A Fuzzy-Analytical Hierarchy Process approach for Assessing Quality in Technical Education

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Abstract

Education is an important aspect of the development and self sustenance of economy. It predicts the growth and living standard. Technical education enhances further economic growth and provides livelihood to the needed. Hence, there is an utmost need to develop an efficient and effective technical education system (TES) which would provide a quality assurance to all the stakeholders: faculty, students, parents, employers etc. of the education industry. In this paper, an analytical tool has been developed to find the important attributes that should be present in a TES for quality assurance. A Fuzzy Analytical hierarchy process (AHP) with extent analysis is used for pair-wise comparison of the attributes taken to find out the most important attributes among them. A questionnaire was prepared for pair-wise comparison of the attributes and reviews were taken from the students, faculty, experts and industries. Triangular fuzzy numbers produced from the experts' view of the questionnaires are used for pair-wise comparison matrices.

Keywords: Technical Education System, Fuzzy Logic, Analytical Hierarchy Process pair-wise comparison

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1. Introduction

Quality is a key factor for determining the success and survival of an economy. It is an important factor in manufacturing and service industries and has been extended to other fields across the world. It acts as a lifeline for the industries and hence they employ the best possible means to ensure quality of their product. One of the most important factors of quality is the technical education. A Technical Education System (TES) or process consists of three different stages: Input, process and the output with a feedback mechanism which makes it a closed loop (fig.1) [1]. The feedback coming from the output can be utilized to assess and improve the quality of a TES.

The main stakeholders of any TES are faculty, students, management and the infrastructure, which are responsible for efficient functioning of a TES. Efficient and effective working of all these stakeholders results into a good or high quality. TES which in turn leads to quality education. Any loopholes in a TES are due to some loopholes in working of any one or more of stakeholders.

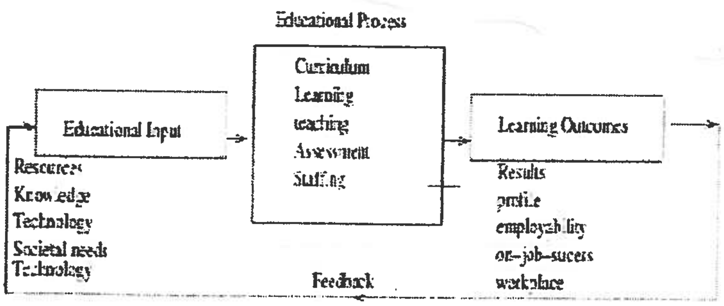


Figure 1: The block diagram of an educational cycle

1.1 Quality in Technical Education

The concept of quality in education has not yet been well defined. So many different approaches have been adopted by the researchers to define quality in the education sector. Some feel quality in education is related to quality of faculty or quality of students, management and many other aspects. Nowadays, students are also becoming very discriminating in choosing the institute. Therefore, the issue of survival of the institute and the retention of the students has become an area of critical concern for most colleges and universities.

From the early 1990s onwards the emphasis was shifted to formal assessment of quality in technical education to spur the institutions to adopt formal systems of quality management. Singh and Sareen [2] described Deming's cycle and its 14 points which are used to ensure the quality of technical education process. Kaur et al. [3] studied and gave some of the quality issues in technical institutions where implementation of ISO 9001:2000 may provide the management a frame work to continually improve the existing resources and process by setting up quality objectives, measurements etc. to achieve higher standards of quality in education. Tartaglia and Tresso [4] developed a Web-based automatic evaluation system for students of engineering faculties.

Temponi [5] of USA analyzed the main elements of continuous improvement (CI) in higher education and the concerns of academia's stakeholders in the implementation of such an approach. Thakkar et al. [28] used a quality function deployment (QFD) which prioritizes technical requirements and correlates them with various customers' students requirements for the present Indian context. Voss and Gruber [6] studied and gave an insight into the desired qualities of the lecturers. They indicated that the students want lecturers to be knowledgeable,. enthusiastic, approachable, and friendly. Mahapatra and Khan [7] gave a measuring instrument known as EduQUAL for evaluation of quality in Technical Education System (TES). Neural network models along with QFD have been proposed to assess the degree of satisfaction of various stakeholders in TES. He gave certain factors that are important for assessing quality in technical education. Venkataram and Giridharan [1] designed a Technical Educational Quality Assurance and Assessment (TEQ-AA) System, which makes use of the information on the web and analyzes the standards of the institution. Mahapatra and Khan [8] designed a measuring instrument known as EduQUAL and an integrative approach using neural networks for evaluating service quality is proposed. The dimensionality of EduQUAL is validated by factor analysis followed by varimax rotation. Bahzad and Irani [9] developed a QA model for military institutions. The research seeks to assess, through a case study how newly established education institutes and assimilates quality assurance systems. Gheorghe et. al. [10] depicted the peculiarity of Quality Function Deployment method (QFD) applied to quality improvement in higher technical education. Wang and Liang [11] used SPC (control charts) technique for quality control or improvement of technical education. Inamullah et. al. [12] studied and highlighted the present profile of technical education in NWFP, Pakistan, and to pinpoint the physical facilities problems of technical education and also to highlight the academic problems in technical education, and to recommend strategies for the improvement of technical education in Pakistan.

