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IDENTIFICATION AND PRIORITIZATION OF TECHNOLOGY INNOVATION CAPABILITY ON TECHNOLOGY INNOVATION PERFORMANCE

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ABSTRACT
In a knowledge-based economy, technological innovation capability is a key factor in upgrading a firm competitive capability. Improving TICs can be beneficial to a firm and leads to enhanced competitiveness. Researchers in the areas of sustainable competitive advantage have come to the conclusion that one of the critical things that give an organization a sustainable edge, is the development of Core Capabilities and - referring to innovation- Technological Innovation Capabilities. Many researchers have adopted several components or multiple dimensions to audit TIC of enterprises. A set of indicators reflects the performance of a firm's technological innovation activities. Four dimensions identified for technological innovation capability.
After reviewing the literature and extract the dimension of each TIP and TIC, the initial model were proposed. The aim was to understand the effectiveness of each dimension. In this study with overview of the major approaches of TIC, a new approach according to the point of view of various industries experts in Iran was presented. The relation between these dimensions was determined by using qualitative analysis. In this paper we focus on prioritizing the TIC and TIP dimensions. For this purpose to construct the model and prioritization of TIC & TIP dimensions, we use DEMATEL method (Decision Making Trial and Evaluation Laboratory).After analyzing data gathered, we found that from seven dimensions identified for TIC, three dimensions have more effect on the others. These three dimensions are strategic planning, resource allocation and organizing. On the other hand three dimensions of TIP are in effect group with this order: Innovation Performance, Sale Performance and Product Performance.

Keywords: *Technological Innovation Capability, Technological Innovation Performance, Competitiveness, DEMATEL method*

1. INTRODUCTION

In a knowledge-based economy, technological innovation capability is a key factor in upgrading a firm's competitive capabilities[1]. The two major issues facing the world economic system today are the globalization and the technological change. Both of them create and foreclose opportunities for the emerging countries to enhance their technological innovation capability (TIC) which is considered as the main driver of competitiveness and long-term economic development[2].

TIC is a special asset of an enterprise, which comprises different key areas[3]. They are a kind of special assets or resources that include technology, product, process, knowledge, experience and organization[4].

By technological capability, company can develop new technology, product, or process as a respond for economic change. Indeed, World Bank confirmed that technological capability is the source of company's competitiveness. In other words, technological capability is what firms need to be able to use technology for

strategic competitive advantage. The better a company's technological capability, the stronger will the company's competitiveness[5].

Most industry analysts agree that innovation is the key to successful competition .At the same time, researchers in the areas of sustainable competitive advantage have come to the conclusion that one of the critical things that give an organization a sustainable edge, is the development of Core Capabilities and -referring to innovation- Technological Innovation Capabilities[6].

Improving TICs can be beneficial to a firm and leads to enhanced competitiveness[7]. Technological innovation is a concept that is sufficiently complex, multi-dimensional, and impossible to measure directly[3]. 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[3].

According to Adler and Shenbar, four types of TICs are identified, including (1) the capability of satisfying market requirement by developing new products; (2) the capability of manufacturing these products by using appropriate process technology; (3) the capability of satisfying future needs by developing and introducing new products and new process technology, and; (4) the capability to respond to an unanticipated technology activity brought about by competitors and unforeseen circumstances. These capabilities exist in a firm and at corporate levels[7].

The question is that what is the component of TIC and which one is more important to growth up the organizational performance especially TIP.

2. LITERATURE REVIEW

Many researchers have adopted several components or multiple dimensions to audit TIC of enterprises. Panda and Ramanathan (1996) 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[3].Christensen (1995) classified TICs into science research asset, process innovation asset, product innovation asset and esthetics design asset[7].

Yan Rianto defined innovation as a development and successful implementation of new or improved product, service, technology, production process or management directed towards gaining a competitive advantage[5].

2.1 Technological Innovation Capability (TIC)

Technological innovation capability (TIC) is a comprehensive set of characteristics of an organization that facilities and supports its technological innovation strategies[4],[8],[9].

