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A new evaluation model for intellectual capital based on computing with linguistic variable

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ABSTRACT

In a knowledge era, intellectual capital has become a determinant resource for enterprise to retain and improve competitive advantage. Because the nature of intellectual capital is abstract, intangible, and difficult to measure, it becomes a challenge for business managers to evaluate intellectual capital performance effectively. Recently, several methods have been proposed to assist business managers in evaluating performance of intellectual capital. However, they also face information loss problems while the processes of subjective evaluation integration. Therefore, this paper proposes a suitable model for intellectual capital performance evaluation by combining 2-tuple fuzzy linguistic approach with multiple criteria decision-making (MCDM) method. It is feasible to manipulate the processes of evaluation integration and avoid the information loss effectively. Based on the proposed model, its feasibility is demonstrated by the result of intellectual capital performance evaluation for a high-technology company in Taiwan.

1. Introduction

In a knowledge-based economy era, knowledge has become a determinant capital for enterprise to retain and improve competitive advantage (Chang & Birkett, 2004; Gandhi, 2004). In other words, how to accumulate and apply knowledge appropriately has become a crucial issue for business managers. Generally speaking, knowledge management (KM) is regarded as a systematic process to acquire and reuse knowledge and create the benefit of products and services (Baum & Silverman, 2004; Bukh, Larsen, & Mouritsen, 2001; Leitner & Warden, 2004; Watson, Stanworth, Healeas, Purdy, & Stanworth, 2005).

The implication of intellectual capital is different from traditional capital in accounting term. Therefore, it is a big challenge for business managers to evaluate the performance of intellectual capital based on financial reports (Han & Han, 2004; Sveiby, 2005; Watson et al., 2005). In order to evaluate the performance of intellectual capital more appropriately, it should consider not only quantitative index but also qualitative dimensions or factors which are evaluated by multiple decision-makers or experts. Thus, the performance evaluation of intellectual capital should be regarded as a group multiple criteria decision-making (GMCDM) problem as well.

As usual, most of intellectual capital evaluation methods obtain the performance evaluation results using the traditional SWA or similar methods (Engström, Westnes, & Westnes, 2003; Joia, 2000; Sveiby, 2005). Even though, the SWA method is easy to calculate the performance ratings while the processes of evaluation integration. Nevertheless, it cannot appropriately manipulate the operation of qualitative factors and expert judgment in the evaluation process of intellectual capital. It also makes information loss happen during the integration processes, and causes the evaluation result of performance level may not be consistent with the expectation of evaluators. Thus, a suitable model based on 2-tuple fuzzy linguistic information is proposed to evaluate the intellectual capital. The 2-tuple fuzzy linguistic approach not only inherits the existing characters of fuzzy linguistic assessment but also overcomes the problems of loss information of other fuzzy linguistic approaches (Herrera-Viedma, Herrera, Martínez, Herrera, & López, 2004).

This paper is structured as follows. Section 2 introduces the concept and measurement of intellectual capital. In Section 3, 2-tuple fuzzy linguistic representation and operation are introduced. In Section 4, a feasible method based on 2-tuple fuzzy linguistic information is proposed to evaluate intellectual capital. In Section 5, it is illustrated with a case study for a high-technology company in Taiwan. Finally, some conclusions are stated at the end of the paper.

2. Related works

2.1. Intellectual capital

The value of enterprise contains not only financial capital but also intellectual capital. Financial capital represents the

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enterprise's book value and includes the value of its financial and physical assets (Joia, 2000). On the other hand, intellectual capital consists of assets created through intellectual activities ranging from acquiring new knowledge (learning) and inventions to creating valuable relationships (Wiig, 1997). Stewart (1998) characterizes intellectual capital as "intellectual material – knowledge, information, intellectual property, experience – that can be put to use to create wealth".

Sveiby (1997) proposed that intellectual capital includes employee competence, internal structure, and external structure. Stewart (1998) identifies human capital, structure capital and customer capital. Edvinsson (1997) divides structure capital into organization capital and customer capital. And then, Liebowitz and Wright (1999) divide intellectual capital into four unique categories such as human capital, customer capital, process capital and innovation capital. Bukh et al. (2001) identify the most model of intellectual capital classify intellectual resource into human capital, customer capital and organization capital.

2.2. Intellectual capital measurement

Recently, numerous methods are proposed to evaluate the performance or value of intellectual capital. They also measure the intangible capital in accordance with tangible aspects of the subject resource based on discounted cash flow (DCF), which is the standard financial technique for value assessment. Even though those methods can simply and clearly reveal the value of corporation in present dollars value. However, it is a hard challenge for evaluator to consider the suitability of resource type selection and measurement model while the processes of evaluation in the aspect of intangible capital.