1.2 The Analytical Hierarchy Process

The Analytical hierarchy process (AHP) is one of the extensively used multi-criteria decision-making methods (MCDM). The advantage of this method lies in its capability to handle multiple criteria and it can also handle both the quantitative and qualitative data effectively. The use of AHP does not involve complex mathematics. It involves the use of principles of decomposition, pair-wise comparisons, priority vector generation and synthesis. The purpose of AHP is to capture the expert's knowledge and analyze it.

The conventional AHP method does not reflect the human thinking style hence, Fuzzy AHP, a fuzzy extension of AHP, was developed to solve the fuzzy problems. The decision maker specifies the preferences in the form of natural language expressions about the importance of each performance attribute (faculty, student, management inputs and infrastructure) and the system combines these preferences using fuzzy-AHP, with existing data (from industrial surveys and statistical analysis) to reemphasize attribute priorities. In the fuzzy-AHP methodology, the pairwise comparisons in the judgment matrices are fuzzy numbers that are modified by the designer. Using fuzzy arithmetic and -cuts, the procedure calculates a sequence of weight vectors that will be used to combine the scores on each attribute. The procedure calculates a corresponding set of scores and determines one composite score that is the average of these fuzzy scores.

1.3 Quality Management and Assurance in Technical Education

The international Standard on Quality management and assurance specifies requirements for a quality management system where an institute

(a) Needs to motivate its faculty to consistently provide knowledge to students that meets the international standards and are able to provide good quality service to the nation and society to grow.

(b) Aims to quality satisfaction through effective application of the system, including processes for continual improvement of the system and the assurance of conformity to students and top authority.

Some of the important main attributes of a TES are:

- Faculty Quality (FQ)
- Students Quality (SQ)
- Management Inputs (MI)
- Infrastructure (IN)

These are main attributes whose efficient working and good performance results into a quality TES. Quality in education can be assessed and improved with high accuracy by monitoring the above attributes. There are certain attributes that comes under the above main attributes. They are:

- **Faculty Quality:** Various attributes are Faculty Expertise, Adequacy of Subject Teacher, Effective Classroom Management, Teaching Quality and Productivity, Amount of Teaching and Industrial experience (T&I Ex), Good communication skills (GCS), Qualifications of Faculty (Qua), Expertise in Subject and Well-Organised Lectures (ES & WOL) etc.
- **Students Quality:** Various attributes are Background and merits of the entering students (B & MES), Fraction engaging in undergraduate research, Fraction completing graduation as per the university or govt. norms, Time taken to complete the degree (TLD), Attitude towards learning (ATL)
- **Management Inputs:** The lack of adequate inputs by the management and non provision of qualified, well paid and professional faculty adversely affects the quality of technical education. Some of the major points to be considered by the management are as follows; Training for Faculty Development (TFD), Timely Assessment of Faculty and Students (T A F&S), Library Standards (LS), Adaptability to modern techniques. Curriculum Design (up gradation of modern techniques) (CD), Opportunities for campus training and placement (T&P), Transparency of official procedure, norms and rules, etc.
- **Infrastructure in an Institution:** Various attributes are; provision of Well-equipped laboratories with modern facilities (WO L&C), Cleanliness, orderliness, systematic and methodical (COSM) approach of the institute, College building and premises (CBP), Hostel and Mess facility (HMF), etc.

An institution has to continually improve the effectiveness of the TES through the use of the quality policy, quality objectives, audit results, analysis of data, corrective and preventive actions and management review.

1.4 Application of Fuzzy AHP for determining important attributes for a Quality TES

The objective of this research is to identify and rate the factors which are responsible for assessing the quality of technical education and thus help in monitoring, controlling and improving the quality of technical education at various levels. In this work we have used a multi criterion decision making (MCDM) tool known as "**FUZZYAHP**". Fuzzy AHP technique is used for finding out the weightage of the main and sub criterion attributes of technical education system. The factors taken in this research have been taken from various experts view and from the previous research and literature review mentioned earlier.

The research allows us to decide which attributes are most and least important and the ranking of the attributes taken.