1) *Learning capability* is a firm's ability to identify, assimilate, and exploit knowledge from the environment.
2) *R&D capability* refers to a firm's ability to integrate R&D strategy, project implementation, project portfolio management, and R&D expenditure. Five items were employed to measure the R&D capability.
3) *Resources allocation capability* ensures that a firm has enough capital, professionals and technology in the innovation process.
4) *Manufacturing capability* refers to a firm's ability to transform R&D results into products, which meets market needs, accords with design request and can be manufactured in batches.
5) *Marketing capability* is a firm's ability to publicize and sell products on the basis of understanding consumer needs, competition situation, costs and benefits, and the acceptance of innovation.
6) *Organizing capability* refers to a firm's ability in securing organizational mechanism and harmony, cultivating organization culture, and adopting good management practices.
7) *Strategic planning capability* is a firm's ability to identify internal strengths and weaknesses and external opportunities and threats, formulate plans in accordance with corporate vision and missions, and acclimatize the plans to implementation[4],[2],[8],[7].

2.2 Technological Innovation Performance (TIP)

Innovation audits use both input and output indicators (e.g. R&D investment, and average patent numbers per year) to evaluate technological innovation performance of firms. Though the performance of the innovation in financial terms is always the best indicator, firms would not easily reveal any confidential financial information and different firms might adopt varied accounting conventions in their inventory valuation, depreciation, and

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salaries computation. Alternate measures have to be used to secure adequate responses. Those measures are widely adopted in different innovation studies; include innovation performance, sales performance, sale growth rate and product performance[8],[4].

A set of indicators reflects the performance of a firm's technological innovation activities.

1) *Innovation performance* is measured in terms of the number of commercialized new products expressed as a percentage of all products in the company over the last three years. According to the OSLO manual (OECD, 1997), the number of innovations alone is not a good indicator for innovation performance because there are significant differences in such numbers across industries. Innovation rate is a better measure as it shows the relative innovative strength of the firm. A firm's competitive advantage could come from the efficiency and capability of new product developments. The increase in product innovation is attributable to the accumulation of capabilities and contributed to innovation outputs. In most circumstances, high performance firms would have stronger capabilities as compared to low performance firms.
2) *Sales performance* is measured in terms of the sales amount due to technologically new or improved products as a percentage of total sales over the last three years.
3) *Sales growth* rate represents the dimension of a firm's market advantage. It shows whether the innovation has had market impact or been financially successfully. It is measured in terms of the average annual sales growth over the last three years.
4) *Product performance* is another dimension of the firm's market advantage. The product competitiveness is a portfolio concept encompassing various aspects, such as 81 average concept-to-launch time, programming product series, quality level, cost, analyzing market competitive intensity, market needs and growth potential, technology characteristics, product manufacturing process, and price/function advantage[8],[7].

3) METHODOLOGY

In this paper we focus on prioritizing the TIC and TIP dimensions. For this purpose to construct the model and prioritization of TIC & TIP dimensions, we use DEMATEL method(Decision Making Trial and Evaluation Laboratory).It is one of the methods to analyze complicated relationship between dimensions .DEMATEL method is to show cause-effect relationship with certain scores by using matrix operation. The other one is to grasp not only direct effect but also indirect effect. To analyze the model, TIC and TIP dimension and its factors were extracted from literature[10].

3.1 Proposed model

After reviewing the literature and extract the dimension of each TIP and TIC, according to expert opinion, extracted dimensions and factors were categories (as shown in fig. 1). Proposed model present the initially relationship between categorized dimension of technological Innovation Capability (TIC) and Technological Innovation Performance (TIP) dimensions. With DIMATEL method these initial relationships will be analyzed (figure 1).

The DEMATEL (Decision Making Trial and Evaluation Laboratory)

The DEMATEL method originated from the Geneva Research Centre of the Battelle Memorial Institute. The method is useful to help visualize the structure of complicated causal relationships through the use of matrices or digraphs. The matrices or digraphs portray relationships between systems components with strengths of relationships amongst these relationships quantitatively portrayed. The DEMATEL method assumes a system contains a set of components C= {C1,C2, . . .,Cn}, with pair wise relations that can be evaluated.

