รายงานวิจัยฉบับสมบูรณ์

การยกระดับบทบาทของอุตสาหกรรมอิเล็กทรอนิกส์:
ปัจจัยหลักแห่งความสำเร็จ และการพัฒนาความสามารถ

โดย

ผศ.ดร.นิศากร สมสุข

เมษายน 2562

สัญญาเลขที่ MRG5980256

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บทคัดย่อ

การแข่งขันที่รุนแรงในตลาดโลกปัจจุบันได้ผลักดันให้ "ผู้รับจ้างผลิต" (Original Equipment Manufacturer: OEM) ต้องพัฒนารูปแบบการผลิตของอุตสาหกรรม จากการรับจ้างผลิตหรือ OEM ซึ่งมีมูลค่าเพิ่มต่ำ ไปสู่รูปแบบการผลิตที่มีมูลค่าเพิ่มสูงขึ้น โดยมีขั้นตอนการออกแบบและพัฒนาผลิตภัณฑ์ และเน้นการผลิตตามความต้องการของลูกค้ามากขึ้น หรือที่เรียกว่า "ผู้ผลิตและการออกแบบสินค้าภายใต้แบรนด์ของผู้ว่าจ้าง" (Original Design Manufacturer: ODM) ตลอดจนการพัฒนาไปสู่การมี แบรนด์ของตนเอง หรือที่เรียกว่า "ผู้ผลิตออกแบบ และขายสินค้าภายใต้แบรนด์ตัวเอง" (Original Brand Manufacturer: OBM) เพื่อส่งเสริมความสำเร็จในการยกระดับบทบาทของอุตสาหกรรมจาก OEM ไปเป็น ODM / OBM ต้องมีการวิเคราะห์ปัจจัยต่าง ๆ ที่นำไปสู่ความสำเร็จในการยกระดับบทบาทของอุตสาหกรรมอย่างรอบคอบ การศึกษาครั้งนี้มีจุดมุ่งหมายเพื่อระบุและจัดลำดับความสำคัญของปัจจัยความสำเร็จในการยกระดับบทบาทของอุตสาหกรรมในอุตสาหกรรมอิเล็กทรอนิกส์ในประเทศไทย โดยงานวิจัยนี้จะนำเอาทฤษฎีว่าด้วยฐานทรัพยากร (Resource-based view) ทฤษฎีเครือข่ายความสัมพันธ์ (Relational view) ทฤษฎีสถาบัน (Institutional theory) และทฤษฎีความสามารถเชิงพลวัต (Dynamic capabilities) มาเป็นฐานในการระบุปัจจัยหลักแห่งความสำเร็จในการดำเนินการยกระดับบทบาทของอุตสาหกรรม ฯ และสร้างตัวแบบโครงสร้างเชิงลำดับเพื่อจัดลำดับความสำคัญของปัจจัย ฯ โดยการประยุกต์ใช้เทคนิคฟัซซีเดลฟาย (Fuzzy Delphi) และกระบวนการลำดับชั้นเชิงวิเคราะห์แบบฟัซซี (Fuzzy Analytic Hierarchy Process) ซึ่งเป็นเทคนิคการตัดสินใจแบบกลุ่มโดยคณะผู้เชี่ยวชาญ ในงานวิจัยนี้ ยังได้วิเคราะห์ความไวเพื่อประเมินความทนทานของการจัดลำดับที่ได้รับ ผลการวิจัยพบว่าปัจจัยความสำเร็จที่มีความสำคัญมากที่สุดสามลำดับแรกคือ ความสามารถทางเทคโนโลยี เครือข่ายที่เข้มแข็ง และนโยบายของรัฐบาล ตามลำดับ ในท้ายที่สุดการศึกษาครั้งนี้ มีข้อเสนอแนะบางประการสำหรับผู้ปฏิบัติงานซึ่งจะช่วยให้การบริหารจัดการที่มีประสิทธิภาพสามารถกำหนดปัจจัยความสำเร็จที่

สำคัญและสำหรับผู้กำหนดนโยบายที่สนับสนุนการพัฒนานโยบายที่มีประสิทธิภาพเพื่อส่งเสริมความสำเร็จในการยกระดับบทบาทของอุตสาหกรรม ฯ เพื่อรักษาขีดความสามารถในการแข่งขันของผู้ผลิตและอุตสาหกรรมอิเล็กทรอนิกส์ในประเทศไทย

คำหลัก: การยกระดับบทบาทของอุตสาหกรรม ปัจจัยหลักแห่งความสำเร็จ ฟัซซีเดลฟาย กระบวนการลำดับชั้นเชิงวิเคราะห์แบบฟัซซี ทฤษฎีองค์กร ทฤษฎีความสามารถเชิงพลวัต

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Project Title: A Functional Upgrading in the Electronics Industry: Critical Success Factors and Capability Development

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Abstract

The intense competition in the current marketplace has pushed the original equipment manufacturers (OEMs) to think about moving their manufacturing to higher value added, such as own design manufacturer (ODM) and own brand manufacturer (OBM). To promote the success of functional upgrading from OEM to ODM/OBM, a careful analysis of factors that contribute to the success of the upgrade must be taken. This study aims to identify and prioritize the critical success factors for functional upgrading in the electronics industry in Thailand, based on the theoretical perspectives of the resource-based, relational, and institutional theories, the dynamic capability view, and a fuzzy group decision-making approach e.g. fuzzy Delphi and fuzzy AHP. A sensitivity analysis is also performed to evaluate the robustness of the ranking obtained. 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 Delphi; fuzzy AHP; organizational theories; dynamic capabilities.

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Nisakorn Somsuk

Eastern Asia University

April 2019

CONTENTS

CONTENTS (Cont.)

Pages

CONTENTS (Cont.)

CHAPTER 1

INTRODUCTION

1.1 Rationale for the Study

The electronics industry is one of the largest manufacturing sectors in Thailand and it is mostly export-oriented (Tippayawong, Tiwaratreewit, & Sopadang, 2015). In Thailand's context, the firms in such industry are mainly original equipment manufacturing (OEM) firms and they are as the low cost and labor intensive manufacturers. In the current era of intense competition, price and cost competitiveness may not be enough for them to sustain their competitiveness anymore. In this regard, in the context of global value chains (GVCs), moving upward along the GVCs, from OEM to ODM original design manufacturing (ODM) and then to OBM original brand manufacturing (OBM) is identified as an important strategy for businesses to enhance their competitiveness (Manzakoğlu & Er, 2018; van Assche, 2017).

To survive and gain a competitive advantage in today's global competitive market, most of OEMs 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 ODM and 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. In other words, moving from OEM to ODM and OBM by focusing on higher value added activities in GVCs such as design, branding and distribution or logistics (Sun, 2011), 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.

Though, many firms from emerging economies attempt to upgrade their functional capabilities to become ODM and OBM by participating in GVCs, in upgrading strategies from low value added activities to high value added activities. However, many firms have failed during the functional upgrading (Chen, Wei, Hu, & Muralidharan, 2016; Manzakoğlu & Er, 2018). This upgrading is not an easy intra-firm task, as it requires the cooperation with other parties including governments and industries for the successful development of this upgrading trajectory. Moreover, in moving upward along the GVCs, many firms require different capabilities. Since the 1990s, many studies in the U.S., Chinese mainland, Chinese Taiwan, and Korea (e.g. Chen, 2010; Yuan, Chiu, Kao, & Lin, 2009; Chen, Shen, & Chiu, 2007; Hsu, Chen, & Jen, 2008; Humphrey & Schmitz, 2000; Kim, 1997) have identified factors influencing a firm's success in upgrading focusing on developing higher value added capabilities. But in many emerging countries including Thailand, especially their priorities, the issue of identification of critical success factors for upgrading has hardly been studied.

Thus, not only to ensure the success of functional upgrading, a careful and comprehensive analysis of the factors that contribute to the success of this upgrading must be taken, but also to be able to focus collective efforts on the most significant factors, a prioritization of critical success factors needs to be made explicit.

Regarding complex prioritization problems, the multi-criteria decision making (MCDM) techniques can provide a logical framework to analyze such problems (Roy, 1996; Svahnberg, Wohlin, Lundberg, & Mattsson, 2002). Analytic hierarchy process (AHP) is one of the MCDM techniques, which can be applied to critical success factor prioritization which based on subjective judgment.

However, 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). An integrated AHP with fuzzy set theory can handle subjectivity in the human decision making process (Mardani, Jusoh, Bagheri, & Kazemilari, 2015; Somsuk & Laosirihongthong, 2016; Zaim, Sevkli, & Tarim, 2003). Moreover, such integrated approach is also able to reflect a human vague thinking/knowledge (Bozdag, Kahraman, & Ruan, 2003). Similarly, an integration of traditional Delphi method with fuzzy theory (fuzzy Delphi method) takes vague concepts involved, and this helps to gather opinions reached to a consensus in only one round of survey in order to ensure that the analysis has been performed in a careful way (Kabir & Sumi, 2012; Mardani et al., 2015).

