Technology Sourcing Evaluation of an Advanced Technology Industry: Taiwan’s Contactless Smart Card

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Abstract

This study uses the analytic hierarchy process method to evaluate technology sourcing modes. With the proposed evaluation process, the suggested technology sourcing mode is suited for advanced contactless smart card technology in Taiwan. The results imply that the proposed method is effective for developing technology sourcing strategies for advanced transportation systems.

Keywords: Analytic hierarchy process, technology sourcing, contact-less smart card, advanced transportation systems

1. Introduction

This research examines the impact of technology sourcing of the advanced transportation technology industry. There has been growing interest in the technology sourcing issue over the course of the last decade (Vanhaverbeke et al., 2002; Tidd et al., 2001). Commensurate with this trend, firms have become more attentive and scrupulous in their management of the technological process. Furthermore, recent research indicates that technology-related issues have attracted more incentives than market-related motivations (Florida, 1997; Tidd et al., 2001).

The extant literature is suffering from benign neglect as far as understanding technology sourcing with respect to advanced transportation technology firms is concerned. A five-year nationwide guideline of Taiwan, “Challenge 2008- National Development Plan”, has selected the smart card technology industry to be one of the critical strategic industries for Taiwan’s government and corporations to develop (MOTC, 2004). The smart card industrial development has relations with the efforts of innovation which is mainly knowledge-based (M’Chirgui, 2005). It can be said that it is a kind of representative of the fast-moving high tech industry. As the resource is becoming limited, the evaluation of appropriate technology sourcing with higher growth potential in contactless smart card technology becomes a critical issue for Taiwan government and the firms.

This paper regards technology sourcing as a process in which a firm obtains the technologies it requires through either an internal or external channel. Its modes include licensing, joint development, and in-house R&D, among others (Alguir et al., 1994; Handfield et al., 1999; Croom, 2001; Zhao et al., 2005; Schiele, 2006; Slowinski et al., 2006). As the number of technological interrelationships continue to multiply at an exponential rate, the
technology sourcing problem becomes ever more critical to many firms. However, given that this responsibility usually devolves to less senior management, a lack of rigorous decision-making becomes generally prevalent.

To solve this complex situation, this research successfully adopts an observational methodology in order to highlight the sourcing of technological knowledge. The proposed analytic hierarchy process (AHP) method can define a structured technique to execute the decision-making process (Bertolini et al., 2006). Therefore, we use it as a decision support tool for technology sourcing.

In this research, the process of technology sourcing in advanced transportation technology firms is analyzed in detail. Before demonstrating the research results, the effects of the technology sourcing will be discussed with reference to the prior work on development and factors exerting the greatest influence on technology sourcing. Then the content of the AHP method is discussed in Section 3. Section 4 describes the research design. The conclusions are described in the last section.

2. Literature review

2.1 Impact of technology sourcing

The importance of technology sourcing for firms is highlighted by the results of prior work relating to different countries and industries. In addition to internal R&D, the technology sourcing via multiple channels turns into an important element for many companies (Zhao et al., 2005). Hemmert (2004) analyzed the effects of internationalization on the technology sourcing of pharmaceutical and semiconductor business units in Germany and Japan. The study concluded that the internationalization of internal technology sourcing facilitates the development of these business units. Beard and Easingwood (1996) explored the effect of innovatory product development. They found that for revolutionary innovations, managers tend to emphasize the technological components of the products and concentrate the influential attribute on technological maturity. Figueroa and Conceicao (2000) explored a model to foster and sustain innovation in a large corporation. According to their research, the effectiveness of technology sourcing is enhanced by communication, which offsets the effects of isolation and bureaucracy. Huisman and Kort (2004) indicated the strategic adoption of technology, where the future availability of superior technology becomes a decisive factor in the management of a firm’s investment portfolio.

2.2 Influential factors of technology sourcing

There are many possible influential factors germane to technology sourcing. In this vein, Vanhaverbeke et al. (2002) demonstrated the choice between innovation-related alliances and acquisitions. Their chief finding was that interrelatedness might be the critical factor for technology sourcing. Gagnon and Sheu (2000) endeavored to assist technology researchers and managers in making more accurate decisions about advanced technology sourcing. According to them, the critical factor is corporate strategy. Belderbos (2001) explored the patent and overseas subsidiary data of 231 large and medium-sized Japanese electronics firms to ascertain the characteristics and determinants of foreign research and development activities. Firm size emerged as the crucial variable, whereas Malik (2002) utilized a conceptual model for intra-firm technology transfer that identified market attributes. Cantwell and Vertova (2004) showed that the historical evolution of technological differentiation presumed a constitutive role for technological interrelatedness.

