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A TFN–ANP based approach to evaluate Virtual Research Center comprehensive performance

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ABSTRACT

The performance evaluation of Virtual Research Center (VRC) is an intrinsically complex multi-dimensional process and it should be evaluated and compared in a multi-criteria analysis method. To solve the problems caused by the fuzzy decision making, quantifying the qualitative indexes and dealing with the interdependence and interaction of some indexes during the process of VRC performance evaluation, a comprehensive performance evaluation method based on triangular fuzzy number and analytic network process (TFN–ANP) is proposed. In the method, an index evaluation system is first established and the interactive relationships of the evaluation indexes are analyzed. Secondly, the index evaluation decision-making matrix is constructed and the indexes attribute values are fuzzed with triangular fuzzy numbers. Thirdly, the evaluative indexes weights are determined by analytic network process. Then the concrete solving process is derived and the fuzzy utility value weights are ranked by the priority method with decision maker risk preference. In the end, the four project teams of Yalong River VRC are taken as examples, then their comprehensive performances are evaluated by TFN–ANP model and the utility value priorities are ranked, which could provide decision supports for VRC to optimize operational performance. In addition, a comparison with the previous method is performed, and experimental results are encouraging, which fully demonstrates the effectiveness and superiority of the proposed approach.

1. Introduction

Virtual Research Center (VRC) is a new kind of organization that is formed by the penetration of virtual organization to science research organization with the development of computer science, network technology and other communication technique. VRC has an extensive application in enterprise and research institute for its flexibility and dynamic characteristic (Luo, Zhou, & Li, 2008). Comprehensive performance evaluation is used to overall evaluate the achievements of research and development in VRC. To maintain and improve the VRC's competitive power, as many researchers emphasized, it's a critical step to construct a fair and effective comprehensive performance evaluation system which is not only beneficial for the decision makers to know the situation of the project development in VRC, but also beneficial to build an effective restriction and incentive mechanism.

A number of alternative approaches have been proposed to evaluate performance, the typical conventional methods include: (1) balanced scorecard (BSC): BSC is a means to evaluate corporate performance from four different perspectives: the financial, the internal business process, the customer, and the learning and growth (Bhagwat & Sharma, 2007; Jyoti & Deshmukh, 2006). (2) Data envelopment analysis (DEA): DEA is based on a previous performance cross-sectional view of several organizational units in a given single period, as measured by their multiple inputs and outputs (Leachman, Pegels, & Shin, 2005; Medina-Borja, Pasupathy, & Triantis, 2007; Talluri, Narasimhan, & Nair, 2006). (3) Analytic hierarchy process (AHP): AHP is via performance indicators establishing a hierarchy utilizes experts to evaluate performance (Kim, Yang, Yeo, & Kim, 2005; Lee, 2009; Yuan, Liu, Tu, & Xue, 2008). (4) Analytic network process (ANP): ANP is a more general form of AHP and several studies had adopted ANP to evaluate performance (Demirtas & Ustun, 2009; Onut, Kara, & Isik, 2009; Wey & Wu, 2007).

The analytic hierarchy process (AHP) was first proposed by Saaty in 1971, and it is one of the most commonly used methods for solving multiple-criteria decision-making (MCDM) problems in political, economic, social and management sciences (Saaty, 1980). The basic assumption of the AHP is that the decision-making problem can be decomposed in a linear top-to-bottom form as a hierarchy, where the upper levels are functionally independent from all lower levels, and the elements in each level are also independent. However, in many cases the decision problems cannot be structured hierarchically because they involve the interaction and dependence of higher-level elements on a lower-level

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element. Among the available multi-attribute decision-making methods only ANP can be used to evaluate performance systematically due to the dependencies and feedbacks caused by the mutual effects of the criteria.

It's a typical multiple-criteria and semi-structured problem to evaluate the VRC performance. On one hand, some indexes of evaluation system are quantified not in exact numbers but in fuzzy numbers. On the other hand, there would be strong dependencies and feedbacks among different indexes. Furthermore, due to incomplete information or knowledge, complexity and uncertainty within the decision environment, it is relatively difficult for the decision maker to make a correct judgment or objective evaluation during the evaluation process. Therefore, this research proposes an approach based on triangular fuzzy number and analytic network process (TFN–ANP) to evaluate VRC performance. Then the Virtual Research Center of Yalong river hydropower development is taken as a case which identifies proposed model capable of choosing an effective monitor to adequately implement a comprehensive performance model in VRC project management practices. The TFN–ANP based decision-making method for constructing an evaluation method can provide decision makers with a valuable reference for evaluating the VRC organizational performance.