Therefore, this study applies a fuzzy group decision-making approach e.g. fuzzy Delphi and fuzzy AHP, based on the experts' subjective judgments to identify and prioritize the critical success factors in order to include the vagueness associated with experts in the decision making process (Duran & Aguilo, 2008; Huang, Chu, & Chiang, 2008).

Besides, the complexity of a prioritization problem needs the integration of different theories to develop the comprehensive prioritization framework and model (Coates & McDermott, 2002). In this study, the analysis of critical success factors draws upon insights from resource-based, relational, and institutional perspectives. These theories are used not just to identify the theoretical factors affecting the success of functional upgrading, but these theories and the dynamic capability view are also used to develop an analytical (theoretical) framework and a hierarchical model to find the most significant factors of functional upgrading process.

Hence, this study explores the applicable critical success factors for functional upgrading in the electronics industry, one major export sector in Thailand, using comprehensive literature reviews and viewing them through the theoretical lenses of the resource-based, relational and institutional perspectives, and the fuzzy Delphi-based group decision-making approach which leads to consensus of expert opinion. The analysis of the critical success factors in a process of functional upgrading, upgrading trajectory in GVCs from OEM to ODM/OBM, is based on the fuzzy AHP-based group decision making according to the views of Thai experts. After that a sensitivity analysis by changing the weights of criteria is performed to evaluate the robustness of ranking obtained through the fuzzy AHP. Finally, based on the findings, this paper provides some important implications for both practitioners and researchers to enable more effective strategic decision making on support for developing the upgrading strategies, and to develop more effective policy for promoting the success of functional upgrading to achieve competitiveness of Thailand's electronics firms, as well as strengthen their position in the global market.

1.2 Objectives

1.2.1 To identify the critical success factors for functional upgrading in the electronic industry with respect to specific internal and relational resources and institutional factors.

1.2.2 To identify the key performance indicators or success criteria for functional upgrading in the electronic industry.

1.2.3 To develop a theoretical framework and a hierarchical decision making model for ranking the critical success factors with regard to dynamic capability development.

1.2.4 To determine the relative weights of critical success factors and criteria.

1.2.5 To evaluate the robustness of the ranking obtained.

1.2.6 To develop the important implications for both practitioners and researchers.

1.3 Overall Research Methodology

To illustrate the methodology and conduct a systematic analysis, a proposed research framework in this study can be summarized and presented as the following three phases (as shown in Figure 1-1):

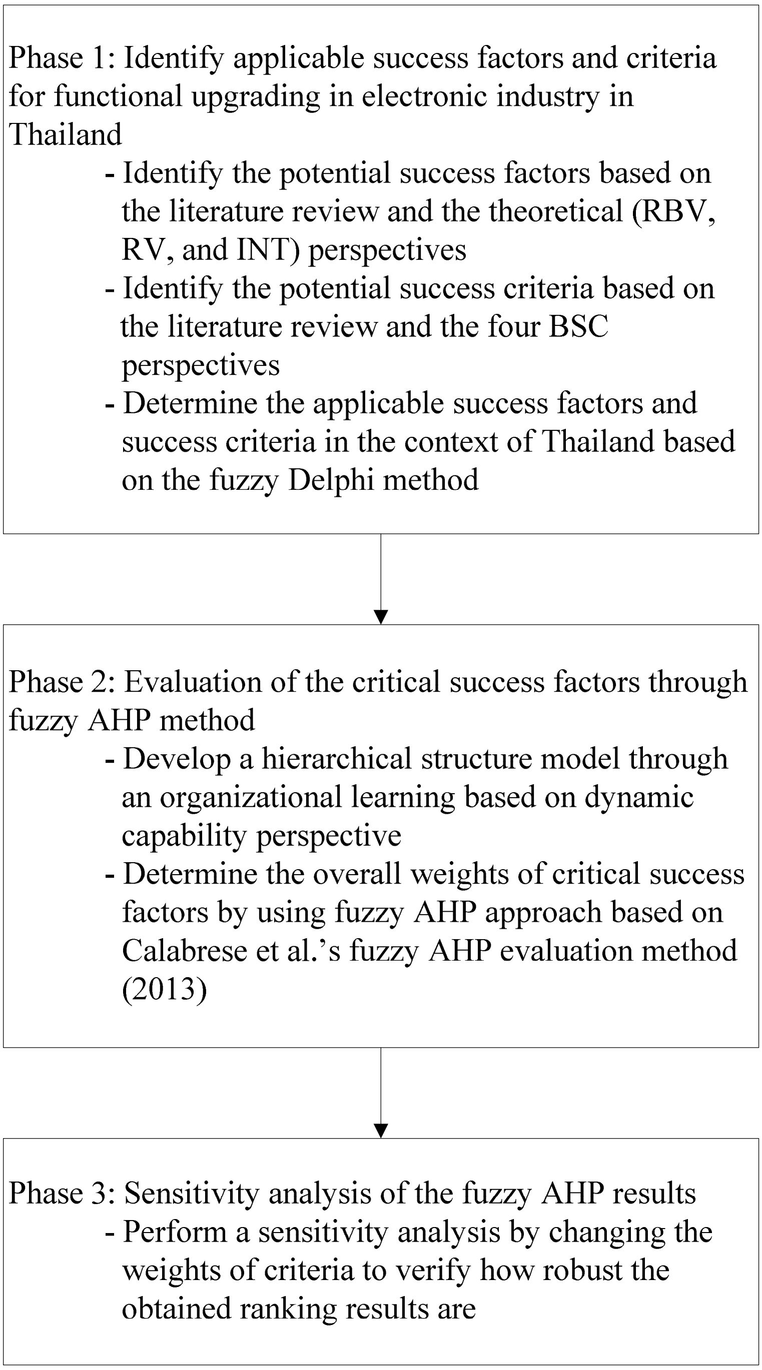

Figure 1-1 The overall research methodology

1.4 Scope of Research

The scope of the research can be summarized as follows:

1.4.1 The area of this study will be confined to the electronics industry in Thailand.

1.4.2 The critical success factors considered will be internal and relational resources and external environmental factors.

1.4.3 The upgrading trajectory will be transitioning from OEM to ODM and then to OBM.

1.4.4 The main specific capabilities including design, new product development, marketing and branding will be considered.

1.5 Expected Benefits

The expected benefits can be classified into two major categories;

1.5.1 Benefits to the academic

1.5.1.1 It may enable the global electronics value chain scholars, especially in Thailand, to realize the role of a unique bundle of resources of the firm and the inter-firm resources and routines as internal and external success factors respectively and to realize the external environmental factors as institutional success factors.

1.5.1.2 It may enable the scholars to realize and utilize the institutional theory and the RBV and RV theories in developing theoretical framework and an AHP-based model for prioritizing the critical success factors through functional upgrading.

1.5.1.3 The proposed theoretical model may be adapted to other industries in similar environmental contexts.

1.5.2 Benefits to the country

1.5.2.1 It may enable manufacturers to be in a stronger position to improve their global competitiveness with a deeper understanding of the required necessary resources and specific capabilities for successful functional upgrade.

1.5.2.2 It may enable policy makers to better guide the potential new entrants and provide relevant government aids by directing support to develop suitable capabilities (e.g. technological, design, and marketing capabilities) to promote transitioning from OEM to ODM, and then OBM.

1.5.2.3 It may enable both practitioners and policy makers to develop an improvement strategy for resource provision and capability development, to increase efficiency in the resource allocation decisions, and to develop effective policy in promoting the success of functional upgrading to gain competitive advantage of Thailand's electronics firms.

1.5.2.4 It may enable manufacturers to efficiently develop their capabilities that will allow them to move into higher value-added activities in the global value chain.

1.5.2.5 The research suggests the policy mechanisms to encourage upgrading according to the capabilities of export-oriented firms and their position within global value networks.

1.5.2.6 The successful functional upgrading can boost 'export capacity' and 'gross domestic product (GDP)'.

1.6 Structure of the Remainder of the Report

The remainder of this report is organized as follows.

Chapter 2 Literature review and background

This chapter presents a review of functional upgrading & electronics industry in Thailand, success criteria and the Balanced Scorecard, a multiple-theory framework for critical success factor analysis. The organizational theories include the resource-based view, the relational view, the institutional theory, and dynamic capabilities for functional upgrading. A review of existing related literature in Chapter 2 was performed to support the study undertaken in this research.

Chapter 3 Research methodology

This chapter elaborates the research design and methodology employed in this study. It also presents justification of the use of research methods in which the methods are used. The details of data collection and analysis are described.

Chapter 4 Identification of critical success factors and criteria for functional upgrading using fuzzy Delphi

This chapter presents the literature review on success factors and criteria for functional upgrading through the lenses of the organizational theories including the RBV of the firm, the relational view, and the institutional theory. The fuzzy Delphi methodology which is applied to identify the potential success factors and criteria is presented.

