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Strategic project portfolio selection for national research institutes

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ABSTRACT

As global competition intensifies, many national research institutes (NRIs) are investing substantial resources in research and development (R&D) to gain competitive advantage and develop the national economy. However, R&D investment involves a high degree of market and technological uncertainty. The literature on project portfolio selection focuses on either quantitative economic benefits or complex criteria to assess project(s). By emphasizing the features of NRIs, the present study proposes a decision model for evaluating a project portfolio at the early initiation stage. This decision model rests on a strategy for differentiating products and services. The decision model provides a solution to a market need to maximize benefits through differentiation. A systematic hybrid multiple-criteria decision-making (MCDM) method comprising a modified Delphi method (MDM), a decision-making trial and evaluation laboratory (DEMATEL) method, and an analytic network process (ANP) offers a systematic approach to the project portfolio-selection problem. The present empirical study on the selection of alternative R&D projects in NRIs investigates the flexible electronics industry, using the hybrid MCDM method to test the decision model's effectiveness. The present study also discusses cognitive differences between NRIs and for-profit organization in terms of their R&D portfolio selection.

1. Introduction

National research institutes (NRIs) contribute substantially to a nation's economic development. In Taiwan, the government commissions NRIs to undertake research and development (R&D) projects. By adopting the outcomes of such projects, firms extend such developments to industry. NRIs play a major role in fulfilling a nation's plans for economic development by enhancing national industrial developments toward diversification and sustainability. Consequently, given limits on time and resources, NRI portfolio management is currently a topic of interest among academics. Specifically, selecting which R&D projects to undertake is crucial to technological trends and future industrial developments.

Allocating funding to R&D projects does not guarantee their success. The innovation process involves a high degree of technological and market uncertainty, which can result in R&D project failure (Doctor, Newton, & Pearson, 2001; Lee, Veloso, Hounshell, & Rubin, 2010; Raz, Shenhar, & Dvir, 2002; Wang, Lin, & Huang, 2010). Company survival relies on continuous investment in developing new products or services. Selecting valuable R&D projects that satisfy future market demands is a challenge for organizations.

Previous studies show that R&D project selection involves three major considerations: (1) the association of the project with corporate strategies (Jiang & Klein, 1999; Liberatore, 1988; Lin & Hsieh, 2004); (2) qualitative benefits and risks of undertaking candidate projects (Coffin & Taylor, 1996; Fox, Baker, & Bryant, 1984; Souder, 1986; Stewart, 1991; Wang et al., 2010); and (3) reconciliation and integration of the stakeholders' needs and desires (Carlsson, Fullér, Heikkilä, & Majlender, 2007; Dey, 2006; Hsu, Tzeng, & Shy, 2003; Huang, Chu, & Chiang, 2008; Lawson, Longhurst, & Ivey, 2006; Meade & Presley, 2002). Despite the numerous project selection criteria appearing in the aforementioned studies, such projects originate to benefit private enterprises. Furthermore, those studies propose methods without considering the interrelationships among criteria or applying a decision model to simplify the evaluation process.

Focusing on NRIs, the present study proposes a decision model for selecting viable alternatives at the early stage of the R&D process. The study contributes by considering project selection separately from the benefits of national technology development and economic value creation. Because product and service differentiation is the key to allowing an enterprise to position itself successfully in a competitive market (Kotler et al., 2009, p. 503), the present study proposes a project selection decision-making framework for NRIs. In this framework, R&D projects aim to provide a solution (S) to a market need (N) and maximize an enterprise's benefit (B) through product, service, or technological differentiation (D). This need, solution, differentiation, benefit (NSDB) framework not only serves to select projects, but also to assist R&D

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practitioners to propose high-potential research projects at the initiation stage.

Accordingly, the present study applies a novel hybrid multiple-criteria decision-making (MCDM) method (Jeng & Bailey, 2012) comprising a modified Delphi method (MDM) (Custer, Scarcella, & Stewart, 1999), a decision-making trial and evaluation laboratory (DEMATEL) method (Fontela & Gabus, 1976; Gabus & Fontela, 1973; Jeng, 2015), and an analytic network process (ANP) (Saaty, 1996). The MDM identifies the criteria of the NSDB framework to establish an investment decision model. Through a survey of experts, the DEMATEL method then analyzes the causal relationships between complex factors to build an impact relation map among the portfolio evaluation dimensions and criteria. This study then applies the ANP to derive weights for each factor of the MCDM problem and thereby select the optimal portfolio. Finally, the process yields the key factors by ranking the data. This research uses a case study to evaluate how NRIs prioritize projects in R&D project selection. Depicting and testing the present decision model may serve as a reference for NRI authorities.