2. Summary of triangular fuzzy number and analytic network process

2.1. Fuzzy set theory

Fuzzy set theory was introduced by Zadeh in 1965 to solve problems involving the absence of sharply defined criteria (Zadeh, 1965). A major contribution of fuzzy set theory is its capability of representing vague data. Because fuzziness and vagueness are common characteristics in many decision-making problems, good decision-making models should be able to tolerate vagueness or ambiguity. Thus, if the uncertainty (fuzziness) of human decision making is not taken into account, the results from the models can be misleading. A fuzzy set is a class of objects with a continuum of grades of membership. Such a set is characterized by a membership function, which assigns to each object a grade of membership ranging between zero and one. There are two most commonly used fuzzy numbers: trapezoidal fuzzy number and triangular fuzzy number. A triangular fuzzy number (TFN) which is denoted simply as (l,m,u) is shown in Fig. 1.

2.2. Analytic network process

ANP was extended from AHP by Saaty in 1996, but it captured the interdependence of decision criteria and improves the limitation of AHP. ANP is a comprehensive decision-making technique appropriate for both quantitative and qualitative data types and capable of overcoming the problem of interdependence and feedback among alternatives or criteria so as to facilitate a more systematic analysis (Saaty, 1996, 2004).

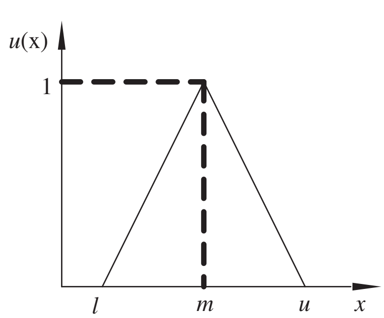

Fig. 1. Triangular fuzzy number.

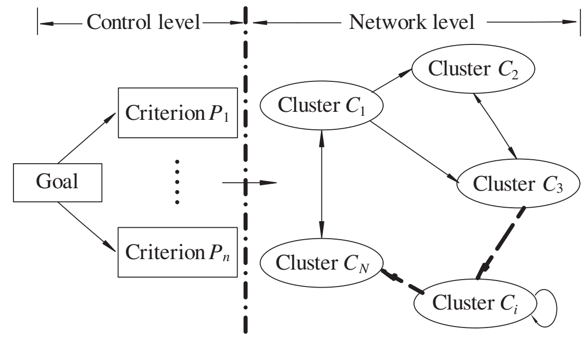

Fig. 2. The typical structural model of ANP.

ANP uses a network without the need to specify levels as in a hierarchy. Generally, the system is divided into two parts: the control level and the network level under ANP. The control level includes the goal and the decision criteria. The network level consists of the elements controlled by the control level. The elements interact on each other and form a network structure. The typical structural model of ANP is shown in Fig. 2.

3. Comprehensive performance evaluation of VRC based on TFN–ANP

3.1. Establish comprehensive performance evaluation index system

VRC is a dynamic and flexible organization, which is based on project development. The main purpose of VRC is to conduct knowledge communication and innovation in the information management platform. The performance management of VRC has the characteristic of network, real-time and dynamic property. It not only concerns the economic benefits and social benefits but also promotes the project process management and core competence to evaluate the VRC performance. Thus, it is necessary to establish comprehensive performance evaluation index system both in qualitative and quantitative aspects and identify the indexes relationship among different clusters. In this research, the four criteria (first grade indexes) such as project value, process management, knowledge achievement and core competence are proposed to evaluate VRC performance and the specific analysis about indexes are described as Table 1.

3.2. Establish index evaluation decision-making matrix

Assume that we have n different criteria $(P_1,\ldots,P_n)$ in the control level and cluster $(C_1,\ldots,C_N)$ in the network level of the index system of VRC performance evaluation. There are n_i elements $e_{i1},\ldots,e_{in_i}$, i=1,...,N in the cluster C_i. Also, assume that there have k (k=1,...,N) alternatives to be evaluated. Let $(V_{i1},V_{i2},\ldots,V_{in})$, be index value vector. Thus we can establish the decision-making matrix as follows:

$$G=\begin{bmatrix} V_{i1} & V_{12} & \cdots & V_{1n} \\ V_{21} & V_{22} & \cdots & V_{2n} \\ \vdots & \vdots & \vdots & \\ V_{m1} & V_{m2} & \cdots & V_{mn} \end{bmatrix} \quad (1)$$

3.3. Fuzz index attribute value

Because the multiple attribute and the respective index weight are involved in VRC performance evaluation, it is difficult to