An Analytic Hierarchy Process Modeling for Technological Innovation Capability Appraisal for Thai Automotive Part firms

Detcharat Sumrit*, Pongpun Anuntavoranich*

* Technopreneurship and Innovation Management Program, Graduate School, Chulalongkorn University, Bangkok, Thailand

Abstract- This study proposes the systematic method by using the Analytic hierarchy process (AHP) to deal with the rational multi decision making on various assessment factors for technological innovation capabilities of Thai automotive part firms. Based on pair wise comparison, an expert group provided the perception of the important relative weight data towards these assessment factors. The results presented this proposed model is one of the effective methods to help managements to easily analyze what is the most influence criteria impact on firms' capabilities and what criteria should be firstly improved. Also last section highlighted this model application on Thai automotive part firms as case study. The comparison outcome may provide the industrial managements for their TICs assessment developments and the insight of others in the same market.

Index Terms- Analytic hierarchy process (AHP), Technological Innovation Capabilities (TICs), Thai automotive part firms, TICs assessment criteria.

I. INTRODUCTION

According to the forward coming launch of Asean Economic Community (AEC) in 2015, Thailand as a large production base of automotive and auto-parts manufacturing, may confront the higher increase of global competitive pressure. The auto-parts manufacturing firms have attracted more interesting from both local private and governmental agency owing to their larger benefits rising from competitive advantage in production and trading and contribution to country. However, undergoing of the volatility of world's economic; these auto-part firms need the innovative management improvement to enhance their competitiveness. Prajogo & Ahmed [1] defined the innovation comes to be a main source of competitive advantage in the current knowledge economy, which firms strongly require the effectively implemented strategies to sustain their competitive advantage [2]. The innovation management is also a key business strategy in the innovative organization to tackle with the decision making, environmental investigation, resource allocation, and project implementation [3], [4], [5]. Also Badawy [3] described the importance of the successful technology management is to focus on the innovation process, the technology development and the utilization of technology in both business and industry. However, the business's activities highly involve the uncertainty of business innovation process, which are difficult to accurately forecast and evaluate their capabilities. Therefore, it is necessary to find what capabilities impact to firms' performance [6]. Thus Technological Innovation Capabilities (TICs) is considered as one of the firms' solutions as well as the way to effectively measure TICs under the multi-dimensions of criteria is also important. The research aims to propose a kind of multi-criteria decision making to help Thai auto-part managements for simply evaluate their TICs appraisal and enlarge the technological innovation competencies.

II. LITERATURE REVIEWS

This study attempts to draw on theoretical literature to explore TICs appraisal. However, it was found that the meanings of technological innovation capabilities are numerous given its multi-dimensional concepts; for example Burgelman and Maidique [7] defined TIC as an inclusive set of a firm's characteristics that simplifies the firms' technological innovation strategies. Guan and Ma [8] determined TICs, as a kind of an enterprise's special assets or resources, composed of the different essential areas of technology, production, process, knowledge, experience and organization. Gamal [9] also described that innovation has the boarded concept and various dimensions as well as the innovation measurement is more complexity.

According to Panda and Ramanathan [10], the important information were obtained from technological capability assessment, which carried out the inputs or the indicators of what requirements firms needed to do in order to enhance more competitiveness and to support its strategic decision making. The result was shown that a medium and high level rate of firms' supporting capability and steering capability could be pointed out as firms' strategic plan. Yam et al. [11] proposed a set of TICs characteristics as relevant framework, to reflect and sustain the Chinese firms' competitiveness. The result showed two main important TICs i.e. R&D capability to prevent the innovation rate and the resource allocation capability to increase sales growth in small enterprises. Moreover they opined the essence of the capability from independent department in firms, which could generate the new idea and the audit framework model, was then developed as functional approach. The development of the important framework to evaluate innovation performance is studied by Yam [12], resulting that the utilization of source of

information created the improved performance due to the affect on firms' TICs enhancement. Forsman and Annala [13] described the diversity of types of developed innovation had an impact on the degree of innovation capabilities of enterprises. The more the level of capabilities is raising, the more the diversity of innovations to be developed.

