APPENDIX

MANUCRIPT

INTEGRATED FUZZY AHP AND FUZZY DELPHI METHODS FOR PRIORITIZING CRITICAL SUCCESS FACTORS IN FUNCTIONAL UPGRADING

A functional upgrading from original equipment manufacturing (OEM) to original design manufacturing (ODM) and original brand manufacturing (OBM), or moving towards higher value adding activities within the global value chain has been considered as the key strategy for the OEM firms to escape the low value-added trap and lead to a sustainable competitive advantage. To increase the chances for success of functional upgrading, this study aims to identify and prioritize critical success factors in functional upgrading in context of the electronics industry in Thailand using the fuzzy Delphi and fuzzy Analytic Hierarchy Process (AHP) approaches. A multi-criteria decision-making model in a multiple theoretical framework is developed encompassing dynamic capabilities considered as mediating factors in the relationship between critical success factors and performance indicators. A sensitivity analysis is performed to evaluate the robustness of the ranking results. Moreover, the theoretical and managerial implications are also discussed. The research result found that the three most significant critical success factors were 'technological capabilities', 'networks', and 'government's policies' respectively. Finally, this study offers some implications for practitioners which contribute to the effective management oriented the critical success factors and for policy makers which contribute to the effective policy development for promoting the success of functional upgrading to sustain competitiveness of electronics manufacturers and industry in Thailand.

Keywords: functional upgrading; critical success factors; fuzzy multi-criteria decision making; fuzzy AHP; organizational theory; dynamic capabilities.

1. Introduction

To survive and gain a competitive advantage in today's global competitive market, most of original equipment manufacturing (OEM) firms which lie in low end of the global value chain (GVC) (Hobday, 1995) have to think about moving upward along the GVCs and transform/upgrade their operations to become original design manufacturering (ODM) and original brand manufacturering (OBM) (Eng & Spickett-Jones, 2009; van Assche, 2017) which will not only provide the benefits of higher prices and margins, and greater customer awareness to the firm's products and brands, but also improve customer loyalty.

Moving from OEM to ODM and OBM by focusing on higher value-added activities in GVCs (e.g. distribution or logistics, product development, design and branding), or so-called a 'functional upgrading' in the GVC literature, is considered as the acquisition of a set of necessary new capabilities/competencies that will allow firms to move into higher value-added (i.e. better remunerated, higher margin) activities. This functional upgrading is identified as a survival strategy for OEM firms to enhance their competitiveness (Manzakoğlu & Er, 2018; van Assche, 2017; Chen, Wei, Hu, & Muralidharan, 2016).

Though, many OEM firms from emerging economies attempt to upgrade to become ODM and OBM. However, many of them have failed during the functional upgrading (Chen et al., 2016; Manzakoğlu & Er, 2018). To increase the chances for the success of functional upgrading, therefore, it is important to identify and prioritize the critical success factors – a careful and comprehensive analysis in particular to identify the specific critical factors influencing the success of this upgrading and determine the most significant factors to which management must pay attention needs to be made explicit. However, in many emerging countries including Thailand, the issue of prioritization of critical success factors has hardly been studied in functional upgrading. Therefore, we studied the critical success factors in functional upgrading from OEM to ODM and OBM and prioritized them using the fuzzy multi-criteria decision making.

Regarding complex prioritization problems, an Analytic Hierarchy Process (AHP) which is a widely used multi-criteria decision making (MCDM) technique, has successfully been applied to many problems (Roy, 1996; Svahnberg, Wohlin, Lundberg, & Mattsson, 2002). The traditional AHP requires precise or crisp judgments from decision makers. However, due to the complexity and uncertainty involved in real-world decision problems and the inherent subjective nature of human judgments (Wang & Chin, 2006), it is difficult for decision makers to provide crisp judgments. It is easier and more suitable to provide fuzzy (imprecise or vague) judgments.

In order to handle uncertainty, subjectivity and vagueness of human judgment in decision-making, the fuzzy analytical hierarchy process (Fuzzy AHP) integrated fuzzy set theory and AHP has been employed (Hsu & Chen, 2007; Hsu, Lee, & Kreng, 2010; Mardani, Jusoh, Bagheri, & Kazemilari, 2015; Zaim, Sevkli, & Tarim, 2003). Similarly, the fuzzy Delphi method which is a combination between the Fuzzy Set Theory and traditional Delphi method, can be used to take vague concepts involved to gather diverse distributed opinions or to reach a consensus in only one round of survey (Kabir & Sumi, 2012; Mardani et al., 2015).

Moreover, the complexity of a prioritization problem needs the integration of different theories to develop the comprehensive prioritization framework and model (Coates & McDermott, 2002). Hence, this study aims to identify and prioritize the critical success factors for functional upgrading in the electronics industry in Thailand, based on multiple theoretical perspectives underpinning, using the fuzzy Delphi and fuzzy AHP approaches. In this study, the potential success factors are extracted from the literature review through the three theoretical lenses including the resource-based and relational views and the institutional theory; furthermore, these theories also represent the factor categories classified into three groups of internal, relational and institutional, whereas, the Balanced Scorecard (BSC) concept is used to determine the initial evaluation criteria for the performance of functional upgrading, which covers four perspectives, namely, financial, customer, internal process, and learning and growth perspectives. The potential performance indicators (as the decision criteria in MCDM) are extracted from the literature review through the four BSC perspectives. The fuzzy Delphi method with multiple theoretical perspectives provides us with a more comprehensive view for what are the critical success factors in such context, whereas the theoretical framework of fuzzy AHP method shows us how the experts evaluate the relative importance and thus prioritize critical success factors when multiple criteria exists.

The remainder of the paper is structured as follows: in the next section, we present literature review. In Section 3, we present our method in detail. In Section 4, we discuss the results of our study and implications based on the findings. In Section 5, we present conclusions from our study, limitations and future research.

2. Literature Review

2.1. *Functional upgrading & the electronics industry in Thailand*

A functional upgrading can be defined as the move towards higher value adding activities within the GVC (Humphrey & Schmitz, 2002). It can be drawn like transforming of OEM (i.e. the manufacturing of low value-added products under contract to a buyer) to become ODM (i.e. the design of products sold under the brand names of other firms) and finally to become OBM (i.e. the sale of its own branded products) which can provide better returns.

Most firms in the electronics industry in Thailand are OEM firms which mainly assemble or manufacture products required by customers (contractors/vendors within the supply chain). Thailand was once a source of low-cost labor which was a source of competitive advantage (Suphachalasai, 1998; Watchravesringkan, Karpova, Hodges, & Copeland, 2010). However, under intense competitive pressure, such low-cost labor cannot be the only source of a national industry's competitive advantage (Jin & Moon, 2006). Since the early 1990s, competitive advantages of manufacturing firms' in Thailand similar to other developing countries have been derived from their technological capabilities accumulated through the incremental learning process (Pananond, 2007).

Thailand is now adopting Industry 4.0, called Thailand 4.0, in which Thailand local suppliers/OEM firms have become increasingly global. To enhance competitiveness and profitability, they tend to gradually upgrade themselves from OEM to ODM and finally OBM by engaging in product design and development and building up their marketing and sales capabilities. According to Intarakumnerd and Charoenporn (2015), OEM firms in Thailand have generally not succeeded to upgrade to ODM or OBM. However, there are some notable exceptions, such as the success stories of Thai domestic electronics companies including the Siam United Hi-Tech Limited and the Hana Microelectronics Group (UNCTAD, 2005), which can serve as models for other firms.

2.2. *Functional upgrading indicators: Measuring upgrading at the firm level*

Performance indicators are metrics used to evaluate the success of a firm's projects, programs, products and other initiatives. 'They can play a role as the criteria in MCDM techniques as they can be measured in both quantitative and qualitative approaches' (Varmazyar, Dehghanbaghi & Afkhami, 2016). There are many different performance indicators when functional upgrading takes place in firms. According to previous studies (e.g. Burger, Jindra, Kostevc, Marek, & Rojec, 2015; Milberg & Winkler, 2011; Yoruk, 2014), the performance indicators of functional upgrading are mainly focused on the increase of market share, the improvement of abilities and skills of employees, productivity through product design, profitability, customer and employee satisfaction, and growth indicators. However, it is very important to limit them to those performance indicators (criteria) that are critical to a firm to easily monitor operations and evaluate the success of a functional upgrading in which the firm engages.

