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Using DEMATEL Method to Analyze the Causal Relations on Technological Innovation Capability Evaluation Factors in Thai Technology-Based Firms

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ABSTRACT

This study analyzes the technology innovation capabilities (TICs) evaluation factors of enterprises by applying the Decision Making Trial and Evaluation Laboratory (DEMATEL) method. Based on the literature reviews, six main perspectives and sixteen criteria were extracted and then validated by six experts. A questionnaire was constructed and answered by eleven experts. Then the DEMATEL method was applied to analyze the importance of criteria and the casual relations among the criteria were constructed. The result showed that the innovation management capability perspective was the most important perspective and influenced the remaining perspectives. This work also presents the significant criteria for each perspective.

1. Introduction

Innovation's importance has continuously increased and aligns with global business growth. Bessant *et al*., (2005), and Huang (2011) clearly stated that Technological Innovation Capabilities (TICs) play a crucial part in the initiation of firms' competency and as the source of sustainable competitive advantage. The enterprises, thus, are strongly required the periodical monitoring their TICs and have to continuously strengthen their weak capabilities in order to

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facilitate the competitive advantage. This study mainly focuses on the technological-based firms since they rely significantly on innovation development to pursue their business growth.

Although TICs were accepted as a main part of enhancing competitive advantage, TICs assessment is rather complicated due to multi-dimensionality. The measuring indicators of TICs are also diverse and difficult to assess by any single-dimension scale as they involve the interaction among various resources (Chiesa *et al*., 1998, Hansen, 2001, Guan and Ma, 2003, Burgelman *et al.*, 2004). Guan *et al.,* (2006) defined TICs measurement framework as benchmark audition on the quantitative evaluation based on traditional DEA approach, which relies on both technological capability and critical capabilities in the area of manufacturing, marketing, organization, strategy planning, learning and resources allocation.

However, Wang *et al*., (2008) proposed the evaluation of high-tech firms' TICs under both quantitative assessment (by applying new fuzzy multi-criteria analytical approach) and qualitative assessment (using five main aspects of capabilities i.e. R&D, innovation decision, marketing, manufacturing and capital). Wang *et al.,* (2008) viewed that the traditional multi-criteria were not wholly suitable for TICs assessment. They also stated that the TICs assessment was considered as subjective and ambiguous.

To clarify and reduce the subjective and ambiguous information, this study uses both qualitative and quantitative methods. In this study, TICs' critical evaluation perspectives and criteria as well as the causal relations among them are presented. The result will aid the managements in the determination of the degree of importance of critical factors/ criteria and their influences on these factors.

Following this introduction, literature reviews of TICs and DEMATEL method were illustrated in Section 2. Research methodology (including research framework, and the procedure and results) was proposed in Section 3. Discussion and results were conducted in Section 4. Finally, Section 5 drew the conclusion.

2. Literature Review

2.1 Technological innovation capability (TICs)

TICs was defined as an enterprises' ability to improve their technological innovativeness in order to create new customer value through the introduction of new products and services, the exploitation of new technologies and the exploration of new skill and competencies (Perdomo-Ortiz *et al*., 2009, Wang *et al*., 2008, Huang, 2011). TICs assessments were also included the aspects of multi-dimensionality, complexity, interactive innovation activities with resource allocation to enhance competitive advantage (Wang *et al*., 2008, Chiesa *et al*., 1996).

Various researchers have developed the technological innovation framework, approaches and components to evaluate a firm's technological or innovation capabilities. For instance, Baark *et al*., (2011) classified the assessment of a firm's TICs into four approaches: (i) the asset approach (Christensen, 1995), (ii) process approach (Chiesa *et al*., 1996; Burgelman *et al*., 2004), (iii) output-based (Romijin and Albaladejo, 2002), and (iv) functional approach (Guan and Ma, 2003; Yam. *et al*., 2004). Yam *et al*., 2004 developed an audit innovation capability model by using functional approach, which consisted of seven components: learning capability, R&D capability, resource allocation capability, manufacturing capability, marketing capability, organizing capability and strategic planning capability. These studies of technological innovation capability development are basically related to our research in view of providing an overall framework for understanding the importance of such capability.

Based on the extensive literature review, overall TICs evaluation factors were concluded in Table 1.

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Table 1: Summary of the perspectives and criteria of TICs' evaluations

Perspectives/ Criteria	Author
***Innovation Management Capability* (*P_1*)**	
Strategic Management Capability (C_1)	Burgelman *et al.*, (2004), O'Regan *et al.,* (2006), Ceylan and Koc (2007), Dobni (2008), Yam *et al.,* (2004), Yam *et al.,* (2011), Türker (2012).
Organization Capability (C_2)	Guan *et al.,* (2006), O'Regan *et al.,* (2006), Burgelman *et al.,* (2004), Yam *et al.,* (2004), Yam *et al.,* (2011), Ceylan and Koc (2007), Dobni (2008), Spyropoulou and Kyrgidou (2012), Türker (2012).
Resource Allocation Capability (C_3)	Chiesa *et al.,* (1996), Barney and Clark (2007), Burgelman *et al.,* (2004), Guan *et al.,* (2006), Dobni (2008), Wang *et al.,* (2008), Ceylan and Koc (2007), Yam *et al.,* (2011), Spyropoulou and Kyrgidou (2012), Voudouris *et al.,* (2012).
Risk Management Capability (C_4)	Amabile *et al.,* (1996), Isaksen *et al.,* (1999), Forsman (2011), Yang (2012).
Collective Learning Capability (P_2)	
Learning Capability (C_5)	Guan *et al.,* (2006), Chiva *and* Alegre (2007), Teece (2007), Alegre and Chiva (2008), Yam *et al.,* (2004), Yam *et al.,* (2011), Camisón and Villar-López (2012).
Absorptive Capacity (C_6)	Ceylan and Koc (2007), Zahra and George (2002), Lane and Koka (2006), Camisón and Forés (2010), Forsman (2011), Wonglimpiyarat (2010), Kim *et al.,* (2011), Gebauer *et al.,* (2012), Lin *et al.,* (2012).
Knowledge Management Capability (C_7)	Forsman (2011), Yang (2012).
Innovation Sourcing Capability(P_3)	
Network Linkage Capability (C_8)	Lin (2004), Chesbrough (2004), Tidd (2006), Kim and Song (2007), Spithoven *et al.,* (2010), Shan and Jolly (2010), Zeng *et al.,* (2010), Huang (2011), Forsman (2011), Mu and Benedetto (2011), Kim *et al.,* (2011), Voudouris *et al.,* (2012).
Technology Acquisition Capability (C_9)	Chiesa *et al.,* (1996), Ceylan and Koc (2007), Lee *et al.,* (2009).
Technology Development Capability(P_4)	
R&D Capability (C_{10})	Guan *et al.,* (2006), Wang *et al.,* (2008), Yam *et al.,* (2004), Yam *et al.,* (2011), Zahra and George (2002), Levitas and Mc Fadyen (2009), Kim *et al.,* (2011), Forsman (2011), Lin *et al.,* (2012).
Project Cross Functional Team Integration Capability (C_{11})	Martins and Terblanche (2003), Lin (2004), Camisón and Forés (2010), Kim *et al.,* (2011), Yam *et al.,* (2011).
Technology Change Management Capability (C_{12})	Jansen *et al.,* (2005), Garrison (2009), Forsman (2011).
Robustness Product & Process Design Capability (P_5)	
Product Structural Design and Engineering Capability (C_{13})	Chiesa *et al.,* (1996), Christensen (1995), Zhang *et al.,* (2000), De Toni and Nassimbeni (2001), Antony *et al.,* (2002), Nassimbeni and Battain (2003), Lin (2004), Ho *et al.,* (2011).
Process Design and Engineering Capability (C_{14})	Chiesa *et al.,* (1996), Zhang *et al.,* (2000), De Toni and Nassimbeni (2001), Antony *et al.,* (2002), Nassimbeni and Battain, (2003).
Technology Commercialization Capability (P_6)	
Manufacturing Capability (C_{15})	Lin (2004), Yam *et al.,*(2004), Guan *et al.* (2006), Wang *et al.,*(2008), Yam *et al.,* (2011), Kim *et al.,* (2011), Yang (2013).
Market Capability (C_{16})	Lin (2004), Yam *et al.,* (2004), Guan *et al.,* (2006), Dobni (2008), Wang *et al.,* (2008), Yam *et al.,* (2011), Forsman (2011), Mu and Benedetto (2011), Kim *et al.,* (2011).