The importance of selecting competent suppliers should not be underestimated (Golfetto and Gibbert, 2006). For our purposes, it can be said that there are five technology sourcing modes frequently used in Taiwan, each of which may be briefly adumbrated here: internal
R&D, licensing, joint development, minority equity, and joint venture. Internal R&D produces firm-specific knowledge, which enables the firm to absorb external technology. Licensing is the acquisition of a license for the use of a specific technology. Joint development references the acquisition of needed technologies with an external firm (Slowinski et al., 2006). Minority equity concerns the acquisition of minority equity shares by the company where the technology of interest is embedded. A joint venture is the creation of a new company from a number of others with a definite technological objective (Cagliano et al., 2000).

As the contactless smart card becomes more popular, the evaluation of technology sourcing modes becomes a critical issue for Taiwan’s high-tech industry. Based on the above assessed references, the need to develop such a process is obvious. We have now understood the problems and this research proposes an efficient approach to solve it. It is discussed in the following sections.

3. The Analytic Hierarchy Process (AHP) model

The AHP model is a powerful methodology used in the analysis of rational decision-making. Its chief virtue has to do with how it allows researchers to simplify a multi-criteria problem (Saaty and Vargas, 2001) entailing prioritization of alternative solutions from pooled expert opinions. This is done by a series of pairwise comparisons. This model has numerous merits including applicability in the elicitation of utility functions, built-in consistency tests, utilization of proper measurement scales and precise specification of judgment. Numerous applications of AHP have been made, ranging from organizational planning to resource allocation (Saaty and Vargas, 1991; Shang and Sueyoshi, 1995; Kagazyo et al., 1997; Lai et al., 1999; Liberatore and Stylianou, 1994; Kengpol and O’Brien, 2001; Ngai, 2003; Wang et al., 2004). This model assists evaluators in arriving at qualitative, systematic decisions by establishing the interaction and hierarchy of factors, thus minimizing the danger of rough estimations. Besides, the computational complex of the AHP method is low. It is a succinct and appropriate method in contrast with other operational research methods (Lai et al., 1999; Yedla and Shrestha, 2003; Bertolini et al., 2006; Chou and Cheng, 2006). On account of the hierarchical structure of decision-making process of technology sourcing, we utilize AHP for evaluating the technology sourcing modes for advanced technologies (such as the contactless smart card) in Taiwan.

AHP usually involves three stages: representation of the objective, comparative judgment of hierarchical elements, and synthesis of priorities (Saaty, 1990). The first stage utilizes the construction of a hierarchical network to represent the problem, with the top representing the overall objective, the middle representing the criteria, and the bottom representing the alternative available decisions. This research aims to evaluate the compatibility of various technological sourcing modes with an advanced transport technology. As such, the primary objective, “selection of technology sourcing mode for the contactless smart card”, is placed at the top level of the hierarchical tree, as shown in Figure 1. The second step identifies the critical evaluation criteria. Eight criteria were selected after industrial experts were interviewed. They are: government policy, market competition, technology level, firm size, technological capability, new product strategy, technology relevance, and maturity of technology. These were then arranged into three dimensions: (a) external environment, (b) internal environment, (c) technological characteristics. The cost factor is excluded owing to the fixed budgets underwriting the technology sourcing strategies of the targeted firms. This situation usually reflects the common difficulty of small-and-medium enterprises (SME) in Taiwan. Finally, the five technology sourcing modes, drawn from interviews with the aforementioned experts, were placed on the bottom layer of the hierarchical tree. These modes
are joint venture, exclusive license, minority equity investment, joint development and internal R&D.

After the hierarchical tree is established, the next step is to develop a corresponding questionnaire which is distributed to experts for conducting the process of evaluation. The experts were asked to compare the factors at the same level in pairs and measure their comparative contribution to the primary objective. A comparison matrix was constructed in the questionnaire to facilitate the comparison. A scale of values ranging from 1 to 9 was utilized to obtain expert’s preferences and opinions. This pairwise comparison allowed the analyst to evaluate the contribution of each factor to the objective independently, thereby simplifying the decision-making process. Eight criteria were identified and compared in pairs to measure their impacts on the objective. The five alternatives were then compared in pairs to measure their importance under each criterion.

In the final stage, synthesis of priorities was performed to calculate a composite weight for each alternative, based on preferences obtained from the comparison matrix. Following the calculation of the composite weight, we obtained the relative priority of the technology sourcing modes for the contactless smart card industry.