2 Present Research Objectives

- To develop an instrument for measuring quality in the technical education sector
- To determine the rank of the attributes capable of affecting quality of a TES.
- To test the adequacy of Fuzzy AHP for modeling the Attributes of quality in education.

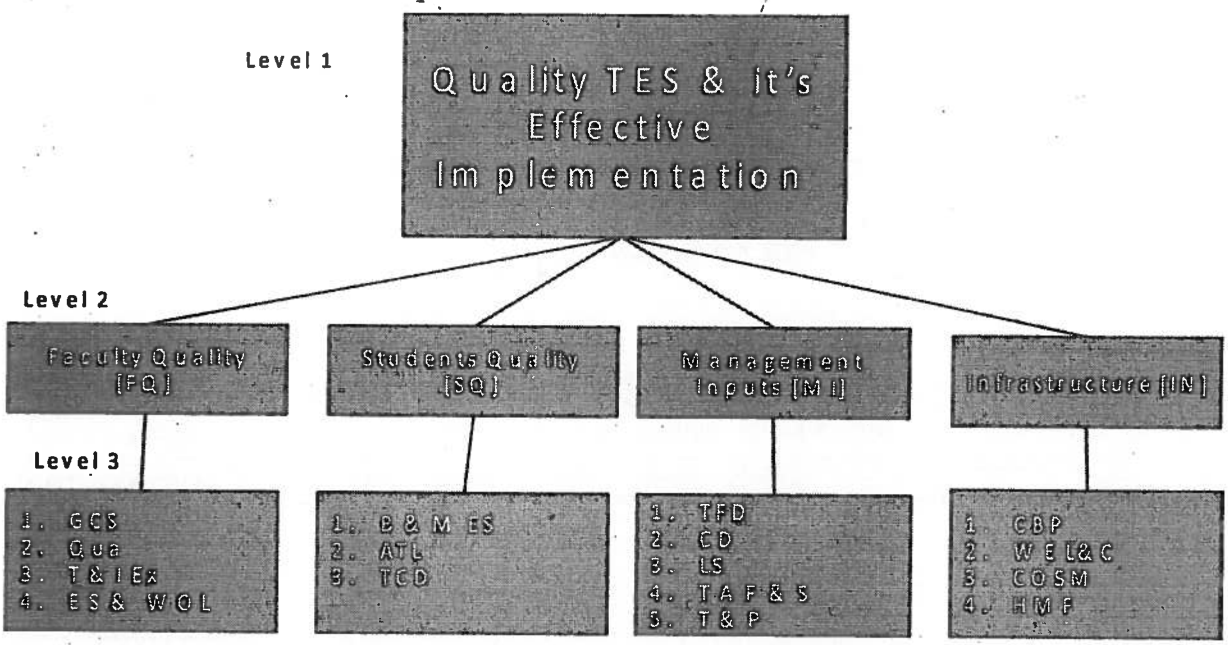


Fig. 2 Hierarchy Model for Quality in Technical Education

2.1 The Proposed Hierarchy Model for Quality in Technical Education

The figure 2 above shows a hierarchy model for quality in technical education. At level 1 is the ultimate goal i.e. to get a quality TES. At the level 2 main attributes of TES are present whose effective implementation and proper running results in a quality TES. At level 3 the Sub attributes of the main attributes are given whose proper functioning in turn effect the effectiveness of the main attributes. It shows the attributes that have been analyzed in the paper. First the main attributes are analyzed and then their sub attributes are prioritized using fuzzy AHP. In the end all the attributes are ranked according to the priority weights obtained and important attributes are recognized.

2.2 Data Collection

Data for the research was collected in the form of the questionnaire. The questionnaire was distributed to a large number of students, faculty, recruiters, alumni and people working in the industries. The questionnaire consisted of the above mentioned attributes (main & sub). The questionnaire was based on pairwise comparison of the attributes. The format of the questionnaire is shown in appendix.

2.3 Data Analysis and Calculations

Tables 1-5 show the pairwise comparison matrix for the main and sub attributes. These were constructed with the responses obtained from the comparison questionnaire. Now by using the formulas mentioned in the appendix, the values were calculated for all the variables in order to get the desired values of priority vectors and finally "W" which gives us the global weight of the attributes.

