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Fuzzy Multiple Criteria Decision Making Approach to assess the Project Quality Management in Project

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Abstract

Project quality management is all of the processes and activities needed to determine and achieve project quality. It includes the processes required to ensure that the project will satisfy the needs for which it was undertaken. Based on the identified evaluation criteria, a hierarchical structure of three dimensions and fifteen criteria is constructed, and a systematic approach with fuzzy ANP (FANP) was employed to assess the relative importance rates and rankings of these criteria. Discussions for the results are made and a brief conclusion is proposed. Therefore, the purpose of this paper is to evaluation project quality management in project. The results found that there were interactive relations between all the criteria, where the dimension of "Quality planning" was the most influential dimensions; Furthermore, criteria "Project management plan", "Project Scope", and "Quality management plan" have the higher influences among each dimension, so we suggest to consider them as the major steps to promote the quality of project management.

Keywords: Project quality management, Fuzzy theory, Fuzzy ANP (fuzzy analytical network processes).

1. Introduction

Project quality management is all of the processes and activities needed to determine and achieve project quality. Quality is a slippery concept, argues Garvin (1992), "easy to visualize, and yet exasperatingly difficult to define." Based on Reeves and Bednar (1994), we explore three concepts of quality developed over time and discuss how these relate to the nature of projects, as expressed in the last section.

Some of the concepts are tailored to embrace quality of goods and others of services. This is an important distinction in project contexts. Although a "project" may be defined as a manufacturing process type (Slack et al., 2004), it is true to say that projects can also be considered a "hybrid" of services and goods. In this article we understand goods as the outcome of the project, e.g. a factory, software code, or a new product, while services refers to the process of developing this outcome, the management of projects, its process, the way stakeholders are engaged in the decision making processes, etc.

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The rest of this paper is structured as follows: in Section 2, we discussed and found the components of project quality management background and requirements in order to construct the evaluation criteria based on literature review. In Section 3, the depiction and application of the Fuzzy theory and Fuzzy ANP are included. Section 4 shows an empirical study of assess the project quality management by using the proposed evaluation model. Finally the discussions and conclusions are presented in Section 5.

2. The Components of Project Quality Management Research

Project Quality Management includes the processes required to ensure that the project will satisfy the needs for which it was undertaken. It includes "all activities of the overall management function that determine the quality policy, objectives, and responsibilities and implements them by means such as quality planning, quality control, quality assurance, and quality improvement, within the quality system"

It is generally accepted that the minimum success criteria of projects are that they should completed to time, to budget and to quality. However when one explores what is meant by quality the answers are often vague and variable. If someone talks about "working on project quality", they may simply mean activities related to quality management systems recommended in bodies of knowledge (e.g. PMI, 2008b; PRINCE2, 2009) and they ensure the compliance to procedures by "ticking boxes". Quality in a broader context has many meanings depending on customers, ranging from luxury and merit to excellence, good value for money or convenience and even practicality. Table 1. provides a component of the following major project quality management.

Table 1. Component of the project quality management

Project Quality Process	Dimensions	Criteria
Planning	D1 Quality planning	C1 Enterprise environment C2 Organization processes assets C3 Project Scope C4 Project management plan C5 Quality management plan C6 Quality measure indicators
Execution	D2 Quality assurance	C7 Quality inspection Checklist C8 Organization processes assets C9 Work performance information C10 Approved Change Request C11 Delivery standards C12 Process improvement plan
Monitor	D3 Quality control	C13 Executive Change Request C14 Executive corrective action C15 Executive preventative actions

These components interact with each other and with the components in the other knowledge areas as well. Each component may involve effort from one or more individuals or groups of individuals based on the needs of the project. Each component generally occurs at least once in every project phase. These processes interact with each other and with the processes in the other knowledge areas as well. Each process may involve effort from one or more individuals or groups of individuals based on the needs of the project. Each process generally occurs at least once in every project phase.

2.1. Quality Planning

Quality planning involves identifying which quality standards are relevant to the project and determining how to satisfy them. It is one of the key facilitating processes during project planning and should be performed regularly and in parallel with the other project planning processes.