Section 2 reviews the literature to establish the foundations of the NSDB framework. Section 3 introduces the hybrid MCDM method. Section 4 describes the process of the empirical study to demonstrate the model's effectiveness. Section 5 reports results, discusses findings, and presents managerial implications. Finally, Section 6 offers concluding remarks.

2. Literature review

R&D project selection plays a key role in many organizations. Hall and Nauda (1990) indicate that R&D project selection requires a strategic perspective and formal interactive process that aim to blend R&D planning with corporate business planning. The aspects of such a perspective include technology forecasting, competitor analysis, and strategic business unit planning.

Liberatore (1988) describes an expert support system for industrial R&D project selection. The modeling framework links the mission, objectives, and strategy of a business unit with the criteria for selecting R&D projects. Meade and Presley (2002) assess the essential factors for project selection to formulate a decision within an enterprise's strategic objectives framework and organizational structure while considering and integrating each project's financial and strategic benefits. Lawson et al. (2006) recommend using six industry-wide categories (i.e., technical, corporate and strategy, regulatory, market, financial, and application) as filters for selecting R&D projects for profit-oriented small and medium-sized enterprises. Huang et al. (2008) list the decision criteria for early-stage project portfolio management, particularly in the selection of projects for Taiwan's Industrial Technology Development Program. These criteria could be suitable for adoption by NRIs. By adopting the analytic hierarchy process for the analysis, however, Huang et al. (2008) ignore the interdependency among the dimensions and criteria. Appendix 1 presents a thorough review of the relevant criteria.

Porter (1980) recommends that firms should focus on creating a highly differentiated product or service line and marketing program to project an image as an industry leader. Matsubayashi (2007) reports a result that contradicts Bertrand's price competition model. In addition to invariably increasing firm profit, differentiation also raises consumer welfare in quality-sensitive markets. Dutta, Lach, and Rustichini (1990) demonstrates that innovation leading to product differentiation and quality improvement is a key dimension of firm competition.

The Stanford Research Institute is the creator of the need, approach, benefits, and competition model (Fenwick, Daim, & Gerdsri, 2009) for developing, assessing, and presenting ideas. This model provides a systematic approach to understanding the value proposition of an original concept. The model enables innovators to present their ideas and simultaneously assesses the value of those ideas by using central parameters. The present study proposes the early-stage project selection NSDB model, which focuses on product and service differentiation. The definitions of the NSDB are as follows.

- **Need (N)** A need should exploit a market opportunity and fulfill customer requirements relating to market size. The market should be large enough to warrant investment in R&D. Market opportunity and market size are the two key criteria for this dimension.
- **Solution (S)** A solution must meet a client's specific needs. Development of the approach to solving a problem is incremental, and the solution changes iteratively until a full proposal or business plan emerges. This business plan may include market segmentation, customer targeting, market positioning, intellectual property (IP) protection, analysis of relevant costs, deliverables, and timescales. For a new product, the solution must contain information about problems relating to product specifications, manufacturing processes, distribution, and sales. IP protection, proposal quality, and value chain information are the key criteria for this dimension.
- **Benefits (B)** Each solution for each need generates unique client benefits, such as lower costs, better performance, or faster responses. To ensure business success, benefits should be quantifiable and should yield substantial improvements rather than simply differing from the benefits that competitors provide.
- **Differentiation (D)** The innovative elements of an idea can generate differentiated solutions that represent optimal value. Access to critical IP is generally a benchmark for attracting commercial customers. Clearly stating why a solution is far superior to competitors' solutions is key to business success.

3. Method: A hybrid MCDM method

The present study proposes a hybrid MCDM method comprising the MDM, DEMATEL method, and ANP. The MDM (Custer et al., 1999) refines and validates the criteria. Because criteria may affect each other, the DEMATEL method (Fontela & Gabus, 1976; Gabus & Fontela, 1973; Jeng, 2015) identifies the structure of interrelations between criteria. Finally, the ANP (Saaty, 1996) yields weights for each criterion.

Jeng and Bailey (2012) show that applying the DEMATEL-based ANP for determining criteria weights and evaluating performance yields a stable converged weighted supermatrix and determines overall priorities. Through a simplified data collection process, combining the DEMATEL and ANP resolves the issue of interdependence among

Table 1
Description of experts.

Organization	Code	Title
NRIs	NRI-1	Deputy Center Director
	NRI-2	Deputy Division Director
	NRI-3	Deputy Division Director
	NRI-4	Department Manager
	NRI-5	Project Manager
	NRI-6	Principle Investigator
	NRI-7	Principle Investigator
	NRI-8	Principle Investigator
	NRI-9	Principle Investigator
	NRI-10	Principle Investigator
For-profit organizations	PO-1	Chairman
	PO-2	CEO
	PO-3	General Manager
Academia	AC-1	Professor
	AC-2	Deputy Professor

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