III. RESEARCH METHODOLOGY

A. Technological Innovation Capabilities

By using AHP model, the process of TICs evaluation framework includes the following steps.

1) Review the extensive of literatures related to TICs and extract to seven criteria and nineteen sub-criteria evaluation as Table 1 and then construct a proposed TICs appraisal model as Fig. 1.

2) In-depth interview with the industrial experts to assure the TICs appraisal model. Then obtain their judgments on the relative important weight data based on pair-wise comparison and next, to employ AHP technique in order to calculate and compare the interrelation among criteria and to weight prioritization. Finally, the sensitivity analysis shows how the changes of relative weights effected to the important criteria prioritization.

3) Apply the final TICs appraisal model as one of auditing tool towards three Thai auto-part firms, as case study.

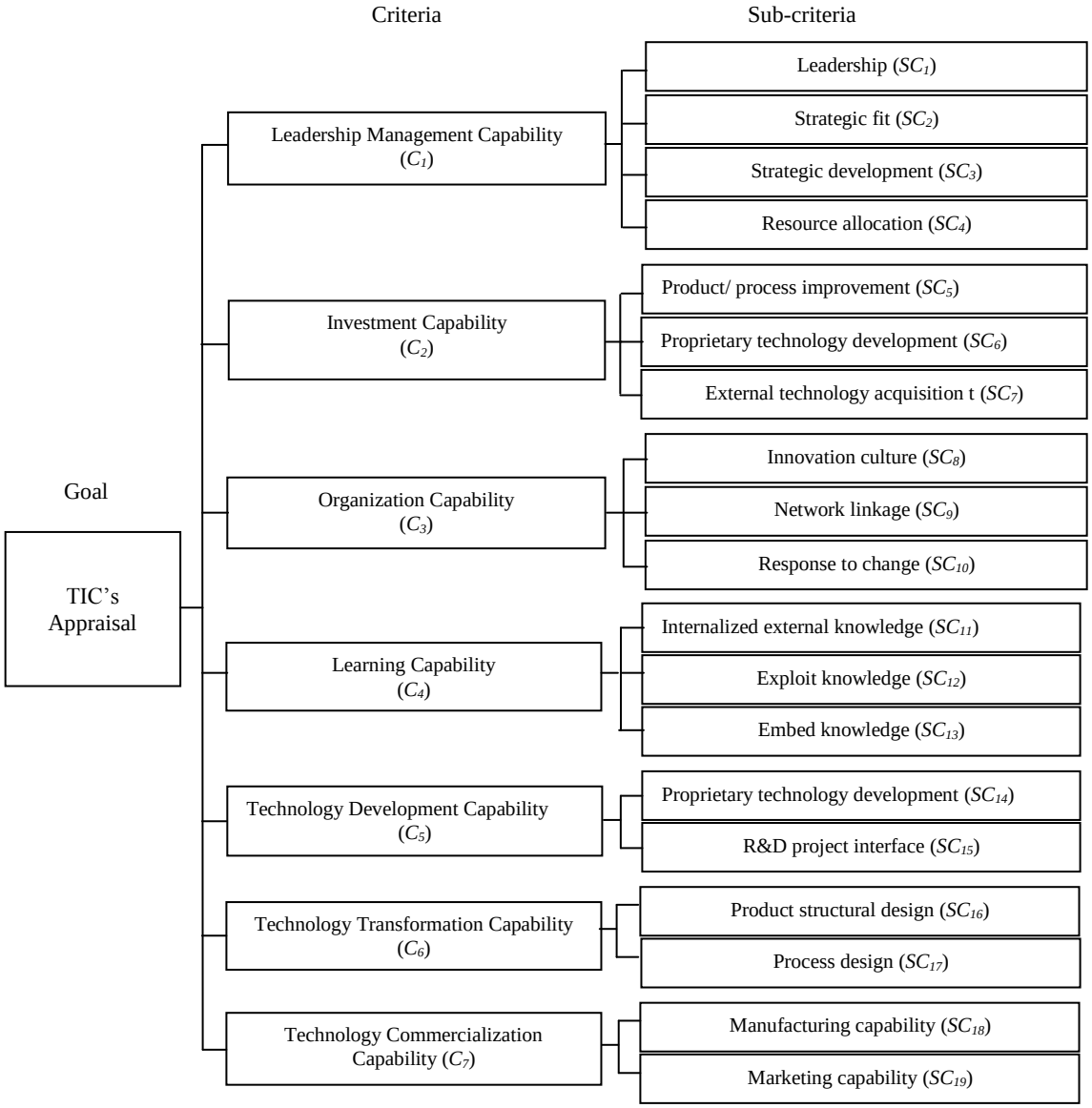

Figure 1: Proposed TIC assessment model

Table 1: Summary of the criteria and sub-criteria from literatures

Evaluation Criteria	Description	Authors
Innovation Management Capability (C_1)		
Leadership commitment *(SC_1)*	Firm's top management actively participates in decisions related to technological issues.	[14], [15], [16], [17]
Strategic fit *(SC_2)*	Firm's technological innovation strategy to support business strategy.	[16], [18], [12]
Strategic deployment *(SC_3)*	Firm's technological innovation strategy be shared and applied to each department/unit.	[16], [18], [19]
Resource allocation *(SC_4)*	Firm's ability to appropriately acquire and allocate capital & technology.	[18], [20], [12]
Investment Capability (C_2)		
Investment in existing product/process improvement *(SC_5)*	Firm's ability in continuous investment in the existing technological product & process improvement.	[18], [19], [21]
Investment in proprietary technology development (SC_6)	Firm's capability in investment in developing proprietary technology.	[12], [22]
Investment in external technology acquisition *(SC_7)*	Firm's ability to invest in external technology acquisition.	[23], [24]
Organization Capability (C_3)		
Innovation culture *(SC_8)*	Firm's ability in cultivate innovation culture.	[19], [17], [25]
Network linkage *(SC_9)*	Firm's ability to transmit information, skills and technology, and to receive them from other departments, clients, suppliers, consultants, technological institutions, etc.	[20], [26], [27], [28], [29], [30], [31], [32],