2.2 DEMATEL Method

DEMATEL method was originally developed between 1972 to 1979 by the Science and Human Affairs Program of the Battelle Memorial Institute of Geneva, with the purpose of studying the complex and intertwined problematic group. It has been widely accepted as one of the best tools to solve the cause and effect relationship among the evaluation criteria (Chiu *et al.*, 2006, Liou *et al.*, 2007, Tzeng *et al.,* 2007, Wu and Lee, 2007, Lin and Tzeng, 2009). This method is applied to analyze and form the relationship of cause and effect among evaluation criteria (Yang *et al.,* 2008) or to derive interrelationship among factors (Lin and Tzeng, 2009). Based on Yu and Tseng (2006), Liou, *et al.,* (2007), Tzeng, *et al.,* (2007), Yang, *et al.,* (2008), Wu and Lee (2007), Shieh *et al.*, (2010), the procedure of DEMATEL method is presented below:

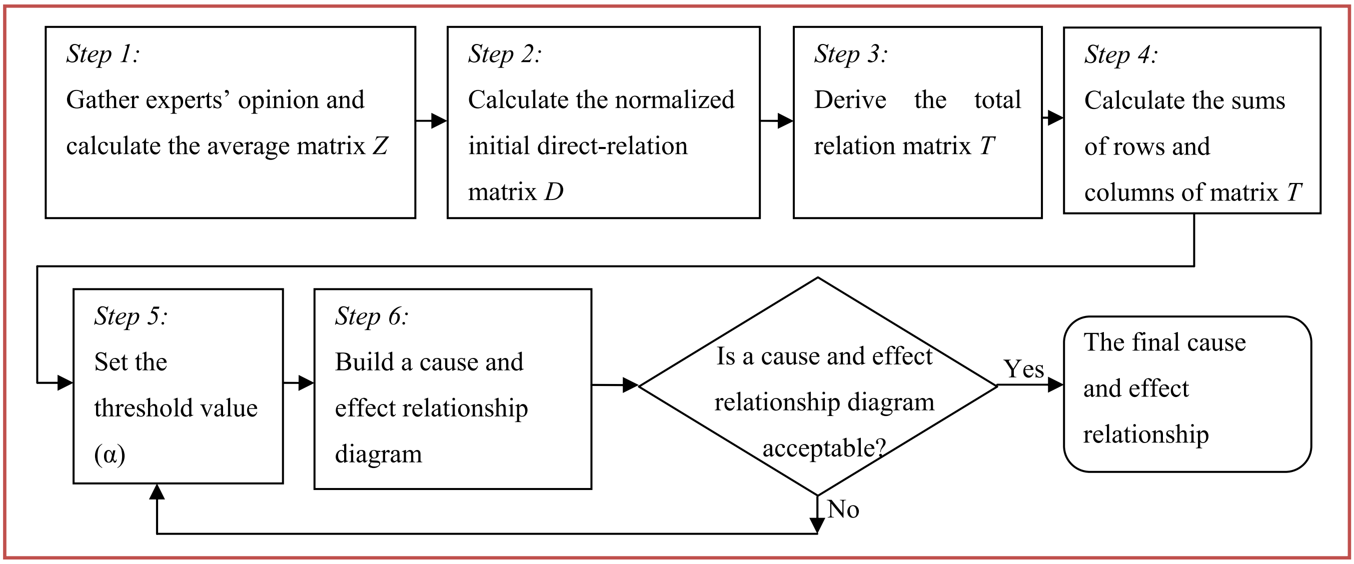

Figure 1: The process of the DEMATEL method.

Step 1: Gather experts' opinion and calculate the average matrix Z

A group of *m* experts and *n* factors are used in this step. Each expert is asked to view the degree of direct influence between two factors based on pair-wise comparison. The degree to which the expert perceived factor *i* affects on factor *j* is denoted as x_{ij}. The integer score is ranged from 0 (no influence), 1 (low influence), 2 (medium influence), 3 (high influence), and 4 (very high influence), respectively. For each expert, an *n x n* non-negative matrix is constructed as $X^k = [x^k_{ij}]$, where *k* is the expert number of participating in evaluation process with $1 \le k \le m$. Thus, X^1, X^2, X^3,..., X^m are the matrices from *m* experts.

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To aggregate all judgments from m experts, the average matrix Z= [z_{ij}] is shown below.

$$z_{ij} = \frac{1}{m}\sum_{i=1}^{m} x_{ij}^{k} \tag{1}$$

Step 2: Calculate the normalized initial direct- relation matrix D

The normalized initial direct-relation matrix D = [d_{ij}], where value of each element in matrix D is ranged between [0, 1]. The calculation is shown below.

$$D = \lambda * Z, \tag{2}$$

or

$$[d_{ij}]_{\mathrm{nxn}} = \lambda\ [z_{ij}]_{\mathrm{nxn}} \tag{3}$$

where

$$\lambda = Min\left[\frac{1}{max\ 1 \le i \le n \sum_{j=1}^{n} |z_{ij}|}, \frac{1}{max\ 1 \le i \le n \sum_{i=1}^{n} |z_{ij}|}\right] \tag{4}$$

Based on Markov chain theory, D^m is the powers of matrix D, e.g. D^2, D^3,..., D^∞ guarantees the convergent solutions to the matrix inversion as shown below.

$$\lim_{m \to \infty} D^m = [0]_{nxn}, \tag{5}$$

Step 3: Derive the total relation matrix T

The total-influence matrix T is obtained by utilizing Eq. (7), in which, I is an n x n identity matrix. The element of t_{ij} represents the indirect effects that factor i had on factor j, then the matrix T reflects the total relationship between each pair of system factors.

$$T \quad = \lim_{m \to \infty} (D + D^2 + \ldots + D^m) \tag{6}$$

$$= \sum_{m=1}^{\infty} D^i$$

where

$$\sum_{m=1}^{\infty} D^i \quad = D^1 + D^2 + \ldots + D^m$$

$$= D(I + D^1 + D^2 + \ldots + D^{m-1})$$

$$= D(I - D)^{-1}(I - D)(I + D^1 + D^2 + \ldots + D^{m-1})$$

$$= D(I - D)^{-1}(I - D^m)$$

$$T = D(I - D)^{-1} \tag{7}$$

Step 4: Calculate the sums of rows and columns of matrix *T*

In the total-influence matrix *T*, the sum of rows and the sum of columns are represented by vectors *r* and *c*, respectively.

$$r = [r_i]_{nx1} = \left(\sum_{j=1}^{n} t_{ij}\right)_{nx1}, \tag{8}$$

$$c = [c_j]'_{1xn} = [\sum_{j=1}^{n} t_{ij}]'_{1xn}, \tag{9}$$

where $[c_j]'$ is denoted as transposition matrix.

Let r_i be the sum of i^{th} row in matrix *T*. The value of r_i indicates the total given both directly and indirectly effects, that factor *i* has on the other factors.

