a single question into two sub-questions, although appears to be more laborious, was found to clarify the questions better, which should arguably minimize the inherent ambiguity.

6.0 CONCLUSION

This paper first presents a set of criteria for the selection of educational institutions. It then proposes a more structured way to prioritize the criteria. Moreover, the paper proposes an enhanced FAHP questionnaire layout which would arguably reduce the ambiguity of the questions.

As part of the future work, a more formal evaluation of the FAHP model will be conducted through a more intensive survey with a larger number of criteria. An automated tool will be developed to automate the generation of the FAHP questionnaire layout, the phrasing of the questions, and the required tedious pairwise comparisons, especially when the number of criteria is more than ten.

REFERENCES

Armacost, R.T. (1994). An AHP framework for prioritizing customer requirements in QFD: An industrialized housing application. *IEEE Transactions*, 26, 72-79.

Balli, S., & Korukoglu, S. (2009). Operating system selection using fuzzy AHP and TOPSIS Methods.

Mathematical and Computational Applications, 14, 119-130.

Begiceviv, N., Divjak, B., & Hunjak, T. (2007). Prioritization of e-learning forms: a multicrietria methodology. *Central European Journal of Operations Research*, 15, 405-419.

Bellman, R. E., & Zadeh, L. A. (1970). Decision making in a Fuzzy environment. *Management Science*, 17, 141-164.

Bottani, E., & Rizzi, A. (2008). An adapted multi-criteria approach to suppliers and products selection – An application oriented to lead-time reduction. *International Journal of Production Economics*, 111, 763-781.

Buckley, J. J. (1985). Fuzzy Hierarchical Analysis. *Fuzzy Sets and Systems*, 17, 233-247.

Chen, P. C. (2009). A Fuzzy multiple criteria decision making model in employee recruitment. *International journal of computer science and network security*, 9, 113-11.

Fei, K., & Yu, L. H. (2009). Applying FAHP to determine the weights of evaluation indices for government websites satisfaction. *Fuzzy info and eng*, 2, 1449-1457.

Jamali, R., & Tooranloo, H. S. (2009). Prioritizing academic library service quality indicators using fuzzy approach, *Library Management*, 30, 319-333.

Kwong, C. K., & Bai, H. (2002). A fuzzy AHP approach to the determination of importance weights of customer requirements in quality function deployment. *Journal of intelligent manufacturing*, 13, 367-377.

Laarhoven, P. & Pedrycz, W. (1983). A fuzzy extension of Saaty's priority theory. *Fuzzy Sets and System*, 11, 229-241.

Nurcahyo, G. W., Shamsuddin, S. M., Alias, R. A., & Sap, N. D. (2003). Selection of defuzzification method to obtain crisp value for representing uncertain data in a modified sweep algorithm. *Journal of computer science and technology*, 3, 22–28.

Parker, K. R., Chao, J. T., Ottawa, T. A., & Chang, J. (2006). A formal language selection for introductory programming courses. *Journal of Information Technology Education*, 5, 133-151.

Saaty, T. L. (1980). *The Analytic Hierarchy Process.* McGraw-Hill, New York.

Tolga, E., Demircan, M. L., & Kahraman, C. (2005). Operating System Selection Using Fuzzy Replacement Analysis and Analytic Hierarchy Process, *International Journal of Production Economics*, 97, 89-117.

Traugott, W. M. & Lavrakas, J. P. (2000). The Voter's Guide to Election Polls, *Second Chatham House Publishers, Seven Bridges Press, LLC.*

Walonick, D. S. (2004). *Survival Statistics*, ISBN 0-918733-11-1, StatPac, Inc., Bloomington, MN.

Zadeh, L. A. (1965). *Fuzzy sets. Information and Control*, 8, 338-353.