The Research on Evaluation of Technological Innovation Capability Based on ANP

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Abstract Technological innovation is a key ingredient in building high performance organizations and the proper evaluation of technological innovation capability (TIC) is very important for decision makers. The objective of this paper is to introduce an analytical network process (ANP) model for technological innovation capability evaluation. This paper reports an application of proposed methodology as a case study related to large and medium-sized industrial enterprises in China. The analysis aims at proper evaluation and improvement of TIC for enterprise or region.

Key words ANP, Technological innovation, TIC

1 Introduction

In recent years, there has been a growing appreciation, amongst academics and policy-makers, of the importance of technological innovation capability to the competitive advantage of enterprise or national economies. This is especially true in the fast changing and complex environment that most organizations exist in today. The emergence of the knowledge economy and intense globalization has increased the role of technological innovation in the efforts of organizations to achieve sustainable competitive advantages. The ability to introduce new products and adopt new processes in shorter time has become an imperative competitive tool. This, in turn, has lead to a flurry of policy initiatives designed to encourage greater business experimentation either by relieving perceived barriers to innovation or by offering greater incentives. Such policy initiatives are likely to be most effective when they evolve from a clear understanding of the factors that are conducive to innovation activity and success [1].

2 Technological Innovation Capability And Evaluation Model

Technological innovation is one of the most widely talked about and researched concepts in organizational and popular literature. In the long run, it is technological innovation capability that forms a major source of competitive advantage [2]. Technological innovation is a concept that is sufficiently complex, multi-dimensional, and impossible to measure directly [3]. Technological innovation is a process that involves the interaction of many different resources. Successful technological innovation depends not only on technological capability, but also on other critical capabilities in the areas of manufacturing, marketing, organization, strategy planning, learning, and resources allocation. Thus, the capability of technological innovation of a firm is reflected by a variety of indicators that cannot be measured by any single-dimension scale [4].

2.1 The indicators for TIC evaluation

Many researchers have adopted several components or multiple dimensions to audit TIC of enterprises. Panda and Ramanathans classify technological capabilities into three major categories: namely (1) strategic capabilities that comprise creation, design and engineering, and construction capabilities, which are perhaps the most dynamic organizational knowledge capabilities given the pace of change in all organizations’ business environments; (2) tactical capabilities that consist of production, marketing and selling, and servicing capabilities; and (3) supplementary capabilities that consist of acquiring and supportive capabilities [5]. Lawson and Samson see innovation capability as a higher order integration capability, that is, the ability to mould and manage multiple capabilities and propose a mixed model comprising vision and strategy, harnessing the competence base, organizational
intelligence, creativity and idea management, organizational structures and systems, culture and climate, and management of technology [6]. Christensen [7] classified TIC into science research asset, process innovation asset, product innovation asset and esthetics design asset. These assets correlate with internal accumulation, experimental acquirement and disquisition. He commented that the combination of more than one of these assets is essential for the success of industrial innovation.

Technological innovation capability is a special asset of an enterprise, which comprises different key areas, such as technology, production, process, knowledge, experiences and organization. In general, a wide variety of assets, resources, and capabilities are required for the success of an innovation. Based on the approach mentioned above, we propose an innovation framework for evaluating technological innovation performance. The framework includes four capability dimensions, namely resource foundation; R&D capability; manufacturing capability; marketing capability, shown as Table 1. Resource foundation refers to whether an enterprise has sufficient professionals, capital and technologies in the innovation processes. R&D capability is an ability to integrate the resource and development new product or technology. Manufacturing capability refers to the ability to transform R&D results into products, which can meet market needs and design requirements. Marketing capability refers to the ability to publicize and sell products on the basis of understanding consumer needs, competition position, cost and benefit, and acceptance of innovation.

2.2 ANP model for TIC evaluation
2.2.1 ANP review

As defined by Saaty [8], the ANP is a general theory of relative measurement used to derive composite priority ratio scales from individual ratio scales that represent relative measurements of the influence of elements that interact with respect to control criteria. The ANP is a coupling of two parts: one is a control hierarchy or network of criteria and subcriteria that control the interactions (interdependencies and feedback); another is a network of influences among the nodes and clusters. Moreover, the control hierarchy is a hierarchy of criteria and subcriteria for which priorities are derived in the usual way with respect to the goal of the system being considered. The criteria are used to compare the components of a system, and the subcriteria are used to compare the elements of a component.

ANP is an attractive multi-criteria decision making tool because it allows for the consideration of interdependencies among and between levels of attributes. ANP does involve representing relationships hierarchically but does not require a strict hierarchical structure as does analytical hierarchy process (AHP). The ANP technique allows for more complex interrelationships among the decision levels and attributes. ANP models problems of systems in which the relationships between the levels are not easily represented as higher or lower, controlling and subordinate. These systems are known as "systems-with-feedback" and refer to systems where a level may both dominate and be dominated, directly or indirectly, by other decision attributes and levels.