Let c_j be the sum of the j^{th} column in matrix *T*. The value of c_j shows the total received both directly and indirectly effects, that all other factors have on factor *j*. If $j = i$, the value of $(r_i + c_i)$ represents the total effects both given and received by factor *i*. In contrast, the value of $(r_i - c_i)$ shows the net contribution by factor *i* on the system. Moreover, when $(r_i - c_i)$ was positive, factor *i* was a net cause. When $(r_i - c_i)$ was negative, factor *i* was a net receiver (Tzeng *et al.,* 2007; Liou *et al.,* 2007; Yang *et al.,* 2008; Lee *et al.,* 2009).

Step 5: Set a threshold value (α)

The threshold value (α), was computed by the average of the elements in matrix *T*, as computed by Eq. (11). This calculation aimed to eliminate some minor effects elements in matrix ***T***. (Yang *et al*., 2008).

$$\alpha = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}[tij]}{\text{N}} \tag{10}$$

where N is the total number of elements in the matrix *T*.

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Step 6: Build a cause and effect relationship diagram

The cause and effect diagram is constructed by mapping all coordinate sets of ($r_i + c_i$, $r_i - c_i$) to visualize the complex interrelationship and provide information to judge which are the most important factors and how influence affected factors (Shieh *et al*., 2010). The factors that t_{ij} is greater than α, are selected shown in cause and effect diagram (Yang *et al*., 2008).

3. Research Methodology

3.1 Research Framework of TICs

This section established a structure for identifying the evaluation perspective and criteria as well as their relationships of TICs factors. An overview of the proposed TICs evaluation framework was illustrated in Figure 2. The details of each procedure and the results were explained in next section.

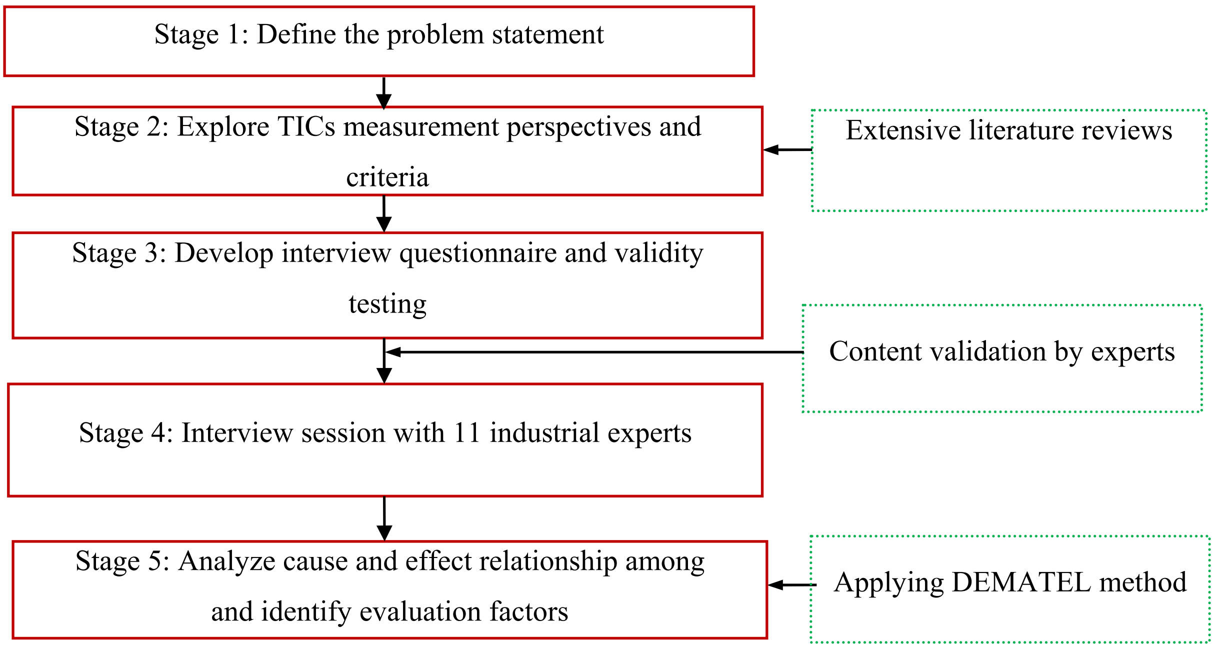

Figure 2: The proposed procedure of TICs criteria assessment.

3.2 Procedure and the result

This section is to describe the process of TICs evaluation perspectives and criteria, according to Figure 2. Not only the determination of TICs evaluation perspectives and criteria but also the measurement of the relationship among them was also performed. The process and the result of each stage were presented in the following stages:

3.2.1 Stage of defining the problem statements

To encounter the fierce competition of the dynamic global environment and the upcoming, TICs are considered as one of the significant factors of Thai technology-based firms to sustain competitiveness. Hence, an evaluation of TICs turns to be a tool to aid managements to define strengths and weaknesses in term of TICs. Appropriate factors of TICs then should be identified. This study presents not only the appropriate factors but also the cause and effect relationship among the perspectives and criteria.

3.2.2 Stage of exploring the TICs measurement perspectives and criteria from literature reviews

The extensive literature review was conducted to identify multi-attributions and multi-dimensionalities of the TICs evaluation factors. Based on the reviews, six perspectives and sixteen evaluation criteria were derived as shown in Table 1.

3.2.3 Stage of developing a questionnaire

After obtaining the sixteen criteria and six perspectives of TICs evaluation factors from literatures, a questionnaire was designed. A group of qualified experts reviewed and tested the designed questionnaire to assure the content validity of questionnaire. The group of qualified experts was consisted of three professionals from academic institutions, two from industrial sector and one from Thai Automotive Institution. After interviewing, the questionnaire was revised based on the experts' aspects.

3.2.4 Stage of interviewing session

Eleven experts were asked to complete the questionnaire. The experts have at least 5 years experiences and worked in management positions in well-known Thai technology-based firms and some of the firms were awarded as Thailand's Most Innovative Company in 2010. After obtaining the completed questionnaires from the experts, DEMATEL analytical technique was used to determine the causal relations and to identify the significant perspectives and criteria. The results of analyses were shown in the next section.

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3.2.5 Stage of analyzing the causal relation and identifying the evaluation perspectives and criteria

Based on the six perspectives and sixteen criteria of TICs evaluation as stated above, this study further employed the DEMATEL method to indicate the complex relationship and identify the significant TICs evaluation perspectives and criteria. In this section, the computation was divided into two parts for calculating on perspectives and criteria, respectively. The procedure of the DEMATEL method and the results of each stage were also presented as follows.

3.2.5.1 Applying DEMATEL method on the six perspectives

X^k showed the data gathered in terms of the six perspectives of expert k, where $X^k = [x_{ij}^k]$. Step procedures of applying DEMATEL method were shown next.

$$X^1=\begin{pmatrix} 0 & 3 & 3 & 3 & 3 & 4 \\ 2 & 0 & 3 & 3 & 2 & 2 \\ 1 & 1 & 0 & 2 & 1 & 1 \\ 1 & 3 & 3 & 0 & 1 & 3 \\ 2 & 1 & 2 & 3 & 0 & 3 \\ 1 & 2 & 2 & 1 & 2 & 0 \end{pmatrix} X^2=\begin{pmatrix} 0 & 2 & 3 & 3 & 2 & 4 \\ 2 & 0 & 3 & 3 & 3 & 3 \\ 1 & 2 & 0 & 2 & 2 & 0 \\ 2 & 4 & 1 & 0 & 2 & 2 \\ 1 & 2 & 2 & 1 & 0 & 3 \\ 2 & 1 & 2 & 3 & 2 & 0 \end{pmatrix} X^3=\begin{pmatrix} 0 & 3 & 2 & 2 & 3 & 4 \\ 2 & 0 & 2 & 3 & 3 & 0 \\ 1 & 3 & 0 & 1 & 2 & 1 \\ 2 & 3 & 2 & 0 & 2 & 1 \\ 1 & 2 & 2 & 2 & 0 & 4 \\ 1 & 2 & 1 & 1 & 2 & 0 \end{pmatrix} X^4=\begin{pmatrix} 0 & 2 & 2 & 3 & 3 & 3 \\ 1 & 0 & 3 & 3 & 3 & 3 \\ 1 & 2 & 0 & 0 & 2 & 2 \\ 1 & 3 & 2 & 0 & 2 & 2 \\ 2 & 2 & 1 & 3 & 0 & 3 \\ 2 & 1 & 2 & 2 & 2 & 0 \end{pmatrix}$$