Table 1 Main Attribute pairwise Comparison Matrix

Main Attributes	FQ	SQ	MI	IF
FQ	(1,1,1)	(7/2,4,9/2)	(3/2,2,5/2)	(2/3,1,3/2)
SQ	(2/9,1/4,2/7)	(1,1,1)	(2/3,1/2,2/3)	(5/2,3,7/2)
MI	(2/5,1/2,2/3)	(3/2,2,5/2)	(1,1,1)	(5/2,3,7/2)
IF	(2/3,1,3/2)	(2/7,1/3,2/5)	(2/7,1/3,2/5)	(1,1,1)

From table 1, S_{FQ}= (6.67, 8.00, 9.50) $\otimes\left[\frac{1}{25.93}, \frac{1}{21.93}, \frac{1}{18.44}\right]$ = (0.26, 0.36, 0.52), S_{SQ}= (4.12, 4.75, 5.46) $\otimes\left[\frac{1}{25.93}, \frac{1}{21.93}, \frac{1}{18.44}\right]$ = (0.16, 0.22, 0.30), S_{MI}= (5.40, 6.50, 7.70)$\otimes\left[\frac{1}{25.93}, \frac{1}{21.93}, \frac{1}{18.44}\right]$= (0.21, 0.30, 0.42) and S_{IN}= (2.25, 2.48, 3.30)$\otimes\left[\frac{1}{25.93}, \frac{1}{21.93}, \frac{1}{18.44}\right]$ = (0.09, 0.12, 0.18) are obtained. Using these values the vectors obtained are as follows; V ($S_{FQ}\geq S_{SQ}$) = 1, V ($S_{FQ}\geq S_{MI}$) = 1, V ($S_{FQ}\geq S_{IN}$) = 1; V ($S_{SQ}\geq S_{FQ}$) = 0.22, V ($S_{SQ}\geq S_{MI}$) = 0.09, V ($S_{SQ}\geq S_{IN}$) = 1; V ($S_{MI}\geq S_{FQ}$) = 0.73, V ($S_{MI}\geq S_{SQ}$) = 1, V ($S_{MI}\geq S_{IN}$) = 1; V ($S_{IN}\geq S_{FQ}$) = 0.15, V ($S_{IN}\geq S_{SQ}$) = 0.25, V ($S_{IN}\geq S_{MI}$) = 0.18 are obtained. Hence the weight vector from table 1 can be calculated as

Table 2 Sub Attribute of Faculty Quality pairwise Comparison Matrix

Faculty Quality Sub- Attributes	GCS	Qua	T&I Ex	E S&WOL
GCS	(1,1,1)	(1,1,1)	(5/2,3,7/2)	(3/2,2,5/2)
Qua	(1,1,1)	(1,1,1)	(7/2,4,9/2)	(3/2,2,5/2)
T&I Ex	(2/7,1/3,2/5)	(2/9,1/4,2/7)	(1,1,1)	(2/3,3,3/2)
E S& WOL	(2/5,1/2,2/3)	(2/3,1/2,2/5)	(2/3,1,3/2)	(1,1,1)

From table 2 we get, S_{GCS}= (0.25, 0.34, 0.45), S_{Qua}= (0.30, 0.39, 0.50), $S_{T\&I\,Ex}$= (0.10, 0.13, 0.18) and $S_{E\&S\,WOL}$= (0.12, 0.15, 0.20); V ($S_{GCS}\geq S_{Qua}$) = 0.75, V ($S_{GCS}\geq S_{T\&I\,Ex}$) = 1, V ($S_{GCS}\geq S_{E\&S\,WOL}$) = 1; V ($S_{Qua}\geq S_{GCS}$) = 1, V ($S_{Qua}\geq S_{T\&I\,Ex}$) = 1,V ($S_{Qua}\geq S_{E\&S\,WOL}$) = 1; V ($S_{T\&I\,Ex}\geq S_{GCS}$) = 0.43, V ($S_{T\&I\,Ex}\geq S_{Qua}$) = 0.28, V ($S_{T\&I\,Ex}\geq S_{E\&S\,WOL}$) = 0.60; V ($S_{E\&S\,WOL}\geq S_{GCS}$) = 0.22, V ($S_{E\&S\,WOL}\geq S_{Qua}$) = 0.15, V ($S_{E\&S\,WOL}\geq S_{T\&I\,Ex}$) = 1 are obtained. Hence the weight vector from table 2 can be calculated as

Table 3 Sub Attribute of Students Quality pairwise Comparison Matrix

Students Quality Sub- Attributes	B & MES	ATL	TCD
B & MES	(1,1,1)	(3/2,2,5/2)	(2/3,1,3/2)
ATL	(2/5,1/2,2/3)	(1,1,1)	(3/2,2,5/2)
TCD	(2/3,1,3/2)	(2/5,1/2,2/3)	(1,1,1)