Chapter 5 Prioritization of critical success factors and criteria for functional upgrading using fuzzy AHP, and sensitivity analysis

This chapter presents an application of the fuzzy AHP model to prioritize the critical success factors and criteria for functional upgrading, and also presents the hierarchical model for prioritizing the factors, which is linked to the RBV of the firm, the relational view, and the institutional theory based on the fuzzy AHP approach. The dynamic capabilities as an intermediating the relationship between a firm's performance and the success factors as well as a sensitivity analysis are presented.

Chapter 6 Discussions, implications, conclusions, limitations and future research

The final chapter summarizes the major conclusion of the research from the studies of identifying and prioritizing critical success factors respectively followed by the implications for practitioners, and concludes with reliability of the research results. This chapter also contains the recommendations of the research, followed by the limitations of the studies of identifying and prioritizing critical success factors respectively, and concludes with possible directions for future research in the field.

Concluding Remark

This chapter illustrated the background and rational of the study, the research gap and the research objectives. The methodology of the research was briefly described. The objectives and contribution of this research and its scope, and limitations were presented. The structure of the research was also outlined.

CHAPTER 2

LITERATURE REVIEW AND BACKGROUND

This chapter presents a review of functional upgrading & electronics industry in Thailand, success criteria and the Balanced Scorecard, a multiple-theory framework to analyze the critical success factors.

2.1 Definitions of OEM, ODM, and OBM

There are many variations in definitions of OEM, ODM, and OBM. In this study, OEM, ODM, and OBM are defined as follows:

Original Equipment Manufacturing (OEM) refers to an equipment manufacturer who creates and assembles products which are then marketed under a brand name or company by a separate vendor or reseller.

Original Design Manufacturing (ODM) refers to a manufacturer who anonymously designs and manufactures its own products. They are usually under contract with OEM companies, who then market the products separately.

Original Brand Manufacturing (OBM) refers to products manufacturers through the products brand that is set up by oneself and on sale throughout the thorough fare, popularizes and sells the products produced by it on the market.

2.2 Global Value Chains in the Electronics Industry

The role of firms from developing economies which is often limited to the lower value-added contract manufacturers, whereas firms from more advanced economies, plays a more dominant ‘lead firm’ role (Sturgeon & Kawakami, 2010). On the other hand, contract manufacturers make products for these lead firms through production services, which are often known as ‘electronics manufacturing services’ or OEM. Manufacturing plus production design services is known as ODM. Contract manufacturers are often located in developing countries and often faced with intense competition and low profitability (Pananond, 2013).

Mudambi (2007) and Mudambi (2008) used the concept of ‘smile of value creation’ to argue that the value-added activities are often concentrated at the upstream and downstream ends of the value chain. Upstream (input) activities are based on R&D knowledge (basic and applied research and development), whereas downstream ones are typically based on marketing knowledge (marketing, advertising, brand management, sale and after-sale services). While upstream and downstream activities tend to be concentrated in advanced economies, those in the middle—mass manufacturing and assembly, are often found in emerging markets (Mudambi, 2008). Applying this concept to the electronics industry, Shin, Kraemer, and Dedrick (2009) and Shin et al., (2012) confirm that value creation is not equally captured throughout different stages of the electronics' GVC. Lead firms and component suppliers, particularly suppliers of key components, capture most of the value created from a successful product in the electronics industry, compared to other players in the GVC.

Thailand has been part of the electronics industry's GVC for the past few decades. Similar to other countries in Southeast Asia, Thailand has been a major production and export base for MNEs producing electronics hardware, especially consumer goods, computing and telecommunication equipment, hard disk drive and semiconductor components. Export-oriented subsidiaries are generally established to perform basic assembly activities, with technology supplied by parent companies. Technological upgrading of both production processes and the type of products manufactured can be mastered next when local subsidiaries acquire useful manufacturing process skills and some limited product design capabilities and limited R&D activities. At that stage, local subsidiaries should be able to perform ODM activities. Through a continuous process of technological upgrading, local subsidiaries may then be able to be engaged in R&D activities that aim at new product and process innovation (Pananond, 2013).

2.3 Industrial Upgrading in Global Value Chains

One of the feasible responses of firms to maintain or increase their competitiveness in the increasingly globalized economy is to upgrade their production. Upgrading involves engaging in the production of higher value-added products, employing more efficient production strategies, and/or increasing the skill content of activities by firms (Humphrey and Schmitz, 2002; Kaplinsky, 2000). In the global value chain (GVC) approach (e.g. Gereffi, Humphrey and Sturgeon, 2005), the concept of industrial upgrading refers to the 'process by which economic actors—nations, firms and workers—move from low-value to relatively high-value activities in global production networks' (Gereffi, 2005). These processes operate at different geographic scales: within factories, within inter-firm enterprise networks, within local or national economies, and within macro regions at the international scale (Gereffi, 1999). Industrial upgrading is vital for creating possibilities to enhance value and thus for creating possibilities for economic development (Henderson, Dicken, Hess, Coe, and Yeung, 2002). Humphrey and Schmitz (2000, 2002, 2004) have identified four different types of upgrading: process, product, functional and inter-sectoral. Process upgrading refers to the introduction of more efficient production methods and better technology leading also to the improved quality of produced goods and increased flexibility of producers. Product upgrading involves moving to the production of more sophisticated and higher value-added products. Functional upgrading is the process during which firms acquire new functions generating higher incomes or abandon old functions generating low incomes in the value-chain. Its goal is to increase the overall skill content of firm's activities. Inter-sectoral upgrading takes place when a firm uses its acquired production knowledge to move horizontally into new sectors. Additionally, Dunn, Sebstad, Batzdorff and Parsons (2006) have identified channel upgrading which refers to firms entering new higher value-added end markets in the value chain in order to lower their risk and increase sales volumes through diversification and receive higher prices for their products.

Firms can enhance their competences in GVCs through four main channels, namely processes, products, functional areas and inter-chain interactions.

1. Process Upgrading.

Process upgrading, concerned with improvements in the production system. This involves acquiring new machinery, implementing a quality control program, shortening delivery times, reducing waste, and in general providing a more efficient transformation of inputs into outputs (Humphrey and Schmitz, 2000).

2. Product Upgrading.

Product upgrading, which deals with introducing new products, changing designs, improving quality, and producing a more sophisticated final output (Humphrey & Schmitz, 2000).

3. Functional Upgrading.

Functional upgrading, which involves moving into different stages (or functions) beyond production. Most commonly this implies moving into new links of the value chain –usually with higher margin and difficult-to-replicate activities– such as original design, branding, and marketing (Humphrey & Schmitz, 2000).

4. Chain, or Inter-sectoral Upgrading.

Chain, or inter-chain upgrading refers to applying the competence acquired in a particular function to move into a new chain. When firms move from one value chain to another, processes and functions may also change, or they may not, but both immediate and final customers are in new sectors. The basic processes of the firm may stay the same, but inter-sectoral shifts come with new customers and requirements (Humphrey and Schmitz, 2000).

2.4 Functional Upgrading

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.

This research consider a functional upgrading as the acquisition of a set of necessary new capabilities that will allow firms to move into higher value-added (i.e. better remunerated, higher margin) activities in the value chain, such as design, marketing, and branding. Therefore, it is important for Thailand's electronics OEMs to (possess and) develop their own capabilities necessary for upgrading or more value-added activities.

According to functional upgrading (Mudambi, 2007; 2008),firms can acquire new functions in the chain, such as moving from production to design or marketing, to increase the overall skill content of activities. For instance, in the global value chain, functional upgrading would involve a move from OEM where the firm offers a wider range of production capacities and services to buyers, to ODM where firms carry out all parts of the production process including design and new product development, to OBM where firms engage in marketing and branding functions.

The process of manufacture upgrade can be described as progression along a value creation chain from OEM, ODM to OBM (Humphrey, 2004). In manufacture upgrade, low cost producers of labor intensive OEM would be moving to operations that create competitive advantage based on product design in ODM, and proprietary technology and brand equity in OBM (Eng & Spickett-Jones, 2009).

In recent years, manufacturers in the global value chain have been transforming and upgrading in the hope that they can gradually transform along the value curve, moving from production activities to R&D or design and marketing business with higher added value. Alternatively, they try to push up the value curve through upgrading the production technology and product quality so as to enhance the overall competitiveness and added value of the business. The value curve of functional upgrading in the global value chain is shown in Figure 2-1.

