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Technology-driven roadmaps for identifying new product/market opportunities: Use of text mining and quality function deployment

Gyungmi Jin, Yujin Jeong, Byungun Yoon *

Department of Industrial & Systems Engineering, Dongguk University, Pil-dong 3-ga, Jung-gu, Seoul 100-715, South Korea

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ABSTRACT

A technology roadmap (TRM), an approach that is applied to the development of an emerging technology to meet business goals, is one of the most frequently adopted tools to support the process of technology innovation. Although many studies have dealt with TRMs that are designed primarily for a market-driven technology planning process, a technology-driven TRM is far less researched than a market-driven one. Furthermore, approaches to a technology-driven roadmap using quantitative technological information have rarely been studied. Thus, the aim of this research is to propose a new methodological framework to identify both profitable markets and promising product concepts based on technology information. This study suggests two quality function deployment (QFD) matrices to draw up the TRM in order to find new business opportunities. A case study is presented to illustrate the proposed approach using patents on the solar-lighting devices, which is catching on as a high-tech way to prevent environmental pollution and reduce fuel costs.

1. Introduction

To compete with a market leader or to secure their positions, firms develop new technology and launch new products in the market. From a corporate standpoint, careful technology and product planning have been considered a continuing challenge in building profitable businesses. Several tools have been suggested to support the process of technology innovation by academic researchers as well as practitioners. The technology roadmap (TRM) is one of the most widely used methods to support the strategic management of technology [1–3]. The TRM method helps organizations plan their technologies by describing the path of technologies, products and markets.

When organizations plan their technologies, two basic strategies can be distinguished, which are often referred to as "technology-push" versus "market-pull" strategies [4,5]. The technology-push strategy is a strategy containing activities that focus on invention without concern for market attractiveness and applications of technologies to products, following capabilities that exist within firms or even the intuition of top managers [6]. In contrast, the market-pull strategy is oriented toward the marketing concept emphasizing the requirements of a targeted market. In both strategies, new products and services have to be accurately responsive to consumer demands [7]. Thus, the market-pull strategy, which reflects the needs of customers, has been considered the general strategy in product development.

Recently, the life cycle of technology has become shorter, and the level of technical complexity and difficulty has been increasing. As the length of time spent replacing existing technology with another technology is shortened, the market-pull strategy to develop products based on consumer reaction causes a delay of the product launch to the market. Moreover, an increase in technical complexity makes consumers ignorant, rendering most consumers unaware of what technologies can be realized. In addition, consumers have requirements that are only associated with existing products, rather than requirements on a latent product. The development of a new product through a market-driven strategy usually means product enhancements, making us overlook promising disruptive technology to meet the latent customer needs that did not exist before. Therefore, it is important to assess whether new technology can provide some benefits to customers as a product. Because the consumers themselves are often unaware of their needs, it has emerged as an important issue for companies to launch new products reflecting the consumers' hidden needs through the technology-push strategy.

As the market-pull strategy holds a dominant position in product development, a technology-driven TRM has been far less

* Corresponding author. Tel.: +82 2 2260 8659; fax: +82 2 2269 2212.
E-mail addresses: jingyungmi@gmail.com (G. Jin), withss501@naver.com (Y. Jeong), postman3@dongguk.edu (B. Yoon).

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studied than the market-driven one. Because TRM has evolved as a management practice, rather than management theory, most early research on TRM has dealt with case examples [8–10], and only a few studies have suggested practical methodologies for TRM [11,12]. From the perspective of a corporate strategy, previous studies have concentrated on technology roadmapping by applying a market-pull strategy [13–15], rather than a technology-driven one [16,17]. From the viewpoint of analysis, the roadmaps depend on qualitative analysis, such as workshop with domain experts and TRM experts [12]. Qualitative analysis is a methodology to prove an existing hypothesis or to configure a new theory based on field observations, conversations and questions. This method requires a lot of time and high costs to investigate the current situation, and it is highly dependent on the judgment of experts. As quantitative analysis involves analyzing the data indicated in the figures, it is easy to ensure objectivity because of the numerical criteria for judgment. In addition, most of the studies on technology-driven roadmaps investigate indirect relationships, such as technology-industry maps, actor-similarity maps and portfolio-affinity maps [17]. Recently, there are attempts to develop the technology roadmap by using QFD [14], the Bayesian network [18], text mining and patent analysis [17,19].