Response to change *(SC_{10})*	Firm's capability in risk assessment , risk taking and responding to technological innovation change and adopting	[33], [21], [15], [30], [29],
Learning Capability (C_4)		
Internalized external knowledge *(SC_{11})*	Firm's ability to recognize and internalize relevant external knowledge	[34], [29], [35],
Exploit knowledge *(SC_{12})*	Firm's ability to bring new knowledge or technologies to develop innovative product	[34], [29]
Embed knowledge *(SC_{13})*	Firm's ability to embed new knowledge into new operational by creating a shared understanding and collective sense-making.	[34], [29]
Technology Development Capability (C_5)		
Proprietary technology development *(SC_{14})*	Firm's ability to develop proprietary technologies though in-house R&D	[15], [16], [20], [29] [31]
R&D Project Interfacing *(SC_{15})*	Firm's ability to coordinate and integrate all phases of the R&D process and its inter-relations with the functional tasks of engineering, production and marketing.	[36], [34], [31], [30]
Technology Transformation Capability (C_6)		
Product structural design and engineering *(SC_{16})*	Ability to design product structure & modularization & compatible with process.	[37], [38], [36], [39]
Process design and engineering *(SC_{17})*	Firm's ability to design process to support design for manufacturing and design for assembly activities.	[37], [40], [38], [39]
Technology Commercialization capability (C_7)		
Manufacturing Capability *(SC_{18})*	Firms' ability in transform R&D output into production and acquire the innovative advanced manufacturing technologies/ methods.	[36], [11], [41], [16], [20], [12], [31], [42]
Marketing Capability *(SC_{19})*	Firm's ability to public and sell products on the basis of understanding customers' needs, competitive environment, costs and benefits, and the innovation acceptance.	[36], [11], [41], [19], [20], [12], [29], [30], [31],

B. The Analytical Hierarchical Process (AHP)

According to Saaty [44], AHP is a key outstanding management tool for complexity of multi-criteria decision problems. The methodology of AHP was developed to support rational decision making on numerous criteria and to flexibly solve not only qualitative problems but also quantitative problems. The analytic process of AHP was shown as following steps [45].