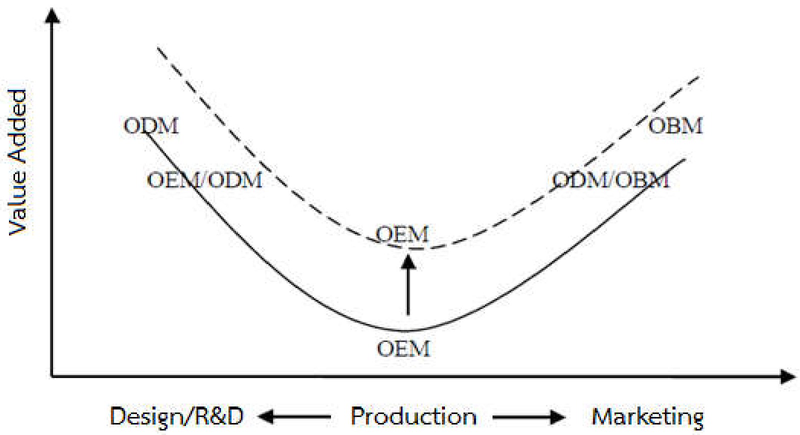

Figure 2-1 Value curve of functional upgrading in the global value chain

Sources: Adapted from Mudambi (2007; 2008)

2.5 Upgrading Trajectory

The reference point for the literature on industrial upgrading is the East-Asian experience. This has often been analyzed in terms of the sequence of acquisition of functional capabilities, as shown in Figure 2-2.

Assembly ↓	The focus is on production alone, often following buyers' specifications and using materials supplied by the buyer.
Original equipment manufacture (OEM) ↓	The supplier takes on a broader range of manufacturing functions, possibly including the sourcing of inputs and logistics functions. The buyer is still responsible for design and marketing.
Original design manufacture (ODM) ↓	In addition to manufacturing, the supplier carries out parts of the design process, possibly in collaboration with the buyer. In the most cases, the buyer merely attaches its own brand to a product designed and made by the supplier.
Original brand manufacture (OBM)	The supplier designs, produces and markets its own products under its own brand. It no longer relies on a buyer for these functions.

Figure 2-2 Upgrading trajectory

Sources: Taken from various sources, including Hobday (1995) and Gereffi (1999)

2.6 Functional Upgrading & Electronics Industry in Thailand

Most firms in the electronics industry in Thailand are OEMs 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).

In the context of Industry 4.0 and Thailand 4.0, Thailand local suppliers/OEMs have become increasingly global. To enhance competitiveness and profitability (and escape the middle-income trap by transitioning towards more knowledge-intensive and higher value-added activities), Thailand local suppliers/OEMs 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. However, upgrading in GVCs (moving up the value chain through process, product, functional and chain upgrading), especially functional upgrading, is not easy to achieve. According to Intarakumnerd and Charoenporn (2015), suppliers/OEMs in Thailand have generally not succeeded to upgrade into ODM. 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.

2.7 Success Criteria and the Balanced Scorecard

Success criteria or performance indicators are ‘the measures by which success or failure of a project or business will be-judged' (Cooke-Davies 2002:185). They should reflect the firm's goals and critical success factors (Bala & Koxhaj, 2017). There are many different success criteria when functional upgrading takes place in firms. According to previous studies (e.g. Anker, Chernyshev, Egger, Mehran, & Ritter, 2003; Burger, Jindra, Kostevc, Marek, & Rojec, 2015; Kamau, 2009; Kaplinsky & Readman, 2005; Milberg & Winkler, 2011), 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 success indicators/criteria that are critical to the firm to easily monitor operations and evaluate the success of a specific project (e.g. functional upgrading) in which the firm engages.

In developing a comprehensive set of performance indicators or success criteria, Kaplan and Norton (1996b) introduced the Balanced Scorecard (BSC), a performance measurement framework which includes both financial and non-financial metrics, and contains four categories/perspectives of measurements (Kaplan & Norton, 1992; 1993; 1996a).

The BSC's four perspectives: financial, customer, internal, and learning & growth, are explained briefly as follows (Kaplan & Norton, 1996b):

Financial perspective: Kaplan and Norton (1996b) defined a financial perspective as 'the readily measurable economic consequences of actions already taken' in the other three perspectives (customer, internal business process, and learning and growth), which are usually related to profitability.

Customer perspective: this perspective considers customers as the source of business profits. An increase in recognition of the importance of customer focus and satisfaction is the objective pursued by firms.

Internal business process perspective: in this perspective, a complete internal business-process value chain that can meet needs and have the greatest impact must be excelled by a firm can help company in achieving competitive advantage.

Learning and growth perspective (or innovation and learning): This perspective considers people as the main resources in a knowledge-worker organization through people learning and development including employee training and corporate culture that relate to individual and organizational improvement.

2.8 A Multiple-Theory Framework to Analyze Critical Success Factors

A functional upgrading is generally considered successful if its goals are achieved and its key stakeholders are satisfied with its outcomes, while success factors can be defined as a set of factors that contribute to the successful functional upgrading or have positive influence on firm performance while also increasing the firm's 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 (or performance) is gained and held from these factors.

2.8.1 The resource-based view

The resource-based view of the firm (RBV) 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 (its broad concept, 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'.

2.8.2 The relational view

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 (Dyer & Singh, 1998; Lavie, 2006). According to the relational view (Dyer & Singh, 1998), four potential sources of inter-organizational competitive advantages are relation-specific assets, knowledge-sharing routines, complementary resources, and effective governance. Therefore, based on the relational view, the firm's relational resources that serve as potential sources of inter-organizational competitive advantages can be considered as ‘potential success factors’.

2.8.3 The institutional theory

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). In such economy, external factors coupled with internal factors (within organization) and relational factors (inter organization) can be more effective in addressing firms’ performance. Institutional factors based on the institutional theory are 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).

Based on the framework of the institutional theory, the social environmental factors are categorized into three groups: regulative, normative and cognitive factors (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 (Scott, 2005; 2008; Yamakawa, Peng, & Deeds, 2008) and occur when firms imitate the actions of successful competitors in an industry (Aerts, Cormier, & Magnan, 2006; Glover, Champion, Daniels, & Dainty, 2014; Sarkis, Zhu, & Lai, 2011). Therefore, based on the institutional theory, the factors in three following groups; regulative, normative and cognitive can be considered as ‘potential success factors’.

In 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 firms’ desirable resources/factors (including within organization, inter organization, and external factors) so-called 'potential success factors'. Consequently, those success factors can be classified into three main categories identified by each of the theories, namely, internal (RBV-based), relational (relational view-based), and institutional (institutional theory-based) factors. Such classification of theoretical success factors is necessary for developing a theoretical framework.

2.9 Dynamic Capabilities and Functional Upgrading

The dynamic capability view (DCV) extend RBV is needed to explain how competitive advantage is gained and held (Teece & Pisano, 1994). 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.

Through an organizational learning based on dynamic capabilities perspective, this study considers dynamic capabilities as an intermediating the relationship between a firm's performance and the success factors. In other words, the dynamic capabilities could play an intermediate role to transform the 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; Lau & Lo, 2015; Palit, 2006; Wang, Chen, Wang, Lutao, & Vanhaverbeke, 2014; Zhao, Tong, Wong, & Zhu, 2005; Zhai, Shi, & Gregory, 2007), ii) innovative capability (Altenburg, Schmitz, & Stamm, 2008; Jean, 2014; Mahmood & Zheng, 2009; Zhao et al., 2005), iii) integrative capability (Chen, Lee, Xing, & Chen, 2014; Chen, Qiao, & Lee, 2014; Huang, Chen, Stewart, & Panuwatwanich, 2013; Liu, 2012), and iv) sensing capability (Holweg & Pil, 2008; Pandit, Joshi, Sahay, & Gupta, 2018; Ralston, Reid, Dunn, & Hainsworth, 2015). The dynamic capabilities' four dimensions are explained briefly as follows (Kaplan & Norton, 1996b):

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.

Innovative capability is a firm's ability to develop new products and/or markets through aligning strategic innovative orientation with innovative behaviors and processes (Wang & Ahmed, 2004).

Concluding Remark

This chapter presented review of GSCM in Thailand, sustainability performance of the triple bottom line, GSCM Practices, GSCM Drivers, and the organizational theories including the RBV of the firm, the relational view, and the institutional theory as the theoretical foundation of the study and the relevant literature that provide a theoretical basis for identifying the theoretical drivers and prioritizing their relative importance.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Methodology

This research was split in three phrases 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 perspective, 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 3-1. 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 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.

3.2 Fuzzy Delphi Method

As the conventional 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 which combines the fuzzy set theory and the conventional Delphi method (Murray, Pipino, & van Gigch, 1985) to identify applicable critical success factors and to establish a series of applicable success criteria based on Thai experts' perspective, and consequently to develop a hierarchical structure model, a fuzzy AHP-based model, to find the most significant factors of functional upgrading process.

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). A triangular membership function of x in $\tilde{A}$ is defined as

$$\mu_{\tilde{A}}(x)=\begin{cases} 0, & \text{for } m < l, \\ (x-l)/(m-l), & \text{for } l \le x \le m, \\ (u-x)/(u-m), & \text{for } m \le x \le u, \\ 0, & \text{for } x > u \end{cases}$$

Thus, the triangular type membership function is as in Figure 3-1.

