Expert Systems with Applications 36 (2009) 9759–9766

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

Evaluating new product development performance by fuzzy linguistic computing

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ARTICLE INFO

Keywords:
New product development
Group decision making
Heterogeneous information
2-Tuple fuzzy linguistic computing

ABSTRACT

New product development (NPD) is indeed the cornerstone for companies to maintain and enhance the competitive edge. However, developing new products is a complex and risky decision-making process. It involves a search of the environment for opportunities, the generation of project options, and the evaluation by different experts of multiple attributes, both qualitative and quantitative. To perceive and to measure effectively the capability of NPD are real challenging tasks for business managers. This paper presents a 2-tuple fuzzy linguistic computing approach to deal with heterogeneous information and information loss problems during the processes of subjective evaluation integration. The proposed method which is based on the group decision-making scenario to assist business managers to measure the performance of NPD manipulates the heterogeneous integration processes and avoids the information loss effectively. Finally, its feasibility is demonstrated by the result of NPD performance evaluation for a high-technology company in Taiwan.

1. Introduction

Product design has been long recognized as an opportunity for differential advantage in the market place. A number of companies successfully focus on product design as a competitive tool (Creusen & Schoormans, 2005). Nowadays, more requirements for enterprises have been put forward, such as more product variety, shorter time-to-market, lower product cost and higher quality. The globalization of competition in the manufacturing industry and the diversification of customers' demands as well as rapid technological developments continue to spur technology-based innovations at a frenetic pace. Product design innovation therefore has developed quickly and has gradually become one of mainstream production modes of manufacturing industries in the 21st century. Therefore, improving product development performance is becoming increasingly important and challenging.

New product development (NPD) is undeniably vital in determining the economic success of manufacturing companies. Firms need to create and sustain competitive advantages in order to survive in today's highly competitive business environment. One major determinant of sustaining competitive advantage is the ability of the firms to develop and launch successful new products. Differentiation through NPD is therefore one of the most effective strategies for achieving success. As competition in global markets has become intense, firms have begun to recognize the importance of NPD and innovation issues. Through innovation and the introduction of new products, new markets and growth possibilities can be created. Increasing international competition accentuates the importance of the NPD process which is secure and accurate (Ozer, 2005; Sherman, Berkowitz, & Souder, 2005). Gemser and Leenders (2001) conclude that being innovative with respect to design and design strategy can enhance competitiveness regardless of industry evolution. Timely, correct and responsive NPD has become even more critical in the highly competitive global environment. The need to respond quickly to these dynamic global market forces requires the firm to establish a specialized evaluation mechanism and platform for NPD performance.

However, the decision-making domain of NPD is highly complex and uncertain due to a demanding environment characterized by increased globalization and segmentation of markets, increased levels of product complexity, changing customer needs, and shorter product life cycles (Belecheanu, Pawar, Barson, Bredehorst, & Weber, 2003). New product introduction in today's technology-driven markets carries significant risk. New product failure rates can be as low as one of every three products or as high as the 90% of new grocery products which are withdrawn within a year of their introduction. New technology, improved communications, increased profit demands and shorter product life cycles have added to the inherent risk. Yet, without the introduction of new products, deterioration of the firm's market position is inevitable. Without new products, firms will inevitably stagnate (Yelkur & Herbig, 1996). In order to evaluate the performance of NPD more appropriately, the firms should consider not only quantitative index but also qualitative dimensions or factors which are evaluated by multiple decision-makers or experts. Thus, the evaluation of NPD performance should be regarded as a group multiple criteria decision-making problem as well.

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doi:10.1016/j.eswa.2009.02.034

Experts devote themselves to judge the NPD performance measurement by their experiential cognition and subjective perception in the decision-making process. However, there exists a considerable extent of uncertainty, fuzziness and heterogeneity (Hwang & Yoon, 1981). This is not a seldom situation. In addition, it is prone to information loss happening during the integration processes, and gives rise to the evaluation result of the performance level which may not be consistent with the expectation of the evaluators. Consequently, developing an easy way to calculate the performance ratings while the processes of evaluation integration and to manipulate the operation of qualitative factors and expert judgment appropriately in the evaluation process of NPD could brook no delay. In this paper we propose a suitable model based on 2-tuple fuzzy linguistic information to evaluate the NPD performance. The proposed approach not only inherits the existing characters of fuzzy linguistic assessment but also overcomes the problems of information loss of other fuzzy linguistic approaches (Herrera-Viedma, Herrera, Martinez, Herrera, & Lopez, 2004).

This paper is organized as follows. In Section 2 the measurement dimensions of NPD are described. In Section 3 we introduce the basic definitions and notations of the fuzzy number, linguistic variable and 2-tuple fuzzy linguistic representation and operation, respectively. In Section 4a NPD performance measurement method based on 2-tuple fuzzy linguistic information is proposed . The proposed model is then illustrated with an example for a high-technology company in Taiwan. In Section 5 conclusion is given.