Step 1: Form the pair wise comparison matrix (C), as Eq.(1).

$$C = (C_{ij})_{nxn} = \begin{pmatrix} C_{11} & C_{12} & \dots & C_{1n} \\ C_{21} & C_{22} & \dots & C_{2n} \\ \vdots & \vdots & \dots & \vdots \\ C_{n1} & C_{n2} & \dots & C_{nn} \end{pmatrix} \quad (1)$$

where C_{ij} is the importance degree of the i^{th} factor compared to the j^{th} factor.

Step 2: Construct the normalized criteria of matrix C. The formula can be shown in Eq. (2).

$$C_{ij}^{Norm} = \frac{C_{ij}}{\sum_{k=1}^{n} C_{kj}}, \qquad i, j = 1, 2, \dots, n \quad (2)$$

Then, Eq. (3) showed the normalization matrix, C^{Norm}.

$$C^{Norm} = (C_{ij}^{Norm})_{nxn} \quad (3)$$

Step 3: Aggregate the each criteria of the same row of normalization matrix C^{Norm} , as computed by Eq. (4).

$$W_i^{Norm} = \sum_{j=1}^{n} C_{ij}^{Norm}, \qquad i = 1, 2, \dots, n \quad (4)$$

Step 4: Formulate the weights vector $W = (w_1, w_2, \dots, w_n)$ as the following Eq. (5).

$$W_i = \frac{W_i^{Norm}}{\sum_{k=1}^{n} W_k^{Norm}}, \qquad i = 1, 2, \dots, n \quad (5)$$

Step 5: Compute the maximum value (λ_{max}) as in Eq. (6).

$$\lambda_{max} = \frac{1}{n} \sum_{i=1}^{n} \frac{(CW)_i}{w_i} \quad (6)$$

where *n* is the dimension of the comparison matrix.

Step 6: Finally compute the consistency ratio (CR) as a consistency check as applied in Eq. (7).

$$CR = \frac{CI}{RI} \quad (7)$$

where *RI* is the random index. RI values can change with the dimension variations. For *CI* is the consistency index, be computed as Eq. (8).

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (8)$$

when CR $\leq$0.10 means that the consistence of the pair-wise comparison matrix is acceptable.

IV. RESULTS AND DISCUSSION

Once the consensus of expert panels confirmed the TICs appraisal model including seven criteria and nineteen sub-criteria, the result of global weights in a hierarchy manner by processing through AHP analysis was represented as Table 2. Synthesis with respect to TICs Evaluation (Overall inconsistency= 0.089) was presented in Fig.2. And the sensitivity analysis for nodes below TICs Evaluation was showed in Fig. 3. Based on the value global weights ranking, the top-five most important criteria that industrial managements in this auto-part industry would prioritizing concerned, were embed new knowledge, development proprietary technology, leadership, strategic fit and product structure design, respectively.

For a case study on three chosen Thai auto-part firms, the industrial experts/ audit team from automotive part industries provided the rating score ranged from 1 (weak) to 5 (excellent) on each TICs criteria appraisal model. Overall result of their final weights contribution was exhibited in Table 3.

Moreover, all score ranking of three companies could be separately plotted on each evaluation criteria, which the multivariate observations could be simply depicted in comparison via the charts, as displayed in Fig 4.

The result comparison among three companies showed that company A was the best innovative company in term of high score value in most TICs appraisal criteria i.e. development proprietary technology, leadership, product structure design, proprietary technology investment, marketing capability, R&D project interface, resource allocation, response to change, embed knowledge, manufacturing capability, improve existing product/ process and network linkage. While company B had greater outstanding in process design, strategic fit and strategic deployment. For company C was considered as the poorest, acquiring the lowest score, which could need the effective improvement in most aspects of TICs appraisal criteria.