In developing a comprehensive set of performance indicators, Kaplan and Norton (1996) introduced the Balanced Scorecard, a performance measurement framework which includes both financial and non-financial metrics and contains four categories/perspectives of measurements (Kaplan & Norton, 1992; 1993). The BSC's four perspectives include financial, customer, internal, and learning & growth perspectives, and are explained briefly as follows: financial perspective – financial indicators which consequence of actions already taken, usually related to profitability; customer perspective – customers are considered as the source of business profits, by increasing in recognition of the importance of customer focus and satisfaction; internal business process perspective – a complete internal business-process value chain that can meet needs and have the greatest impact can help firm in achieving competitive advantage; and learning and growth perspective – people learning and development in a knowledge-worker organization are vital to both individual and organizational improvement.

2.3. *Dynamic capabilities and functional upgrading*

Dynamic capabilities are defined as 'the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments' (Teece, Pisano, & Shuen, 1997: 516). According to Wu (2007), dynamic capabilities enable a firm to leverage its resources to improve its performance, and moreover, dynamic capabilities mediate between firm's resources and performance, without dynamic capabilities to convert resources into competitive advantage, the resources cannot translate into performance.

This study considers dynamic capabilities as mediating factors in the relationship between the critical success factors and the functional upgrading performance indicators. In other words, the dynamic capabilities could play an intermediate role to transform the critical success factors into performance in order to create a competitive advantage and performance consequences through strategic upgrade from OEM to ODM and OBM.

Based on literature review, the following four core dimensions of dynamic capabilities were identified to explain the successfully achieved functional upgrading in manufacturing industries such as the electronics industry: i) absorptive capability (Jean, 2014; Palit, 2006; Wang, Chen, Wang, Lutao, & Vanhaverbeke, 2014), ii) innovative capability (Altenburg, Schmitz, & Stamm, 2008; Jean, 2014), iii) integrative capability (Chen, Qiao, & Lee, 2014; Huang, Chen, Stewart, & Panuwatwanich, 2013; Liu, 2012), and iv) sensing capability (Holweg & Pil, 2008; Pandit, Joshi, Sahay, & Gupta, 2018). The dynamic capabilities' four dimensions are explained briefly as follows: absorptive capability is a firm's ability to utilize (identify, assimilate and exploit) external knowledge and information to firm's own competitive advantage e.g. producing commercial products or services (Malhotra, Gosain, & El Sawy, 2005); integrative capability is a firm's ability to integrate knowledge within and across organizational boundaries (Henderson, 1994) and utilize it productively (Woiceshyn & Daellenbach, 2005); sensing capability is a firm's ability to understand new technology developments (technology-sensing), customer needs and market dynamics (market-sensing) better than its competitors; and innovative capability is a firm's ability to develop new products and/or markets through aligning strategic innovative orientation with innovative behaviours and processes (Wang & Ahmed, 2004).

2.4. *A multiple theoretical framework for success factor analysis*

A functional upgrading is generally considered successful if its goals (at acquiring new functions to increase the overall skill content of activities) are achieved and its key stakeholders are satisfied with its outcomes. While critical success factors can be defined as a set of vital factors that provide a firm with the success of functional upgrading and increase its competitive advantage. In this study, three complementary theoretical perspectives i.e.

resource-based, relational and institutional perspectives are used to articulate success factors and help explain how competitive advantage is gained and held from these factors. Three theories are explained briefly as follows:

2.4.1. *The resource-based view (RBV)*

The resource-based view of the firm explains that a sustainable competitive advantage stems from firm-specific resources that are valuable, rare, inimitable, and non-substitutable, so-called VRIN attributes (Barney, 1991; Lin & Wu, 2014). In other words, resources (i.e., assets and capabilities) which are controlled by a firm and its employees (Barney, 1991; 2001) must fulfill VRIN criteria in order to provide competitive advantage and sustainable performance. Therefore, based on this interpretation, internal resources with VRIN attributes, within the control of an organization's management, can be considered as potential success factors.

2.4.2. *The relational view (RV)*

In the relational view, a firm's competitiveness not only comes from internal resources, but also the resources that may span firm boundaries and may be embedded in inter-firm resources and routines (Dyer & Singh, 1998). This view emphasizes that firms may be able to generate rents by partnering and establishing relationships with other firms (Lavie, 2006). According to the relational view (Dyer & Singh, 1998), four potential sources of inter-organizational competitive advantages including relation-specific assets, knowledge-sharing routines, complementary resources, and effective governance can be considered as potential success factors.

2.4.3. *The institutional theory (INT)*

Among supplementary views that can be incorporated with resource-based and relational views for explaining firms' performance, particularly in the global economy, is the institutional theory (DiMaggio & Powell, 1983). Institutional factors, which are external factors, together with internal and relational factors can be more effective in addressing firms' performance. Institutional factors can be considered as the critical success factors (see Gudienė, Audrius, Nerija, & Jorge, 2013) due to their highly effect on firms' strategy and performance (Hoskisson, Eden, Lau, & Wright, 2000; Peng, Wang, & Jiang, 2008). These factors are categorized into three groups: regulative, normative and cognitivefactors (Scott, 1995). Regulative (coercive) factors, related to government organizations and dominant trading partners, include rules, laws and regulations. Normative factors, associated with professional associations, include societal values, responsibilities, and role expectations. Cognitive (mimetic) factors include shared conceptions of social reality andoccur when firms imitate the actions of successful competitors in an industry.

To give a comprehensive view, this study considers three complementary theoretical perspectives with the interpretation of each perspective as mentioned above as a means of pre-selecting the potential success factors. Consequently, the factors can be classified into three main categories identified by each theory, namely, internal (RBV-based), relational (RV-based), and institutional (INT-based) factors.

3. Methodology

Our research was split in three phases as follows:

Phase 1: *An identification of critical success factors and performance indicators (criteria) for functional upgrading*

With a comprehensive review of performance indicators through the four BSC perspectives: financial, customer, internal process, and learning and growth perspectives, and success factors through the lenses of three theoretical perspectives: RBV, relational view, and institutional theories, the all potential success factors and performance indicators were first extracted. After that, the fuzzy Delphi method – a method of expert consensus building, has been applied to screen the key critical success factors and performance indicators for functional upgrading in electronic industry through experts' consensus as follows:

An anonymous (fuzzy Delphi-based) questionnaire was prepared, and fourteen experts consisting of two senior managers, eight middle managers and four consultants, with more than ten years experience in upgrading process practices in the electronics industry in Thailand, were asked to evaluate the most pessimistic (minimum) value and the most optimistic (maximum) value of the importance of each potential success factor and each potential performance indicator in a range from 1 to 10. A convergence of their opinions was obtained, and the key critical success factors and performance indicators were extracted. A higher consensus significance value indicates a higher degree of importance. Therefore, we subjectively set 8 as the threshold value for the geometric mean of experts' consensus significance values. The factors and indicators with the consensus significance value, g_i greater than the threshold of 8 were selected to be critical success factors and key performance indicators for functional upgrading process.