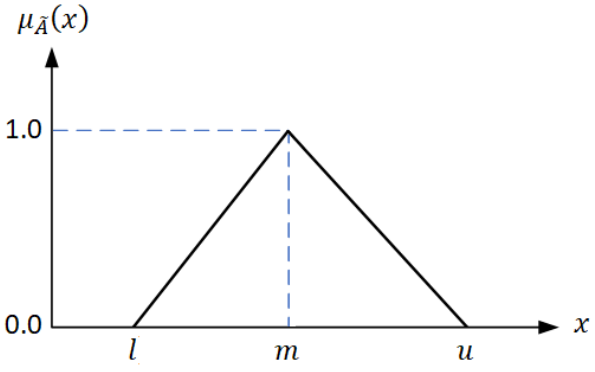

Figure 3-1 The membership function of triangular fuzzy number

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; Somsuk & Laosirihongthong, 2016; 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 3-2, is used to examine the consensus of experts in each factor and calculate its consensus significance value, g_i.

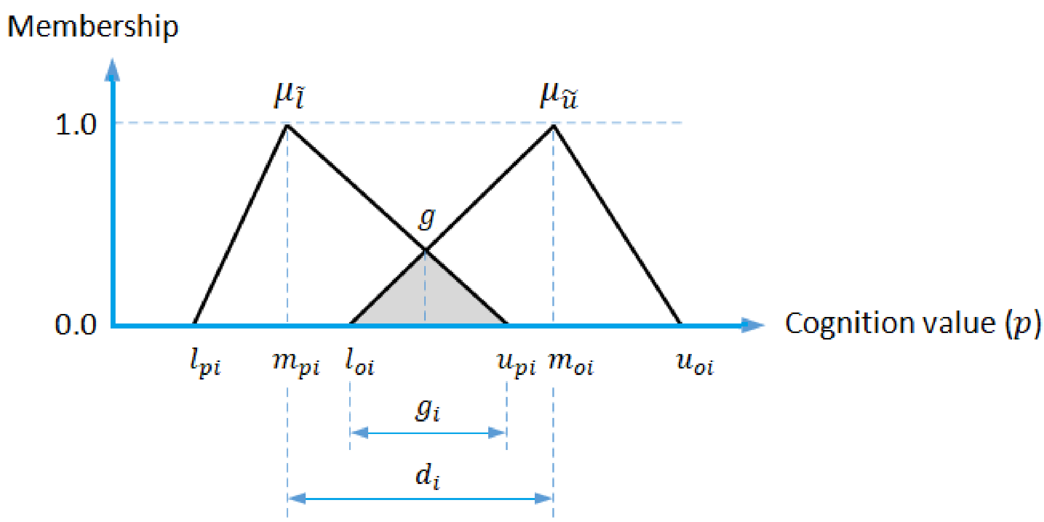

Figure 3-2 Gray zone of p_i and o_i

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

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

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, $g_i \leq d_i$, then the consensus significance value g_i of each factor can be calculated by Eq. (3) (Wang, 2015):

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

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 candidate 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 (Hsiao 2006; Ishikawa et al. 1993; Lee et al. 2010). If $g_i > T$, factor i is then selected for further analysis.

3.3 Fuzzy Analytic Hierarchy Process

The analytic hierarchy process (AHP) is a multiple-criteria decision analysis 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 multi-criteria decision-making 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 points (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 3-1.

Table 3-1

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)

Linguistic scale	Triangular fuzzy scale	Triangular fuzzy reciprocal scale
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)

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

There have been a number of methods introduced (cf., e.g. Buckley, 1985; Calabrese, Costa, & Menichini, 2013; Chang, 1996; Csutora & Buckley, 2001; Mikhailov, 2003; van Laarhoven & Pedrycz, 1983; Wang, Luo, & Hua, 2008) to handle fuzzy AHP to obtain relative weights from fuzzy comparison matrices. 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, Luo, and Hua (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.

3.4 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 $\widetilde{A}$ is constructed as shown below.

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

where $(l_{ij}, m_{ij}, u_{ij}) = (1/u_{ji}, 1/m_{ji}, 1/l_{ji})$, for $i = i, \dots, n,\ j = 1, \dots, n$ 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 pairwise 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 pairwise 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 ≤ 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 $\tilde{A}$ as follows:

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

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 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 $i = 1, \ldots, n$

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):

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

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

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

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

$$W = \left(w_1', w_2', \ldots, w_n'\right)$$

Concluding Remark

This chapter presented the research design, methodology employed in this study, and the justification of the use of research methods: fuzzy Delphi, fuzzy AHP, and the Calabrese et al.'s (2013) fuzzy AHP evaluation method. The details of data collection and analysis were described.

CHAPTER 4

IDENTIFICATION OF CRITICAL SUCCESS FACTORS AND CRITERIA FOR FUNCTIONAL UPGRADING

In this chapter, the potential (or critical) success factors and criteria are determined based on the literature review through the lenses of the theoretical perspectives, however, it is necessary to verify the appropriateness or applicability of these theoretical success factors and criteria to determine whether or not these drivers appropriate or applicable to implement functional upgrading in the Thailand's electronics industry context. Thus, the fuzzy Delphi method as a group decision making technique will be applied to ensure that the success factors and criteria are appropriate/ applicable for the particular context before further prioritizing them.

4.1 Results of Literature Review on Success Factors

To determine (potential) success factors for functional upgrading based on comprehensive literature reviews (Bastic, 2004; Chang, Hsu, & Tsai, 1999; Deng, 2012; Dunn, Sebstad, Batzdorff, & Parsons, 2006; Hobday & Rush, 2007; Hsu & Chiang, 2001; Humphrey & Schmitz, 2002; Jean, 2014; Jespersen, 2008; Lall, 1992; Luo, 2000; Martinez-Covarrubias, Lenihan, & Hart, 2017; Matthyssens, Vandenbempt, & Weyns, 2008; Palpacuer, Gibbon, & Thomsen, 2005; Pananond, 2013; Pietrobelli & Rabellotti, 2006; Sun, Lin, & Tzeng, 2009; Wang, 2010; Zhang & Duan, 2010; Yu & Hsu, 2002; Yamakawa et al., 2008; Zhao & Wang, 2009) and view them through the lenses of the three competitive advantage theories (RBV, RV, and INT), we screened twenty potential factors for upgrading under three categories including the internal (RBV-based), relational (RV-based) and external (INT-based) factors. By applying these theories, the set of factors of twenty are derived from characteristics as described by theorists (Barney, 1991; DiMaggio & Powell, 1983;

Dyer & Singh, 1998; Lavie, 2006; Lin & Wu, 2014) as mentioned above, so, identifying these factors is theoretically well grounded.

The potential success factors which can be extracted from the characteristics of three significant competitive advantage theories mentioned above are summarized as follows:

Internal Factors:

Financial resources refer to availability of sufficient capital or access to sufficient capital for additional investment in functional upgrading, and are able to manage associated risks.

International experience refers to the degree to which the firm's management has experience with transnational operations and in specific foreign markets and industries; furthermore it represents knowledge that supports the achievement of the firm's exporting objectives and goals.

Knowledge sharing capability refers to the ability of employees to share their work-related experience, expertise, know-how and (valuable) information with other employees within an organization (Darroch & McNaughton, 2002) which creates the opportunity for applying knowledge.

Managerial skills refer to the skills of manager by which they perform their task effectively and efficiently. These skills include human skills (ability to interact and motivate), technical skills (knowledge and proficiency in the trade), and conceptual skills (ability to understand concepts, develop ideas and implement strategies).

Quality capabilities refer to quality control capabilities that enable a firm to ensure the quality of its products and services for complete customer satisfaction and established standards including regulatory, environmental, and safety standards.

R&D laboratory refers to an R&D facility ((i.e., a location engaged mainly in research, or research and development) 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.

Technology commercialization capabilities refer to the capability of firms to successfully bring their (technical) innovative products/services and technologies to market and grow in terms of sales and profitability.

Technological capabilities refer to the (R&D) capabilities to make effective use of technical knowledge, skills, and experience to generate and manage technological change in response to the competitive business environment, as well as to develop and design products and processes, and to operate facilities effectively.

Top management support refers to the involvement, commitment and support of top management during the functional upgrading process, by providing the necessary resources (such as human, technical and budgetary resources) and leadership.

Relational Factors:

Collaborative awareness refers to 'the extent to which a firm perceives its trust in and committed relationship with their supply chain partners' (Barnes & Liao, 2012) which results in sharing costs, risks, and benefits among supply chain partners (Simatupang & Sridharan, 2005).

Commitment to learning and training refers to the value (trust and mutual commitment) that a firm places on learning in which top managements are committed to training their staff, and continuing development activities in order to improve their skills required for functional upgrading and enable them to acquire an accurate understanding of the newly designed technological products, services and systems.