From table 3 we get, $S_{B\&MES}=(0.26,0.40,0.61)$, $S_{ATL}=(0.24,0.35,0.51)$ and $S_{TCD}=(0.17,0.25,0.39)$; $V(S_{B\&MES}\geq S_{ATL})=1$, $V(S_{B\&MES}\geq S_{TCD})=1$; $V(S_{ATL}\geq S_{B\&MES})=0.84$; $V(S_{ATL}\geq S_{TCD})=1$, $V(S_{TCD}\geq S_{B\&MES})=0.47$, $V(S_{TCD}\geq S_{ATL})=0.61$; are obtained. Hence the weight vector from table 3 can be calculated as

Table 4 Sub Attribute of Infrastructure pairwise Comparison Matrix

Management Inputs Sub- Factors	TFD	CD	LS	TA F&S	T&P
TFD	(1,1,1)	(2/9,1/4,2/7)	(3/2,2,5/2)	(1,1,1)	(2/3,1,3/2)
CD	(7/2,4,9/2)	(1,1,1)	(5/2,3,7/2)	(3/2,2,5/2)	(1,1,1)
LS	(2/5,1/2,2/3)	(2/7,1/3,2/5)	(1,1,1)	(2/5,1/2,2/3)	(2/7,1/3,2/5)
TA F&S	(1,1,1)	(2/5,1/2,2/3)	(3/2,2,5/2)	(1,1,1)	(1,1,1)
T&P	(2/3,1,3/2)	(1,1,1)	(5/2,3,7/2)	(1,1,1)	(1,1,1)

From table 4 we get the weight vector as $W_{INSA}=(0.17,0.68,0.09,0.06)^T$

Table 5 Sub Attribute of Management Inputs pairwise Comparison Matrix

CBP	(1,1,1)	(2/9,1/4,2/7)	(3/2,2,5/2)	(3/2,2,5/2)
WE LC	(7/2,4,9/2)	(1,1,1)	(5/2,3,7/2)	(3/2,2,5/2)
COSM	(2/5,1/2,2/3)	(2/7,1/3,2/5)	(1,1,1)	(1,1,1)
HMF	(2/5,1/2,2/3)	(2/5,1/2,2/3)	(1,1,1)	(1,1,1)

From table 5 we get the weight vector as $W_{MISA}=(0.11,0.47,0.07,0.18,0.17)^T$

Table 6 Summary of Global Priority Weights of Main Attributes and Sub Attributes for Assessing Quality in Technical Education

Ranking of Main and Sub Attributes	Global Priority Weights
Faculty Quality (FQ)	**0.4800**
❖ Good Communication Skills (GCS)	0.1632
❖ Qualification of Faculty (Qua)	0.2208
❖ Teaching & Industrial Experience (T&I Ex)	0.0624
❖ Expertise in Subject and Well Organized Lectures (ES &WOL)	0.0336
Students Quality (SQ)	**0.1100**
❖ Background & Merit of Entering Students (B&M ES)	0.0473
❖ Attitude Towards Learning (ATL)	0.0407
❖ Time Taken to Complete Degree (TCD)	0.0220
Management Inputs (MI)	**0.3500**
❖ Training for Faculty Development (TFD)	0.0385
❖ Curriculum Design (CD)	0.1645
❖ Library Standards (LS)	0.0245
❖ Timely Assessment of Faculty & Students (TA F& S)	0.0630
❖ Training & Placement (T&P)	0.0595
Infrastructure (IN)	**0.0600**
❖ College Building & Premises (C B&P)	0.0102
❖ Well Equipped Labs and Classrooms (WE L&C)	0.0408
❖ Cleanliness, Orderliness, Systematic and Methodical (COSM)	0.0054 0.0036

3. Conclusion

The major contribution of this paper is in providing a systematic integrated approach for modeling various attributes of a quality TES. Education is a service sector, hence its quality is not dependent on one or two people. The stakeholders in an education sector ranges from students, faculty, recruiters, etc. hence an educational set up has the responsibility to satisfy everyone's needs. This often results in difficulties for implementing quality control and improvement programmes and policy planning. Therefore, it is advisable to identify the minimum number of important attributes that suit all the stakeholders before implementing any quality improvement programme.

In this work a survey-based model, has been specially developed to suit a technical education system. A literature review was done and certain important attributes of a quality TES was determined. Some of the attributes were taken from experts also. Then a questionnaire was constructed and a review was taken from a large number of students, faculty, etc. and then the fuzzy AHP comparison matrices were made and by using the Fuzzy AHP along with extent analysis method, global priority weights for each attribute were calculated. The analysis concluded that the following are the most important attributes of quality TES and should be given utmost importance. They are: (global priority weight >0.04) Qualification of Faculty (Qua), Curriculum Design (CD), Good Communication Skills (GCS), Timely Assessment of Faculty & Students (TA F& S), Teaching & Industrial Experience (T&I Ex), Training & Placement (T&P), Background & Merit of Entering Students (B&M ES), Well Equipped Labs and Classrooms (WE L&C) and Attitude Towards Learning (ATL).