Phase 2: *A prioritization of critical success factors through fuzzy AHP*

Based on the critical success factors and key performance indicators, a hierarchical model was developed by using the dynamic capabilities which were considered as mediating factors in the relationship between critical success factors and performance. The fuzzy AHP-based group decision making, based on the fuzzy AHP evaluation method of Calabrese et al. (2013) was applied to determine the relative importance of critical success factors as follows:

The group of experts consisted of twenty persons: six senior-level managers, seven middle-level managers, and seven consultants in electronics industry in Thailand with more than ten years experience in implementing upgrading practices. The fuzzy AHP-based questionnaires were provided to collect information from the experts. Each expert was asked to assign linguistic terms based on his/her subjective judgment, to the pair-wise comparisons by asking which one of two elements was more important and how much more important it was with respect to their upper level. In decision-making, each expert gave his/her preference on the elements using fuzzy judgment matrix. After getting the answers from experts in linguistic terms, these linguistic judgments were then converted to triangular fuzzy sets as defined in Table 1. The opinions from several experts were then combined by using geometric mean. Based on the Calabrese et al.'s (2013) fuzzy AHP evaluation method, the local priority weights for all levels in hierarchy were calculated. Finally, the global priority weight of each element was calculated by multiplying its local weight with its corresponding weight along the hierarchy. The final priority results of the elements were ranked based on their own global weights.

Phase 3: *A validation of the fuzzy AHP results via sensitivity analysis*

To verify how robust the obtained ranking results are, or to analyze how changing the indicator weights influence on the ranking results, a sensitivity analysis was carried out by exchanging the weights of two performance indicators among themselves, while the weights of other performance indicators remain unchanged. Due to the five key performance indicators identified, ten different scenarios were created based on the combination of performance indicator weights, and then, ten different calculations for re-determining the weights of critical success factors for each scenario were performed. The sensitivity analysis was conducted to observe how the overall rankings of critical success factors change with respect to the priority weights of each performance indicator under the different scenarios. By using the Spearman's rank correlation coefficient, we measured the degree of correspondence between two rankings: the original ranking achieved by the base scenario (S0) which had no exchanging of weights and the ranking gained from each of ten scenarios (S1, S2… S10). Finally, the important implications for both practitioners and researchers were derived based on the findings.

3.1. *Fuzzy Delphi method*

As the traditional Delphi method fails to deal with the fuzziness (or uncertainty) in expert opinions (Chang, Chang, & Lee, 2014) and it needs repetitive surveys of the experts (Chang, Huang, & Lin, 2000; Ishikawa et al., 1993; Kuo & Chen, 2008; Wey & Wu, 2007). Thus, this study adopted the fuzzy Delphi method to identify critical success factors and key performance indicators based on experts' perspective, and consequently to develop a hierarchical structure model to find the most significant critical success factors.

According to Zadeh (1965), a fuzzy set is characterized by a membership function ranging within the interval [0, 1]. The triangular fuzzy sets of lower (l), medium $(m)$and upper (u) values can be used to capture a range of numerical values, and a triangular fuzzy number (TFN) can be expressed as a triplet (l, m, u).

The procedure for executing the fuzzy Delphi method is as follows (Chang et al. 2014; Dzeng & Wen, 2005; Kuo & Chen, 2008; Lee, Wang, & Lin, 2010; Parameshwaran, Baskar, & Karthik, 2015; Wang, 2015):

Step 1: Conducting a fuzzy Delphi-based questionnaire and asking experts for their most pessimistic value and the most optimistic value of the importance of each factor in the possible factor set S in a range from 1 to 10. A score is denoted as $p_{ik} = (l_{ik}, u_{ik}),\ i \in S,$ where l_{ik} and u_{ik} are the pessimistic index and the optimistic index of factor i rated by expert k respectively.

Step 2: Organizing expert opinion collected from questionnaires and determining the TFNs for the most pessimistic index $p_i = (l_{pi}, m_{pi}, u_{pi})$ and the most optimistic index $o_i = (l_{oi}, m_{oi}, u_{oi})$ for each factor i. Taking $p_i = (l_{pi}, m_{pi}, u_{pi})$ as an illustrative example, l_{pi} and u_{pi} indicate the minimum and maximum of all the experts' most pessimistic value respectively. The m_{pi} is the geometric mean of all the experts' most conservative value of factor, it is obtained through Eq. (1)

$$m_{pi} = \sqrt[k]{l_{i1} \times l_{i2} \times \ldots \times l_{ik}} \tag{1}$$

In the same way, the minimum (l_{oi}), geometric mean (m_{oi}), and the maximum (u_{oi}) of the group's most optimistic values for factor i can be obtained.

Step 3: Calculating the TFNs for the most pessimistic index $p_i = (l_{pi}, m_{pi}, u_{pi})$ and the most optimistic index $o_i = (l_{oi}, m_{oi}, u_{oi})$ for the remaining strategies, $A_i, i \in S$.

Step 4: Examining the consistency of experts' opinions and calculating the consensus significance value, g_i for each factor. The gray zone (Hsiao, 2006; Lee et al., 2010), the overlap section of p_i and o_i in Figure 1, is used to examine the consensus of experts in each factor and calculate its consensus significance value, g_i as follows:

Insert Figure 1 here

First, if the TFN pair does not overlap (or the value of $u_{pi} \le l_{oi}$) and no gray zone exists, the expert options in factor i achieve consensus, the consensus significance value is calculated by Eq. (2):

$$g_i = (m_{pi} + m_{oi})/2. \tag{2}$$

Second, if there is an overlap (or the value of $u_{pi} > l_{oi}$) and the gray zone interval value g_i is equal to $u_{pi} - l_{oi}$, and g_i is less than the interval value of p_i and $o_i(d_i = m_{oi} - m_{pi})$ that is, $g_i \le d_i$, then the consensus significance value g_i of each factor can be calculated by Eq. (3) (Wang, 2015):

$$g_i = \frac{(u_{pi} \times m_{oi}) - (l_{oi} \times m_{pi})}{(u_{pi} - m_{pi}) + (m_{oi} - l_{oi})} \tag{3}$$

Third, if the gray zone exists and $g_i > d_i$, then there are great discrepancies among the experts' opinions. Repeat Step 1 to Step 4 until a convergence is attained.

Step 5: Extracting factors from the potential list. Comparing consensus significance value with a threshold value, T, which is determined by experts subjectively based on the geometric mean of all consensus significance value g_i. If $g_i > T$, factor i is then selected for further analysis.

3.2. *Fuzzy Analytic Hierarchy Process*

An analytic hierarchy process (AHP) is a MCDM technique used to derive the relative weights of alternatives based on some defined criteria (Saaty, 1980). The AHP enables the decision makers to structure a complex MCDM problem into a hierarchical manner (Dyer & Forman, 1992), with the goal at the top, above the lower levels of criteria and alternatives. In AHP analysis, the criteria and alternatives (or so-called elements) are compared pair-wise at each level of the hierarchy with respect to an upper level element (e.g. criterion). By using pair-wise comparisons, judgments are usually expressed on a numerical scale of 1–9 by decision maker based on their expertise and experiences. Actually, people tend to express uncertainty or imprecision rather than single values (Moisiadis, 2002).

Although the AHP has been widely used for 'assessing multiple criteria and deriving priorities for decision-making purposes' (Liedtka, 2005), however, the AHP is criticized for its inability to deal with the inherent uncertainty and vagueness of the human decision-making process (Chan & Kumar, 2007; Kwong & Bai, 2003). To overcome this difficulty, fuzzy AHP was developed by combining traditional AHP with fuzzy set theory, to handle uncertainty and vagueness of human's subjective judgments to reach an effective decision (Chen & Hung, 2010; Chiou, Tzeng, & Cheng, 2005; Naghadehi, Mikaeil, & Ataei, 2009).

In this study, we employed fuzzy set theory introduced by Zadeh (1965), to deal with the uncertainty and subjective nature of human thinking in the prioritization process, in which the opinions of human in pair-wise comparison (linguistic judgments) will be converted into the fuzzy numbers that represent them. This study used triangular fuzzy numbers, a 9-point scale, to represent subjective pair-wise comparisons of prioritization process. This is due to the simplicity of the triangular fuzzy numbers in its implementation in practice and in its computation. In this study, the conversion scale used to convert linguistic judgments (or linguistic scales) to triangular fuzzy numbers (or triangular fuzzy scales) is shown in Table 1.

