Expert Systems with Applications 39 (2012) 9868–9885

Contents lists available at SciVerse ScienceDirect

Expert Systems with Applications

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

Managing uncertainty to improve decision-making in NPD portfolio management with a fuzzy expert system

Jeongsu Oh [a], Jeongsam Yang [b,*], Sungjoo Lee [b]

[a] PDEM Development Group, Samsung SDS, Republic of Korea
[b] Department of Industrial & Information Systems Engineering, Ajou University, San 5, Wonchun-dong, Yeongtong-gu, Suwon 443-749, Republic of Korea

ARTICLE INFO

Keywords:
Portfolio management
New product development (NPD)
Project selection
Uncertainty
Fuzzy expert system

ABSTRACT

The importance of new product development (NPD) for a company's growth and prosperity is emphasized and a number of methods have been suggested to help decision-making for NPD project portfolio management. In spite of their utilities, however, little attention was paid to develop a supporting system for portfolio management that can help quick but careful decision-makings under uncertainties. Therefore, this research proposes a decision-making framework that uses a fuzzy expert system in portfolio management for dealing with the uncertainty of the fuzzy front-end of product development. For the purpose of developing the framework, we adopted the three tools – strategic bucket for strategic resource allocation, scoring models for evaluating projects and portfolio matrixes for balancing projects – to find an optimal set of projects in the portfolio. In particular, this research established fuzzy inference-based models for evaluation criteria which are too ambiguous to be numerically described. Also, based on the evaluation results, the final selection of projects is made by an expert system, which can encompass the operational knowledge and company strategy in the rule-based system. The suggested framework was applied to the portfolio analysis in an electronics firm in Korea and verified its feasibility.

1. Introduction

As a management strategy, new product development (NPD) is critical for the survival and growth of companies in a rapidly changing market. Successful NPD can provide increased sales, profits, and competitive advantage for most companies: many leading high-tech companies, for example, have found that more than 50% of their current sales come from new products (Balbontin, Yazdani, Cooper, & Souder, 2000). Therefore it is apparent that a firm's NPD strategy is a primary determinant of performance. Particularly these days, consumer markets are becoming more versatile and technology is changing more rapidly than ever. Thus, new products need to be adapted to variable and dynamically changing markets. These uncertainties have forced a firm to dedicate much effort to NPD, being attentive to the needs of customers and the vicissitudes of modern technology for maintaining a market share.

However, although companies are continuously striving to develop new products using much resource, NPD pressure is exacerbating the risk factor and causing abnormally high failure rates in the early stages of development. NPD success depends on the ability to predict potential demands in the market and to select the most feasible NPD candidates for the demands. We therefore need an effective decision-making process: a process that can accurately evaluate numerous NPD projects with limited resources and make a sound selection of the optimum set of products. Further, the necessity of such a systematic and judicious decision-making process is highlighted particularly for NPD projects, which are often hard to stop once initiated.

NPD strategies can be realized by implementing an objective decision-making process through successful portfolio management, which includes the development of product and technology roadmaps that link business strategy and technology planning. Through portfolio management, companies can make various NPD decisions in association with both long-term and short-term strategies; they can also make decisions on strategic investment and resource allocation to achieve business goals. Building a strategic NPD portfolio while giving due consideration to business goals and constraints is an important and challenging task. As a result, various methods including multi-criteria decision-making tools (e.g. analytic hierarchy process (AHP)) and optimization techniques (e.g. linear programming), have been proposed to help evaluate the characteristics of NPD projects and build optimal portfolios. In spite of the meaningful contributions of these methods to portfolio management, most of the existing methods fail to reflect the uncertainty of portfolio decision-making. Moreover, the potential use of these methods as practical management models is limited because they apply the same evaluation criteria to all projects during the

* Corresponding author. Tel.: +82 31 219 1879; fax: +82 31 219 1610.
E-mail addresses: windboy@ajou.ac.kr (J. Oh), jyang@ajou.ac.kr (J. Yang), sungjoo@ajou.ac.kr (S. Lee).

0957-4174/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
doi:10.1016/j.eswa.2012.02.164

decision-making process, even though various selection criteria can be chosen to match the project characteristics.

To overcome this limitation, we propose a decision-making method that uses a fuzzy expert system in portfolio management for dealing with the uncertainty of the fuzzy front end of product development. Depending on the market environment, marketing evaluations in the planning phase of a new product are often conducted in an uncertain or ambiguous state, particularly in cases involving the expected sales and profits. This paper establishes fuzzy inference-based portfolio evaluation models for items which are too ambiguous to be numerically evaluated. With this evaluation model, major NPD projects that should be planned under uncertainty in a firm can be evaluated and prioritized. For this purpose, we developed a portfolio expert system which facilitates the selection of right projects to develop balanced investment R&D programs and satisfy the goal of portfolio management. The research results are expected to support effective and efficient decision-making in association with NPD strategy, especially in environments where markets and technology are changing rapidly.