Table 2: Final local and global weights of TICs Appraisal criteria

Criteria	Sub-Criteria	Local weights	Global weights
Innovation Management Capability (C_1)	Leadership *(SC_1)*	0.485	0.163
	Strategic Fit *(SC_2)*	0.344	0.115
	Strategic Deployment *(SC_3)*	0.130	0.044
	Resource Allocation *(SC_4)*	0.041	0.014
Investment Capability (C_2)	Improve Existing Product/Process *(SC_5)*	0.178	0.005
	Invest in Proprietary Technology *(SC_6)*	0.763	0.022
	External Technology Acquisition *(SC_7)*	0.058	0.002
Organization Capability (C_3)	Innovation Culture *(SC_8)*	0.757	0.050
	Network Linkage *(SC_9)*	0.054	0.004
	Response to Change *(SC_{10})*	0.189	0.013
Learning Capability (C_4)	Internalized External Knowledge *(SC_{11})*	0.230	0.064
	Exploit Knowledge *(SC_{12})*	0.062	0.017
	Embed Knowledge *(SC_{13})*	0.708	0.197
Technology Development Capability (C_5)	Development Proprietary Technology *(SC_{14})*	0.889	0.169
	R&D Project Interfacing *(SC_{15})*	0.111	0.021
Technology Transformation Capability (C_6)	Product Structure Design *(SC_{16})*	0.889	0.066
	Process Design *(SC_{17})*	0.111	0.008
Technology Commercialization Capability (C_7)	Manufacturing Capability *(SC_{18})*	0.002	0.006
	Marketing Capability *(SC_{19})*	0.800	0.022

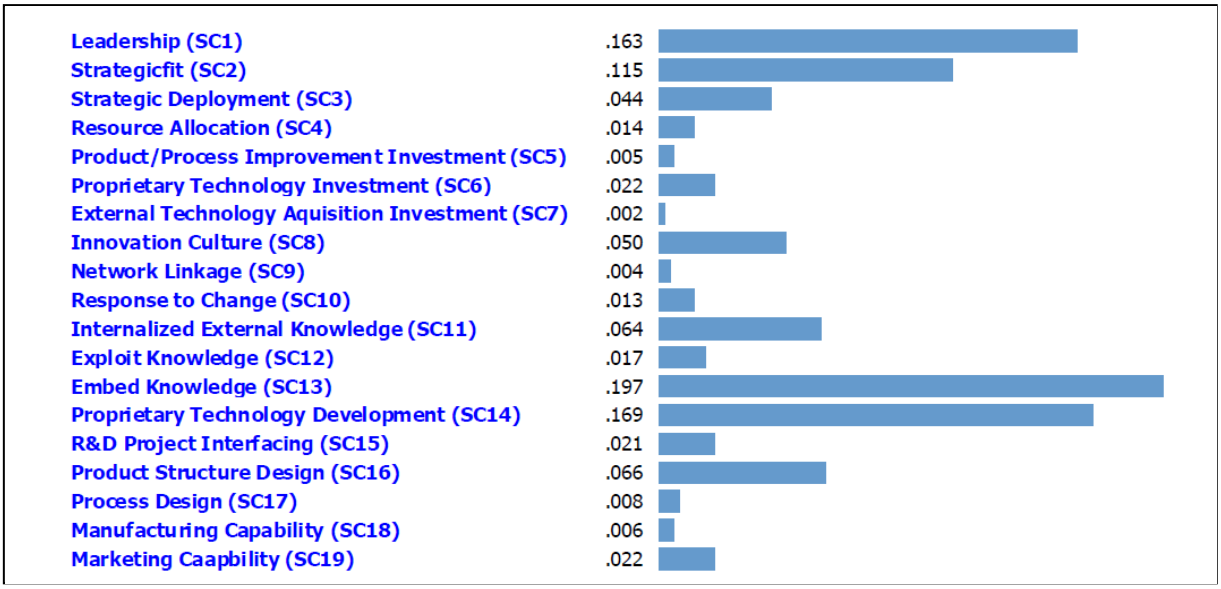

Figure 2: Synthesis with respect to TICs Appraisal (Overall inconsistency = 0.089)