DEMATEL incorporates four generic stages:

1. Develop a pair wise direct-relation matrix between system components through evaluator or decision maker input.
2. Determine the initial influence matrix, through normalization of the direct-relation matrix.
3. Determine a total relation (influence) matrix.
4. Determine the cause/effect relationships (prominence-causal diagram) amongst the components and relative strengths[11].

STEP 1: Producing the direct-relation matrix

Firstly, for the purpose of measuring the relationship between criteria, it is required to design the comparison scale. Next, experts make sets of the pair wise comparisons in terms of influence and direction between criteria. Then, as the result of these evaluations, the initial data can be obtained as the direct-relation matrix that is a $n \times n$ matrix A, in which a_{ij} is denoted as the degree to which the criterion i affects the criterion j (Table 1).

STEP 2: Normalizing the direct-relation matrix

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On the base of the direct-relation matrix A, the normalized direct-relation matrix X can be obtained through the formulas (1) and (2) (Table2).

$$X = s \cdot A \tag{1}$$

$$s = \frac{1}{\max\limits_{1 \le i \le n} \sum\limits_{j=1}^{n} a_{ij}} \quad (i, j = 1, 2, ..., n) \tag{2}$$

STEP 3: Attaining the total-relation matrix

Once the normalized direct-relation matrix X is obtained, the total-relation matrix T can be acquired by using the formula (3), in which the I is denoted as the identity matrix (table 3).

$$T = X(I - X)^{-1} \tag{3}$$

STEP 4: Analyzing the results

In this step, the sum of rows and the sum of columns is separately denoted as D and R within the total-relation matrix T through the formulas (4), (5), and (6). Then, the horizontal axis (D+R) named "Prominence" is made by adding D to R, and that shows how much importance the criterion has. Similarly, the vertical axis (D-R) named "Relation" is made by subtracting D from R, that may divide criteria into cause group and effect group. Generally, when the D-R is plus, the criterion belongs to the cause group. Otherwise, if the D-R is minus, the criterion belongs to the effect group. Therefore, the causal diagram can be acquired by mapping the dataset of the (D+R , D-R), providing valuable insight for making decisions[12] (Table 4).

$$T = t_{ij} \quad (i, j = 1, 2, ..., n) \tag{4}$$

$$D = \sum_{j=1}^{n} t_{ij} \tag{5}$$

$$R = \sum_{i=1}^{n} t_{ij} \tag{6}$$

3 CONCLUSION

Today's, one of the key indicators of corporate success is innovation and technological innovation in particular. The business of knowledge and competitive age is the one which economy is based on updated knowledge. Updated means keep in cycle of competition with industry leader and the pioneer's level of competition. The motives that lead companies to his propose are technology and capabilities of technological innovation. Thus Technology innovation capability (TIC) is one of the main drivers of competitiveness and economic development in the long term.

In literature, various dimensions have been introduced TIC. According to a similar study done in China (Yam et al., 2004), the most influential factor on innovation performance is R&D capability. The most influential factor on sales growth is resources allocation capability. The most influential factor on product performance varies according to the size of the firm. For large firms, they are R&D capability and resources allocation capability. For medium-sized firms, they are R&D capability and strategic planning capability. For small firms, they are resources allocation capability and marketing capability.

William Lo Wai Lam, in his study found that different TIC has different impacts on different TIP measure except the learning capability, Resources allocation capability, manufacturing capability and organization capability have a positive relationship with sales performance. Organization capability has a positive relationship with innovation performance. R&D capability and strategic planning capability have positive relationship with product performance. Marketing capability has a positive relationship with sales growth. Although different TICs contribute to different TIPs, it can be concluded that all six TICs are needed to enhance the TIPs of a firm. He added that, learning capability is also needed .Learning capability is found to be correlated with all the other six TICs but no direct relationship with any TIP measure.

Based on the data in table 4 the first column depicts the influential factors and in the second column the affected level of each factor has been shown.

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The third column shows the sum of the factors influencing and affected, indicating the importance of standards. On the other hand, decision makers using the information in this table, can take the most appropriate decisions. The factors that are the most influential and affected are the most important factors in the improvement and change. By focusing on these factors can be achieved in the best possible results. In this study, three factors, strategic planning, R&D and marketing are the most important factors. With an overview of the research results can be found in Iran, like many countries, these three factors are very important.