$$X^5=\begin{pmatrix} 0 & 2 & 2 & 0 & 2 & 3 \\ 2 & 0 & 2 & 3 & 2 & 2 \\ 1 & 2 & 0 & 2 & 2 & 1 \\ 2 & 3 & 1 & 0 & 3 & 2 \\ 2 & 1 & 2 & 2 & 0 & 3 \\ 2 & 1 & 2 & 2 & 2 & 0 \end{pmatrix} X^6=\begin{pmatrix} 0 & 2 & 2 & 3 & 2 & 4 \\ 2 & 0 & 2 & 3 & 3 & 3 \\ 1 & 2 & 0 & 2 & 2 & 1 \\ 2 & 3 & 2 & 0 & 0 & 1 \\ 2 & 2 & 2 & 3 & 0 & 2 \\ 1 & 2 & 2 & 2 & 1 & 0 \end{pmatrix} X^7=\begin{pmatrix} 0 & 2 & 3 & 2 & 2 & 3 \\ 2 & 0 & 3 & 3 & 2 & 0 \\ 2 & 3 & 0 & 2 & 3 & 2 \\ 1 & 4 & 2 & 0 & 2 & 1 \\ 2 & 1 & 2 & 2 & 0 & 3 \\ 2 & 1 & 1 & 1 & 2 & 0 \end{pmatrix} X^8=\begin{pmatrix} 0 & 1 & 2 & 3 & 2 & 3 \\ 2 & 0 & 3 & 3 & 2 & 2 \\ 1 & 2 & 0 & 2 & 2 & 2 \\ 2 & 4 & 1 & 0 & 1 & 2 \\ 1 & 2 & 2 & 1 & 0 & 3 \\ 3 & 1 & 2 & 1 & 1 & 0 \end{pmatrix}$$

$$X^9=\begin{pmatrix} 0 & 1 & 2 & 3 & 2 & 4 \\ 3 & 0 & 3 & 3 & 3 & 2 \\ 2 & 3 & 0 & 2 & 2 & 2 \\ 2 & 4 & 2 & 0 & 3 & 2 \\ 2 & 2 & 2 & 0 & 0 & 3 \\ 2 & 1 & 1 & 1 & 2 & 0 \end{pmatrix} X^{10}=\begin{pmatrix} 0 & 2 & 3 & 2 & 2 & 3 \\ 2 & 0 & 2 & 3 & 3 & 0 \\ 1 & 2 & 0 & 2 & 2 & 2 \\ 2 & 3 & 2 & 0 & 2 & 3 \\ 2 & 2 & 1 & 1 & 0 & 3 \\ 2 & 1 & 1 & 2 & 2 & 0 \end{pmatrix} X^{11}=\begin{pmatrix} 0 & 2 & 1 & 1 & 2 & 3 \\ 1 & 0 & 2 & 3 & 2 & 2 \\ 1 & 2 & 0 & 2 & 2 & 1 \\ 2 & 3 & 1 & 0 & 2 & 2 \\ 2 & 1 & 2 & 2 & 0 & 2 \\ 1 & 1 & 2 & 2 & 3 & 0 \end{pmatrix}$$

(1) The computation of the average matrix Z was constructed by using Eq. (1).

$$Z = \begin{pmatrix} 0 & 2 & 2.2727 & 2.2727 & 2.2727 & 3.4545 \\ 1.90909 & 0 & 2.54545 & 3 & 2.5454 & 1.7272 \\ 1.18181 & 2.1818 & 0 & 1.7272 & 2 & 1.3636 \\ 1.72727 & 3.3636 & 1.72727 & 0 & 1.8181 & 1.9090 \\ 1.72727 & 1.6363 & 1.81818 & 1.8181 & 0 & 2.9090 \\ 1.72727 & 1.2727 & 1.63636 & 1.6363 & 1.9090 & 0 \end{pmatrix}$$

(2) The normalized initial direct-relation matrix D was calculated by using Eq. (2) to Eq.(5).

$$D = \begin{pmatrix} 0.0000 & 0.1760 & 0.2000 & 0.2000 & 0.2000 & 0.3040 \\ 0.1680 & 0.0000 & 0.2240 & 0.2640 & 0.2240 & 0.1520 \\ 0.1040 & 0.1920 & 0.0000 & 0.1520 & 0.1760 & 0.1200 \\ 0.1520 & 0.2960 & 0.1520 & 0.0000 & 0.1600 & 0.1680 \\ 0.1520 & 0.1440 & 0.1600 & 0.1600 & 0.0000 & 0.2560 \\ 0.1520 & 0.1120 & 0.1440 & 0.1440 & 0.1680 & 0.0000 \end{pmatrix}$$

(3) The total relation matrix T was calculated by using Eq. (6) to Eq. (7) as shown below.

$$T = \begin{pmatrix} 1.1983 & 1.6022 & 1.5638 & 1.6194 & 1.6335 & 1.7897 \\ 1.3147 & 1.4312 & 1.5522 & 1.6366 & 1.6189 & 1.6449 \\ 0.9837 & 1.2421 & 1.0379 & 1.2130 & 1.2383 & 1.2532 \\ 1.2195 & 1.5575 & 1.4040 & 1.3262 & 1.4714 & 1.5434 \\ 1.1290 & 1.3342 & 1.3001 & 1.3464 & 1.2203 & 1.4966 \\ 0.9883 & 1.1431 & 1.1256 & 1.1653 & 1.1928 & 1.1104 \end{pmatrix}$$

(4) The sums of rows and columns of matrix T were calculated by using Eq. (8) to Eq. (9) as shown in Table 2.

Table 2: The sums of given and received among six perspectives.

	P_1	P_2	P_3	P_4	P_5	P_6	r_i	c_j	(r_i+c_j)	(r_i-c_j)
P_1	1.1983	1.6022*	1.5638*	1.6194*	1.6335*	1.7897*	9.4068	6.8335	16.2403	2.5733
P_2	1.3147	1.4312*	1.5522*	1.6366*	1.6189*	1.6449*	9.1985	8.3103	17.5087	0.8882
P_3	0.9837	1.2421	1.0379	1.2130	1.2383	1.2532	6.9683	7.9836	14.9519	-1.0153
P_4	1.2195	1.5575*	1.4040*	1.3262	1.4714*	1.5434*	8.5219	8.3069	16.8288	0.2151
P_5	1.1290	1.3342	1.3001	1.3464	1.2203	1.4966*	7.8266	8.3752	16.2018	-0.5486
P_6	0.9883	1.1431	1.1256	1.1653	1.1928	1.1104	6.7255	8.8382	15.5637	-2.1127

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(5) The set up of the threshold value (α)

The threshold value was derived from the average of elements in matrix T, which was calculated by using Eq. (10).

$$\alpha = \frac{48.6477}{36} = 1.351$$

(6) The construction of the cause and effect relationship diagram

The values of t_{ij} in Table 2, which were greater than α (1.351), were shown as t_{ij}^*, which presented the interaction between perspectives, e.g. the value of t_{12} (1.6022) > α (1.351), the arrow in the cause and effect diagram was drawn from P_1 to P_2. The cause and effect diagram of six perspectives was constructed as Figure 3.