2.2. Quality Assurance

Quality assurance is all the planned and systematic activities implemented within the quality system to provide confidence that the project will satisfy the relevant quality standards. It should be performed throughout the project.

2.3. Quality Control

Quality control involves monitoring specific project results to determine if they comply with relevant quality standards and identifying ways to eliminate causes of unsatisfactory results. It should be performed throughout the project.

3. Research method

A MCDM model combined with fuzzy ANP, for evaluating and improving problems is more suitable in the real world than the previously available methods. This study used the fuzzy ANP technique to acquire the structure of the MCDM problems.

3.1. The fuzzy theory and fuzzy numbers

Zadeh (1965) introduced the fuzzy set theory to incorporate the uncertainty of human thoughts in modeling. The most critical contribution of fuzzy set theory is its capability of representing imprecise or vague data. A fuzzy set theory is defined to be a class of objects with a continuum of grades of membership. Such a set is characterized by a membership (characteristic) function, which assigns to each object a grade of membership ranging between zero and one (Kahraman et al., 2003).

A tilde "~" will be placed above a symbol if the symbol represents a fuzzy set. A triangular fuzzy number (TFN), $\widetilde{\mathrm{M}}$ is shown in Fig. 1. A TFN is denoted simply as $(\mathrm{l}/\mathrm{m}, \mathrm{m}/\mathrm{u})$ or $(\mathrm{l}, \mathrm{m}, \mathrm{u})$. 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 Eq.(1)

$$\mu(X/\widetilde{\mathrm{M}}) = \begin{cases} 0, & X < l \\ (X-l)/(m-l), & l \le X \le m \\ (u-\mathrm{X})/(u-m), & m \le X \le u \\ 0, & X > u \end{cases} \tag{1}$$

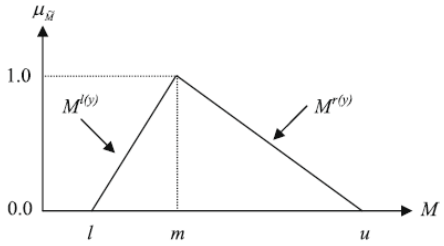

Fig. 1. A triangular fuzzy number

If X value is less than lower level of a fuzzy number (l), the function gets the value of zero, bigger than/equal lower level (l) and less than/equal to mean level (m), the function gets the value of X-l / m-l, and bigger than/equal mean level (m) and less than/equal to upper level (u), the function gets the value of u-X / u-m.

A fuzzy number can always be given by its corresponding left and right representation of each degree of membership as in Eq.(2)

$$\widetilde{\mathrm{M}} = \left(\mathrm{M}^{l(\mathrm{y})}, \mathrm{M}^{\mathrm{r(y)}}\right) = (l + (m - l)y, u + (m - u)y), y \in [0,1] \quad (2)$$

Where $\mathrm{l(y)}$ and $\mathrm{r(y)}$ denote the left side representation and the right side representation of a fuzzy number, respectively.

3.2. The Fuzzy ANP method

The ANP is the general form of the Analytic Hierarchy Process (AHP) (Saaty, 1980) which has been used in MCDM method to release the restriction of hierarchical structure. The purpose is to solve the relaying and feedback problems of criteria. Whereas AHP represents a framework with a unit-directional hierarchical AHP relationship, ANP allows for complex interrelationships among decision levels and attributes.

Within ANP, there is an outer dependence among clusters and an inner dependence within the criteria of clusters, as illustrated in Figure. 2.

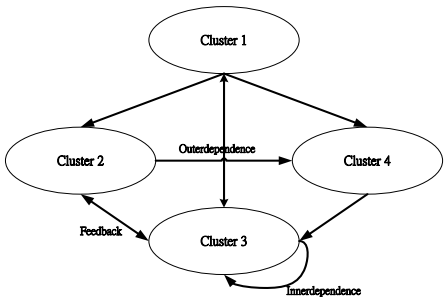

Fig.2. Relation of clusters

The ANP feedback approach replaces hierarchies with networks in which the relationships between levels are not easily represented as higher or lower, dominant or subordinate, direct or indirect (Meade & Sarkis, 1999). For instance, not only does the importance of the criteria determine the importance of the alternatives, as

in a hierarchy, but also the importance of the alternatives may have impact on the importance of the criteria (Saaty, 1996). There are many fuzzy AHP methods proposed by various authors (Buckley, 1985; Chang, 1992, 1996; Cheng, 1997; Deng, 1999; Leung & Cao, 2000; Mikhailov, 2004; Van Laarhoven & Pedrycz, 1983). These methods are systematic approaches to the alternative selection and justification problem by using the concepts of fuzzy set theory and hierarchical structure analysis.

