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Using a novel conjunctive MCDM approach based on DEMATEL, fuzzy ANP, and TOPSIS as an innovation support system for Taiwanese higher education

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ABSTRACT

Increasing numbers of Taiwanese higher education institutes are pursuing innovation operation. However, these institutes generally rely greatly on academic research to evaluate innovation performance. Nevertheless, the performance of innovation may be affected by numerous factors that are often beyond the scope of a single academic study. Thus, to address this concern, this paper constructs an innovation support system (ISS) for Taiwanese higher education institutes to comprehensively evaluate their innovation performance. Previous research often evaluates performance by independently considering a number of criteria. However, this assumption of independence does not model the so-called "real world"; thus, we present a novel conjunctive multiple criteria decision-making (MCDM) approach that addresses dependent relationships among each measurement criteria. As such, we utilize a decision-making trial and evaluation laboratory (DEMATEL), a fuzzy analytical network process (FANP), and a technique for order preference by similarity to an ideal solution (TOPSIS) forming order to develop an innovation support system (ISS) that considers the interdependence and the relative weights of each measurement criterion.

1. Introduction

Due to a recent drop in the birthrate, an increase in the number of higher educational institutions, and Taiwan's recent membership in the WTO, higher educational institutions in Taiwan will not have competitive advantages when faced with competitions from the West and Asia (Chen, 2005). Thus, the need to increase innovative operations, improve performance, and develop core competitive abilities is an urgent issue currently faced by higher educational institutions in Taiwan (Chen & Chen, 2008).

The most utilized evaluations used for innovation performance by Taiwanese higher educational institutions emerge from academic research (Chen & Chen, 2008). However, the factors that can affect innovation performance are numerous. One way to overcome the problem of evaluation performance with regard to numerous factors involves the use of multiple criteria decision-making (MCDM), which is often characterized by multiple, conflicting criteria (Hwang & Yoon, 1981; Liou, Tzeng, & Chang, 2007). Along these lines, various research studies have produced different measurement dimensions, and criteria (Chen & Chen, 2008; Chin & Pu, 2006; Lin, Wang, & Yen, 2006; Tang, 2006). Some of this research assumes independence of criteria; however, in the real world, most criteria are not mutually independent.

In this paper, a decision-making trial and evaluation laboratory (DEMATEL) method is adapted to model complex interdependent relationships and construct a relation structure using measurement criteria for innovation evaluation. A fuzzy analytic network process (FANP) is conducted to address the problem of dependence as well as feedback among each measurement criteria. A technique for order preference by similarity to an ideal solution (TOPSIS) is finally utilized to find optimal alternatives for innovation configurations. Here, we combine DEMATEL, fuzzy ANP and TOPSIS approaches to develop a novel innovation support system (ISS).

2. An innovation support system

Some literature has indicated that an organization must continually innovate to avoid failure (Daft, 2004; Krause, 2004). Innovation performance evaluations, involve numerous complex factors, including member innovation, administrative innovation, marketing innovation, and so on. However, an innovation criterion that follows academic research may be imperfect.

Although a large body of academic studies offers numerous insights involving innovation performance, evaluation tools developed by these studies do not evaluate innovation performance completely. Recent studies have argued that the factors influencing

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innovation in higher education are numerous (Bantel & Jackson, 1989; Damanpour, 1996; O'Sullivan, 2000; Wolfe, 1994). Thus, after summarizing relevant studies, we introduce a novel conjunctive MCDM approach that combines DEMATEL, Fuzzy ANP, and TOPSIS. In doing so, we consider increasingly complex relationships and utilize them to develop an innovation support system (ISS).

3. A novel conjunctive MCDM approach

Quantifying values with precision in a complex measurement system is difficult; nevertheless, such systems can be partitioned into separate subsystems to facilitate the evaluation of each partition. Here, DEMATEL is used to develop interrelations among each measurement criterion. Next, the weights of each criterion are calculated using fuzzy ANP. After that, TOPSIS is utilized to rank the alternatives. Finally, we construct an innovation support system (ISS) based on these results.

3.1. Illustrating interrelations among measurement criteria

All factors in a complex system may be either directly or indirectly related; therefore, it is difficult for a decision maker to evaluate a single effect from a single factor while avoiding interference from the rest of the system (Liou et al., 2007). In addition, an interdependent system may result in passive positioning; for example, a system with a clear hierarchical structure may give rise to linear activity with no dependence or feedback, which may cause problems distinct from those found in non-hierarchical systems (Tzeng, Chiang, & Li, 2007).

To avoid such problems, the Battelle Geneva Institute created DEMATEL in order to solve difficult problems that mainly involve interactive man-model techniques as well as to measure qualitative and factor-linked aspects of societal problems (Gabus & Fontela, 1972). In addition, DEMATEL has been utilized in numerous contexts, such as industrial planning, decision-making, regional environmental assessment, and even analysis of world problems (Huang, Shyu, & Tzeng, 2007); in all cases, it has confirmed interdependence among criteria and restricted the relations that reflect characteristics within an essential systemic and its developmental trends (Liou et al., 2007).