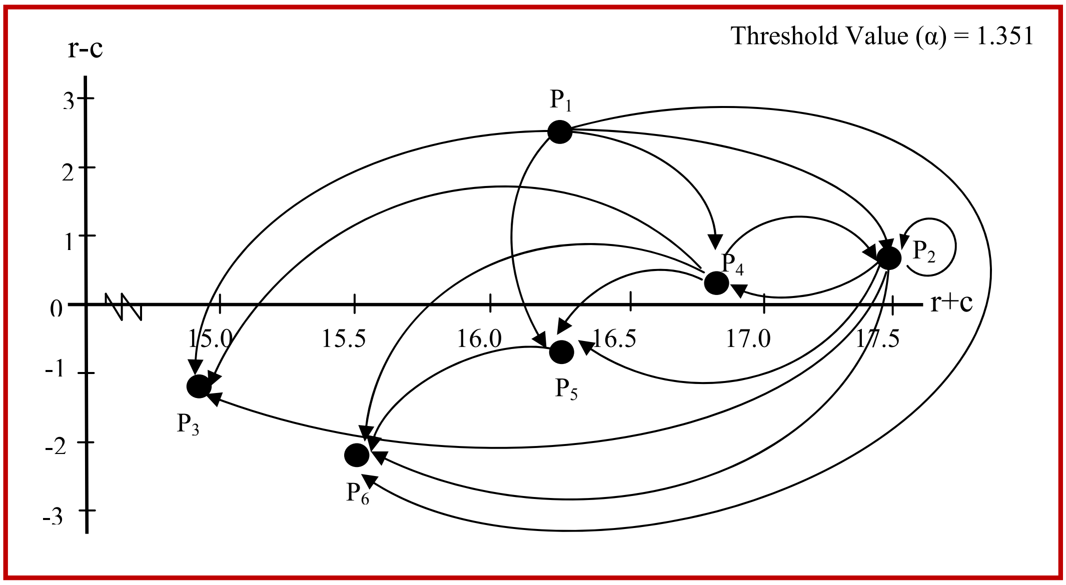

Figure 3: The visualization of the causal relationship among perspectives of TICs.

3.2.5.2 Applying DEMATEL method on the sixteen criteria

Under each perspective, the significant criteria were determined by using the same procedures as described in (1) to (6) above. Both direct and indirect effects of the criteria under six perspectives were summarized in Table 3 and the cause and effect diagrams among criteria under each perspective were shown in Figure 4 to Figure 9.

4. Discussion and Results

4.1 Results on the Perspectives

The important of evaluation perspectives was determined by (r+c) values. Based on Table 3, Collective Learning Capability (P_2) was the most important evaluation perspective with the largest (r+c) value = 17.5087, whereas Innovation Sourcing Capability (P_3) was the least important perspective with the smallest (r+c) value = 14.9519. Regarding to (r+c) values, the prioritization of the importance of six evaluation perspective was $P_2 > P_4 > P_1 > P_5 > P_6 > P_3$.

Table 3: The direct and indirect effects of the criteria under each perspective.

Criteria	(r+c)	(r-c)
The overall effects of the four criteria of Innovation Management Capability perspective		
Strategic Management Capability (C_1)	17.8235	2.1543
Organization Capability (C_2)	19.7564	0.1836
Resource Allocation Capability (C_3)	17.0986	-1.3492
Risk Management Capability (C_4)	17.7238	-0.9887
The overall effects of the three criteria of Collective Learning Capability perspective		
Learning Capability (C_5)	9.3937	0.3263
Absorptive Capability (C_6)	9.3174	1.3097
Knowledge Management Capability(C_7)	9.0972	-1.6360
The overall effects of the two criteria of Innovation Sourcing capability perspective		
Network Linkage Capability (C_8)	6.3333	1.0000
Technology Acquisition Capability (C_9)	6.3333	-1.0000
The overall effects of the three criteria of Technology Development Capability perspective		
R&D Capability (C_{10})	71.7604	2.8446
Project Cross Functional Team Integration Capability (C_{11})	68.7422	1.7228
Technology Change Management Capability(C_{12})	65.4969	-4.5675
The overall effects of the two criteria of Robustness Product & Process Design Capability perspective		
Product Structural Design and Engineering Capability (C_{13})	7.8000	1.0000
Process Design and Engineering Capability (C_{14})	7.8000	-1.0000
The overall effects of the two criteria of Technology Commercialization Capability perspective		
Manufacturing Capability (C_{15})	21.000	1.0000
Market Capability (C_{16})	21.000	-1.0000

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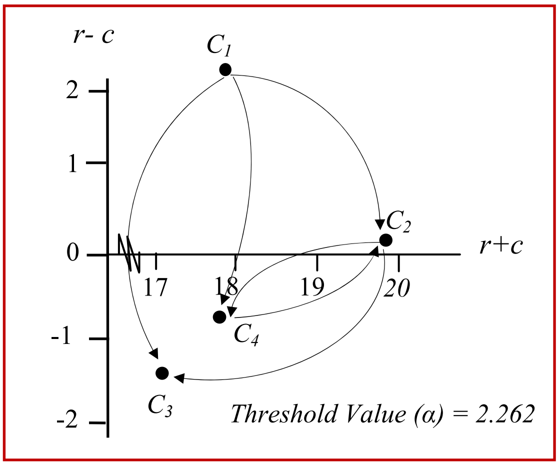

Figure 4: The cause and effect diagram of the four criteria of Innovation Management Capability

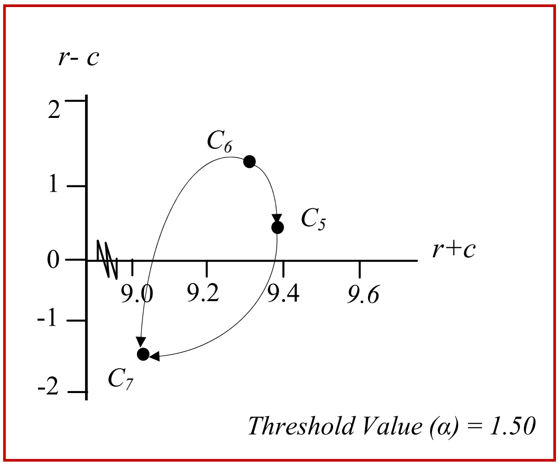

Figure 5: The cause and effect diagram of the three criteria of Collective Learning Capability

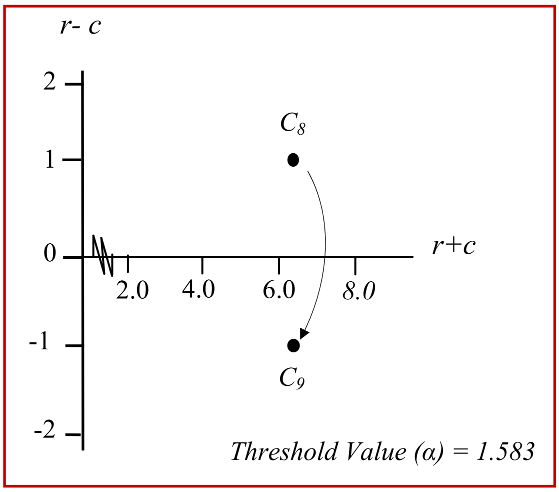

Figure 6: The cause and effect diagram of the two criteria of Innovation Sourcing Capability.