The results showed that the qualification of the faculty is one of the most important attribute; hence the TES should employ a highly qualified faculty in order to achieve quality in technical education. The present technical education system throughout the country urgently needs to design the curriculum on the basis of new trends, rapid technological growth, etc. There is also a great need to modernize the laboratories and classrooms with the latest technology so that students would be aware of the recent developments around the world. Along with faculty; students, management and the infrastructure also plays a vital role in obtaining quality in technical education. Hence all these main attributes with some of their important sub attributes should be there in a TES to achieve quality in technical education.

References

1. Venkataram P & Giridharan A, "Quality Assurance and Assessment in Technical Education System: A Web Based Approach", ICEE 2007.
2. Singh C & Sareen K, "Application of Deming's Philosphy to Improve the Quality of Technical Education", emerald 2001.
3. Kaur M, Singh C, & Sareen K.K, " Improving Quality of Technical Education using ISO 9000:2000", emerald 2002.
4. Tartaglia A & Tresso E, "An Automatic Evaluation System for Technical Education at the University Level", IEEE 2002, VOL.45, No.3.
5. Temponi C, "Continuous improvement framework: implications for academia", Emerald Group, Quality Assurance in Education Vol. 13 No. 1, 2005.
6. Voss R & Gruber T, "The desired teaching qualities of lecturers in higher education: a means end analysis", Emerald Group Quality Assurance in Education Vol. 14 No. 3, 2006.
7. Mahapatra S. S & Khan M. S, "A neural network approach for assessing quality in technical education: an empirical study", International Journal of Productivity and Quality Management 2007, Vol.2, No.3.
8. Mahapatra S. S & Khan M. S, "A framework for analyzing quality in education settings",

European Journal of Engineering Education Vol. 32, No. 2, May 2007, 205–217.
9. Bahzad Y and Irani Z, "Developing a Quality Assurance Model for Small Military Institutions", European and Mediterranean Conference on Information Systems 2008 (EMCIS2008) May 25-26 2008.
10. Gheorghe C.M, Constantinescu D & Covrig M, "The Determination of Factors Underlying Decision Making Process on Quality Improvement in Technical Education", IEEE 2008
11. Wang Z and Liang R, "Discuss on Applying SPC to Quality Management in University Education", The 9th International Conference for Young Computer Scientists, IEEE, 2008.
12. Inamullah H.M, Naseeruddin M & Hussain I, "The Development of Technical Education in Pakistan", International Business & Economics Research Journal – January 2009 Volume 8, Number 1.
13. Zadeh, L., 1965. Fuzzy sets, Information Control 8, 338–353
14. Chang, D.-Y., 1996. Applications of the extent analysis method on fuzzy AHP. European Journal of Operational Research 95, 649–655.
15. Laarhoven V, P.J.M., Pedrycz, W., 1983. A fuzzy extension of Saaty's priority theory. Fuzzy Sets and Systems 11,229–241.
16. Stam, A., Minghe, S. & Haines, M., 1996. Artificial neural network representations for hierarchical preference structures. Computers and Operations Research 23 (12), 1191–1201.
17. Cheng, C.-H., 1997. Evaluating naval tactical missile systems by fuzzy AHP based on the grade value of membership function. European Journal of Operational Research 96 (2), 343–350.
18. Kahraman C, Cebeci U & Ruan D, 2003, "Multi-attribute comparison of catering service companies using fuzzy AHP: The case of Turkey", Int. J. Production Economics 87 (2004) 171–184.
19. Weck, M., Klocke, F., Schell, H., R.uenauver, E., 1997. Evaluating alternative production cycles using the extended fuzzy AHP method. European Journal of Operational Research 100 (2), 351–366.
20. Deng, H., 1999. Multicriteria analysis with fuzzy pairwise comparison. International Journal of Approximate Reasoning21 (3), 215–231.
21. Lee, M., Pham, H. & Zhang, X., 1999. A methodology for priority setting with application to software development process. European Journal of Operation al Research 118,375–389.
22. Cheng, C.-H., Yang, K.-L., Hwang, C.-L., 1999. Evaluating attack helicopters by AHP based on linguistic variable weight. European Journal of Operation al Research 116 (2), 423–435.
23. Zhu, K.-J., Jing, Y., Chang, D.-Y., 1999. A discussion of extent analysis method and applications of fuzzy AHP. European Journal of Operational Research 116, 450–456.
24. Chan, F.T.S., Chan, M.H., Tang, N.K.H., 2000a. Evaluation methodologies for technology selection. Journal of Materials Processing Technology 107, 330–337.
25. Leung, L.C., Cao, D., 2000. On consistency and ranking of alternatives in fuzzy AHP. European Journal of Operational Research.124, 102–113.
26. Chan, F.T.S., Jiang, B., Tang, N.K.H., 2000b. The development of intelligent decision support tools to aid the design of flexible manufacturing systems. International Journal of Production Economics 65 (1), 73–84.
27. Kahraman, C., Ulukan, Z. & Tolga, E., 1998. A fuzzy weighted evaluation method using objective and subjective measures. In: Proceedings of the International ICSC Symposium on Engineering of Intelligent Systems (EIS'98), Vol. 1, University Laguna Tenerife, Spain, pp. 57–63.
28. Thakkar J & Shastree A, "Total quality management (TQM) in self-financed technicalinstitutions", Emerald Group. Quality Assurance in Education Vol. 14 No. 1, 2006.

