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A hybrid approach using two-level SOM and combined AHP rating and AHP/DEA-AR method for selecting optimal promising emerging technology

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ABSTRACT

Emerging technologies are playing an important role in establishing competitive advantage for technology based companies. Selecting an efficient and important emerging technology to invest in is significant to the companies also. In this study, we propose a method for selecting optimal emerging technology which is efficient, important and the most suitable to a company's actual levels of input resource among various emerging technology alternatives. In order to select optimal emerging technology, the proposed method uses two-level-SOM to cluster the emerging technology alternatives based on alternatives' required levels of input resource. For selecting efficient and important promising emerging technology, the proposed method calculates emerging technology alternatives' efficiency score by using AHP/DEA-AR and their importance score by using AHP rating method in each technology cluster generated by two-level-SOM. Finally, the proposed method selects optimal promising emerging technology according to a company's actual levels of input resource and each emerging technology alternative's combined scores which is calculated by adding its efficiency score and importance score. A Korean company's case of selecting optimal promising nanotechnology is employed to illustrate the proposed method. The result shows that the proposed method can provide an effective and reasonable selection of optimal promising emerging technology.

1. Introduction

Emerging technologies are technologies which have not yet demonstrated potential for changing the basis of competition (Hung & Chu, 2006). Emerging technologies have significant implications and profound consequences for firms, markets, government policy, and society (Hu, Hung, & Gao, 2011). Emerging technologies are also characterized by rapid development in terms of significance and development rate of new ideas and technologies (Van der Valk, Moors, & Meeus, 2009). Nowadays, many technology based companies try to use various emerging technologies in their products and services to contribute on value added streams and establish competitive advantages.

Among so many emerging technologies, it is not easy to select an optimal promising emerging technology. To select an optimal emerging technology is difficult because many different emerging technologies need different requirements on the levels of input resource such as R&D capability, cost, etc. and the companies also have different levels of input resource capability. For selecting optimal emerging technology which is suitable to a company, consideration of the company's actual levels of input resource is necessary. If a company selects a technology ignoring the difference between its own actual levels of input resource and the selected technology's required levels of input resource, the selected technology cannot be carried out in reality. In this case, it is not an optimal technology to the company.

Selecting a promising emerging technology is also difficult because of the increasing number and complexity of emerging technology alternatives, and the considerations of multi-criteria in technology selection. In order to select a promising emerging technology, emerging technology alternatives especially should be evaluated at many aspects such as efficiency or importance and so on. In technology selection, the information of technology alternatives should be collected under the predefined selection criteria, then evaluate the technology alternatives against each other based on the identified criteria (Lamb & Gregory, 1997). But many companies, especially many small and medium-sized enterprises (SMEs), they don't have enough resources and capabilities to evaluate various emerging technologies and invest in several emerging technologies simultaneously. In this case, among so many emerging technology alternatives, companies should select an optimal promising emerging technology.

In this study, we present a new method to select an optimal promising emerging technology which is efficient and important, and suitable to a company's actual levels of input resource. In order

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to select an optimal emerging technology, the proposed method first uses two-level self-organizing map (two-level SOM) to cluster emerging technology alternatives with similar levels of input resource. Two-level SOM is a clustering method which is composed of self-organizing map (SOM) and K-means (Vesanto & Alhoniemi, 2000).

In order to select promising emerging technologies, the proposed method combinedly uses AHP/DEA-AR and AHP rating method. Analytic hierarchy process (AHP)/Data Envelopment Analysis-Assurance Region (DEA-AR) is used to measure the efficiency of emerging technology alternatives by hybrid using AHP and DEA. The efficiency of emerging technology alternatives can be evaluated by comparing emerging technology's input resource and output result. In AHP/DEA-AR, AHP is used first to set assurance region (AR) to restrict the weights' distributions for using DEA-AR, then, DEA-AR uses the AR set by AHP to calculate the efficiency of emerging technology alternatives. The efficiency value is defined as DEA score in this study. AHP rating method is used to evaluate the importance of emerging technology alternatives, which is different from the traditional AHP. The importance of emerging technology alternatives can be evaluated by degree of society's need and government's support to an emerging technology. When there are a large number of alternatives and pair-wise comparison is impracticable, AHP rating method is particularly useful (Sueyoshi, Shang, & Chiang, 2009). In this study, we use AHP rating method instead of pair-wise comparison to evaluate importance of emerging technology alternatives because of the large number of emerging technology alternatives which are independent with each other. The importance value is defined as AHP score in this study. At last, the proposed method calculates each emerging technology alternative's combined score by adding the alternative's DEA score and AHP score. The promising emerging technology is selected according to combined scores of emerging technology alternatives.