Insert Table 1 here

Arithmetic operations on triangular fuzzy numbers: Dubois and Prade (1979) derive basic arithmetic operations on two triangular fuzzy numbers $\widetilde{A}$ and $\widetilde{B}$ as follows:

Let $\widetilde{A} = (l_1, m_1, u_1)$ and $\widetilde{B} = (l_2, m_2, u_2)$ then

addition: $\widetilde{A} \oplus \widetilde{B} = (l_1 + l_2, m_1 + m_2, u_1 + u_2)$,

subtraction: $\widetilde{A} \ominus \widetilde{B} = (l_1 - l_2, m_1 - m_2, u_1 - u_2)$,

multiplication: $\widetilde{A} \otimes \widetilde{B} \cong (l_1 \times l_2, m_1 \times m_2, u_1 \times u_2)$,

division: $\widetilde{A} \oslash \widetilde{B} \cong (l_1/u_2, m_1/m_2, u_1/l_2)$, and

reciprocal: $\widetilde{A}^{-1} \cong (1/u_1, 1/m_1, 1/l_1)$.

To handle fuzzy AHP to obtain relative weights from fuzzy comparison matrices, there have been a number of methods introduced (cf., e.g. Buckley, 1985; Calabrese, Costa, & Menichini, 2013; Chang, 1996; Csutora & Buckley, 2001; Mikhailov, 2003; Mikhailov & Tsvetinov, 2004; Tyagi, Agrawal, Yang, & Ying, 2017; van Laarhoven & Pedrycz, 1983; Wang, Luo, & Hua, 2008). Among these methods, the extent analysis method of triangular fuzzy AHP developed by Chang (1996) is widely applied (Calabrese et al., 2013). Nevertheless, there are strong criticisms of Chang's method (1996) (Wang & Elhag, 2006; Wang et al., 2008; Zhü, 2014). Wang et al. (2008) have shown that Chang's method (1996) cannot estimate the true weights from a fuzzy comparison matrix as it may assign a zero weight to some elements (criteria, sub-criteria or alternatives/critical success factors) and such elements will not be considered, possibly leading to a wrong prioritization of the elements. Moreover, Chang's method (1996) is proved theoretically that why it yields zero-weight which may lead to poor robustness, unreasonable priorities and information loss (Zhü, 2014).

In order to overcome some weaknesses of Chang's method (1996), Calabrese et al. (2013) introduced a modified (row sum) method based on the modified normalization formula which has been proposed by Wang and Elhag (2006) and Wang et al. (2008) to resolve the zero-weight issue. Therefore, in this study, we adopted the fuzzy AHP evaluation method proposed by Calabrese et al. (2013) to avoid possibly obtaining zero-weight elements to obtain the correct prioritization of the elements.

3.3. *Calabrese et al.'s (2013) fuzzy AHP evaluation method*

The modified Fuzzy AHP evaluation method developed by Calabrese et al. (2013) can be summarized as the following steps:

Step 1: Construct fuzzy pair-wise comparison matrices

According to Chang's method (1996), for each decision maker, the fuzzy pair-wise comparison matrices are constructed at each level of the hierarchy relative to each element at the next higher level. A triangular fuzzy comparison matrix $\tilde{A}$ is constructed as shown below.

$$\tilde{A} = (\tilde{a}_{ij})_{n\times n} = \begin{bmatrix} (1,1,1) & (l_{12}, m_{12}, u_{12}) & \dots & (l_{1n}, m_{1n}, u_{1n}) \\ (l_{21}, m_{21}, u_{21}) & (1,1,1) & \dots & (l_{2n}, m_{2n}, u_{2n}) \\ \vdots & \vdots & \ddots & \vdots \\ (l_{n1}, m_{n1}, u_{n1}) & (l_{n2}, m_{n2}, u_{n2}) & \dots & (1,1,1) \end{bmatrix}$$

where $(l_{ij}, m_{ij}, u_{ij}) = (1/u_{ji}, 1/m_{ji}, 1/l_{ji})$, for $i = 1, \dots, n, j = 1, \dots, n$ and $i \neq j$.

Individual judgments can be aggregated in one consolidated matrix by using the geometric mean of their preferences.

Step 2: Examine the consistency of the fuzzy pair-wise comparison matrices.

After the aggregation of the judgments of all decision makers in one consolidated matrix, the consistency of the fuzzy pair-wise comparison matrices, is examined by defuzzifying (or conversing) the fuzzy number $\tilde{A} = (l, m, u)$ in the fuzzy pair-wise comparison matrices into a form of crisp number using $a_{ij}(\tilde{a}_{ij}) = (m + l + u)/3$. The consistency ratio (index) can be then computed using the crisp AHP method (Saaty, 1980). The consistency ratio value for each of the crisp comparison matrices should be maintained $\leq$ 10%. Nevertheless, the judgments from decision makers as inputs of the matrix need to be reviewed until the satisfactory consistency is obtained.

Step 3: Sum each row of the fuzzy pair-wise comparison matrix $\widetilde{A}$ as follows:

$\widetilde{RS}_i = \sum_{j=1}^{n} \tilde{a}_{ij} = \left(\sum_{j=1}^{n} l_{ij}, \sum_{j=1}^{n} m_{ij}, \sum_{j=1}^{n} u_{ij}\right), i = 1, \dots, n.$

Step 4: Normalize the rows by the row sums

The correct normalization formula as proposed by Wang et al. (2008) for local fuzzy weights is given as follows:

$$\tilde{S}_i = \frac{\widetilde{RS}_i}{\sum_{j=1}^{n} \widetilde{RS}_j} = \left(\frac{\sum_{j=1}^{n} l_{ij}}{\sum_{j=1}^{n} l_{ij} + \sum_{k=1,k\neq i}^{n}\sum_{j=1}^{n} u_{kj}}, \frac{\sum_{j=1}^{n} m_{ij}}{\sum_{k=1}^{n}\sum_{j=1}^{n} m_{kj}}, \frac{\sum_{j=1}^{n} u_{ij}}{\sum_{j=1}^{n} u_{ij} + \sum_{k=1,k\neq i}^{n}\sum_{j=1}^{n} l_{kj}}\right) = (l_i, m_i, u_i)$$

for $i = 1, \dots, n$

Step 5: Define the priority vector of the fuzzy comparison matrix

Ultimately, by converting fuzzy weights to the crisp weights, the local weight is given by the following equation (Calabrese et al., 2013):

$w_i = S_i(\tilde{S}_i) = \frac{l_i + m_i + u_i}{3}$, for $i = 1, \dots, n$

By normalizing the crisp weight, the normalized crisp weight (w') is described by the following equation:

$w'_i = \frac{S_i(\tilde{S}_i)}{\sum_{i=1}^{n} S_i(\tilde{S}_i)}$, for $i = 1, \dots, n$.

The normalized crisp vector (W) of weights is as follows:

$W = (w'_1, w'_2, \dots, w'_n)$

4. Results and implications

4.1. *Results*

4.1.1. *The potential performance indicators through the four BSC perspectives*

We conducted a comprehensive review of performance indicators of upgrading process through the four BSC perspectives: financial, customer, internal process, and learning and growth perspectives. By doing so, eleven potential performance indicators under the four BSC perspectives extracted were identified as summarized in Table 2.

Insert Table 2 here

4.1.2. *The potential success factors through the theoretical lenses*

We also conducted a comprehensive review of success factors of upgrading process through the lenses of three theoretical perspectives (RBV, RV, and INT). Twenty potential success factors were extracted from characteristics as described by theorists (Barney, 1991; DiMaggio & Powell, 1983; Dyer & Singh, 1998; Lavie, 2006; Lin & Wu, 2014) as mentioned above. By doing so, identifying the potential success factors was theoretically well grounded. We classified these factors into three categories including the internal (RBV-based), relational (RV-based) and external (INT-based) factors according to their characteristics. The potential success factors extracted are summarized as in Table 3.

Insert Table 3 here

4.1.3. *The fuzzy Delphi results*

By using the fuzzy Delphi approach, the the consensus significance value, g_i of each possible success factors and performance indicators were calculated as shown in Tables 4 and 5 respectively.