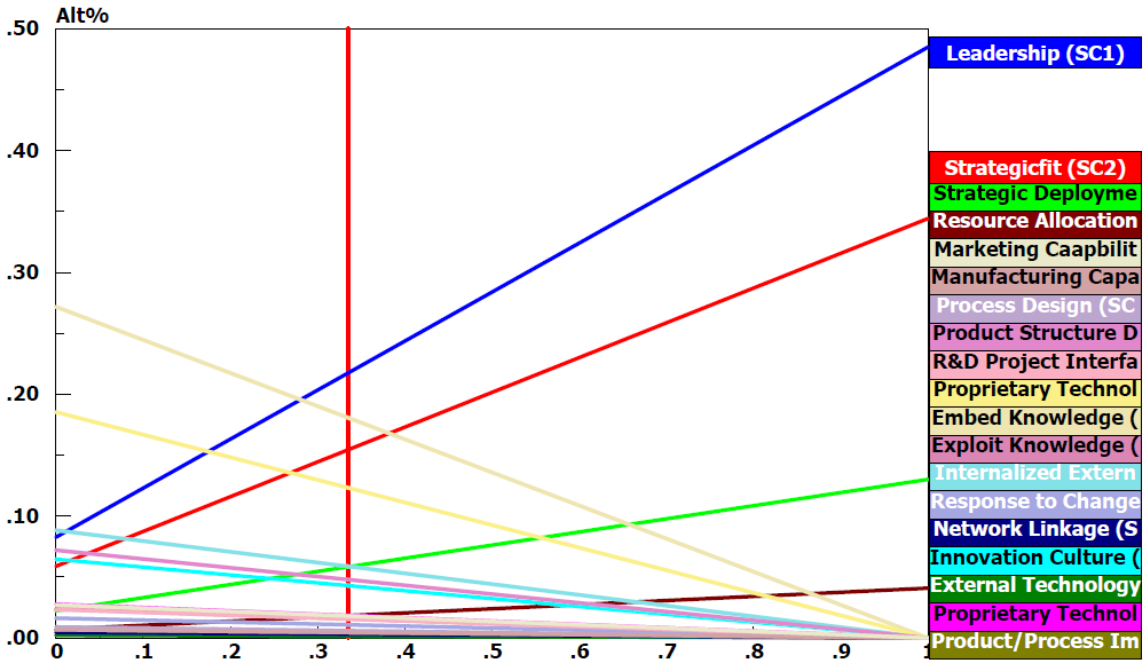

Figure 3: Sensitivity analysis for nodes below TICs Appraisal

Table 3: Overall score of TICs appraisal criteria among three companies, a case study

TICs Appraisal Criteria	Global weights	Company A		Company B		Company C	
		Score	Net Score	Score	Net Score	Score	Net Score
Leadership *(SC_1)*	0.163	4	0.652	3	0.489	1	0.163
Strategic Fit *(SC_2)*	0.115	4	0.46	5	0.575	2	0.23
Strategic Deployment *(SC_3)*	0.044	3	0.132	4	0.176	2	0.088
Resource Allocation *(SC_4)*	0.014	5	0.07	3	0.042	2	0.028
Improve Existing Product/Process *(SC_5)*	0.005	4	0.02	3	0.015	1	0.005
Invest in Proprietary Technology *(SC_6)*	0.022	5	0.11	4	0.088	1	0.022
External Technology Acquisition *(SC_7)*	0.002	4	0.008	3	0.006	2	0.004
Innovation Culture *(SC_8)*	0.050	3	0.15	3	0.15	2	0.1
Network Linkage *(SC_9)*	0.004	4	0.016	4	0.016	1	0.004
Response to Change *(SC_{10})*	0.013	5	0.065	3	0.039	2	0.026
Internalized External Knowledge *(SC_{11})*	0.064	4	0.256	4	0.256	1	0.064
Exploit Knowledge *(SC_{12})*	0.017	3	0.051	4	0.068	2	0.034
Embed Knowledge *(SC_{13})*	0.197	3	0.591	3	0.591	2	0.394
Development Proprietary Technology *(SC_{14})*	0.169	4	0.676	3	0.507	2	0.338
R&D Project Interfacing *(SC_{15})*	0.021	4	0.084	3	0.063	2	0.042
Product Structure Design *(SC_{16})*	0.066	4	0.264	2	0.132	1	0.066
Process Design *(SC_{17})*	0.008	3	0.024	4	0.032	3	0.024
Manufacturing Capability *(SC_{18})*	0.006	5	0.030	2	0.012	1	0.006
Marketing Capability *(SC_{19})*	0.022	4	0.088	3	0.066	2	0.044