This study organizes the remaining structure as follows. In the literature review, technology selection, introduction of two-level SOM, DEA-AR and AHP rating method are introduced. The third section introduces the procedures of the proposed method. Then, the proposed method is applied to a case of the Korean company A's optimal promising nanotechnology selection and the process of optimal promising nanotechnology selection is explained. The final section discusses the conclusion.

2. Literature review

2.1. Emerging technology

Emerging technologies are core technologies which are uniquely necessary to product, production, or services of the industry, but have not been improved to be potential for changing the basis of competition (Hung & Chu, 2006). The emerging technologies embedded in the enabled products or processes contribute to adding values and establish competitive advantages for newly established companies. The emerging technologies also have the potential to create a new industry (Adner & Levinthal, 2002; Day, Schoemaker, & Gunther, 2000). Therefore, when selecting or developing any emerging technology, it is important and necessary to identify the technology fields with strategic importance and technological competitive advantage to invest in Shen, Chang, Lin, and Yu (2010).

Emerging technology has been researched by many researchers recently. For example, Shen et al. (2010) researched the organic light emitting diode (OLED) technology in Taiwan. Hung and Chu (2006) discussed the situation of biochips and nanotechnology in Taiwan. In emerging technological fields, demand is unclear, so it reduces the applicability of diffusion research (Van der Valk et al., 2009). Many approaches that have been employed on emerging technologies are the socio-cognitive and institutional approach (Bijker & Law, 1992; Garud & Rappa, 1994; Rao and Singh,2001; Van de Ven, Polley, Garud, & Venkataraman, 1999). These researches have provided deep analyses of ways in which a specific invention can evolve in laboratories and new business ventures, and they reported shifting evaluation criteria to the function and quality of inventions. These studies showed how an invention is developed. At the early stage of their development, the direction of the innovation process can be influenced, but their implications can hardly be foreseen. This poses considerable challenges for evaluating the emerging technologies (Torsten, Michael, & Ulrich, 2005).

In this study, in order to help companies to evaluate emerging technologies accurately and select an optimal promising emerging technology to invest in, we propose a method considering a company's actual levels of input resource to evaluate the efficiency and importance of emerging technology alternatives.

2.2. Technology selection

Technology selection is a process that involves identifying and evaluating alternatives and choosing among them (Shen et al., 2010). In this process, information about technology alternatives should be collected through many channels and alternatives should be evaluated against each other or some criteria (Lamb & Gregory, 1997). AHP, a popular method of solving multi-criteria problems (Saaty, 1980), is widely used in technology selection (Tran & Daim, 2008). For example, a healthcare technology assessment application using AHP was also presented (Sloane, 2004), AHP was used to select the most appropriate technology for seawater desalination (Hajeeh & Othman, 2005), AHP was used to identify criteria and obtain their relationship and weights to select the proposed OLED technology (Shen et al., 2010).

DEA is also used in some researches of technology selection. For example, a novel practical common weight multi-criteria decision-making (MCDM) DEA approach was proposed for technology selection (Karsak & Ahiska, 2005), a decision method using DEA for technology selection problems was proposed (Moutaz, 1995). In previous studies on technology selection, most researchers usually used AHP or DEA alone although the integrated use of AHP and DEA can yield more valid results. The integrated AHP and DEA method has been applied on site selection, evaluation system selection, project evaluation, evaluating facility layout design, and so on (Bowen, 1990; Ertay, Ruan, & Tuzkaya, 2006; Seifert & Zhu, 1998; Shang & Sueyoshi, 1995; Sinuany-Stern, Mehrez, & Hadad, 2000; Takamura & Tone, 2003; Zhang & Cui, 1991), but seldom used on technology selection.

Another problem in the previous studies on technology selection is that they ignore technology alternative's required levels of input resource, and just simply ranked the alternatives after the alternatives were evaluated under the identified criteria by using AHP or DEA. To overcome the limitations in the previous studies, in this study we propose a method that uses a combined AHP/DEA-AR and AHP rating method considering technology alternative's required levels of input resource for optimal promising emerging technology selection.

The previous studies on technology selection method focused on dealing with cardinal data, not ordinal data (Saen, 2006). In general, however, technology selection is conducted by carrying out surveys to several experts and then evaluating ordinal rating data collected through surveys. Thus, it is essential to have the technology selection method which can accurately analyze ordinal rating data, because some or all of the criteria in technology evaluation may be ordinal (qualitative), and should be treated as such (Saen, 2006). The addition of subjective judgments to the purely