Eventually, the last column- which depicts the subtraction of influential and affected factors- shows the sum of net operating effectiveness. The result of this table describes the most influential and the least affected and also the most affected and the least influential factor. Among the seven criteria for TIC, three criteria strategic planning, resource allocation and organization are the most influential and the least affected. Also according to the experts TIP's three factors that were considered as dependent and affected variables; product functionality is the most affected factor then so the sale performance and the innovation performance, respectively.

Based on the overall result assessed by the survey in Iran in order to achieve innovative performance, professionals believe that should pay special attention to the strategic planning, resource allocation and how to properly organize their companies.

On one hand the result of this survey and the explaining of the impact model test on the other hand, by Questionnaire design and development of the statistical community Using factor analysis and path analysis the results obtained will be developed and their comprehensiveness will be considered too.

One of the important limitations of this research is the access to experts who have studied in the TIC. The study is proposed to be placed in one of the leading organizations in Iran which have high potential of technological innovation and to be used by modeling and simulation of dynamic systems in order to examine the results of this method.

FIGURE (S) and TABLE (S)

Figure 1. Proposed model

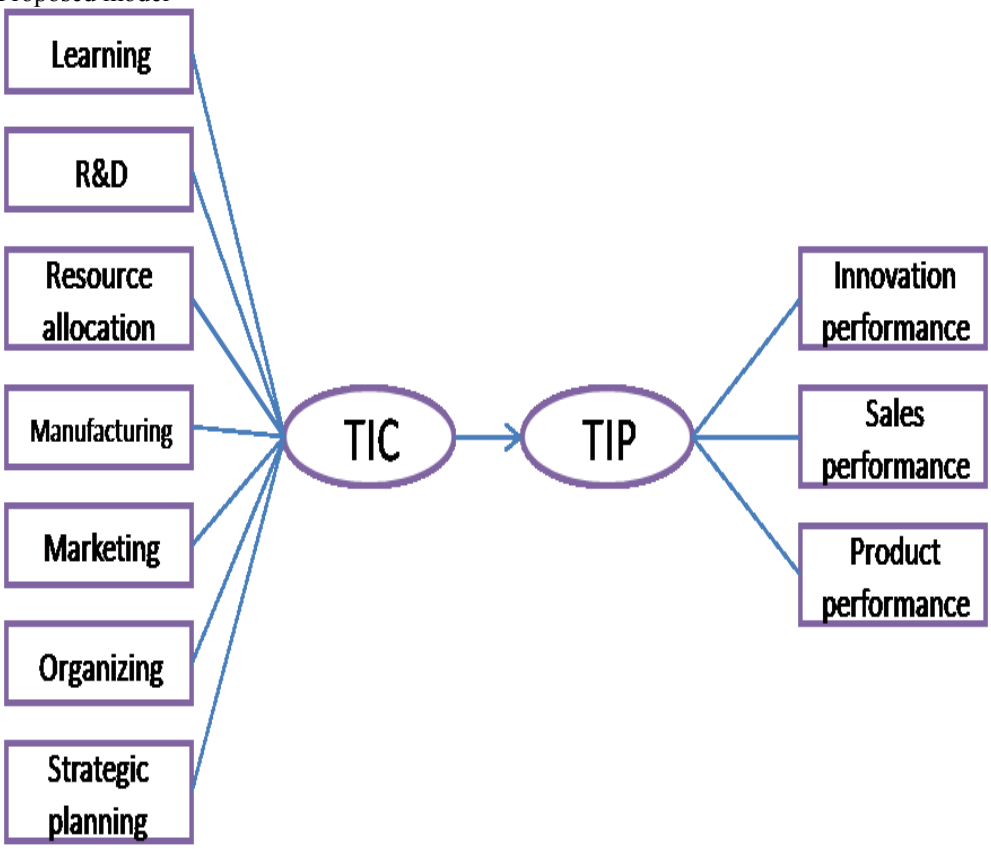

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Table 1.Direct-Relationship Matrix