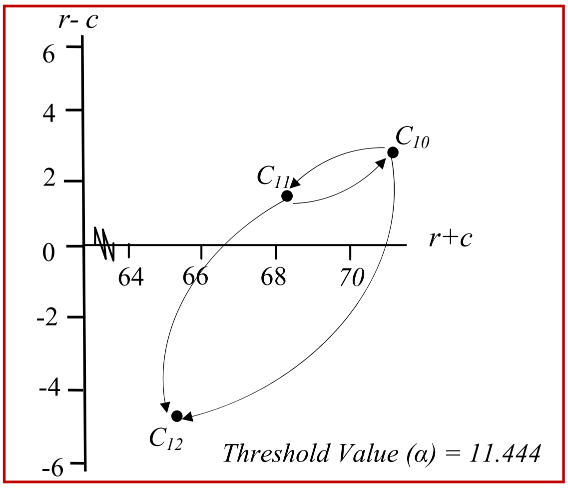

Figure 7: The cause and effect diagram of the three criteria of Technology Development Capability

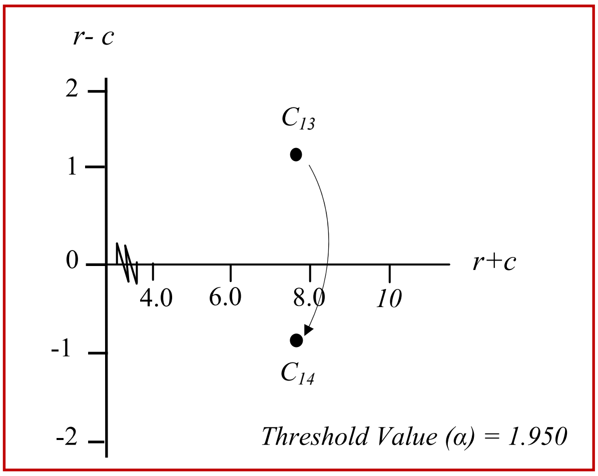

Figure 8: The cause and effect diagram of the two criteria of Robustness Product & Process Design Capability

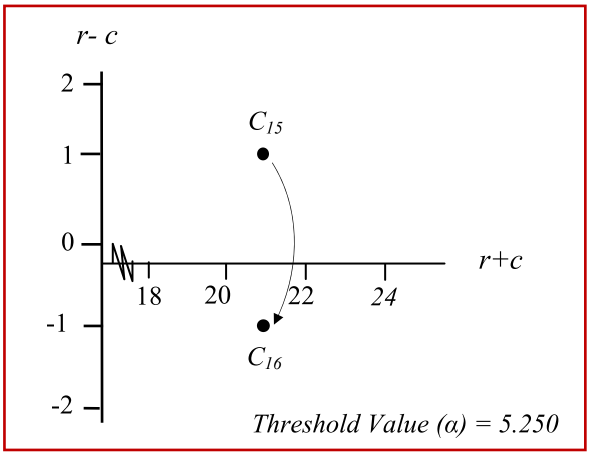

Figure 9: The cause and effect diagram of the two criteria of Technology Commercialization Capability

Based on (r-c) values, the six perspectives were divided into (i) cause group and (ii) effect group.

(i) If the value of (r-c) was positive or net cause, such perspective was classified in the cause group, and directly affected the others. The highest (r-c) factors also had the greatest direct impact on the others. In this study, Innovation Management Capability (P_1), Collective Learning Capability (P_2), and Technology Development Capability (P_4) were classified in the cause group, having the (r-c) values of 2.5733, 0.8882, and 0.2151, respectively. It also indicated that P_1 (Innovation Management Capability) was the most critical impact factor on the others. Based on the matrix T in Table 2, it was found that P_2 (Collective Learning Capability) and P_4 (Technology Development Capability) had a mutual interaction as both the value of t_{24} (1.6366) and t_{42} (1.5575) were greater than α (1.351).

(ii) If the value of (r-c) was negative or net receive, such perspective was classified in the effect group, and largely influenced by the others. For this study, Technology Commercialization Capability (P_6), Innovation Sourcing Capability (P_3) and Robustness Product and Process Design Capability (P_5) were categorized in the effect group, with the (r-c) values of -2.1127, -1.0153 and -0.5484, respectively. And P_6 (Technology Commercialization Capability) was the most affected by the other factors (P_1), (P_2), (P_4), *and* (P_5).

4.2 Results on the Criteria

According to Table 3, under Innovation Management Capability perspective (P_1), this study found that Organization Capability (C_2) and Strategic Management Capability (C_1) were the two most important criteria based on first and second highest (r+c) values of 19.7564 and 17.8235, respectively. Whereas both Strategic Management Capability (C_1) and Organization Capability (C_2) were in the cause group based on their positive (r-c) values of 2.1543 and 0.1836, respectively. For Resource Allocation Capability (C_3) and Risk Management Capability (C_4) were in the effect group, given negative (r-c) values of -1.3492 and -0.9887, respectively. From Figure 4, Strategic Management Capability (C_1) was the most critical criteria because it directly influenced on the other three criteria. Organization Capability (C_2) had a direct impact on Resource Allocation Capability (C_3) and a mutual interaction on Risk Management Capability (C_4).

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For the perspective of Collective Learning Capability (*P_2*), Learning Capability (*C_5*) and Absorptive Capability (*C_6*) were the two most important criteria based on higher (*r+c*) values of 9.3937 and 9.3174, respectively. They were also the net cause group with higher positive (*r-c*) values of 0.3263 and 1.3097, respectively. For Knowledge Management Capability (*C_7*) was net receive with the (*r-c*) value of -1.6360. From Figure 5, Absorptive Capability (*C_6*) presented as the most significant criteria given impact to the other two criteria.

For the perspective of Innovation Sourcing capability (*P_3*) in Table 3, Network Linkage Capability (*C_8*) and Technology Acquisition Capability (*C_9*) showed the same importance level of the (*r+c*) values 6.3333. However, based on the (*r-c*) value of 1.0 (Figure6), Network Linkage Capability (*C_8*), was a net cause and largely impacted Technology Acquisition Capability (*C_9*).

According to Technology Development Capability perspective (*P_4*), R&D Capability (*C_{10}*) and Project Cross Functional Team Integration Capability (*C_{11}*) were the two most important criteria with highest (*r+c*) values of 71.7604, and 68.7422, respectively. Both of them were net cause. As shown in Figure7, R&D Capability (*C_{10}*) had the greatest (*r-c*) value of 2.8446, which directly affected Technology Change Management Capability (*C_{12}*) and had a mutual interaction on Project Cross Functional Team Integration Capability (*C_{11}*).

For the perspective of Robustness Product & Process Design capability (P_5), both criteria Product Structural Design and Engineering Capability (C_{13}) and Process Design and Engineering Capability (C_{14}) had the same importance level of the (r+c) values equaling to 7.80. However, as Figure 8, Product Structural Design and Engineering Capability (C_{13}) was net cause with the (r-c) value of 1.0, and affected Process Design and Engineering Capability (C_{14}).

For the perspective of Technology Commercialization Capability (P_6), there were the same importance level of the two criteria i.e. Manufacturing Capability (C_{15}) and Market Capability (C_{16}), based on their equal (r+c) values of 21.0. However, as Figure 9, Manufacturing Capability (C_{15}) was a net cause having the (r-c) value of 1.0 and affected Market Capability (C_{16}).

5. Conclusion

This study applied DEMATEL method not only to analyze the TIC evaluation perspectives and criteria, consisting of six perspectives and sixteen criteria for Thai technology-based firms' but also to describe the cause and effect relationship among them. The result implied that the management should concentrate on improving the three core perspectives in the cause group i.e. Innovation Management Capability, Collective Learning Capability, and Technology Development Capability. The three remaining perspectives were found in the effect group i.e. Technology Commercialization Capability, Innovation Sourcing Capability and Robustness Product and Process Design Capability, which they were also affected by the ones in the cause group.

By the aspect of prioritizing the importance of criteria and the cause and effect relationship among criteria under the three core perspectives, this study found that the Strategic Management Capability, Absorptive Capability and R&D Capability were the most critical criteria. Therefore, in order to enhance the overall competitive advantage in term of TICs, Thai technology-based firms should allocate more resources in these core perspectives. In the case of having limited resources, firms should emphasize on their Strategic Management Capability since it is the main critical criteria in the adjustment of corporate planning and would yield highest positive results on TICs.