For the purpose of measuring the relationships among each dimension, it is required to using comparison linguistic terms of importance as shown in Table 2. The different degrees of importance are expressed with five linguistic terms and the equivalent fuzzy membership functions for linguistic values are shown in Fig 3.

Table 2. Linguistic terms of importance for evaluation

Linguistic term	Abbrev.	Triangular fuzzy scale
Very High	(VH)	(0.75, 1.0, 1.0)
High	(H)	(0.5, 0.75, 1.0)
Low	(L)	(0.25, 0.5, 0.75)
Very Low	(VL)	(0, 0.25, 0.5)
None	(N)	(0, 0, 0.25)

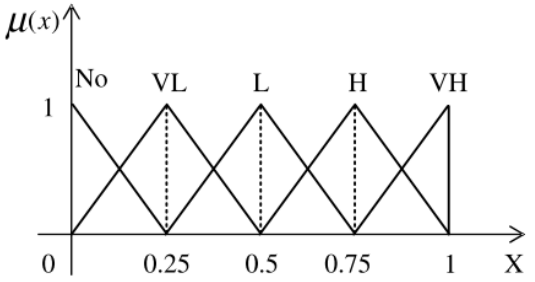

Figure. 3. Fuzzy membership functions for linguistic values

To evaluate the decision maker's judgments, pair-wise comparison matrices are created by using TFNs in Table 2. This comparison fuzzy matrix can be denoted as in Eq. (3) (Ramik, 2006).

$$\tilde{A} = \begin{pmatrix} (a_{11}^l, a_{11}^m, a_{11}^u) & (a_{12}^l, a_{12}^m, a_{12}^u) & \cdots & (a_{1n}^l, a_{1n}^m, a_{1n}^u) \\ (a_{21}^l, a_{21}^m, a_{21}^u) & (a_{22}^l, a_{22}^m, a_{22}^u) & & (a_{2n}^l, a_{2n}^m, a_{2n}^u) \\ \vdots & & \ddots & \vdots \\ (a_{m1}^l, a_{m1}^m, a_{m1}^u) & (a_{m2}^l, a_{m2}^m, a_{m2}^u) & \cdots & (a_{mm}^l, a_{mm}^m, a_{mm}^u) \end{pmatrix} \quad (3)$$

The element $\tilde{a}_{\mathrm{mn}}$ which is given by $(a_{mn}^l, a_{mn}^m, a_{mn}^u)$ represents the comparison of the component m with the component n. Due to the operational laws of fuzzy numbers (Wang & Chang, 2007), the matrix $\tilde{\mathrm{A}}$ can be rewritten as in Eq. (4) by replacing $\tilde{a}_{\mathrm{mn}}$ with the corresponding reciprocal values (i.e. $1/a_{\mathrm{mn}}$) (Tuzkaya & Onut, 2008)

$$\tilde{A} = \begin{pmatrix} (1,1,1) & (a_{12}^l, a_{12}^m, a_{12}^u) & \cdots & (a_{1n}^l, a_{1n}^m, a_{1n}^u) \\ \left(\frac{1}{a_{21}^u}, \frac{1}{a_{21}^m}, \frac{1}{a_{21}^l}\right) & (1,1,1) & & (a_{2n}^l, a_{2n}^m, a_{2n}^u) \\ \vdots & & \ddots & \vdots \\ \left(\frac{1}{a_{m1}^u}, \frac{1}{a_{m1}^m}, \frac{1}{a_{m1}^l}\right) & \left(\frac{1}{a_{m2}^u}, \frac{1}{a_{m2}^m}, \frac{1}{a_{m2}^l}\right) & \cdots & (1,1,1) \end{pmatrix} \quad (4)$$

