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A new approach for selecting portfolio of new product development projects

Chiu-Chi Wei [a,*], Houn-Wen Chang [b]

[a] Department of Industrial Engineering and System Management, Chung-Hua University, Taiwan
[b] Institute of Technology Management, Chung-Hua University, Taiwan

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ABSTRACT

The most decisive factor that survives enterprises under stiff competition is the development of new product (NPD), and when entering the product development stage after the fuzzy front end, a best project portfolio should be finalized in order to potentially create expected revenue and competitive advantage. However, even it reaches the end of the fuzzy front stage; the NPD project is still significantly involved with uncertainties, complexities and fuzziness. To assist R&D managers making decision in this environment, this study proposes a new approach which combines fuzzy set theory and multi-criteria group decision making method into a NPD project portfolio selection model. This model takes into account project performance, project delivery and project risk, and formulates the selection decision of NPD project portfolio as a fuzzy linear programming problem. The illustrative example shows that the model proposed can generate projects with the highest success rate under limited resources and manpower.

1. Introduction

Campbell and Cooper indicated that, in this chaotic and fast-changing environment, the continuing growth and ever-lasting existent of enterprises depends upon successful new product development (Campbell & Cooper, 1999). However, the in-coming new competitors, endless technology innovation and dynamic customer demands have significantly shortened the product life cycle. Lin and Chen concluded that, though the new product development requires complex management processes and involves high risk, a successful NPD project can certainly generate vast profit and competitive advantage (Lin & Chen, 2004). Unfortunately, although managers acknowledge the importance of new product development, most NPD project failed. Stevens and Burley observed that only 60% of NPD projects survive from the fuzzy front end to commercialization, even systematic stage-gate processes are employed (Stevens & Burley, 2003). The primary reason is that the NPD processes were not strictly controlled so that projects that are unlikely to be beneficial survive from the Go–Kill gate, leading to product outcomes nonconforming to market requirements.

Because NPD processes consists of fuzzy front end stage (FFE), product development stage and product launch stage, Kim and Wilemon implied that decision of NPD project selection is tangled with uncertainties of technology, market, resources, environment and capability (Kim & Wilemon, 2002). Zhang and Doll observed that uncertainties of NPD are due to customer demands, competition and ever-changing technology (Zhang & Doll, 2001).

Machacha and Bhattacharya pointed out that, when selecting the project portfolio, the most difficult task that manager faces is screening the project with the best potential profitability and meeting enterprises objective (Machacha & Bhattacharya, 2000), especially, if the decision is to be made within dynamic environment and under competition pressure. Therefore, a good project portfolio is extremely important for enterprises to generate competitive advantage. Cooper revealed three cornerstones affecting new product development performance as product development processes, new product strategy and resource commitment, and most organizations allocated more resources to maintain high quality product development processes than others (Cooper, 1996). Avineri et al. recognized that the problem the enterprises need to solve is to select the best project out of a vast amount of NPD projects within resources constraints, thus, an effective resources allocation system is highly needed (Avineri, Prashker, & Ceder, 2000). In other words, a NPD project management system should be established to ensure that those with high feasibility and conforming to business strategy while meeting customer needs can be finally selected.

To help ease the decision of finding the best project portfolio, this study proposes a new fuzzy multi-criteria group decision making approach to select the NPD project portfolio which considers project performance, project delivery and project risk, and a fuzzy linear programming model is formulated to analyze the best NPD portfolio that most suits enterprises objective.

* Corresponding author.
E-mail addresses: a0824809@gmail.com (C.-C. Wei), chang_hw2001@yahoo.com.tw (H.-W. Chang).

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2. Fuzzy multi-criteria group decision

Because of various uncertain aspects involved in resources, technology, environment and competition, the decision of selecting NPD project can be regarded as a fuzzy multi-criteria group decision problem. By using the fuzzy method, the management would be able to make adequate decision based on incomplete and vague information under various kinds of pressure. Lin and Chen implied that traditional quantitative methods such as mathematical programming and economic models require information of the target market, financial prediction, resources availability and decision timing, which are all unreliable and imprecise; consequently, the decision made would be in great doubt (Lin & Chen, 2004).

Herrera and Herrera-Viedma concluded that alternatives selection is to choose the one that can maximize enterprises benefit from a set of feasible projects. However, the information needed for making a good decision may be uncertain, vague and imprecise; therefore, fuzzy multi-criteria group decision making can be an appropriate technique to reach better decisions of this kind (Herrera & Herrera-Viedma, 2000).

2.1. Fuzzy set

The classical logic focuses on duality of yes or no, and most discrete events are solved using traditional means. Therefore, the value of outcome can only be classified as zero and one. Obviously, when an event is with value of outcome between zero and one, the duality cannot be applied. Event of this kind is called continuous event and can be solved by fuzzy theory, which measures the relationship between element and set using membership function, and the result is the degree of membership (Chen, 2000; Chen, 2001). A fuzzy set is defined as Eq. (1):

$$A = \{(x, \mu_A(x)) | x \in X\} \tag{1}$$

where X is a fuzzy set and $\mu_A(x)$ is the degree of membership of element x to the fuzzy set A.