![Figure 1. The proposed AHP model.](image-url)

4. Research design

4.1 Survey design

A survey was conducted to determine how the experts perceived the relative importance of the evaluation criteria and the technology sourcing modes. A questionnaire was developed on the basis of the analytic hierarchy shown in Figure 1. Government policy considers the extent to which a policy aims to attract and develop technology sourcing. Market competition focuses on the future competitive growth of the contactless smart card industry. Technology level reflects the technological capabilities possessed domestically. Firm size refers to the amount of assets and labor utilized for development of specific technologies. Technological
capability captures the extent of technological aptitude possessed by internal staff, which can in turn be harnessed by the firm. New product strategy describes the product policy applied to specific technologies. Technological maturity benchmarks the extent of progressive development, whilst technology relevance contextualizes local technologies in relation to advanced technologies.

Each question consisted of a pairwise comparison of two elements at the same level in the hierarchy. As such, the eight criteria resulted in a total of 28 questions. For each, the respondents were asked to indicate the relative importance of the two criteria with respect to the objective. The respondents were then asked to compare the technology sourcing modes with respect to each criterion. There are five technology sourcing modes for the eight criteria, resulting in a total of 90 questions.

4.2 Data collection and analysis

The respondents included industry analysts and researchers experienced in the development of the contactless smart card and technology sourcing modes in Taiwan. Industry analysts and researchers were associated with research institutes and transport technology firms. Five experts were first interviewed in order to formulate the hierarchy with the evaluation criteria and the alternative technology sourcing modes. They are two college professors and three corporate directors. Forty questionnaires were next sent to the targeted experts and 20 usable responses from 14 firms were received. The average size of these firms was about 800 employees. Those effective samples include 13 senior administrators/managers and 7 engineers. The firms contain electronic corporations, mass rapid transit and high speed rail corporations. A script was included to ensure consistency and eliminate any biases inadvertently caused by the phrasing of the questions. The analytic hierarchy process was programmed using ExpertChoice 2000 software, a decision support system that is designed to assist the process. We first calculated the geometric means of the marked responses in each question from each of the survey respondents. Then the comparison matrix was entered into ExpertChoice 2000 to produce local weights at each level of the hierarchy. These were then combined by an additive value model to produce a set of global weights or priorities for the alternatives.

4.3 Contactless smart card and advanced transportation systems

The contactless smart card is usually a small plastic card featuring embedded computer chips. It provides greater amounts of memory compared to older generation electronic cards and is able to support multiple applications. It is convenient for users who simply have to present their cards near a reader (Davis, 2007). Advanced transportation systems are the systems that utilize advanced technologies to make the movements of people and cargos more efficient and economical. The contactless smart card has been developed in Taiwan for several years now. This kind of advanced transportation technology is also a representative of the fast-moving innovative technology (M’Chirgui, 2005). However, the development of key components of the contactless smart cards is usually dominated by foreign firms. If they are to successfully compete, Taiwanese firms will have to acquire relevant technological knowledge through technology sourcing.

5. Results and discussion

5.1 Comparison of the evaluation criteria

We first examined the criteria by evaluating the importance of each criterion with respect to the selection of technology sourcing. In keeping with the analytic hierarchy methodology, pairwise comparisons were performed to clarify the relative importance of the factors. Table 1
shows the pairwise comparison matrix for the evaluation dimensions with the objective. The normalized weights and the rank for the dimensions are given in the last two columns, respectively. It shows that external environment is the highest ranked dimension to achieve the objective of selecting technology sourcing mode. On the other hand, criteria associated with technology characteristics are the least important with respect to the objective.

The results in Table 2 indicate that the criterion of government policy has the highest weight of 0.247, followed by the criterion of market competition, which recorded 0.199. From these figures it is clear that, besides technology level, government policy and market competition are the most critical factors to be considered in the adoption of technology sourcing modes for the advanced transportation technology industries.

Table 1. Pairwise comparison of dimensions with respect to objective.

<table>
<thead>
<tr>
<th>Relative importance</th>
<th>Pairwise comparisons</th>
<th>Weight</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>External environment</td>
<td>Internal environment</td>
<td>Technological characteristics</td>
</tr>
<tr>
<td>External environment</td>
<td>1.000</td>
<td>3.500</td>
<td>2.500</td>
</tr>
<tr>
<td>Internal environment</td>
<td>1.000</td>
<td>1.350</td>
<td>0.211</td>
</tr>
<tr>
<td>Technological characteristics</td>
<td>1.000</td>
<td>1.000</td>
<td>0.193</td>
</tr>
</tbody>
</table>

Maturity of technology and technology relevance are equivalent to the secondary level of factors, based on the comparison results in Table 2. When a transport technology industry attains an appropriate level, with the encouragement of government policies, these two criteria become tactical issues for the adoption of any specific technology sourcing mode. New product strategy and technological capability are comparatively less important.