The logarithmic least squares method (Chen, Hwang, & Hwang, 1992) is the most effective and efficient one and was used in our study. In this way, the triangular fuzzy weights for the relative importance of the factors, the feedback of the factors, and alternatives according to the individual factors can be calculated (Ramik, 2006). To compute the triangular fuzzy numbers, the logarithmic least squares method is used as described in Eqs. (5) and (6) (Onut, Kara, & Isik, 2009).

$$\widetilde{W_k} = \left(W_k^l, W_k^m, W_k^u\right), \quad k = 1,2,\dots,n \quad (5)$$

Where

$$W_k^s = \frac{(\prod_{j=1}^n a_{ij}^s)^{1/n}}{\sum_{k=1}^n (\prod_{j=1}^n a_{kj}^m)^{1/n}} \ , s \in \{l, m, u\} \quad (6)$$

4. Empirical Analysis

4.1. Background and problem description

During the 1980s and early 1990s, Enterprises in the USA and other countries tried to improve global competitiveness by instituting process and project quality improvement. With process-oriented efforts it is possible to perform sampling and other quality measures. But most projects' key results cannot be rigorously evaluated until near the project end, or later.

Several Quality-related problems are unique to projects. For one, it is difficult to measure. In fact, often key stakeholders cannot evaluate the true quality of the results until the benefit realization point, and then it is too late to do anything to resolve gaps.

From this paper, we follow the calculating steps of ANP method for acquiring Table 3 to explain the weight. It means the degree of impact of these dimensions and criteria. The primary survey experts included scholars of project and managers of project.

4.2. Data collection

We discussed the capacity of project quality through dividing them into 3 dimensions, totally 15 criteria (as shown in Table.1), to analyze the interrelation among them by questionnaire survey. Project experts and managers (including scholars) were the subjects of this research. A total 15 samples were divided into 9 project team members and 6 PM experts of company. This study was carried out in January 2013, and it took 30 to 60 minutes for every expert to fill out the questionnaires and be interviewed.

4.3. Calculating weights of Fuzzy ANP

To analyze the interrelationships between the 15 determinants found in the literature review, the Fuzzy ANP

method in Section 3.2 was used. The initial super matrix dimensions and criteria of project quality management was evaluation, as shown in Table 3. and Table 4. As a result, a project quality management network structure of the evaluation framework was built, as shown in Figure. 4.

Table 3. Initial supermatrix dimensions of project quality management

	D1	**D2**	**D3**
D1	0.134	0.126	0.114
D2	0.115	0.119	0.103
D3	0.113	0.115	0.101

Table 4. Initial supermatrix criteria of project quality management

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**	**C13**	**C14**	**C15**
C1	0.18	0.28	0.26	0.27	0.23	0.25	0.25	0.27	0.26	0.23	0.25	0.24	0.26	0.26	0.25
C2	0.29	0.19	0.27	0.28	0.26	0.25	0.26	0.27	0.26	0.29	0.25	0.26	0.26	0.24	0.26
C3	0.23	0.24	0.18	0.23	0.23	0.22	0.22	0.20	0.22	0.23	0.22	0.23	0.21	0.23	0.23
C4	0.28	0.27	0.27	0.19	0.26	0.26	0.26	0.24	0.24	0.23	0.25	0.25	0.26	0.25	0.25
C5	0.33	0.33	0.31	0.33	0.24	0.37	0.37	0.34	0.32	0.34	0.34	0.31	0.32	0.33	0.34
C6	0.33	0.33	0.33	0.32	0.36	0.23	0.35	0.32	0.33	0.33	0.32	0.33	0.33	0.32	0.32
C7	0.33	0.33	0.35	0.34	0.38	0.38	0.26	0.33	0.34	0.32	0.33	0.35	0.34	0.33	0.33
C8	0.28	0.28	0.29	0.29	0.31	0.30	0.32	0.21	0.32	0.32	0.28	0.30	0.30	0.31	0.30
C9	0.31	0.32	0.28	0.28	0.28	0.29	0.30	0.35	0.22	0.38	0.32	0.29	0.31	0.31	0.31
C10	0.40	0.39	0.42	0.42	0.39	0.40	0.37	0.43	0.44	0.29	0.39	0.39	0.37	0.36	0.37
C11	0.25	0.24	0.27	0.25	0.25	0.28	0.23	0.23	0.24	0.24	0.19	0.27	0.27	0.26	0.23
C12	0.27	0.28	0.28	0.27	0.28	0.29	0.27	0.27	0.26	0.27	0.30	0.20	0.29	0.29	0.28
C13	0.33	0.34	0.33	0.34	0.34	0.34	0.34	0.34	0.34	0.33	0.36	0.35	0.35	0.35	0.26
C14	0.33	0.33	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.35	0.34	0.34	0.34	0.39
C15	0.33	0.32	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.32	0.28	0.29	0.30	0.30	0.33