Insert Tables 4 and 5 here

Since the geometric mean values of the consensus significance values of all potential success factors and all potential performance indicators were calculated to be 8.02 and 8.00 respectively. Therefore, we subjectively set 8 as the identical threshold value for the geometric mean of consensus significance values to select the most significant factors and indicators.

Based on the results in Tables 4 and 5, the seven potential success factors (35% of the total) and six potential performance indicators (54.5% of the total) were screened out (g_i< 8) and the thirteen factors and five indicators were retained (g_i≥ 8) and used as the 'critical success factors' and 'key performance indicators' for further analysis. These 13 critical success factors were then grouped into three categories: internal, relational, and institutional factors.

It is important to understand that not all of the potential success factors or indicators can be critical success factors or key performance indicators in the Thailand context. Since, these potential success factors and performance indicators are theoretically based rather than empirically based (Pinto & Slevin, 1987). Therefore, some of the potential success factors and performance indicators which are generic in scope were screened out, while others which address specific issues of interest in Thai context are determined as 'applicable critical success factors and key performance indicators'.

After all of the applicable critical success factors and key performance indicators were identified through the fuzzy Delphi-based group decision-making approach, these factors were then further prioritized by using the fuzzy AHP method as described in the next sub-section.

4.1.4. *The fuzzy AHP results*

In developing a hierarchical model for prioritizing the critical success factors, the model shown in the Figure 2 is constructed with five levels. The top level presents the overall goal of this study, which is the prioritization of critical success factors for functional upgrading in electronics industry. The second level presents the decision criteria that comprise the five performance indicators within four BSC clusters. The third level presents the four of dynamic capabilities as mediating factors in the relationship between critical success factors and performance indicators. The fourth level presents the three categories of critical success factors whereas the lowest level denotes the critical success factors.

Insert Figure 2 here

By using the Calabrese et al.'s (2013) fuzzy AHP evaluation method, the local and global weight scores of the elements as well as their priority rankings are obtained shown in Table 6.

Insert Table 6 here

According to this result, the most significant (highest-global weight) performance indicator is 'profits growth' for functional upgrading, followed by 'market share', whereas the least significant performance is 'productivity growth'. In level 3 of the model, the 'sensing capability' is viewed as the most significant dynamic capabilities, which enables functional upgrading through economic and value-added products meet market needs and accomplish its aims, followed by 'innovative capability', whereas the experts viewed 'absorptive capability' as the least significant one. In level 4, the category of 'internal factors' is the most significant for dynamic capability development, followed by the 'relational factors' and 'institutional factors' respectively. And in level 5, the three most significant critical success factors are 'technological capabilities', 'networks', and 'government's policies' respectively, whereas 'in-house R&D' is the least significant one.

4.1.5. *Results of sensitivity analysis*

In order to be more confident about the ranking obtained under the vagueness and imprecision in expert judgment, it is important to carry out a sensitivity analysis to investigate the robustness of the ranking results (Guo & Zhao, 2015). Sensitivity analysis was carried out by exchanging the weights of two performance indicators (or criteria) among themselves, while the weights of other performance indicators remain unchanged (Gumus, 2009; Hussain, Mandal, & Mondal, 2018; Önüt, Kara, & Isik, 2009; Önüt & Soner, 2008) to analyze how changing the performance indicator weights influence on the ranking results (the outputs of the model).

In this study, since there were five performance indicators involved in the decision-making problem (and we chose to switch the weights of two performance indicators from the set of five performance indicators), therefore, total of ten combinations were analyzed for the sensitivity analysis, with each combination stated as a scenario (S). Therefore, ten scenarios were obtained, and accordingly, ten different calculations for re-determining the weights of critical success factors for each scenario were performed.

Different names were given for each calculation. For example, the 'C1-2'meant that the weights of the 1st and 2nd performance indicators were switched (while the weights of the 3th, 4th, 5th, and 6th performance indicators remained the same), and this new scenario was named 'S1'. The weights of critical success factors were re-calculated, and then, the critical success factors were re-ranked for each scenario. The results of sensitivity analysis are shown in Table 7.

Insert Table 7 here

Based on the results in Table 7, the rankings are similar across all scenarios. Besides, under all scenarios, the results of sensitivity analysis indicate that, 'technological capabilities' is the highest priority factor, followed by the'networks' that influence the performance of functional upgrading, whereas 'in-house R&D' and 'a quest for legitimacy' are the two lowest priority factors.

Furthermore, the ranking gained from each of ten scenarios (S1, S2… S10) was compared with the original ranking achieved by the base scenario (S0) which had no exchanging of weights, and were then validated comparatively using the Spearman's rank correlation coefficient (r_S) by using Eq. 4:

$$r_S = 1 - \frac{6\sum_{i=1}^{n}(d_i)^2}{n(n^2-1)} \qquad (4)$$

where d_i is the difference between each pair of ranks and n is the number of pairs of values.

The Spearman's rank correlation coefficients for paired-comparison rankings are given in Table 8.

Insert Table 8 here

According to this result in Table 8, it is found that p-values of all ten paired-comparison rankings < 0.01, it is clearly evident that the original ranking achieved by the base scenario (S0) is significantly correlated with the ranking gained from each of ten scenarios. So, it can be concluded that there is no statistically significant difference between the two comparative rankings of critical success factors with 99% confidence interval. Moreover, it can be said that there is a convergence of their opinions on the ranking as well.

4.2. *Implications*

Finally, some theoretical and managerial implications were derived based on the findings. We accomplished this by interpreting the results derived from the fuzzy AHP, and the analyzed critical success factors in the context of Thailand. The derived implications are as follows:

According to the findings in Table 6, from the RBV perspective, 'technological capabilities' are considered as the most important internal factor in the implementation of functional upgrading, followed by 'top management support'. It can imply that a functional upgrading requires comprehensive technological capabilities, including R&D, new product and process design, systems design, component selection, and post-production logistics, as well as sophisticated marketing techniques. To develop a firm's technological capabilities, firms need various activities to develop their technological capabilities. In this situation, top management has important roles in supporting the activities and developing a firm's technological capabilities during the functional upgrading process, by providing the necessary resources (such as human, technical, R&D lab and budgetary resources) and providing early involvement for helping the various support firms in functional upgrading.

From the RV perspective, 'networks' are considered as the most important relational factor in functional upgrading implementation, followed by 'strategic alliances'. It means that a functional upgrading requires networks of cooperating firms within the cluster and non-governmental and governmental organisations to achieve collective efficiency, penetrate and conquer markets, and overcome common problems. To develop local and regionalsupply networks, firms need to build a good relationship in networks by building trust between the partners (Morgan & Hunt, 1994). Long term cooperation e.g. long-term supply arrangements for exchanging resources for mutual benefits, is about building a relationship based on trust. Inter-firms' linkages such as strategic alliances may allow firms to get to knowledge/technology transfer between the partners, or within the networks.

From the INT perspective, 'government's policies' are considered as the most important institutional factor for functional upgrading, followed by 'business associations'. Thus, to upgrade the firms' current position within the electronics GVCs, Thai government needs to formulate and implement technology development strategies/policies aimed at supporting the functional upgrading from OEM to ODM and OBM, such as technology and innovation support, human resource development, financial means, and development of the necessary infrastructure (Hsu & Chiang, 2001; Shih, 1999). Moreover, business associations include federations (e.g. the Federation of Thai SME Association, the Federation of Thai Industries, Electrical, Electronics and Allied Industries Club), chambers of commerce, and trade and industrial groups need to play an important role in macroeconomic stabilize and reform, (horizontal and vertical) coordination, reducing information cost, setting standards, quality upgrading, and employee training, in order to improve the functional upgrading in Thailand as well.

From a dynamic capability viewpoint, the 'sensing capability' is viewed as the most (relative) significant dynamic capabilities, which enables functional upgrading through economic and value-added products meet market needs and accomplish a firm's aims, in order to achieve competitive advantage. Helm and Gritsch (2014) suggest that, to improve the sensing capability of the firm, external networking is needed since it could be sources of information on market developments and thus increases a firm's sensing capability. This suggestion is consistent with our findings; networks are the most important success factor if we respect to just sensing capability.