2.2.2 The proposed model in TIC evaluation

According the below mentioned factors a model is developed by using ANP in TIC evaluation.
Table 1 Factors and Sub-factors for TIC Evaluation (Weight)

<table>
<thead>
<tr>
<th>Factors</th>
<th>Sub-factors</th>
<th>Quantitative description of sub-factors</th>
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</thead>
<tbody>
<tr>
<td>X1: Resource foundation (0.2858)</td>
<td>X11: Percentage of R&amp;D personal in a firm’s total employment (0.0910)</td>
<td>R&amp;D personal/total employment</td>
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<td></td>
<td>X12: Average number of technological transformation projects (0.0601)</td>
<td>Number of technological transformation projects/number of firms</td>
</tr>
<tr>
<td></td>
<td>X13: Number of firms having scientific and technological (S&amp;T) institutions (0.0624)</td>
<td>Number of scientific and technological institutions/number of firms</td>
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<tr>
<td></td>
<td>X14: Funding for S&amp;T activities (0.0723)</td>
<td>Total funding for S&amp;T activities/number of firms</td>
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<tr>
<td></td>
<td>X15: Expenditure on R&amp;D (0.0876)</td>
<td>Total expenditure on R&amp;D/number of firms</td>
</tr>
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<td></td>
<td>X16: Expenditures for indraft of technology (0.0520)</td>
<td>Total expenditure for indraft of technology/number of firms</td>
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<tr>
<td>X2: R&amp;D capability (0.2519)</td>
<td>X21: Expenditures for absorb and digest (0.0530)</td>
<td>Total expenditure for absorb and digest/number of firms</td>
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<td></td>
<td>X22: Full-time Equivalent of R&amp;D Personnel (0.0624)</td>
<td>Total time spent in R&amp;D activities/norm of working hour one R&amp;D person per year</td>
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<td></td>
<td>X23: Achievements in S&amp;T and national prizes won (0.0589)</td>
<td>Total achievements in S&amp;T and national prizes won/number of firms</td>
</tr>
<tr>
<td></td>
<td>X24: Average number patent applications certified (0.0621)</td>
<td>Total patent applications certified/number of firms</td>
</tr>
<tr>
<td></td>
<td>X25: Yield ratio of new product development (0.0867)</td>
<td>Selling profit of new product/expenditures on R&amp;D</td>
</tr>
<tr>
<td>X3: Output capability (0.2902)</td>
<td>X31: Content of new technology (0.0825)</td>
<td>Industrial output value of new product/gross industrial output value</td>
</tr>
<tr>
<td></td>
<td>X32: Percentage of new product sales to sales revenue (0.0915)</td>
<td>Sales of new product/sales revenue</td>
</tr>
<tr>
<td></td>
<td>X33: Transaction value in technical market (0.0806)</td>
<td>Total transaction value in technical market/number of firms</td>
</tr>
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</table>

• Several criteria and alternatives can be evaluated with the scope of the decision problem.
• Both objective and subjective factors can take into consideration in the decision problem.
• There exists an interaction between and within TIC evaluation criteria and alternatives.

Nodes of the network represent components of the evaluation system, a arc is used to show the interdependency relationships that occur within them. The directions of the arcs signify dependence, arcs emanate from an attribute to other attributes that may influence it. As it is shown in figure 1, X Y means that the elements of a component Y depends on component X. In order to build the decision problem, all interactions among the elements should be considered.

2.2.3 Determine the weight of ANP

(1) Establish the weights of factors

Decision elements regarding each factor are compared pairwise in terms of their importance for their control criterion, and the factors themselves are also compared pairwise with respect to their contribution to achieving the goal. The relative importance values are determined on a scale of 1 to 9, where a score of 1 indicates that the two elements have equal importance, while a score of 9 indicates extreme importance of one element (row component in the matrix) compared to the other (column component in the matrix) [9]. Then four matrixes of pairwise comparison are established, calculate the
largest eigenvalue of the four matrixes and adopt the consistency index (CI) and consistency ratio (CR) to verify the consistency of the comparison matrix. If CR is accepted, normalize the eigenvector and establish a $4 \times 4$ weighted matrix.

(2) Establish the weights of subfactors

Establish the weighted matrix of subfactor reference to factor, thus get a $14 \times 14$ supermatrix. The supermatrix is a partitioned matrix, in which each matrix segment denotes a relationship between two system nodes clusters.

(3) Establish the weighted supermatrix

The weighted supermatrix is the product of the weighted matrix in step 1 and the partitioned matrix in step 2, which reflects the influence and feedback among the factors and sub-factors.

(4) Determine the final weights of indicators

Solve the weighted supermatrix according to its attribute [10], thus get the weights of 14 indicators, shown as table 1.

3 Case Study

In the paper, we take the statistical data of large and medium-sized industrial enterprises as input, according to《China statistical yearbook》in 2006, evaluate and rank the technological innovation capability of enterprises in every province, autonomous region, and municipality directly under the central government, using TIC indicators and weights in table 1. The results are shown in table 2.
4 Conclusion

The ANP methodology has proven to be beneficial in considering both quantitative and qualitative characteristics which need to be considered, as well as taking non-linear interdependent relationships among the attributes into consideration. Eliciting information from the decision maker for the large number of pairwise comparisons can become tedious. Due to the time and effort required for a typical ANP process, an application of this framework should be targeted at more strategic decisions.

The quest for evaluating technological innovation capability of enterprises is a continuous task. The evaluation model presented in this paper is an attempt to aid decision makers in the complex task of prioritizing their options. The paper establishes indicators for TIC evaluation, and these indicators should be adjusted with the economy development. Further studies are therefore needed to investigate these issues.

References


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