6. Appendix

The definitions of criteria are identified in Table A:

Table A: terms and definitions of criteria used in this study

Terms	Definitions
Strategic Management Capability	The firm's ability to identify internal strengths and weaknesses and external opportunities and threats, to formulate plans in accordance with the corporate vision and missions, and to adjust the plans for implementation (Yam et al., 2004).
Organization Capability	The firm's ability to secure the organizational mechanism and harmony, to cultivate the organization culture, and to adopt the better management practices (Yam et al., 2004).
Resource Allocation Capability	The firm's ability to acquire and to allocate appropriately capital, exercise and technology in the innovation process (Yam et al., 2004).
Risk Management Capability	The firm's ability to assess the risk of technological innovation and to take the risk of technological innovation adoption (Forsman, 2011).

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Table A: terms and definitions of criteria used in this study (continue)

Terms	Definitions
Learning Capability	The firm's ability to identify, to assimilate, and to exploit the knowledge from internal organization (Yam et al., 2004).
Absorptive Capacity	The firm's ability to recognize, to assimilate, and to apply the value of new external information to commercial ends (Cohen and Lavinthal, 1990).
Knowledge Management Capability	The firm's ability to accumulate critical knowledge resources and to manage its assimilation and exploitation (Miranda et al., 2011).
Network Linkage Capability	The firm's ability to transmit information, skills and technology, and to receive them from other departments of the firm, including third parties such as the clients, the suppliers, the consultants, the technological institutions (Shan and Jolly, 2010).
Technology Acquisition Capability	The firm's ability to acquire and to adopt external technology from other parties (Hemmert, 2004).
R&D Capability	The firm's ability to integrate R&D strategy, project implementation, project portfolio management, and R&D expenditure (Yam et al., 2004).
Project Cross functional team integration capability	The firm's ability to coordinate and to integrate all phases of the R&D process and the inter-relations with the functional tasks of engineering, production and marketing (Camisón and Forés, 2010).
Technology Change Management Capability	The firm's ability to accurately predict future technological trends and to response the technology changes (Jansen et al., 2005).
Product Structural Design and Engineering Capability	The firm's ability to design product structure, to build product modularization and to make product and process compatible (De Toni and Nassimbeni, 2001).
Process Design and Engineering Capability	The firm's ability to design process for supporting the manufacturing design and to design the assembly activities (De Toni and Nassimbeni, 2001).
Manufacturing Capability	The firm's ability to transform R&D result into products, which meet the market's need as required design, and able to produce (Yam et al., 2004).
Market Capability	The firm's ability to sell products on the basis of the understanding of customers' need, the competitive environment, costs and benefits, and the acceptance of the innovation (Yam et al., 2004).

7. References

Alegre, J. and Chiva, R. (2008). Assessing the impact of organizational learning capability on product innovation performance: An empirical test. Technovation, 28(6), 315–326.

Antony, J., Leung, K., Knowless, G. and Gosh, S. (2002). Critical success factors of TQM implementation in Hong Kong industries. International Journal of Quality and Reliability Management, 19(5), 551–566.

Amabile, T., Conti, R., Coon, H., Lazenby, J. and Herron, M. (1996). Assessing the work environment for creativity. Academy of Management Journal, 39 (5), 1154–1184.

Baark, E., Lau, Antonio, K.W., William, L. and Sharif, N. (2011). Innovation Sources, Capabilities and Competitiveness: Evidence from Hong Kong Firms. Paper presented at the DIME (Dynamics of Institutions & Markets in Europe) Final Conference, 6-8 April, 2011, Maastricht, 1-40.

Barney, J.B. and Clark, D.N. (2007). Resource-based Theory Creating and Sustaining Competitive Advantage, Oxford University Press, Oxford.

Bessant, J., Lamming, R., Noke, H. and Phillip, W. (2005). Managing innovation beyond the steady state. Technovation, 25(12), 1366-1376.

Burgelman, R., Maidique, M.A. and Wheelwright, S.C. (2004). Strategic Management of Technology and Innovation. McGraw-Hill, New York, 8-12.

Camisón, C. and Forés, B. (2010). Knowledge absorptive capacity: New insights for its conceptualization and measurement. Journal of Business Research, 63, 707–715.

Camisón, C. and Villar-López, A. (2012). Organizational innovation as an enabler of technological innovation capabilities and firm performance. Journal of Business Research. In Press, corrected proof, available online 22 Jun, 2012.

Ceylan, C. and Koc, T. (2007). Factors impacting the innovative capacity in large-scale companies. Technovation, 27, 105-114.

Cohen, W.M. and Lavinthal, D.A. (1990). Absorptive Capacity: A New Perspective on Learning and Innovation. Administrative Science Quarterly, 35, (1), 128-152.

Chesbrough, H.W. (2004). Managing open innovation. Research Technology Management, 47, (1), 23–26.

Chiesa, V., Coughlan, P. and Voss, C.A. (1996). Development of a technical innovation audit. Journal of Product Innovation Management, 13(2), 105–136.

Chiesa, V., Coughlan, P. and Voss, C.A. (1998). Development of a technical innovation audit. *IEEE Engineering Management Review*, 26(2), 64-91.

Chiva, R. and Alegre, J. (2007). Measuring organizational learning capability among the workforce. *International Journal Manpower*, 28(3/4), 224-242

Chiu, Y.J., Chen, H.C., Tzeng, G.H. and Shyu, J.Z. (2006). Marketing strategy based on customer behavior for the LCD-TV. *International Journal of Management and Decision Making*, 7 (2/3), 143-165.

Christensen, J.F. (1995). Asset profiles for technological innovation. *Research Policy*, 24, 727–745.

De Toni, A. and Nassimbeni, G. (2001). A method for the evaluation of suppliers' co design effort. *International Journal of Production Economics*, 72(2), 169-180.

Dobni, C.B. (2008). Measuring innovation culture in organizations, The development of a generalized innovation culture construct using exploratory factor analysis. *European Journal of Innovation Management*, 11(4), 539-559

Forsman, H. (2011). Innovation capacity and innovation development in small enterprise, A comparison between the manufacturing and service sector. *Research Policy*, 40,

*Corresponding author (P.Anuntavoranich). Tel: +66-2-657-6334. E-mail: dettoy999@gmail.com, p.idchula@gmail.com. Volume 4 No.2 ISSN 2228-9860 eISSN 1906-9642. Online Available at http://TuEngr.com/V04/081-103.pdf

739-750.

Garrison, G. (2009). An assessment of organizational size and sense and response capability on the early adoption of disruptive technology. *Computers in Human Behavior*, 25, 444–449.

Gebauer, H., Worch H. and Truffer B. (2012). Absorptive capacity, learning processes and combinative capabilities as determinants of strategic innovation. *European Management Journal*, 30, 57-73.

Guan, J. and Ma, N. (2003). Innovation capability and export performance of Chinese firms. *Technovation*, 23(9): 737-747.

Guan, J.C., Yam, R.C.M., Mok, C.K. and Ma N. (2006). A study of the relationship between competitiveness and technological innovation capability based on DEA models. *European Journal of Operational Research*, 170, 971–986.

Hansen, J. A. (2001). Technology innovation indicators, a survey of historical development and current practice. In: Feldman, M.P., Link, A. N. (Eds.). *Innovation Policy in the Knowledge-Based Economy*, 73-103.

Hemmert, M. (2004).The influence of institutional factors on the technology acquisition Performance of high-tech firms: survey results from Germany and Japan. *Research Policy,* 33, 1019–1039.

Ho, Y.C., Fang, H.C. and Lin, J.F. (2011). Technological and design capabilities: is ambidexterity possible? *Management Decision*, 49 (2), 208 – 225.

Huang, H.C. (2011). Technological innovation capability creation potential of open innovation: a cross-level analysis in the biotechnology industry. *Technology Analysis & Strategic Management,* 23(1), 49-63.