5.2 Comparisons of the technology sourcing modes with respect to the criteria

We conducted pairwise comparisons on the alternative technology sourcing modes with respect to each criterion. Table 2 shows a summary of the normalized relative weights for the five technology sourcing modes with respect to the eight criteria. The last two columns express the overall weights for the five technology sourcing modes and their ranks, respectively.

The mode of exclusive license has the highest weight of 0.254, followed by the joint venture with a weight of 0.247. The remaining technology sourcing modes, ranked in order of their decreasing importance, are joint development, minority equity investment and internal R&D. This is primarily due to the non-equity attribute of exclusive license compared to the equity-based joint venture. Indeed, from a “transaction cost” viewpoint, exclusive license might require the lowest cost over other equity-based technology sourcing modes. The internal R&D had the lowest weight which is most likely due to the lack of R&D resources in current practice.

These findings portray the future directions of the development of technology sourcing modes in Taiwan. The joint development has been the strategic development priority for the past years. Recently, the Taiwanese industry has shifted its attention to other modes of technology sourcing, such as exclusive licensing and joint ventures.

The higher scores associated with exclusive licensing suggest its likelihood as the technology sourcing mode most likely to be adopted by the contactless smart card firms. According to the non-equity attribute of licensing, the medium-sized advanced transportation technology firms in Taiwan theoretically prefer licensing to other technology sourcing modes due to their limited resources. Steensma and Corley (2000) stated that licensing reduces financial exposure and accesses proven technology rapidly. The results from the AHP model thereby support the theoretical analysis.
Table 2. Overall results of comparative study.

<table>
<thead>
<tr>
<th>Technology Sourcing mode</th>
<th>Criteria</th>
<th>Weight Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Government policy (0.247)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Market competition (0.199)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Technology level (0.142)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Firm size (0.072)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Technology capability (0.070)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>New product strategy (0.069)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Technology relevance (0.100)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maturity of Technology (0.101)</td>
<td></td>
</tr>
<tr>
<td>Joint venture</td>
<td>0.269</td>
<td>0.240</td>
</tr>
<tr>
<td>Exclusive license</td>
<td>0.272</td>
<td>0.227</td>
</tr>
<tr>
<td>Minority equity investment</td>
<td>0.119</td>
<td>0.159</td>
</tr>
<tr>
<td>Joint development</td>
<td>0.198</td>
<td>0.238</td>
</tr>
<tr>
<td>Internal R&amp;D</td>
<td>0.142</td>
<td>0.136</td>
</tr>
<tr>
<td>Total</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

5.3 Suitability of the AHP method as a decision tool

The suitability of the AHP method as a technology sourcing decision tool can be attributed to several factors. The technology sourcing process of the advanced transportation technology is complicated and multi-criteria oriented. This inherent characteristic is compatible with the strength of the AHP method. The AHP model is a powerful analytical methodology for rational decision-making, thanks to its simplification of multi-criteria problems. It also reduces the danger of unsystematic, inaccurate estimations. One limitation of this method is that it takes much time to make the pair-wise comparisons. In addition, too many levels of hierarchy would induce an inconvenient use of this method. Except for those limitations, it is believed that the AHP method would be an appropriate tool for sourcing decisions.

The proposed AHP method can define a structured technique to execute the decision-making process (Bertolini et al., 2006). Therefore, it is suitable for research and for companies to use it as a decision support tool for technology sourcing.

6. Conclusions

This research explored the appropriate technology sourcing process of Taiwanese advanced transportation technology firms. A 3-stage hierarchical analysis was employed to evaluate five alternative forms of technology sourcing with respect to numerous expert criteria. The proposed AHP model has proven to be a useful tool in dealing with technological management concerns for advanced transportation technology firms. It improves the multi-criteria and complicated technology sourcing evaluation process and helps the firms adequately come to terms with the problems inherent to technological analysis.

In this study, we have demonstrated the evaluation process best suited to technology sourcing decision-making in Taiwan’s advanced transportation technology firms. Further research in this area might benefit from the integration of stakeholders and expert groups. Hence any potential wider applicability of the process awaits vindication in future studies.
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