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Development of the scenario-based technology roadmap considering layer heterogeneity: An approach using CIA and AHP☆

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ABSTRACT

Scenario-based roadmapping has been considered as an effective means to deal with the dynamics of business environments. However, previous research on the scenario-based roadmap has commonly employed a single methodology to develop technology roadmaps, even if the characteristics of layers in technology roadmaps are different. The market planning deals with 'external scenarios' which are uncontrollable, whereas the product and technology planning is associated with 'internal scenarios' which are controllable. The former is related to the analysis and evaluation, whereas the latter is associated with strategic decision-making. This leads to the important implication that we have to consider two different perspectives of planning and have to utilize two different methodologies. In response, this paper employs an approach using cross impact analysis (CIA) and the analytical hierarchy process (AHP) as a tool for scenario-based roadmapping. CIA is employed for roadmapping the market layer due to its ability to measure the impact of the external environment, whereas AHP is employed to roadmap the technology and product layers, due to its characteristics of decision-making process. To illustrate the working of proposed approach, a case study was conducted for the u-healthcare services.

1. Introduction

Today, the business environment has become fierce, volatile, and dynamic due to rapid technological innovation and the increasing bargaining power of customers. For this reason, uncertainty and flexibility are two important issues: the former as a motivation, and the latter as a solution. This is especially important in long-term planning, typically with a ten-year timeframe (Phaal and Muller, 2009).

To deal with uncertainty, what has been vigorously discussed is the use of 'scenarios.' Scenarios are defined as hypothetical sequences of events, through which possible future developments are made visible (Gausemeier et al., 1998). Therefore, scenario planning has been utilized as an effective means to deal with the dynamics of business environments (Chermack, 2005; Godet, 1987; Postma and Liebl, 2005). Quite naturally, scenarios have also taken a front seat in the development of the technology roadmap (TRM) which has been discussed as a prominent strategic planning tool.

There exists a broad spectrum of literature to study the integration of scenarios and technology roadmapping, which can be summarized from two different perspectives. The first category deals with multi-path roadmapping, representing various scenarios in a single roadmap (Postma and Liebl, 2005; Strauss and Radnor, 2004; Gerdsri and Kocaoglu, 2003; Gerdsri and Kocaoglu, 2007a; Robinson and Propp, 2008). The second category is related to the methodological approach to reflecting on the impact of scenarios on the technology planning (Chermack, 2004; He et al., 2005; Lee et al., 2010). This research employs a probabilistic approach, such as the Bayesian network (Lee et al., 2010), a simulation approach such as system dynamics (He et al., 2005), and a decision making approach (Chermack, 2004) such as the analytic hierarchy process (AHP) (Martin and Daim, 2012).

However, previous studies on TRMs have employed a single methodology to develop the TRMs. However, layers of the TRM, known as the market, product, and technology layers, clearly have different characteristics. First, the market layer, the top layer, is related to the changes in market trends, customer needs, and innovation drivers (Phaal and Muller, 2009). This means that scenarios in the market layer are a given problem, which is an uncontrollable factor. However, the characteristics of the other layers are quite different. The middle and bottom layers, the product layer and the technology layer (sometimes including a service layer), represent the product functions, product features and product performance that firms want to develop (Phaal and Muller, 2009). Therefore, these layers are related to the internal decision-making,

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i.e. what kinds of products we have to consider, and what kinds of technology we have to develop. Therefore, a scenario in the product layer and the technology layer is a decisive problem, which is controllable factor in the firm.

This is also found in the previous literatures. Phaal et al. (2005) mentioned that the top layer of the roadmap is concerned with know-why, together with factors influencing the purpose of firms, which are trends and drivers. They also mentioned that the market layer includes both external and internal perspectives, which are market and business. Yoon et al. (2008) mentioned that roadmapping processes identify product or technology functions that can satisfy market needs, which means that product or technology layers are decisive but the market layer is predictive factor. In many studies, the development of market layer has been discussed with the market identification, i.e. market evaluation (Ibarra et al., 2008; Ibarra et al., 2014; Jin et al., 2015).

However, despite the fact, many studies on technology roadmapping have employed a single methodology. Methodological approach to the technology roadmapping can be summarized from two different perspectives: decision making approach such as linking grid (Geum et al., 2011), QFD (An et al., 2008; Geum et al., 2011; Jin et al., 2015), and AHP (Gerdsri and Kocaoglu, 2007b; Martin and Daim, 2012), and prediction approach such as system dynamics (Geum et al., 2011), cross-impact analysis (Pagani, 2009), and Bayesian network approach (Suharto, 2013). However, what is required in the market layer is the evaluation of the external environment, whereas what is needed in the product/technology layer is the selection of internal strategy. Therefore, different methodologies are required to develop scenario-based TRMs.