Inter-organizational information sharing refers to a communication of information among supply chain partners, by using an inter-organizational information system to manage interdependencies between firms in mediating among supply chain partners transactions and relationships.

Networks (inter-firm collaboration networks) refer to relationships between firms within the cluster and non-governmental and governmental organisations (Saxenian, 1994) that cooperate in order to achieve collective efficiency, penetrate and conquer markets, and overcome common problems beyond their individual reach (Ceglie & Dini, 1999).

Partnership with leading firms refers to a relationship between global leading OBM firms (multinational company affiliates) and their corresponding OEM/ODM partners (Yu & Hsu, 2002) to help them in order to enhance the development capabilities (e.g. new product design and marketing) of the OEM/ODM firms.

Strategic alliances refer to several forms of inter-firms linkages including joint venture, joint research and development, joint marketing ventures, and long-term supply arrangements for exchanging resources for mutual benefits, as well as such alliances may allow firms to get close enough to transfer even tacit knowledge.

Institutional Factors:

A quest for legitimacy (creating integrated business and environmental value) refers to the environmental management practices, implemented in firms, to certify the environmental management systems (EMS) under ISO 14001 standards, or adopts a sustainable/ green/ environmental supply chain management practices, or create green jobs or even recycle waste electrical and electronic equipment.

Business associations refer to organizations formed as self-help bodies by groups of businesses to further the interests of and respond to external events of their members, e.g. macroeconomic stabilization and reform, (horizontal and vertical) coordination, reducing information cost, setting standards, quality upgrading, and employee training. Business associations include federations, chambers of commerce, and trade and industrial groups.

Government's technology development strategies refer to 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; Shih, 1999).

Regulation environment refers to 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, as well as tax reform, trade reform, and financial account liberalization.

(Successful) Entrepreneurial traits, from the cultural-cognitive pillar, (successful) entrepreneurial traits refer to the common entrepreneurial characteristics among the different cultures, including creativity, innovation (Ward, 2005; Weitzel, Urbig, Desai, Sanders & Acs, 2010), risk-taking propensity, internal locus of control and need for achievement, which play an essential role in making entrepreneurial decisions.

We 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 4-1.

Table 4-1

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

Theoretical perspectives (Categories)	Potential success factors	Sources
RBV (Internal factors)	Financial resources	Bastic, 2004; Luo & Bu, 2018
	International experience	Yamakawa et al., 2008

Theoretical perspectives (Categories)	Potential success factors	Sources
	Knowledge sharing capability	Eng, 2006; Darroch & McNaughton, 2002
	Managerial skills	Luo, 2000
	Quality capabilities	Jean, 2014; Lall, 1992
	R&D laboratory (in-house R&D)	Martinez-Covarrubias et al., 2017; Pietrobelli & Rabellotti, 2007
	Technology commercialization capabilities	Chang et al., 1999
	Technological capabilities	Jean, 2014; Pietrobelli & Rabellotti, 2007; Lall, 1992
	Top management support	Trkman, 2010; Bandara et al., 2005
RV	Collaborative awareness	Krishnapriya & Baral, 2014
(Relational factors)	Commitment to learning and training	Wang, 2010; Holden & Kortzfleisch, 2004
	Inter-organizational information sharing	Krishnapriya & Baral, 2014; Simatupang & Sridharan, 2005
	Networks	Jean, 2014; Deng, 2012; Matthyssens et al., 2008

Theoretical perspectives (Categories)	Potential success factors	Sources
	Partnership with leading firms	Yu & Hsu, 2002
	Strategic alliances	Yamakawa et al., 2008
INT	A quest for legitimacy	Yamakawa et al., 2008
(Institutional factors)	Business associations	Jespersen, 2008; Pietrobelli & Rabellotti, 2007; Yamakawa et al., 2008
	(Successful) Entrepreneurial traits	Yamakawa et al., 2008; Wang, 2010
	Government's technology development strategies	Hsu & Chiang, 2001; Hobday & Rush, 2007; Shih, 1999
	Regulation environment	Yamakawa et al., 2008

4.2 Results of Literature Review on Success Indicators (Criteria)

After classifying the four main categories of measurement, based on the four perspectives of the balanced scorecard and conducting comprehensive literature review on the performance criteria/success indicators of leading upgrading success stories and the relevant literature (Amaghini, 2006; Anker et al., 2003; Barrientos, Gereffi, & Rossi, 2011; Burger et al., 2015; Eng & Spickett-Jones, 2009; Habaradas & Tolentino, 2010; Hsu et al., 2008; Humphrey & Schmitz, 2002; Kamau, 2009; Kaplinsky, 2000; Kaplinsky & Readman, 2005; Milberg & Winkler, 2011; Yoruk, 2014), 14 performance indicators under four BSC perspectives extracted are identified as follows:

Financial Perspectives:

Cost reduction refers to the reduction in the unit cost of goods/service without compromising its quality.

Profits growth refers to increasing financial returns such as profit margin, return on investment, return on assets, and return on equity.

Sales growth refers to changing in sales volume of product or services for a period of time, typically from year to year.

Customer Perspective:

Customer retention refers to 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.

Customer growth refers to the growth rate on the number of unique customers that a business has, over a given period of time.

Market expansion refers to the expansion of its customer base by acquiring new customers/ markets, or increasing sales of the same products in different markets/new customers (increasing customer satisfaction).

Market share refers to increasing market share in the target market, as measured by units sold or revenue, achieved through increased customer demand or competitive advantages.

Internal Business Perspective:

Increase strategic partnerships refer to increasing strategic partnerships with key suppliers (that support program delivery) to ensure customer satisfaction through long-term purchasing and service agreements.

Process effectiveness improvement refers to making a process more effective and efficient, including reduction of time to market (shorter lead time), innovation enhancement, and quality improvement

Productivity growth refers to 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.

Learning & Growth Perspective:

Employee satisfaction refers to improving job satisfaction among employees including, decent work, safe work environment, wage growth, improved labor standards which results in employee retention and growth.

Employee skills improvement refers to improving core competencies and strategic skills among employees, as well as workplace culture and technologies to support an organization's strategy, by engaging in employee training and development, increased R&D expenditures information systems development.

Improved labor standards refer to improved labor standards including job safety, child labor, forced labor, employment discrimination.

Value added growth refers to providing higher value-added products to customers. The added value can result from improvement of existing products or introduction of new products.

We also 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 4-2.

Table 4-2

Potential Performance Indicators Extracted from the Four Perspectives of BSC

BSC perspectives	**Potential performance indicators (criteria)**	**Sources**
Financial perspective	Cost reduction	Yoruk, 2014; Marcato & Baltar, 2017; Milberg & Winkler, 2011
	Profits growth	Milberg & Winkler, 2011; Gereffi, 1999; Lau & Lo, 2015
	Sales growth	Chen & Lien, 2013; Lau et al., 2010; Storbacka, 2011
Customer perspective	Customer retention	Chen et al., 2013; Huang et al., 2013
	Customer growth	Huang et al., 2009; Storbacka, 2011
	Market share (growth)	Milberg & Winkler, 2011; Lu & Yang, 2004
Internal business perspective	Process improvement	Azadegan & Wagner, 2011; Lau & Lo, 2015
	(R&D) Productivity growth	Milberg & Winkler, 2011; Burger et al., 2015; Wang et al., 2010
Learning & growth perspective	Employee skill improvement	Milberg & Winkler, 2011; Lau et al., 2010

BSC perspectives	Potential performance indicators (criteria)	Sources
	Improved labor standards	Milberg & Winkler, 2011
	Value-added growth	Milberg & Winkler, 2011; Gereffi, 1999

4.3 The Fuzzy Delphi Results

An anonymous 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 appropriateness/applicability of each potential success factor and each potential success criteria. A convergence of their opinions was obtained, and thirteen applicable factors were extracted. In this research, we subjectively set 8 (80% of the assessment scale of 10) as the threshold value for all categories by the 80/20 rule (Kuo & Chen 2008; Somsuk & Laosirihongthong, 2016).

The results are shown in Tables 4-3 and 4-4, and the success factors and criteria with the consensus significance value, g_i greater than the threshold of 8 are selected to be applicable or critical success factors and criteria in functional upgrading process in Thai expert perspective.

Table 4-3

Key Performance Indicators after Fuzzy Delphi Method Screening

Perspectives	**Potential performance indicators (criteria)**	**Pessimistic values**			**Optimistic values**			$\mathbf{g_i}$	**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 4-4

Critical Success Factors after Fuzzy Delphi Method Screening

Categories	**Success factors**	**Pessimistic values**			**Optimistic values**			$\mathbf{g_i}$	**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)	Collaborative awareness	5	7.28	9	7	9.16	10	8.11	Accepted
	Commitment to	4	6.12	8	7	7.96	9	7.34	Deleted

Categories	Success factors	Pessimistic values			Optimistic values			g_i	Screening results
		l_p	m_p	u_p	l_o	m_o	u_o		
factors	learning and training								
	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

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 4-3 and 4-4, 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 ($g_i \geq 8$) 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 section.