Moreover, the research also contributes three main managerial implications. First, this study will help industry to identify, prioritize and evaluate critical factors for successful implementation of functional upgrading in the electronics GVC. OEM/ODM firms could regulate and utilize in their dynamic capability development activities and initiatives for managing the critical success factors in better and more effective and efficient ways. The obtained ranking priorities are helpful to establish their strategic plans and policies to develop the firms' capabilities required to move up the value chain. Second, the knowledge on the top priority of critical success factors of implementing functional upgrading will lead to better understanding and planning of the operational and strategic management in the future. In order to effectively and efficiently implement functional upgrading, this study enables managers, practitioners, and policy makers to use their limited resources to firstly focus on the most important factors for successful functional upgrading, and after achieving initial implementation success (or desired outcomes), their organizations will allow to further implementing other critical success factors by allocating more resources. Third, this study allows all parties concerned to realize their role in functional upgrading. The firms, industry, and government which had the important roles in internal, relational, and institutional factor categories respectively, should concentrate in managing the most important critical success factors in each category, through collaboration to create synergy between all parties for the success of functional upgrading in the electronics firms and industry.

5. Discussions

In this paper, we have investigated several aspects. First, we have determined the applicable critical success factors based on Thai experts' perspectives by a double-screening method as following: after reviewing literature on the success factors in upgrading, the initial screening for the potential success factors was the theoretical analysis of their characteristics from the RBV, RV, and INT. The second screening method was performed with the fuzzy Delphi method to achieve consensus among experts in the field on the critical success factors in the context of electronics industry in Thailand.

Second, we have proposed the hierarchical model for prioritization of all thirteen critical success factors in a multiple-theory framework and all five key indicators in the BSC framework. On the basis of the theories (RBV, RV, and INT), the model was developed encompassing dynamic capabilities framework which showed the relationships between the critical success factors and the key performance indicators, by which the dynamic capabilities mediate among them. The study contributes in terms of linking the research with the theories of RBV, RV, and INT as well as dynamic capabilities.

Third, to summarize, we have carried out sensitivity analysis of the effects of uncertainty by exchanging the weights of two performance indicators among themselves to ensure the robustness of results. Based on the results of the sensitivity analysis and the Spearman's rank correlation coefficient, it could be concluded that there was the robustness of the ranking results. After that, we have utilized the robust rankings to further develop implementations.

The priority ranking of critical success factors for functional upgrading in electronics industry, based on Thai experts' perspectives were provided in Table 6. However, different industries might have a different viewpoint about prioritization of critical success factors. It may also vary from country to country (Mathiyazhagan, Govindan, NooruHaq, & Geng, 2013). Therefore, our findings based on Thai experts' perspectives may differ from other countries.

6. Conclusions, Limitations, and Future Research

We have identified and prioritized critical success factors for functional upgrading from OEM to ODM and OBM using fuzzy Delphi and fuzzy AHP approaches. In this study, the fuzzy approach was exploited to deal with vagueness of the judgments in the decision-making process. Twenty potential success factors obtained from the literature were extracted from the three theoretical perspectives including RBV, RV and INT, as well as eleven performance indicators obtained from the literature were identified in the four perspectives of the BSC framework. All of these critical success factors and key performance indicators were then validated through the fuzzy Delphi method. Afterwards based on the fuzzy Delphi method these critical success factors and key performance indicators were screened out and a total of thirteen applicable critical success factors and five performance indicators were determined – practical important for the electronic industry based on Thai experts' view. Based on these applicable critical success factors and key performance indicators, we have developed the critical success factor prioritization model that can be practically applied by OEM firms in Thailand. The model with grounded theory utilizes the dynamic capabilities as mediating factors in the relationship between critical success factors and functional upgrading performance.

The determined factors and were categorized into three groups: internal, relational, and institutional factors, and were further analyzed using the Calabrese et al.'s (2013) fuzzy AHP evaluation method. The rationale for selecting this method is to avoid possibly obtaining zero-weight elements in order to obtain the correct prioritization.

The findings of the fuzzy AHP which were mainly the priority rankings of the performance indicators, the dynamic capabilities, the factor categories, and the critical success factors were revealed as follows: 'Profits growth' was viewed as the most significant performance indicator, the 'sensing capability' was the most significant dynamic capabilities, the internal (RBV-based) factors were viewed as the most significant category of factors, while the three most significant critical success factors were 'technological capabilities', 'networks', and 'government's policies' respectively. According to the results of the sensitivity analysis by changing the weights of performance indicators, and the Spearman's rank correlation coefficient, it could be concluded that there was the robustness of the ranking results. Finally, this paper provided implications for both practitioners and scholars.

The findings would not only lead to increase the chances for success of functional upgrading of OEM firms to become ODM and OBM, but also lead to supportive policy development to create sustainable competitive advantages for electronics firms and industry in the future.

The results of this study relied on judgments of experts from only industrial background which might be prejudiced. These experts might not represent all of the experts (stakeholders) involved in functional upgrading. For the future, extended research is needed to replicate this study with a larger number of (functional upgrading) experts with a variety of backgrounds (e.g. academic, commercial and industrial) in order to avoid the bias and provide impartiality in decision making process of prioritization as well as to increase the ability to generalize this study's results.

It should be noted that this study has been primarily concerned with the ranking results obtained by using fuzzy AHP method in order to deal with vagueness of the judgment, without a comparative analysis to investigate whether using fuzzy AHP can truly make a significant difference compared to traditional AHP. Therefore, a comparative analysis of fuzzy AHP and traditional AHP or even other (fuzzy-based) MCDM methods, in prioritization of critical success factors for functional upgrading will be further studied to choose the best effective approach to make consistent final ranking results and then lead to an effective decision.

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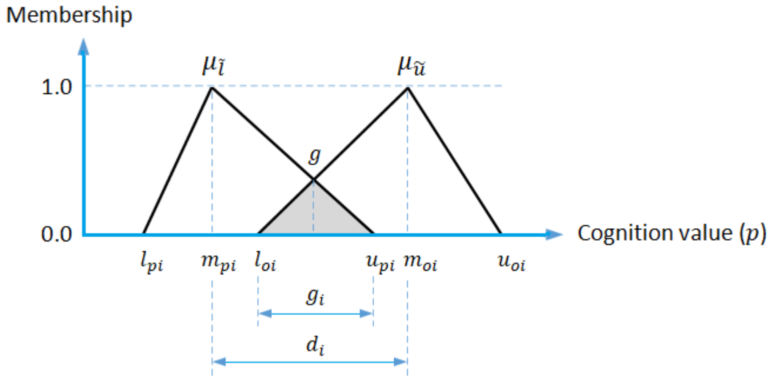