In response, this paper focused on the needs for the differentiated methodologies to develop scenario-based TRMs. Therefore, this paper applies different methodology for each layer of the TRM: the cross-impact analysis (CIA) for the market layer and the analytical hierarchy process (AHP) for the remaining layers. CIA and AHP fit the purpose of scenario-based planning for the following reasons.

First, CIA is a practical method for scenario planning (Weimer-Jehle, 2006), specifically for forecasting the emergence of new events and identifying the interrelations between events (Sarin, 1978; Weimer-Jehle, 2006). The essence of CIA lies in the determination of the likelihood of future events and the forecasting of future events based on probabilistic calculation (Sarin, 1978). For this reason, CIA is appropriate for the measurement of the market layer of a scenario-based roadmap. Market changes, with their unpredictable characteristics, are not to be decided, but to be predicted and evaluated. In particular, under the complex circumstances of multiple scenarios, CIA plays a key role in measuring the impact of several scenarios, assessing the occurrence probability of each event. Therefore, the use of CIA can contribute to the planning of the market layer of the TRM.

Second, the use of AHP fits the purpose of planning the technology and product layers. Following on market (or environmental) planning, firms now decide what products to develop and how to develop them (Phaal et al., 2004b). Therefore, this is a matter of multi-criteria decision making, in which AHP plays a key role. AHP has been actively employed for product selection or technology selection, considering firms' internal and external circumstances (Chen et al., 2006; Banuls and Salmeron, 2008). Considering many relevant decision criteria, AHP works as a prominent decision-making tool for developing product/technology layers of the TRM.

The remainder of this paper is organized as follows. Literature review deals with both the theoretical and methodological background of this paper. Proposed approach describes the concept of our approach. The structure and procedures are provided in detail. Illustrative examples are provided to illustrate the working of the proposed approach. A summary and the limitations of this study are given in the Conclusion.

2. Literature review

2.1. Scenario planning

The term 'scenario' originates from Kahn and Wiener (1967) introduction of 'future-now' thinking. Since then, scenario planning has been defined in several ways and many different definitions are suggested regarding scenario planning. Schwartz (1991) defined scenarios as "a tool for ordering one's perceptions about alternative future environments in which one's decisions might be played out." Schoemaker (1995) offered the following definition of scenario planning: "A disciplined methodology for imagining possible futures in which organizational decisions may be played out." In general, scenarios are defined as hypothetical sequences of events, through which possible future developments are made visible (Gausemeier et al., 1998). Scenarios were used primarily by enterprises operating in unstable political and social environments and that took 'long-term views' as a basis for their planning (Gausemeier et al., 1998).

To conduct scenario planning, an important question arises: how we can develop a good scenario? Many studies have attempted to answer this question. Van der Heijden (1997) developed the six features of well-written scenarios. In terms of the comprehensive and fundamental view, Chermack (2005) provided a scenario-planning approach based on Dubin (1978)'s eight-step theory building. As quantitative approaches to the scenario planning, structural algorithms and mathematical modeling of operational research/management science (OR/MS) were applied to scenario planning by Amara and Lipinski (1983). The integrative approach of intuitive and quantitative techniques was also proposed by Millett and Randles (1986), creating procedural scenarios.

2.2. The use of the TRM for scenario planning

Among the many techniques for scenario-planning, the TRM has occupied the front seat. TRMs are prominent tools for the strategic planning of R&D activities (Kostoff and Schaller, 2001; Lee and Park, 2005; Lee et al., 2007; Phaal et al., 2004b; Phaal et al., 2006; Rinne, 2004). The use of a TRM was first introduced in Motorola in the 1980s and has since been extended to many industries. The main purpose of TRMs lies in the strategic planning for products or technologies, as well as in forecasting technological or market trends. TRMs helps organizations plan their technologies by describing a path to integrate a given technology into products and services (Caetano and Amaral, 2011). The TRM is composed of two-dimensional structures, making the horizontal axis the timeline and the vertical axis the layered structure of the market, product, technologies, and R&D, as shown in Fig. 1. It provides a graphical means for exploring and communicating relationships between markets, products, and technologies over time (McCarthy et al., 2001; Phaal et al., 2003; Lee and Park, 2005; Geum et al., 2011).

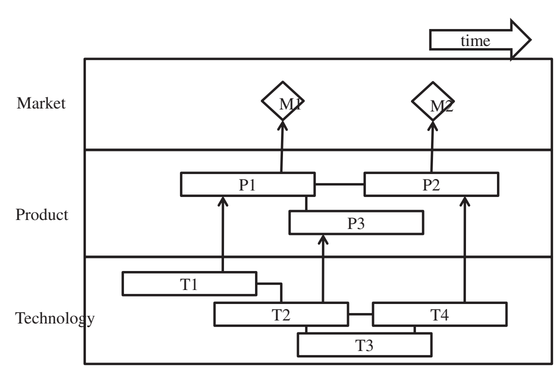

Fig. 1. Technology roadmap.