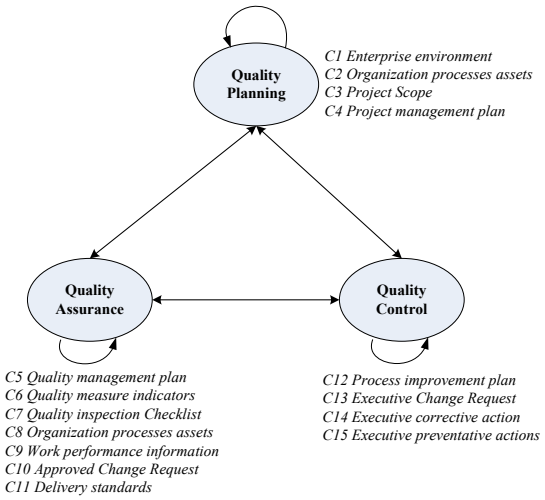

Figure. 4. Network structure of the evaluation framework

Figure. 4. Depicts the impact-direction map for a project quality management model, that is identified the dimension and criteria that were found influential in the model. The level of importance of 3 dimensions and 15 criteria can be calculated by Fuzzy ANP shown as Table 5.

Table 5. The weights of dimensions and criteria for evaluation of a PQM

Dimensions	**Local Weight**	**Criteria**	**Local Weight**	**Global Weight (by ANP)**
D1Quality Planning	*0.208*	C1 Enterprise environment	*0.333*	*0.069 (4)*
		C2 Organization processes assets	*0.328*	*0.068 (5)*
		C3 Project Scope	*0.352*	*0.073 (2)*
		C4 Project management plan	*0.359*	*0.075 (1)*
D2Quality Assurance	*0.195*	C5 Quality management plan	*0.342*	*0.071 (3)*
		C6 Quality measure indicators	*0.305*	*0.063 (8)*
		C7 Quality inspection Checklist	*0.298*	*0.062 (9)*
		C8 Organization processes assets	*0.275*	*0.057 (10)*
		C9 Work performance information	*0.270*	*0.056 (11)*
		C10 Approved Change Request	*0.255*	*0.053 (14)*
		C11 Delivery standards	*0.323*	*0.067 (6)*
D3Quality Control	*0.172*	C12 Process improvement plan	*0.312*	*0.065 (7)*
		C13 Executive Change Request	*0.264*	*0.055 (12)*
		C14 Executive corrective action	*0.243*	*0.051 (15)*
		C15 Executive preventative actions	*0.259*	*0.054 (13)*

5. Discussions and conclusions

This research adopts Fuzzy ANP, for assessing the project quality management in project. We prove that all

criteria influence one another and find relative importance of essential criteria of PQM.

In evaluating the PQM model, experts considered "Project management plan" to be the most important criteria (the weight is 0.075). This shows that in the limited time and cost, program managers of organization should consider that first when they have to improve and keep the quality in project. Program managers should also consider "Project Scope" because this is the second most important criterion in project quality management (Project Scope has a weight of 0.073).

This study only discussed the structure of evaluation hierarchy and examination of importance of criteria. In a decision making process of project quality management, it should contain the process of alternatives evaluation. Because it is not enough time to simulate the alternatives evaluation in this study, therefore, in the future work, we will combine more evaluation method, such as TOPSIS, VIKOR, etc. to calculate performance value from each of dimension and criteria in project quality management.

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