Therefore, the aim of this study is to offer a new methodological framework to identify both profitable markets and promising product concepts with existing technology using quantitative analysis. The concept of technology-driven TRM is addressed on the basis of the assumption that a specific technology has been developed. Patent information is used for analysis by text mining that uncovers the wealth of information from the literature to compensate for the fact that the early studies used qualitative analysis. While patents are used to analyze technologies, product manuals are collected to investigate the products, and market reports are applied to scrutinize markets. This study suggests two quality function deployment (QFD) matrices to link between each layer to draw up a technology-driven TRM that starts with a given technology that has been developed as a method to find new business opportunities. When a new technology is developed in the firm, it is placed in the technology layer. Next, a product layer is created by the technology layer based on technological information, and then a market layer is drawn up by the derived product layer. Through the results of an interpretation of the identified product opportunities, a promising market can be found in which the firm has the possibility to earn money. Although the proposed approach serves as a new, valuable method for exploring new opportunities for new products and markets by systematically analyzing current technology and their relationship in advance, it is not regarded as a panacea for all issues related to business strategies. Because this method will depend on the relationship among existing technologies, products and markets, the scope of relevant technologies to which it can be applied is restricted to technological areas where past information is sufficient to anticipate future trends of technology/product/market development. In addition, the suggested process is not an expert-free approach because it includes semi-automatic techniques, such as text mining and QFD. Although many users want to utilize an automatic system that produces useful outputs without domain knowledge of experts, the involvement of experts is mandatory for valuable information to draw roadmaps.

The basics of TRM and patent analysis are briefly reviewed in Section 2. Section 3 presents the method for TRM by using reversed QFD targeted at obtaining the relationship between technologies and products, and between products and markets, as well as the method for mapping on the TRM. An illustration is presented in Section 4, and Section 5 summarizes the contributions of this study and discusses their implications. The limitations of this study and the directions for future research are also discussed in this section.

2. Background

2.1. Technology roadmap

Along with the rapid development of technology, the role of technology planning is becoming increasingly important. The appropriate use of these techniques and methodologies significantly contributes to improving the productivity of a company. The technology roadmap, Delphi, scenario, analytic hierarchy process (AHP) and quality function deployment (QFD) are known as techniques and methodologies for technology planning [20]. The technology roadmap is broadly used for planning technology, products and markets because it gives action plans for achieving the goals. It also serves as a tool for technology forecasting in that the technology roadmap provides ample information related to diverse technology alternatives, competitors and timing for entering a market in the future through analyzing current technological specification and customer requirements, comparing their advances to the current status of technology development.

The technology roadmap is defined as a medium- and long-term technology planning methodology to derive products and technologies that need to be developed to meet the future demand and to select the best alternative technologies based on the future market forecasts. In other words, the technology roadmap is one of the methods to support the strategic management of technology, exploring the relationships among organizational goals, technical resources held by the organization and changing market opportunities. With these technology roadmaps, technology planning is promoted to establish details of the related project. The technology roadmap can support a process to understand the core technology and technology gap with the performance target and provide a means to reconcile R&D investment decisions by coordinating research activities among the relevant members [21]. In particular, because in the manufacturing sector, equipment supplier selection can influence technology planning, a new technology roadmap was proposed to reflect the cooperation with suppliers [22].

The technology roadmap approach is very flexible in terms of the different organizational aims that roadmaps intend to address and the range of graphical forms that roadmaps can take. In terms of the intended purpose, eight types of roadmaps have been identified: product planning [23], service/capability planning [24], strategic planning, long-range planning [25,26], knowledge asset planning [27], program planning, process planning and integration planning [28]. Furthermore, eight types of roadmaps have been identified relating to graphical format: multiple layers [29], bars [30], tables [31], graphs [31], pictorial representations [32], flow charts [33], single layer [30] and text [34]. The most frequently used technology roadmap is basically a time-based graphical chart that has several layers, such as the technology layer, product layer and market layer. Recently, a bibliometric analysis is applied to enhance the role of the technology roadmap by mapping the knowledge evolution and expert networks [35,36].

2.2. Patent analysis

Patent documents contain important research results that are valuable to the industry, business, law and policy-making communities. If carefully analyzed, they can show technological details and relations, reveal business trends, inspire novel industrial solutions or help make investment policies [37–39]. In addition, patents are used to search and assess external technical knowledge, accumulating technological knowledge. Recently, numerous studies of patents focus on patent information analyses to determine the value of patents [40,41].

In general, patent information comprehensively covers all information arising from the moment when an applicant submits