Even though, financial report methods can manifest the value of intangible capital in dollar value clearly. Those methods are inadequate and improper for business managers to recognize the performance of intellectual capital in a corporation. Besides, it is essential to consider multiple dimensions or factors which are evaluated by decision makers or experts in the evaluation processes of intellectual capital as well. Therefore, qualitative evaluation methods of intellectual capital are proposed to tackle the existing problems of traditional financial report methods such as analytic hierarchy process (AHP), balanced score card (BSC), European foundation of quality management (EFQM) and value-chain scoreboard etc. (Eckstein, 2004; Han & Han, 2004; Leitner & Warden, 2004).

Because intellectual capital includes many intangible factors and items, it is difficult to evaluate intellectual capital performance using traditional crisp value directly. Under this situation, linguistic variables are suitable used by experts to evaluate the ratings of intellectual capital. The 2-tuple fuzzy linguistic approach applies linguistic variable to represent the difference of degree and carry out processes of computing with words easier and without loss information (Herrera-Viedma et al., 2004). In other words, decision-makers and experts can apply linguistic variable to evaluate items and obtain the final evaluation result with appropriate linguistic variable. It is an effective method to reduce the time and mistakes of information translation and avoid information loss through computing with words.

3. 2-Tuple fuzzy linguistic approach

Fuzzy set theory is a very feasible method to handle the imprecise and uncertain information in a real world (Yager, 1995). Especially, it is more suitable for subjective judgment and qualitative assessment in the evaluation processes of decision-making than other classical evaluation methods applying crisp values (Lin & Chen, 2004; Wang & Chuu, 2004).

Definition 1. A positive triangular fuzzy number (PTFN) $\widetilde{T}$ can be defined as $\widetilde{T} = (l, m, u)$, where $l \leqslant m \leqslant u$ and $l > 0$, shown in Fig. 1. The membership function, $\mu_{\widetilde{T}}(x)$, is defined as (Zimmermann, 1991)

$$\mu_{\widetilde{T}}(x) = \begin{cases} \frac{x-l}{m-l}, & l < x < m \\ \frac{u-x}{u-m}, & m < x < u \\ 0, & \text{otherwise} \end{cases} \tag{1}$$

Definition 2. A linguistic variable is a variable whose values are expressed in linguistic terms. In other words, variable whose values are not numbers but words or sentences in a nature or artificial language (Herrera-Viedma & Peis, 2003; Zadeh, 1975). For example, "weight" is a linguistic variable whose values are very low, low, medium, high, very high, etc. These linguistic values can also be represented by fuzzy numbers. It is suitable to represent the degree of subjective judgment in qualitative aspect than crisp value.

3.1. 2-Tuple fuzzy linguistic term

In order to identify the diversity of each evaluation item and facilitate to compute, linguistic terms often possess some characters like finite set, odd cardinality, semantic symmetric, ordinal level and compensative operation (Herrera-Viedma, Cordón, Luque, Lopez, & Muñoz, 2003). Additionally, it is feasible to represent the diversity of degree instead of traditional crisp value in qualitative evaluation processes (Wang & Chuu, 2004). For example, a linguistic term set S contains five linguistic terms, '*Very Poor*', '*Poor*', '*Fair*', '*Good*', and '*Very Good*', which are denotes s_0, s_1, s_2, s_3, and s_4, respectively. Each of the linguistic term is assigned one of five triangle fuzzy numbers whose membership functions are shown as Fig. 2.

Definition 3. A value β whose value belongs to interval [0, 1] will be obtained after aggregating the result of evaluation using the linguistic variable set S (Herrera & Martinez, 2000). Then the symbolic translation process is applied to translate β into a 2-tuple linguistic variable. The generalized translation function (Δ) can be represented as

$$\Delta : [0,1] \rightarrow S \times [-\frac{1}{2g}, \frac{1}{2g})$$
$$\Delta(\beta) = (s_i, \alpha) \text{ with} \begin{cases} s_i & i = \text{round}(\beta \cdot g) \\ \alpha = \beta - \frac{i}{g} & \alpha \in [-\frac{1}{2g}, \frac{1}{2g}) \end{cases} \tag{2}$$
$$\text{where } \beta \in [0,1]$$

A value β is translated into the closest linguistic term s_i in S with a value α through the symbolic translation. The 2-tuple fuzzy linguistic approach applies the concept of symbolic translation to represent the linguistic variable using 2-tuples (s_i, α), $s_i \in S$. The

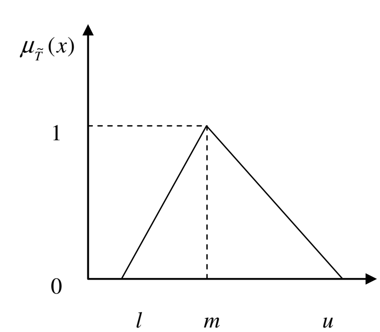

Fig. 1. Triangular fuzzy number $\widetilde{T}$.