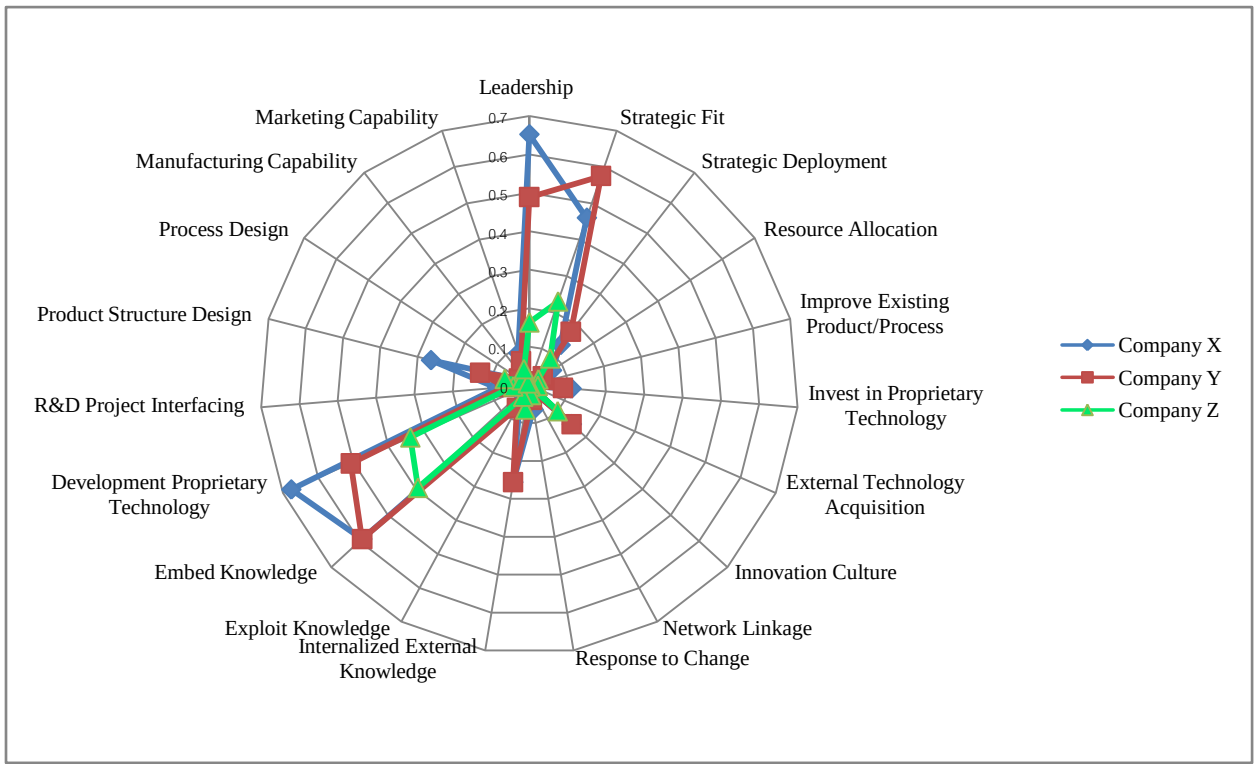

Figure 4: Comparison of each TICs appraisal criteria among three companies

V. CONCLUSION

This research proposed a comprehensive TICs appraisal method based on employing the Analytical Hierarchy Process (AHP) method to simply assist top managements towards their innovation business strategic for improving firms' competitiveness. The role of this active method can be an extensive method application to other related industries. It also provides a guidance of TICs evaluation improvement for not only Thai automotive part firms but also other industry firms. With new adjustable experts' perception data depending on each characteristic of a specific industry, other top-level managements in different industry would obtain the new set of relative weight criteria data served as an outcome of managerial information.

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AUTHORS

First Author – Detcharat Sumrit, Ph.D. Candidate at Technopreneurship and Innovation Management Program, Graduate School, Chulalongkorn University, Bangkok, Thailand, Detcharat.S@Student.chula.ac.th

Correspondence Author – Asst. Prof. Dr. Pongpun Anuntavoranich, Technopreneurship and Innovation Management Program, Graduate School, Chulalongkorn University, Bangkok,Thailand, p.idchula@gmail.com.