Figure 1. Gray Zone of p_i and o_i

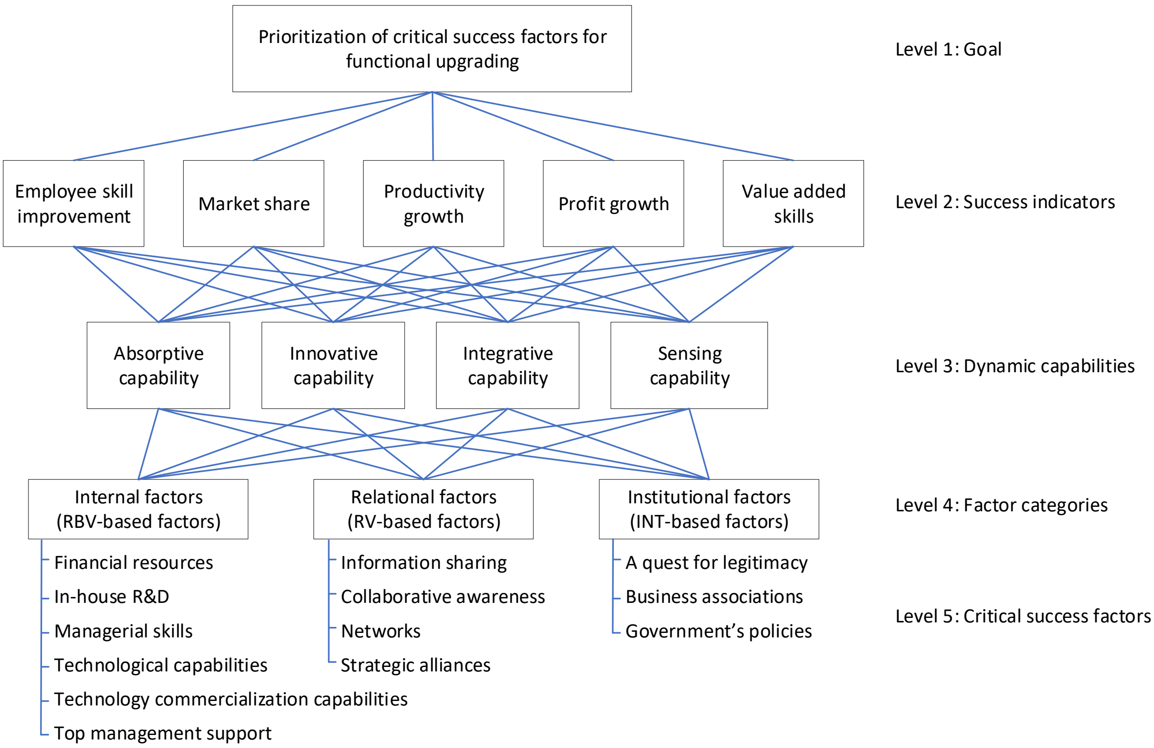

Figure 2. A Hierarchical Model for Prioritization of Critical Success Factors for Functional Upgrading

Table 1. Triangular Fuzzy Conversion Scale

Linguistic scale	Triangular fuzzy scale	Triangular fuzzy reciprocal scale
Equally important	(1, 1, 3)	(1/3, 1, 1)
Moderately important	(1, 3, 5)	(1/5, 1/3, 1)
Fairly important	(3, 5, 7)	(1/7, 1/5, 1/3)
Very strongly important	(5, 7, 9)	(1/9, 1/7, 1/5)
Absolutely important	(7, 9, 9)	(1/9, 1/9, 1/7)

Table 2. Potential Performance Indicators Extracted from the Four Perspectives of BSC

BSC perspectives	Potential performance indicators (criteria)	Descriptions	Sources
Financial perspective	Cost reduction	The reduction in the unit cost of goods/service without compromising its quality	Yoruk, 2014; Marcato & Baltar, 2017; Milberg & Winkler, 2011
	Profits growth	Increasing financial returns such as profit margin, return on investment, return on assets, and return on equity	Milberg & Winkler, 2011; Gereffi, 1999; Lau & Lo, 2015
	Sales growth	Changing in sales volume of product or services for a period of time, typically from year to year	Chen & Lien, 2013; Lau et al., 2010; Storbacka, 2011
Customer perspective	Customer retention	The ability of a company or product to retain its customers, over a given period of time, as measured by the repeat business of the customers	Chen et al., 2013; Huang et al., 2013
	Customer growth	The growth rate on the number of unique customers that a business has, over a given period of time	Huang et al., 2009; Storbacka, 2011
	Market share (growth)	Increasing market share in the target market, as measured by units sold or revenue, achieved through increased customer demand or competitive advantages	Milberg & Winkler, 2011; Lu & Yang, 2004
Internal business perspective	Process improvement	Making a (production/design) process more effective and efficient, including reduction of time to market (shorter lead time), innovation enhancement, and quality improvement	Azadegan & Wagner, 2011; Lau & Lo, 2015
	(R&D) Productivity growth	Increasing in the value of outputs produced for a given level of inputs (within a time period, quality considered), usually by working smarter with the help of technology and management	Milberg & Winkler, 2011; Burger et al., 2015; Wang et al., 2010
Learning & growth perspective	Employee skill improvement	Improving core competencies and strategic skills among employees, workplace culture and technologies by engaging in employee training and development, and increased R&D expenditures information systems development	Milberg & Winkler, 2011; Lau et al., 2010
	Improved labor standards	Improved labor standards including job safety, child labor, forced labor, and employment discrimination	Milberg & Winkler, 2011
	Value-added growth	Providing higher value-added products to customers which leads to improvement of existing products or introduction of new products	Milberg & Winkler, 2011; Gereffi, 1999

Table 3. Potential Success Factors Extracted from the RBV, RV, and INT Perspectives

Theoretical perspectives (Categories)	Potential success factors	Descriptions	Sources
RBV (Internal factors)	Financial resources	An availability of sufficient capital or an access to sufficient capital for additional investment in functional upgrading and for managing associated risks	Bastic, 2004; Luo & Bu, 2018
	International experience	A firm's overseas experience with transnational operations and in specific foreign markets and industries	Yamakawa et al., 2008
	Knowledge sharing capability	An ability of employees to share their work-related experience, know-how, expertise and information with other employees	Eng, 2006; Darroch & McNaughton, 2002
	Managerial skills	The skills (i.e. human, technical and conceptual skills) of managers by which they perform their task effectively and efficiently	Luo, 2000
	Quality capabilities	Capabilities that enable a firm to ensure the quality of its products and services for complete customer satisfaction and established standards	Jean, 2014; Lall, 1992
	R&D laboratory (in-house R&D)	An R&D facility which separately dedicated R&D establishment within a firm, to improve existing products and procedures or to lead to the development of new products and procedures	Martinez-Covarrubias et al., 2017; Pietrobelli & Rabellotti, 2007
	Technology commercialization capabilities	Firm’s capabilities to successfully bring their innovative products/services and technologies to market and grow in terms of sales and profitability	Chang et al., 1999
	Technological capabilities	Firm’s capabilities to make effective use of technical knowledge, skills, and experience to generate and manage technological change in response to the competitive business environment	Jean, 2014; Pietrobelli & Rabellotti, 2007; Lall, 1992
	Top management support	The involvement, commitment and support of top management during the functional upgrading process, by providing the necessary resources (i.e. human, technical and budgetary resources) and leadership.	Trkman, 2010; Bandara et al., 2005
RV (Relational factors)	Collaborative awareness	A firm perceives its trust in and committed relationship with their supply chain partners’ which leads to sharing costs, risks, and benefits among partners	Krishnapriya & Baral, 2014
	Commitment to learning and training	The value that firm places on learning – top managements’ commitment to training their staff, and continuing development activities in order to improve their skills required for functional upgrading	Wang, 2010; Holden & Kortzfleisch, 2004
	Inter-organizational information sharing	A communication of information among supply chain partners, by using an inter-organizational information system to manage interdependencies between firms in mediating among partners’ transactions and relationships	Krishnapriya & Baral, 2014; Simatupang & Sridharan, 2005
	Networks	Relationships between firms within the cluster and organizations that cooperate in order to achieve collective efficiency penetrate and conquer markets, and overcome common problems	Jean, 2014; Deng, 2012; Matthyssens et al., 2008
	Partnership with leading firms	A relationship between global leading OBM firms and their corresponding OEM/ODM partners to	Yu & Hsu, 2002