2. Related works

A project portfolio is a set of projects conducted under the management of a specific company. Project portfolio selection is the periodic activity to select a portfolio from project candidates (both available project proposals and projects currently underway) to meet the organization's stated objectives in a desirable manner within available resources or without violating other constraints (Archer & Ghasemzadeh, 1999). Therefore, decision-making needs to be based on the features of individual projects as well as on the overall portfolio and strategic goals. Cooper (1994) suggested the following three drivers for effective portfolio management:

- Maximization of value: projects with high profitability and high chance for success should be selected;
- Balanced projects: an appropriate balance of projects in terms of long-term and short-term objectives, degree of risks, and diversity of markets and technologies;
- Strategy alignment: resource allocation strategy and corporate investment strategy should be reflected in the portfolio strategy.

Various methods of analyzing portfolios, such as the AHP, have been proposed as a means of satisfying the goals of the dynamic and multi-criteria decision-making process.

2.1. Methods of NPD portfolio management

The literature features more than a hundred methods of analyzing project portfolios, which can be classified into three main categories. The first category is a prioritization approach, in which expected project outcomes are evaluated and projects are prioritized based on them. This category includes comparative methods, such as a scoring method (Martino, 1995), Q-sort (Souder & Mandakovic, 1986), and AHP (Brenner, 1994), as well as financial analysis methods, such as the net present value (NPV) method (Chun, 1994), the return on investment method (Martino, 1995), and option pricing theory (Perlitz, Peske, & Schrank, 1999). These methods are simple and useful but are limited in the way they manage the portfolio balance. According to Cooper, Edgett, and Kleinschmidt (2004a, 2004b, 2004c), companies that rely solely on a financial method in NPD portfolio selection tend to have the worst outcomes. Nevertheless, the financial method is still the most widely used method.

The second category involves a mathematical optimization approach. These methods try to optimize various objective functions within the constraints of resources, project logic and dynamics, technology, and project-related strategies. They include a range of methods, such as linear, nonlinear, integer, dynamic, goal, and stochastic mathematical programming methods (Heidenberger & Stummer, 1999). The mathematical optimization method is the best method from a theoretical perspective and a number of techniques have been suggested to model practical portfolio selection process, considering partial funding, and the interrelation of projects and their periods (Beaujon, Marin, & McDonald, 2001; Dickinson, Thornton, & Graves, 2001; Kester, Hultink, & Lauche, 2009). The drawback of these methods is the unreliability of the results, a problem attributed to the paucity of correct input data for calculating the optimized values.

The last category involves a strategic management approach. This approach overcomes the limitations of the prioritization approach and ensures a balanced portfolio. Examples include a bubble diagram, a portfolio map, and a strategic bucket method (Balbontin et al., 2000; Wang & Hwang, 2007). It also enhances the relationships between the NPD projects and strategy. Recent research suggests that differences between the most innovative companies and less innovative companies depend on how well they define and utilize a strategic bucket (Barczak, Griffin, & Kahn, 2009). Therefore, in this paper, we suggest a portfolio selection method that achieves the maximization value proposed by Cooper, Edgett, and Kleinschmidt (2004a, 2004b, 2004c), particularly with regard to the selection of balanced projects and strategy alignment. Specifically, we use a strategic bucket and a portfolio map that supplement each other; we also take advantage of the prioritization approach by using a scoring model and a financial analysis method. The outcome of these efforts is the development of a fuzzy-based expert system.

2.2. Methods of decision-making in conditions of uncertainty

Portfolio decision-making deals with a long-term vision based on uncertainty. Uncertainty means insufficient information (Spender, 1993); it may lead to unreliable decision-making. Several recently suggested methods have therefore attempted to reflect uncertainty in the evaluation and selection of projects.

One popular method involves the use of fuzzy logic (Buyukozkan & Feyzioglu, 2004). The evaluation of NPD projects can be more or less ambiguous, particularly with regard to the numerical expression of evaluation criteria or evaluation results. A number of studies have demonstrated the usefulness of fuzzy logic for the selection of NPD projects. Kuchta (2001) used fuzzy numbers to show the NPV and resource leveling of each project. Wei and Chang (2011) used a fuzzy multi-criteria approach for the selection of portfolios. In a similar context, Buyukozkan and Feyzioglu (2004) and Chen, Lee, and Tong (2006) adopted a fuzzy-AHP method, while Wang and Hwang (2007) used a fuzzy set and option pricing in their proposed R&D portfolio selection methods. In addition, Lin and Hsieh (2004) proposed a framework with a fuzzy decision-making system for strategic portfolio management. In this paper, we develop a fuzzy-based expert system for selecting a portfolio of NPD projects under uncertainty.

3. NPD portfolio framework

3.1. Concept of the framework

Portfolio management and project prioritization involve decision-makings on the assignment of limited resources to the right project. Since these processes determine the future products and markets for a firm, a rapid and sound decision-making system as well as sharing the same information across the firm is necessary.