Concluding Remark

This chapter presented the fuzzy Delphi methodology which was applied to ensure that the success factors and criteria are appropriate/ applicable for the particular context before further prioritizing them. Based on the literature review on the success criteria for functional upgrading and the existing organizational theories including the RBV of the firm, the relational view, and the institutional theory, the preliminary drivers were grouped into three theoretical categories: internal (RBV-based), relational (RV-based) and institutional (INT-based) factors. According to the fuzzy Delphi results, applicable success factors and criteria for functional upgrading and their categories were presented.

CHAPTER 5

PRIORITIZATION OF CRITICAL SUCCESS FACTORS AND SENSITIVITY ANALYSIS

This chapter, an application of the fuzzy AHP model to prioritize the critical success factors and criteria for functional upgrading is presented. The hierarchical model for prioritizing the critical success factors, which is linked to the RBV of the firm, the relational view, and the institutional theory based on the fuzzy AHP approach, is developed. Besides sensitivity analysis performed to evaluate the robustness of the ranking results is also presented.

5.1 The Fuzzy AHP Results

To determine the weights of applicable success factors by using fuzzy AHP method, a multi-level hierarchical model was formed based on the applicable success factors and criteria, and then they were prioritized using fuzzy AHP approach as follows:

First, the selection of experts is crucial and should be well-considered (Laws et al., 2004). In this study, the middle- and senior-level professionals in electronics industry in Thailand with more than ten years experience in implementing upgrading practices as well as Thai senior consultants with more than ten years experience in functional upgrading implementing are preferred as experts for the collection of their opinions and concerns. Chen, Ho, and Kocaoglu (2009) argued that the number of experts should be large enough to assure multiple perspectives, and small enough to make the research manageable. Hence, the experts consisted of twenty persons: six senior-level managers, seven middle-level managers, and seven consultants. Therefore, there exists a (rather) balanced representation of all groups of experts, with multiple perspectives to be incorporated in the prioritization process (Hoffman, 1982).

The procedure of fuzzy AHP approach to calculate weights of the factors is as follows:

1. Developing a hierarchical model for prioritizing the success factors: In developing a hierarchical model for prioritizing the critical success factors, the model shown in the Figure 5-1 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.

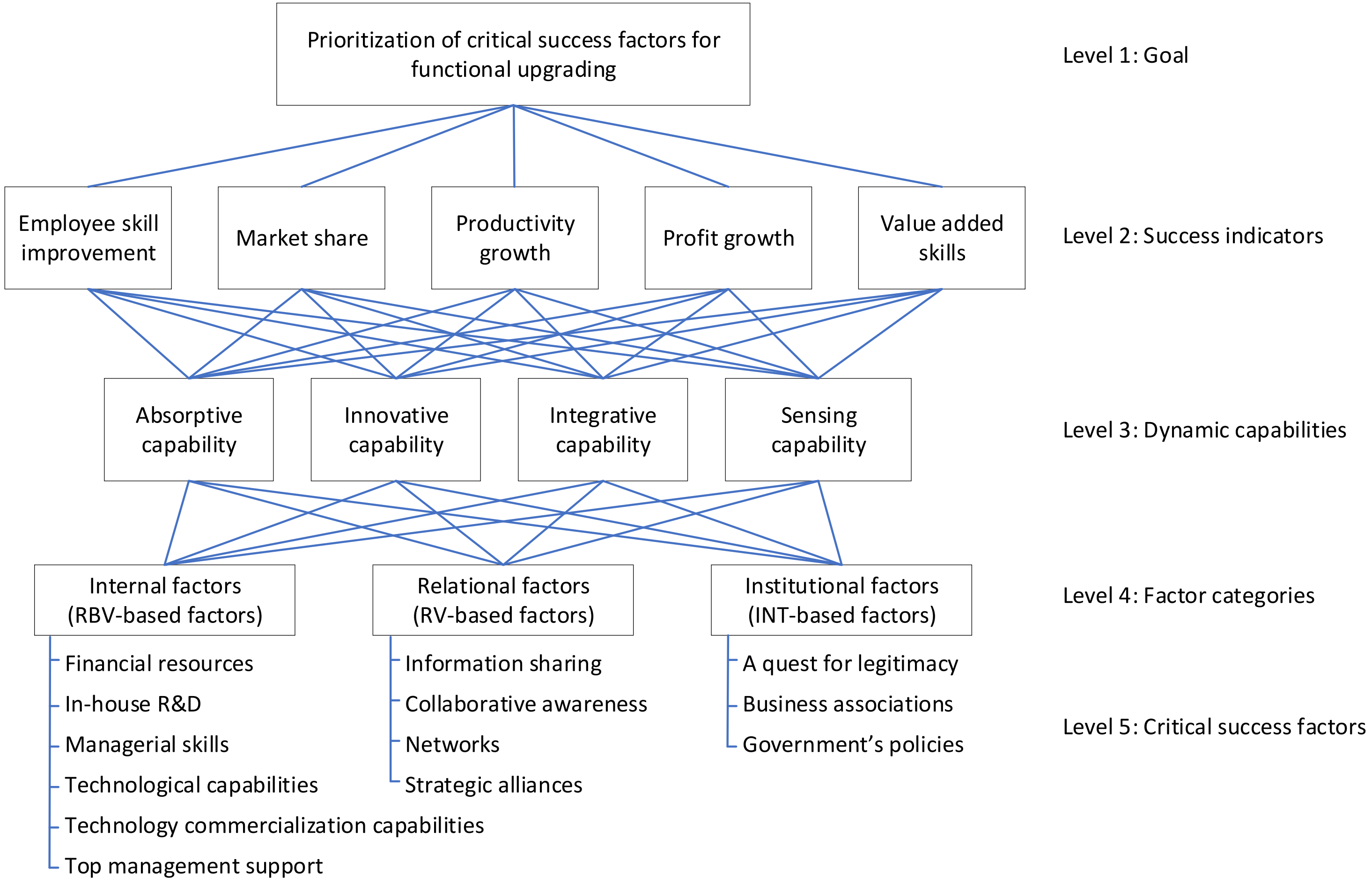

Figure 5-1 A hierarchical model for prioritization of critical success factors for functional upgrading in electronics industry from Thai experts' perspective

2. Establishing a fuzzy judgment matrix (or a pair-wise comparison matrix): 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 is more important and how much more important it is 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 3-1.
3. Combining the opinions from several experts by using geometric mean: the perception of each expert varied according to individual experience and knowledge.
4. Repeating the calculation of the local priority weights for all levels in hierarchy.
5. Calculating the global priority weight of each element: the global priority weight of each element was calculated by multiplying its local weight with its corresponding weight along the hierarchy.

Accordingly, the fuzzy AHP model was developed to determine the weights of thirteen success factors in three categories for functional upgrading process. Table 5-1 shows the local and global weight scores of the elements as well as their priority rankings. The final priority results are ranked based on their own global weights.

Table 5-1

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	0.250	1	0.114	1

Performance indicators (criteria)	Global weights	Ranking	Dynamics capabilities	Global weights	Ranking	Critical success factors	Local weights	Local Ranking	Global weights	Global Ranking
						capabilities				
						(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

Performance indicators (criteria)	Global weights	Ranking	Dynamics capabilities	Global weights	Ranking	Critical success factors	Local weights	Local Ranking	Global weights	Global Ranking
						(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

Note. Parentheses () denote the global weight of each category of critical success factors

According to this result (Table 5-1), the most significant (highest-global weight) performance indicator is ‘profits growth’ for functional upgrading, followed by ‘market share’, whereas the least significant indicator 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.

5.2 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, 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 5-2.

Table 5-2

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

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**
(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} criteria are switched, while the rest of the criteria weights remained the same.

Based on the results in Table 5-2, 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:

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

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 5-3.

Table 5-3

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*

Comparison	Spearman's rank correlation coefficient (r_s)
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)*

According to this result in Table 5-3, 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.

Concluding Remark

This chapter presented an application of the fuzzy AHP model to prioritize the critical success factors and criteria for functional upgrading, and also presented the hierarchical model for prioritizing the factors (as in Figure 5-1), which is linked to the RBV of the firm, the relational view, and the institutional theory based on the fuzzy AHP approach. The local and global weight scores of the elements as well as their priority rankings were explored (as in Table 5-1). Besides, sensitivity analysis was carried out by exchanging the weights of two performance indicators (or criteria) among themselves, and the ranking gained from each of ten scenarios were then validated comparatively using the Spearman's rank correlation coefficient.

CHAPTER 6

DISCUSSIONS, IMPLICATIONS, CONCLUSIONS, LIMITATIONS AND FUTURE RESEARCH

This chapter, the discussions, conclusions, and formulated implications of the research from the studies of identifying and prioritizing critical success factors respectively is summarized followed by the implications for practitioners, and concludes with reliability of the research results. This chapter also contains the recommendations of the research, followed by the limitations of the studies of identifying and prioritizing critical success factors respectively, and concludes with possible directions for future research in the field.