Theoretical perspectives (Categories)	Potential success factors	Descriptions	Sources
		help them in order to enhance the development capabilities (e.g. new product design and marketing) of OEM/ODM firms.	
	Strategic alliances	Inter-firms linkages (e.g. joint venture, joint R&D, joint marketing venture, and long-term supply arrangements) for mutual benefits, which allow firms to get close enough to transfer even tacit knowledge	Yamakawa et al., 2008
INT (Institutional factors)	A quest for legitimacy	Creating integrated business and environmental value – the environmental management practices implemented in firms to certify the environmental management systems (EMS) under ISO 14001 standards, or adopt a sustainable/environmental supply chain management practices	Yamakawa et al., 2008
	Business associations	Firms formed as self-help bodies by groups of businesses (e.g. federations, chambers of commerce, and trade and industrial groups) to further the interests of and respond to external events of their members, e.g. macroeconomic stabilization and reform, coordination, reducing information cost, setting standards, and employee training	Jespersen, 2008; Pietrobelli & Rabellotti, 2007; Yamakawa et al., 2008
	(Successful) Entrepreneurial traits	The common entrepreneurial characteristics, e.g. creativity, innovation risk-taking propensity, internal locus of control and need for achievement, which play an essential role in making entrepreneurial decisions	Yamakawa et al., 2008; Wang, 2010
	Government's technology development strategies	Government policies aimed at supporting the functional upgrading from OEM to ODM and OBM, such as technology and innovation support, human resource development, financial means, and development of the necessary infrastructure	Hsu & Chiang, 2001; Hobday & Rush, 2007; Shih, 1999
	Regulation environment	An environment comprised of government regulations, policies, and laws, for business and intellectual property protection (e.g. trademarks, copyrights, patents, and trade secrets), due process, and prevention of unfair competition and deceptive trade practices, tax reform, trade reform, and financial account liberalization	Yamakawa et al., 2008

Table 4. Key Performance Indicators after Fuzzy Delphi Method Screening

Perspectives	Potential performance indicators (criteria)	Pessimistic values			Optimistic values			g_i	Screening results
		l_p	m_p	u_p	l_o	m_o	u_o		
Financial	Cost reduction	5	6.01	8	7	8.02	10	7.34	Deleted
	Profits growth	7	8.12	9	9	9.63	10	8.87	Accepted
	Sales growth	6	6.81	9	7	8.25	10	7.73	Deleted
Customer	Customer growth	5	6.80	8	7	8.95	10	7.62	Deleted
	Customer retention	5	6.29	8	6	8.00	10	7.08	Deleted
	Market share	7	7.55	9	8	9.18	10	8.45	Accepted
Internal business	Process effectiveness improvement	5	7.07	9	7	8.74	10	7.95	Deleted
	Productivity growth	6	7.53	9	9	9.49	10	8.51	Accepted
Learning & Growth	Employee skill improvement	6	7.16	9	8	9.04	10	8.36	Accepted
	Improved labor standards	5	6.94	8	8	8.76	10	7.85	Deleted
	Value added growth	5	7.21	9	8	9.33	10	8.43	Accepted

Table 5. Critical Success Factors after Fuzzy Delphi Method Screening

Categories	Success factors	Pessimistic values			Optimistic values			g_i	Screening results
		l_p	m_p	u_p	l_o	m_o	u_o		
Internal (RBV-based) factors	Financial resources	7	7.90	9	9	9.63	10	8.76	Accepted
	International experience	5	6.33	7	7	8.25	10	7.29	Deleted
	Intra-organizational knowledge sharing	5	5.95	7	7	8.25	10	7.10	Deleted
	Managerial skills	5	7.21	9	8	9.11	10	8.38	Accepted
	Quality control capabilities	5	6.58	8	7	8.46	10	7.51	Deleted
	R&D laboratory	5	7.36	9	9	9.70	10	8.53	Accepted
	Technological capabilities	5	7.14	9	7	9.03	10	8.04	Accepted
	Technology commercialization capabilities	6	7.46	9	9	9.42	10	8.44	Accepted
	Top management support	7	7.82	9	8	9.47	10	8.56	Accepted
Relational (RV-based) factors	Collaborative awareness	5	7.28	9	7	9.16	10	8.11	Accepted
	Commitment to learning and training	4	6.12	8	7	7.96	9	7.34	Deleted
	Inter-organizational information sharing	5	7.77	9	7	9.24	10	8.29	Accepted
	Partnership with leading firms	5	6.20	8	7	7.89	9	7.33	Deleted
	Networks (inter-firm collaboration networks)	6	7.54	9	9	9.49	10	8.51	Accepted
	Strategic alliances	7	7.55	9	9	9.63	10	8.59	Accepted
External (INT-based) factors	A quest for legitimacy	6	7.39	9	8	9.13	10	8.41	Accepted
	Business associations	6	7.45	9	8	9.48	10	8.49	Accepted
	Entrepreneurial traits	5	6.37	8	6	8.16	9	7.14	Deleted
	Government's functional upgrading related policies	6	7.60	9	8	9.17	10	8.46	Accepted
	Regulation environment	5	6.62	8	7	8.63	10	7.54	Deleted

Table 6. Local and Global Weight Scores and Rankings of Critical Success Factors

Performance indicators (criteria)	Global weights	Ranking	Dynamics capabilities	Global weights	Ranking	Critical success factors	Local weights	Local Ranking	Global weights	Global Ranking
Employee skill improvement	0.144	4	Absorptive capability	0.193	4	***Internal factors (0.454)***				
Market share	0.269	2	Innovative capability	0.250	2	(RBV-1) Financial resources	0.187	3	0.085	6
Productivity growth	0.095	5	Integrative capability	0.236	3	(RBV-2) In-house R&D	0.099	6	0.045	13
Profits growth	0.297	1	Sensing capability	0.321	1	(RBV-3) Managerial skills	0.128	4	0.058	10
Value added growth	0.195	3				(RBV-4) Technological capabilities	0.250	1	0.114	1
						(RBV-5) Technology commercialization capabilities	0.125	5	0.056	11
						(RBV-6) Top management support	0.212	2	0.096	4
						Relational factors (0.337)				
						(RV-1) Inter-organizational Information sharing	0.199	3	0.067	8
						(RV-2) Collaborative awareness	0.187	4	0.063	9
						(RV-3) Networks	0.331	1	0.112	2
						(RV-4) Strategic alliances	0.282	2	0.095	5
						Institutional factors (0.209)				
						(INT-1) A quest for legitimacy	0.215	3	0.045	12
						(INT-2) Business associations	0.324	2	0.068	7
						(INT-3) Government's policies	0.461	1	0.097	3

Table 7. Results of Sensitivity Analysis

Critical success factors	Rankings										
	S0	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
	No change	C1-2	C1-3	C1-4	C1-5	C2-3	C2-4	C2-5	C3-4	C3-5	C4-5
(RBV-1) Financial resources	6	6	6	6	6	6	6	6	6	6	6
(RBV-2) In-house R&D	13	13	12	13	13	12	13	13	12	12	13
(RBV-3) Managerial skills	10	10	10	10	10	10	10	10	10	10	10
(RBV-4) Technological capabilities	1	1	1	1	1	1	1	1	1	1	1
(RBV-5) Technology commercialization capabilities	11	11	11	11	11	11	11	11	11	11	11
(RBV-6) Top management support	4	4	4	4	4	3	4	4	3	3	4
(RV-1) Inter-organizational Information sharing	8	8	8	8	8	8	8	8	7	8	8
(RV-2) Collaborative awareness	9	9	9	9	9	9	9	9	9	9	9
(RV-3) Networks	2	2	2	2	2	2	2	2	2	2	2
(RV-4) Strategic alliances	5	5	5	5	5	5	5	5	5	5	5
(INT-1) A quest for legitimacy	12	12	13	12	12	13	12	12	13	13	12
(INT-2) Business associations	7	7	7	7	7	7	7	7	8	7	7
(INT-3) Government's policies	3	3	3	3	3	4	3	3	4	4	3

Note. S1, S2… S10 are scenarios 1, 2… 10 respectively, and 'Ci-j' means the weights of the i^{th} and j^{th} performance indicators are switched, while the rest of the performance indicator weights remained the same.

Table 8. Spearman's Rank Correlation Coefficients

Comparison	Spearman's rank correlation coefficient (r_s)
S0 vs S1	1.000*
S0 vs S2	0.995*
S0 vs S3	1.000*
S0 vs S4	1.000*
S0 vs S5	0.989*
S0 vs S6	1.000*
S0 vs S7	1.000*
S0 vs S8	0.984*
S0 vs S9	0.989*
S0 vs S10	1.000*

Note. *Correlation is significant at the 0.01 level (2-tailed)