	Learning	R&D	Resource allocation	Manufactuning	Marketing	Organizing	Strategic planning	Innovation Performance	Sales Performance	Product Performance
Learning	0.00	0.09	0.00	0.07	0.10	0.10	0.09	0.08	0.00	0.08
R&D	0.06	0.00	0.00	0.13	0.12	0.06	0.11	0.14	0.00	0.13
Resource allocation	0.06	0.08	0.00	0.11	0.11	0.00	0.00	0.00	0.00	0.07
Manufacturing	0.08	0.11	0.00	0.00	0.09	0.06	0.06	0.09	0.09	0.10
Marketing	0.06	0.12	0.00	0.09	0.00	0.05	0.09	0.11	0.14	0.11
Organizing	0.07	0.08	0.00	0.08	0.10	0.00	0.09	0.07	0.10	0.07
Strategic planning	0.11	0.11	0.13	0.10	0.11	0.10	0.00	0.10	0.12	0.12
Innovation Performance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.10
Sales Performance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08
Product Performance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00

Table2. Normalizing the direct-relation matrix

	Learning	R&D	Resource allocation	Manufactuning	Marketing	Organizing	Strategic planning	Innovation Performance	Sales Performance	Product Performance
Learning	0.00	0.09	0.00	0.07	0.10	0.10	0.09	0.08	0.00	0.08
R&D	0.06	0.00	0.00	0.13	0.12	0.06	0.11	0.14	0.00	0.13
Resource allocation	0.06	0.08	0.00	0.11	0.11	0.00	0.00	0.00	0.00	0.07
Manufacturing	0.08	0.11	0.00	0.00	0.09	0.06	0.06	0.09	0.09	0.10
Marketing	0.06	0.12	0.00	0.09	0.00	0.05	0.09	0.11	0.14	0.11
Organizing	0.07	0.08	0.00	0.08	0.10	0.00	0.09	0.07	0.10	0.07
Strategic planning	0.11	0.11	0.13	0.10	0.11	0.10	0.00	0.10	0.12	0.12
Innovation Performance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.10
Sales Performance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08
Product Performance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00

Table 3.Direct and Indirect (total)-Relationship Matrix

	Learning	R&D	Resource allocation	Manufactuning	Marketing	Organizing	Strategic planning	Innovation Performance	Sales Performance	Product Performance
Learning	0.06	0.16	0.02	0.14	0.17	0.15	0.15	0.16	0.11	0.19
R&D	0.12	0.09	0.02	0.20	0.19	0.12	0.17	0.23	0.14	0.25
Resource allocation	0.10	0.14	0.01	0.16	0.16	0.04	0.05	0.07	0.07	0.15
Manufacturing	0.13	0.18	0.02	0.07	0.16	0.11	0.12	0.17	0.19	0.21
Marketing	0.12	0.18	0.02	0.16	0.08	0.11	0.15	0.19	0.25	0.23
Organizing	0.12	0.15	0.02	0.15	0.17	0.06	0.15	0.15	0.20	0.19
Strategic planning	0.18	0.21	0.15	0.19	0.21	0.17	0.09	0.21	0.25	0.28
Innovation Performance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.11
Sales Performance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.09
Product Performance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.01