The foundation of the DEMATEL method is graph theory. It allows decision-makers to analyze as well as solve visible problems. In doing so, decision-makers can separate multiple measurement criteria into a cause and effect group to realize causal relationships much more easily. In addition, directed graphs, called digraphs, are much more helpful than directionless graphs since they depict the directed relationships among subsystems. In other words, a digraph represents a communication network or a domination relationship among entities and their groupings (Huang et al., 2007).

The steps in DEMATEL are as follows (Liou et al., 2007):

Step 1: Calculate the initial average matrix by scores.Sampled experts are asked to point the direct effect based on their perception that each element i exerts on each other element j, as presented by a_{ij}, by utilizing a scale ranging from 0 to 4. No influence is represented by 0, while a very high influence is represented by 4. Based on groups of direct matrices from samples of experts, we can generate an average matrix $\boldsymbol{A}$ in which each element is the mean of the corresponding elements in the experts' direct matrices.

Step 2: Calculate the initial influence matrix.After normalizing the average matrix $\boldsymbol{A}$, the initial influence matrix $\boldsymbol{D}$,$[d_{ij}]_{n\times n}$, is calculated so that all principal diagonal elements equal zero. In accordance with $\boldsymbol{D}$, the initial effect that an element exerts and/or acquires from each other element is given. The map depicts a contextual relationship among the elements within a complex system; each matrix entry can be seen as its strength of influence. This is depicted in Fig. 1; an arrow from d to g represents the fact that d affects g with an influence score of 1. As a result, we can easily translate the relationship between the causes and effects of various measurement criteria into a comprehensible structural model of the system based on influence degree using DEMATEL.

Step 3: Develop the full direct/indirect influence matrix.The indirect effects of problems decreases as the powers of D increase, e.g., to $\boldsymbol{D}^2, \boldsymbol{D}^3, \ldots, \boldsymbol{D}^\infty$, which guarantees convergent solutions to the matrix inversion. From Fig. 1, we see that the effect of c on d is greater than that of c on g. Therefore, we can generate an infinite series of both direct and indirect effects. Let the (i,j) element of matrix A be presented by a_{ij}, then the direct/indirect matrix can be acquired by following Eq. (1) through (4)

$$\boldsymbol{D} = s^*A, \quad s > 0 \tag{1}$$

or

$$[d_{ij}]_{n\times n} = s[a_{ij}]_{n\times n}, \quad s > 0, \ i,j \in \{1,2,\ldots,n\} \tag{2}$$

where

$$s = \mathrm{Min}\left[\frac{1}{\max\limits_{1\leqslant i\leqslant n}\sum_{j=1}^{n}|a_{ij}|}, \frac{1}{\max\limits_{1\leqslant i\leqslant n}\sum_{i=1}^{n}|a_{ij}|}\right] \tag{3}$$

and

$$\lim_{m\to\infty} \boldsymbol{D}^m = [0]_{n\times n} \text{ where } \boldsymbol{D} = [d_{ij}]_{n\times n}, \quad 0 \leqslant d_{ij} < 1. \tag{4}$$

The total-influence matrix $\boldsymbol{T}$ can be acquired by utilizing Eq. (5). Here, $\boldsymbol{I}$ is the identity matrix

$$\boldsymbol{T} = \boldsymbol{D} + \boldsymbol{D}^2 + \cdots + \boldsymbol{D}^m = \boldsymbol{D}(\boldsymbol{I} - \boldsymbol{D})^{-1} \text{ when } m \to \infty. \tag{5}$$

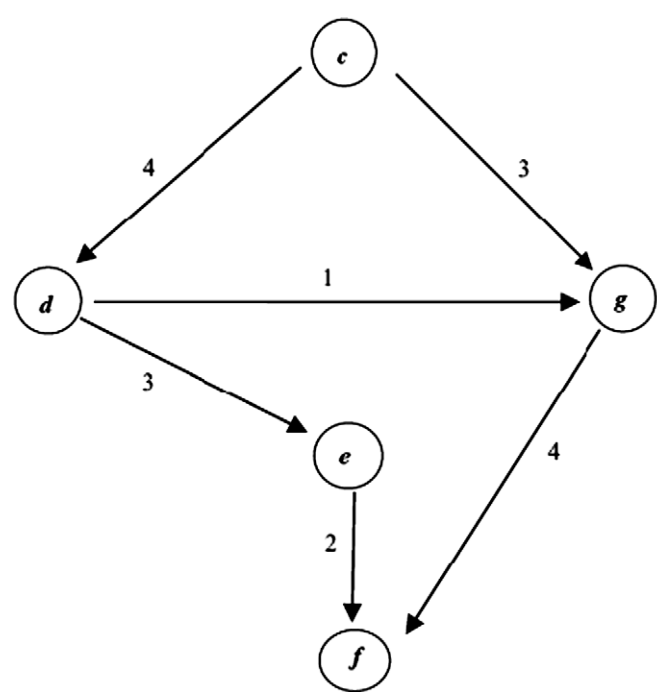

Fig. 1. An influential map.