6.1 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 5-1. 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.

6.2 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 5-1, 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 regional supply 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.

6.3 Conclusions

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.

6.4 Limitations of the Research

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.

6.5 Future Research Direction

There are two directions in which this research might be extended. First, replicating this research with a larger sample size including a variety of stakeholder types will be recommended. Second, as mentioned above, different industries/countries might have a different viewpoint about the rankings of critical success factors for functional upgrading. Therefore, a comparative study on rankings of critical success factors for functional upgrading between different industries will be needed to further explore their differences.

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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 $u_{pi} \leq l_{oi}$) 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, $g_i \leq d_i$, 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:

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

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:

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

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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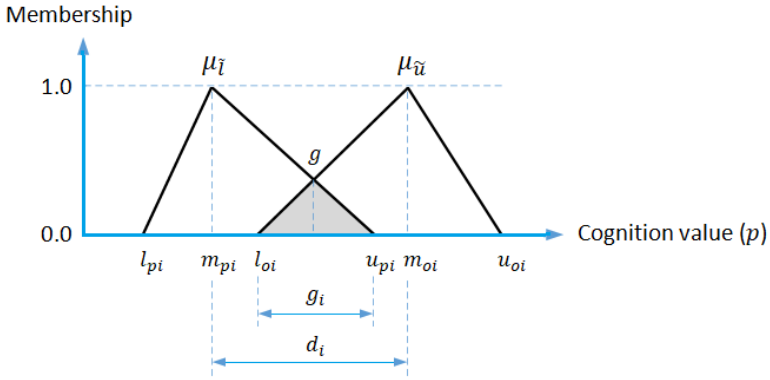

Figure 1. Gray Zone of p_i and o_i

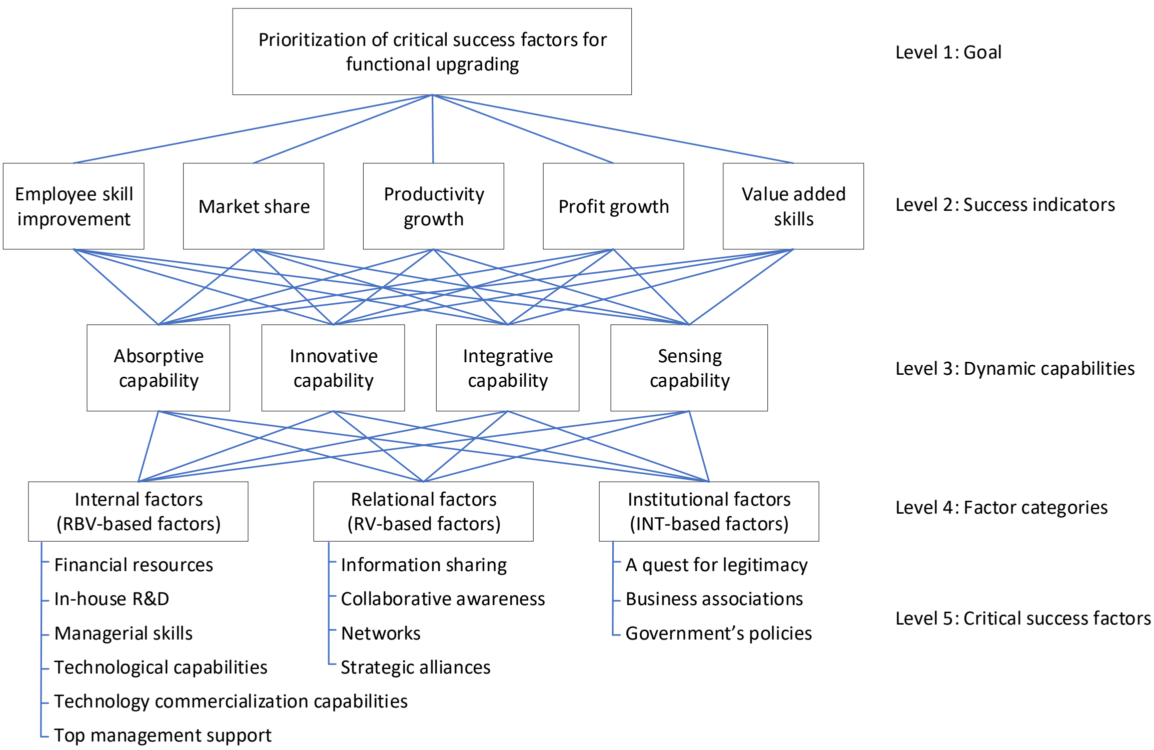

Figure 2. A Hierarchical Model for Prioritization of Critical Success Factors for Functional Upgrading

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)

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 $u_{pi} \leq l_{oi}$) 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, $g_i \leq d_i$, 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 $\tilde{A}$ 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:

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

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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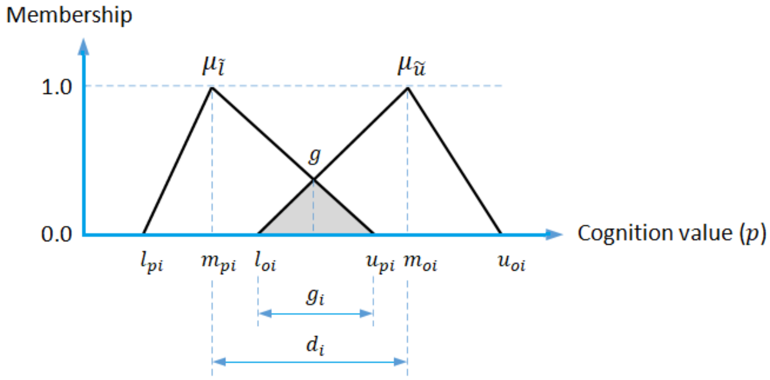

Figure 1. Gray Zone of p_i and o_i

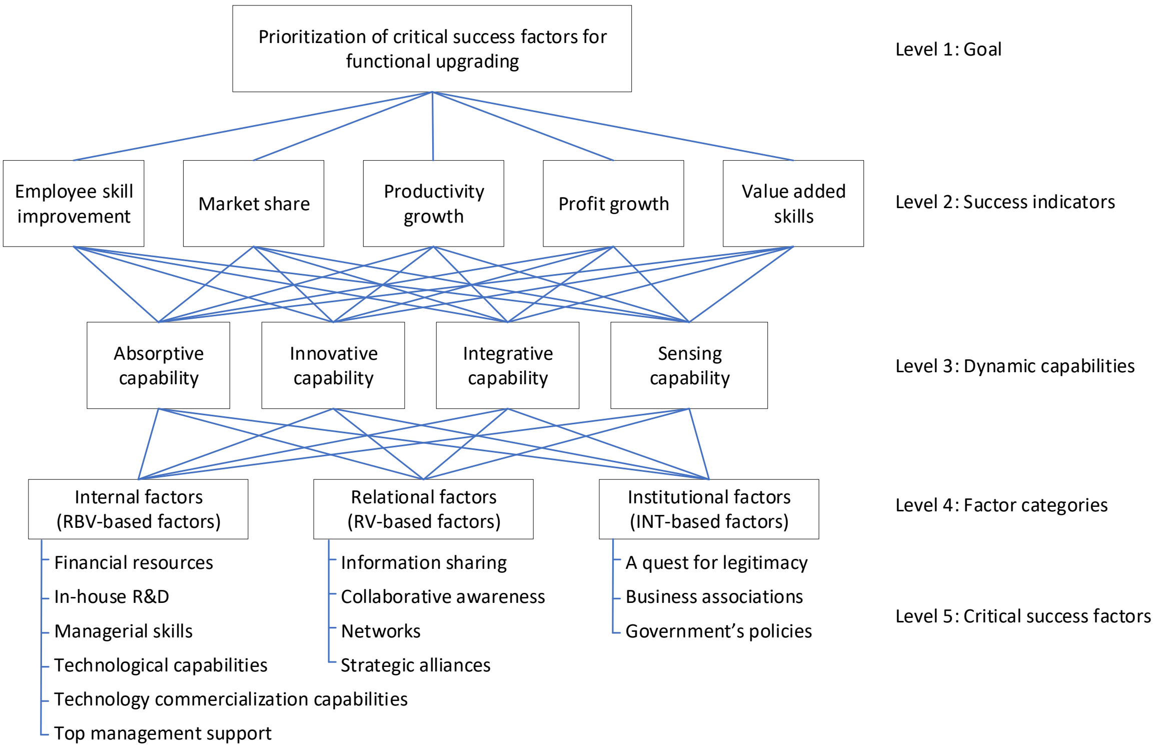

Figure 2. A Hierarchical Model for Prioritization of Critical Success Factors for Functional Upgrading

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)