2.2. Fuzzy number

A fuzzy number is a fuzzy subset of the real number, and it is the extension of the concept of confidence interval. The characteristics of fuzzy number can be stated using a triangle membership function as below (Chen, 2000; Chen, 2001; Fan, Ma, & Zhang, 2002; Wang & Chuu, 2004; Wang & Lin, 2003):

1. Let A be a fuzzy number, then the following features can be applied:
   (1) A is convex, and the inequality of Eq. (2) holds,

$$\mu_A[\lambda x_1 + (1-\lambda)x_2] \geqslant \min[\mu_A(x_1), \mu_A(x_2)],\quad x_1, x_2, \in X,\ \ \lambda \in [0,1] \tag{2}$$

   (2) A is normal and its height is 1.
   (3) The α-cut (A_α) of A must be a close area, where $\alpha \in [0,1]$.
2. If A is a Triangle Fuzzy Number (TFN) with three elements such as $A = (L,M,U)$, then its membership function can be expressed as Eq. (3) and Fig. 1.

$$\mu_A = \begin{cases} 0, & x \leqslant L, \\ (x-M)/(M-L), & L \leqslant x \leqslant M, \\ (U-x)/(U-L), & M \leqslant x \leqslant U, \\ 0, & x > U, \end{cases} \tag{3}$$

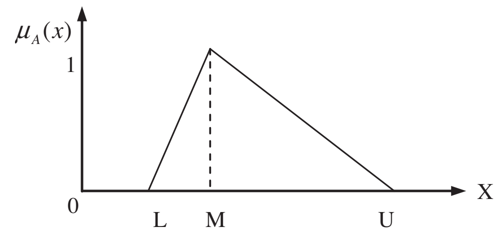

Fig. 1. Triangle fuzzy membership function.

2.3. The decision index of NPD project

Based on method of fuzzy weighted average (FWA), this paper proposes a decision index (DI) shown as Eq. (4). DI is an information measure which consolidates fuzzy rating and fuzzy weight of all factors that will impact the success of NPD project

$$\mathrm{DI}_{(P,D,R)} = \frac{\sum_{n=1}^{N}(r_n \otimes w_n)}{\sum_{n=1}^{N} w_n} \tag{4}$$

where P, D, and R represent NPD project's performance, delivery and risk, r_n and w_n are the fuzzy rating and fuzzy weight, $n = 1,\ldots,N$ is set of criteria. Lee and Park (1997) proposed an algorithm called the efficient fuzzy weighted average (EFWA) to simplify the computation. EFWA utilizes binary search to determine FWA, and in the worst case, it needs computation of $O(n\log n)$. Therefore, Kao and Liu use mathematical programming technique to develop an easier algorithm named fractional programming approach (FPA) (Kao & Liu, 2001). There are also some studies dedicated to solving FWA and making the remarkable achievement (Chang, Wei, & Lin, 2008; Chang & Hung, 2005; Lin & Hsieh, 2004; Lin, Tan, & Hsieh, 2005; Lin & Chen, 2004; Lin & Chen, 2004). Because FPA is an efficient and powerful algorithm for the current work, this study adopted FPA to obtain DI of each NPD project. Performing α-cut of r_n and w_n, $(r_n)_\alpha = \left[(r_n)_\alpha^L, (r_n)_\alpha^U\right]$ and $(w_n)_\alpha = \left[(w_n)_\alpha^L, (w_n)_\alpha^U\right]$ can be obtained. Let $t = 1/\sum_{n=1}^{N} w_n$ and $v_n = tw_n$, the membership function of DI can be constructed using formulations (5) and (6), where P, D and R are performance, delivery and risk of NPD project

$$\begin{aligned} \mathrm{DI}^L_{(P,D,R)_\alpha} &= Min \sum_{n=1}^{N} v_n\ (r_n)^L_\alpha \\ &\text{s.t.} \\ &\quad t(w_n)^L_\alpha \ \leqslant\ v_n\ \leqslant\ t(w_n)^U_\alpha \\ &\quad \sum_{n=1}^{N} v_j = 1 \\ &\quad t \geqslant 0 \end{aligned} \tag{5}$$

$$\begin{aligned} DI^U_{(P,D,R)_\alpha} &= Max \sum_{n=1}^{N} v_n\ (r_n)^L_\alpha \\ &\text{s.t.} \\ &\quad t(w_n)^L_\alpha \ \leqslant\ v_n\ \leqslant\ t(w_n)^U_\alpha \\ &\quad \sum_{n=1}^{N} v_n = 1 \\ &\quad t \geqslant 0 \end{aligned} \tag{6}$$

2.4. Ranking the fuzzy number

The obtained DI for each NPD project is a fuzzy number. Therefore, it is important to compare the crisp rating (CDI) of DI with the threshold of Go–Kill. Moreover, the threshold of Go–Kill is