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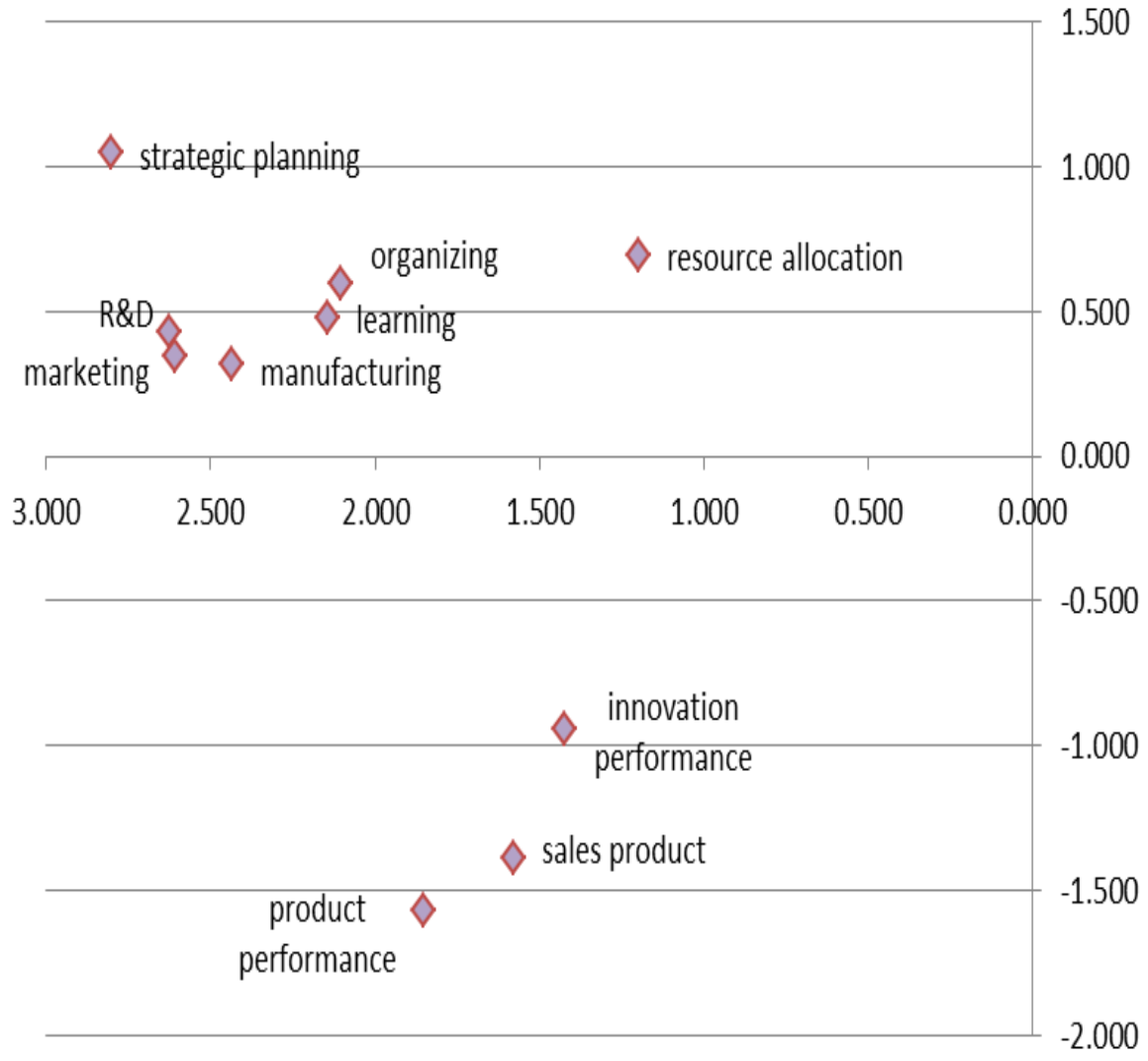
Table 4

	D		R		D+R		D-R
Strategic planning	1.924	**Product Performance**	1.712	**Strategic planning**	2.803	**Strategic planning**	1.046
R&D	1.529	**Sales Performance**	1.483	**R&D**	2.628	**Resource allocation**	0.691
Marketing	1.479	**Innovation Performance**	1.183	**Marketing**	2.610	**Organizing**	0.597
Manufacturing	1.376	**Marketing**	1.131	**Manufacturing**	2.436	**Learning**	0.476
Organizing	1.350	**R&D**	1.098	**Learning**	2.145	**R&D**	0.431
Learning	1.311	**Manufacturing**	1.060	**Organizing**	2.103	**Marketing**	0.348
Resource allocation	0.943	**Strategic planning**	0.879	**Product Performance**	1.852	**Manufacturing**	0.315
Innovation Performance	0.238	**Learning**	0.834	**Sales Performance**	1.579	**Innovation Performance**	-0.945
Product Performance	0.140	**Organizing**	0.753	**Innovation Performance**	1.421	**Sales Performance**	-1.387
Sales Performance	0.096	**Resource allocation**	0.252	**Resource allocation**	1.195	**Product Performance**	-1.572

Figure 2.The prominence-causal DEMATEL graph with digraph relationships for most influential relationships.



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