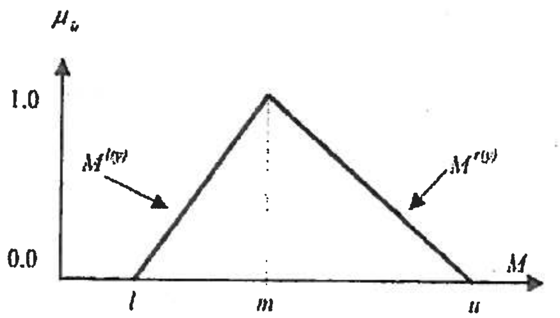
Appendix

Fuzzy Arithmetic

Fuzzy Logic Theory was introduced by Zadeh [13] and has since gained much importance in practical applications such as Process Control, Flexible Manufacturing Systems, Flexible Automation, MCDM etc.

A Fuzzy set theory has capability of representing vague data. The theory also allows mathematical operators and programming to apply to the fuzzy domain. A fuzzy set is a class of objects with a continuum of grades of member - ship. Such a set is characterized by a membership (characteristic) function, which assigns each object a grade of member ship ranging between zero and one.

A triangular fuzzy number (TFN) [6] is shown in fig. below.



A TFN is denoted simply as (l/m, m/u) or (l, m, u) [14]. The parameters l, m, and u respectively, denote the smallest possible value, the most promising value, and the largest possible value that describe a fuzzy event. Each TFN has linear representations on its left and right side such that its membership function can be defined as,

$$\mu(x|\tilde{M}) = \begin{cases} 0, & x < l, \\ (x-l)/(m-l), & l \leqslant x \leqslant m, \\ (u-x)/(u-m), & m \leqslant x \leqslant u, \\ 0, & x > u. \end{cases}$$

Various mathematical operations that can be performed by the fuzzy numbers have been discussed below. These operations include addition, multiplication etc. of the fuzzy numbers. Consider two triangular fuzzy numbers M_1 and M_2 such that, $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$. Their operational laws are as follows:

1. $(l_1, m_1, u_1) \oplus (l_2, m_2, u_2)$
   $= (l_1 + l_2, m_1 + m_2, u_1 + u_2).$
2. $(l_1, m_1, u_1) \odot (l_2, m_2, u_2)$
   $\approx (l_1 l_2, m_1 m_2, u_1 u_2).$
3. $(\lambda, \lambda, \lambda) \odot (l_1, m_1, u_1) = (\lambda l_1, \lambda m_1, \lambda u_1),$
   $\lambda > 0, \lambda \in R.$
4. $(l_1, m_1, u_1)^{-1} \approx (1/u_1, 1/m_1, 1/l_1).$

Fuzzy AHP

Many fuzzy AHP methods have been proposed by various authors. These methods are systematic and useful approaches to the alternative selection and gives justification to the problem by using the concepts of fuzzy set theory and hierarchical structure analysis. Decision makers have experienced that it is more confident and easy to give interval judgments than fixed value judgments. This is due to the fuzzy nature of the comparison process. Brief literature review is as follows [18]:

The earliest work in fuzzy AHP started from 1983. Laarhoven and Pedrycz [15] compared fuzzy ratios described by triangular membership functions. Chang introduced a new approach for handling fuzzy AHP, with the use of triangular fuzzy numbers for pairwise comparison scale of fuzzy AHP, with the use of the extent analysis method for the synthetic extent values of the pairwise comparisons. Stam et al. [16] explored the recently developed artificial intelligence techniques that can be used to determine or approximate the preference ratings in AHP. They concluded that the feed-forward neural network formulation is a powerful tool for analyzing discrete alternative multi-criteria decision problems with imprecise or fuzzy ratio-scale preference judgments. Cheng [17] proposed an algorithm for evaluating naval tactical missile systems by using fuzzy AHP, based on grade value of membership function. Later in the same year, Weck et al. [19] gave a method for evaluating different production cycle alternatives which, added mathematics of fuzzy logic to the classical AHP.