2. Literature review

A contemporary NPD process usually consists of hundreds or thousands of activities, where the activities may be dependent or interdependent on one another. A rapidly changing competitive landscape and dynamic customer expectations require manufacturers to seek flexibility in product development. Unlike the manufacturing processes, product development is a creative and discovering process that tends to create something new from trial-and-error and learning from the errors made (Wang & Lin, forthcoming). The purpose of NPD is to accumulate the knowledge and capability necessary to determine an appropriate new product. Superior product design, potential for breakthrough innovation, low project and product cost, shorter lead time, better communication of cross-functional teamwork, and increased customer satisfaction and market share are among many other advantages for successful NPD. Suchlike concerns enable firms in making NPD decisions while ensuring full knowledge of the customer, the technology, and with the team's support. In view of this, a performance evaluation method or approach that is capable of systematically analyzing and accurately quantifying those subjective experiences and judgments of the NPD team is highly required.

Ozer (2005) indicated that the quality of new product evaluation decisions is affected by four major sets of factors, namely the nature of the task, the type of individuals who are involved in the decisions, the way the individuals' opinions are elicited and the way the opinions are aggregated. The main drivers of NPD include: quality and speed to market; widening customer choice and expectation; competitive priorities of responsiveness, delivery, flexibility, concern for the environment and international competitiveness. For example, Wang and Lin (forthcoming) pointed out that the introduction timing of new products is important for high-technology industries to gain premium pricing and higher sales volume. A NPD project in nature should possess four latent abilities: delivering value to the customer; being ready for change; valuing human knowledge and skills; and forming virtual partnerships (McCurry & McIvor, 2002).

NPD is thus a key factor for survival for business firms. Most of the fast-growing companies achieve above 50% of their total sales from the new products developed within 5 years (Lee, Lee, Koo, & Yan, 1996). Not only is the technology changing rapidly, but the process of the commercialization of technological change–the industrial innovation process–is also changing. Nowadays due to the increasingly competitive climate, more and more managers are forcing themselves to update on the range of factors that determine product innovation success. Takeuchi and Nonaka (1986) indicated that all profits of new products would account for 30–40% of total sales. Griffin (1997) represented a substantial anticipated increase in the profit impact of new products. Sales from establishments which were part of the business five years earlier represented 32.4% of total annual sales. Especially, high-technology industries attained a great percentage of 42.3% and this increased continuously. Even so, the average failure rate of new products also reached a great percentage of 41%. In sum, the firms are in urgent need of developing a specialized NPD performance evaluation mechanism and platform for their effective management and for enhancing business competitiveness further.

It is however difficult and laborious to measure NPD performance using traditional crisp value directly as the process of NPD performance measurement possesses many intangible or qualitative factors and items. Linguistic variable representation is therefore favorable for experts to express and evaluate the ratings of NPD under such a situation. The fundamentals of 2-tuple fuzzy linguistic approach are to apply linguistic variables to stand for the difference of degree and to carry out processes of computing with words easier and without information loss during the integration procedure (Herrera-Viedma et al., 2004). That is to say, decision participants or experts can use linguistic variables to estimate measure items and obtain the final evaluation result with proper linguistic variable. It is an operative method to reduce the decision time and mistakes of information translation and avoid information loss through computing with words.

3. Fuzzy linguistic computing approach

Many aspects of different activities in a real world cannot be assessed in a quantitative form, but rather in a qualitative one, i.e., with vague or imprecise knowledge. Whereas characteristics of the fuzziness and vagueness are inherent in various decision-making problems, a proper decision-making approach should be capable of dealing with vagueness or ambiguity (Yager, 1995). Fuzzy set theory is a very feasible method to handle the imprecise and uncertain information in a real world. 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). Basic definitions and concepts of fuzzy sets are briefly reviewed as follows; and further, notations given below will be used throughout the paper until otherwise stated.

3.1. Fuzzy number

A positive triangular fuzzy number (PTFN) $\widetilde{A}$ can be denoted as $\widetilde{A} = (a, b, c)$, where $a \leqslant b \leqslant c$ and $a > 0$, which are illustrated in Fig. 1. The membership function, $\mu_{\widetilde{A}}(x)$, is defined as (Zimmermann, 1991)

$$\mu_{\widetilde{A}}(x) = \begin{cases} (x-a)/(b-a), & a \leqslant x \leqslant b \\ (x-c)/(b-c), & b \leqslant x \leqslant c \\ 0, & \text{otherwise} \end{cases} \tag{1}$$

where x takes its values on the real line. A larger $\mu_{\widetilde{A}}(x)$ means a stronger degree of belongingness for x in X. Triangular fuzzy num-