Isaksen, S.G., Lauer, K.J. and Ekvall, G. (1999). Situational outlook questionnaire: a measure of the climate for creativity and change. *Psychological Reports*, 85, 665–674.

Jansen, J., Van den Bosch, F. and Volberda, H. (2005). Managing potential and realized absorptive capacity: how do organizational antecedents matter. *The Academy of Management Journal*, 48(6), 999-1015.

Kim, C. and Song, J. (2007). Creating new technology through alliances: an empirical investigation of joint patents. *Technovation*, 27 (8), 461–470.

Kim, K.K., Lee B.G., Park, B.S. and Ohm, K.S. (2011). The effect of R&D, technology commercialization capabilities and innovation performance. *Technological and Economic Development of Economy*, 17(4), 563-578.

Lane, P.J. and Koka, B.R. (2006). The reification of absorptive capacity: a critical review and rejuvenation of the construct. *Academy of Management Review*, 31 (4), 833–863.

Lee, H., Lee, S. and Park, Y. (2009). Selection of technology acquisition mode using the analytic network process. *Mathematical and Computer Modelling*, 49, 1274-1282.

Lee, H.I., Kang, H.Y., Hsu, C.F. and Hung, H.C. (2009). A green supplier selection model for high-tech industry. *Expert System Application*, 36 (4), 7917-7927.

Levitas, E. and McFadyen, M.A. (2009). Managing liquidity in research-intensive firms: signaling and cash flow effects of patents and alliance activities. *Strategic Management Journal*, 30 (6), 659–678.

Lin, B.-W. (2004). Original equipment manufacturers (OEM) manufacturing strategy for network innovation agility: the case of Taiwanese manufacturing networks. *International Journal Production Research*, 42(5), 943–957.

Lin, C., Wu, Y-J., Chang, C., Wang, W. and Lee, C-Y. (2012). The alliance innovation performance of R&D alliances - the absorptive capacity perspective. *Technovation*, 32(5), 282–292.

Lin, C. L. and Tzeng, G. H. (2009). A value-created system of science (technology) park by using DEMETEL. *Expert Systems with Applications*, 36, 9683-9697.

Liou, J.J.H., Tzeng, G.H. and Chang, H.C. (2007). Airline safety measurement using a novel hybrid model. *Journal of Air Transport Management*, 13 (4), 243-249.

Martin, E.C. and Terblanche, F. (2003). Building organizational culture that stimulates creativity and innovation. *European Journal of Innovation*, 6(1), 64-74.

Miranda, S.M., Lee J-N. and Lee J-H. (2011). Stocks and flows underlying organizations' knowledge management capability: Synergistic versus contingent complementarities over time. *Information & Management*, 48 (8), 382-392.

Mu, J. and Benedetto, C.A.D. (2011). Strategic orientations and new product commercialization: mediator, moderator, and interplay. *R&D Management*, 41(4), 337-359.

Nassimbeni, G. and Battain, F. (2003). Evaluation of supplier contribution to product development: fuzzy and neuro-fuzzy based approaches. *International Journal of Production Research*, 41(13), 2933-2956.

O'Regan, N., Ghobadian, A. and Sims, M. (2006). Fast tracking innovation in manufacturing SMEs. *Technovation*, 26(2), 251–261.

Perdomo-Ortiz, J., González-Benito, J. and Galende, J. (2009). The intervening effect of business innovation capability on the relationship between total quality management and technological innovation. *International Journal of Production Research*, 47(18), 5087–5107.

Romijin, H. and Albaladejo, M. (2002). Determinants of innovation capability in small electronics and software firms in Southern England. *Research Policy,* 31, 1053-1067.

*Corresponding author (P.Anuntavoranich). Tel: +66-2-657-6334. E-mail: dettoy999@gmail.com, p.idchula@gmail.com.

Shan, J. and Jolly, D. R. (2010). Accumulation of Technological Innovation Capability and Competitive Performance in Chinese firms: A quantitative study. *The International Association for Management of Technology (IAMOT) in Cairo, Egyp*t, 1-21.

Shieh, J. I., Wu, H. H. and Huang, K. K. (2010). A DEMATEL method in identifying key success factors of hospital service quality. *Knowledge-Based Systems*, 23, 277-282.

Spithoven, A., Clarysse, B. and Knockaert, M. (2010). Building absorptive capacity to organize inbound open innovation in traditional industries. *Technovation*, 30(2), 130–141.

Spyropoulou, S. and Kyrgidou, L.P. (2012). Drivers and Performance Outcomes of Innovativeness: An Empirical Study. *British Journal of Management*.

Teece, D. J. (2007). Explicating dynamic capabilities: The nature and micro-foundations of (sustainable) enterprise performance. *Strategic Management Journal*, 28(8), 1319–1350.

Tidd, J. (2006). A review of innovation models. *Discussion Paper*, Imperial College London: 1-16.

Türker, M.V. (2012). A model proposal oriented to measure technological innovation capabilities of business firms – a research on automotive industry. *Procedia - Social and Behavioral Sciences,* 41, 147 – 159.

Tzeng, G.H., Chiang, C.H. and Li, C.W. (2007). Evaluating intertwined effects in e-learning programs: a novel hybrid MCDM model based on factor analysis and DEMATEL. *Expert Systems with Applications*, 32 (4), 1028-1044.

Voudouris, I., Lioukas, S., Iatrelli, M. and Caloghirou, Y. (2012). Effectiveness of technology investment: Impact of internal technological capability, networking and investment's strategic importance. *Technovation*, 32(6), 400-414

Wang, C.H., Lu, I.Y. and Chen, C. B. (2008). Evaluating firm technological innovation capability under uncertainty. *Technovation*, 28(6), 349-363.

Wonglimpiyarat, J. (2010). Innovation index and the innovation capacity of nation. *Futures*, 42 (3), 788-801.

Wu, W.W. and Lee, Y.T. (2007). Developing global managers' competencies using the fuzzy DEMATEL method. *Expert Systems with Applications*, 32 (2), 499-507.

Yam, R.C.M., Guan, J.C., Pun, K.F. and Tang, E.P.Y. (2004). An audit of technological innovation capabilities in Chinese firms: some empirical finding in Beijing, China. *Research Policy*, 33(8), 1123-1140.

Yam, R.C.M., Lo, W., Tang, E.P.Y. and Lau A.K.W. (2011). Analysis of sources of innovation, technological innovation capabilities, and performance: An empirical study of Hong Kong manufacturing industries. *Research Policy*, 40, 391-402.

Yang, J. (2012). Innovation capability and corporate growth: An empirical investigation in

China. *Journal of Engineering and Technology Management*, 29(1), 34–46.

Yang, L-R. (2013). Key practices, manufacturing capability and attainment of manufacturing goals: The perspective of project/engineer-to-order manufacturing. *International Journal of Project Management*, 31(1), 109-125.

Yang, Y.P., Shieh, H. M., Leu, J.D. and Tzeng, G.H. (2008). A novel hybrid MCDM model combined with DEMATEL and ANP with applications. *International Journal Operational Research*, 5(3), 160-168.

Yu, R. and Tseng, G.H. (2006). A soft computing method for multi-criteria decision making with dependence and feedback. *Applied Mathematics Computation*, 180(1), 63-75.

Zahra, S.A. and George, G. (2002). Absorptive capacity: a review, reconceptualization, and extension. *Academy of Management Review*, 27(2), 185–203.

Zeng, S.X., Xie, X.M. and Tam, C.M. (2010). Relationship between cooperation networks and innovation performance of SMEs. *Technovation*, 30(3), 181-194.

Zhang, Z., Waszink, A. and Wijngaard, J. (2000). An instrument for measuring TQM implementation for Chinese manufacturing companies. *International Journal of Quality & Reliability Management*, 17 (7), 730–755.

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