Kahraman et al. [27] employed a fuzzy objective and subjective method and obtained the weights from AHP and then made a fuzzy weighted evaluation. Deng [20] presented a fuzzy approach for tackling qualitative multi-criteria analysis problems in a simple and easier way. Lee et al. [21] review the basic ideas behind the AHP. Based on the ideas, they introduced the concept of comparison interval and proposed a methodology based on stochastic optimization to achieve global consistency and to accommodate the fuzzy nature of the comparison process. Cheng et al. [22] proposed a new method for evaluating weapon systems by AHP which was based on linguistic variable weight. Zhu et al. [23] carried out a discussion on extent analysis method and applications of fuzzy AHP. Later, Chan et al. [24] developed a technology selection algorithm to quantify both tangible and intangible benefits that are present in fuzzy environment. They described an application of the fuzzy set theory to hierarchical structural analysis and economic evaluations. Leung and Cao [25] proposed a fuzzy consistency definition by considering tolerance deviation. Then the fuzzy ratios of relative importance with certain tolerance deviation were formulated as constraints on the membership values of the local priorities. Later in the same year, Chan et al. [26] presented an integrated approach for automatic design of FMS, which used simulation and MCDM techniques. Kahraman et al. employed fuzzy AHP technique for comparison of catering service companies. He carried out the process on certain main and sub attributes which were proposed by experts that are required in a catering firm. He then proposed the best firm out of the three firms presented and also concluded that fuzzy AHP can be effectively applied in the given field.

In the following, a brief description of the extent analysis method on fuzzy AHP is discussed and then the application of the method in the education sector is discussed.

Let X = {x1, x2... xn} be an object set, and U = {u1, u2... um} be a goal set. According to the method of Chang's[5] extent analysis, each object is taken and extent analysis for each goal, gi, is performed, respectively. Therefore, m extent analysis values for each object can be obtained, with the following signs:

$$M_{gi}^{1}, M_{gi}^{2}, \ldots, M_{gi}^{m}, i = 1,2,\ldots, n$$

Where, all the M_{gi}^{j} (j = 1, 2.....m) are TFNs.

The steps of Chang's extent analysis can be given as in the following [14,18],

Step 1: The value of fuzzy synthetic extent with respect to the i^{th} object is defined as,

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1}$$

To obtain $\sum_{j=1}^{m} M_{gi}^{j}$, we perform the fuzzy addition operation of m extent analysis [14,18] values for a particular matrix such that,

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

and to obtain $\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1}$, we have to perform the fuzzy addition operation of M_{gi}^{j} (j = 1, 2.....m) values such that;

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

The inverse of the vector in the above equation can be written as,

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i} \right)$$

Step 2: The degree of possibility of $M_2 = (l_2, m_2, u_2) \geq$

$$V(M_2 \geq M_1) = \sup_{y \geq x} \left[\min\left(\mu_{M_1}(x), \mu_{M_2}(y) \right) \right]$$

and can be equivalently expressed as follows:

$$V(M_2 \geq M_1) = \text{hgt}(M_1 \cap M_2) = \mu_{M_2}(d) = \begin{cases} 1, & \text{if } m_2 \geq m_1, \\ 0, & \text{if } l_1 \geq u_2, \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & \text{otherwise.} \end{cases}$$

To compare M_1 and M_2, we need both the values of $V(M_2 \geq M_1)$ and $V(M_1 \geq M_2)$

Step 3: The degree possibility for a convex fuzzy number to be greater than k convex fuzzy numbers M_i (i=1,2,....., k) can be defined by [14]

$$V(M \geq M_1, M_2, \ldots, M_k) = V[(M \geq M_1) \text{ and } (M \geq M_2) \text{ and } \ldots \text{ and } (M \geq M_k)] = \min V(M \geq M_i),\ i = 1, 2, 3, \ldots, k.$$

Assume that

$$d'(A_i) = \min V(S_i \geq S_k).$$

for, k=1,2,.....,n and k≠ i . Now the weight vector can be given by the following formulae,

$$W' = \left(d'(A_1), d'(A_2), \ldots\ldots\ldots, d'(A_n)\right)^T$$

, Where, Ai (i=1, 2, 3...... n) are n elements.

Step 4: Via normalization, the normalized weight vectors are given as [14],

$$W = \left(d(A_1), d(A_2), \ldots\ldots\ldots, d(A_n)\right)^T,$$

Where, "W" is a non- fuzzy number.