# THE DEVELOPMENT OF SUPPLY CHAIN PERFORMANCE INDEX BY STRUCTURAL EQUATION MODEL APPROACH: A CASE OF THAI AUTOMOTIVE INDUSTRY

**BY**

**NITIPON TANSAKUL**

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DISSERTATION

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# ABSTRACT

The supply chain is influenced by various factors in an ecosystem. The dynamic environment of the global supply chain differently influences the firm's performance. The situation and influential factors of each supply chain are different due to the variety of industries, countries, organizational cultures, and other directly and indirectly related factors. Since the performance of suppliers critically influences the overall supply chain performance (SCP), the identification and evaluation of SCP through the standard index is an important approach to improving SCP. Therefore, it is imperative to develop a SCP measurement index in a specific context and environment. In addition, the index for SCP should be adjustable to be compatible with a specific ecosystem (industry, country, culture, etc.). The purpose of this research is to construct an adaptable SCP measurement model based on the perception of stakeholders who directly take participate in a supply chain. In order to validate the research method, the most complex and huge supply chain of the automotive industry is carefully chosen as an illustration of the index development. Furthermore, the automotive sector is one of the most popular industries in the world due to the transformation of key components from the internal combustion engine to the electric system and business platform. Moreover,

Thailand is known as a stronghold for global automotive and parts producers. Hence, a case of Thai automotive industry can be a representative of the index development for SCP. This research conducted an empirical survey of 210 companies from 1st tier, 2nd tier, and other suppliers of automotive companies in Thailand to test the proposed model. The field survey, interview, and mail survey were employed from the perceptive of stakeholders in supply chains. Then, the structural equation model (SEM) was employed to test relationships among influential factors in a supply chain. In consequence, an index is constructed by employing influential weights obtained from SEM. The result of SEM indicates both direct and indirect relationships among critical factors for improving SCP. It is expected to provide a crucial benefit for SCM development under the era of the disruptive technology.

**Keywords**: Supply chain performance index, Supply chain flexibility, Supply chain integration, Ecosystem, Automotive industry, Structural equation modeling

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# LIST OF SYMBOLS/ABBREVIATIONS

| Symbols/Abbreviations | Terms |
|---|---|
| AEC | ASEAN economic community |
| ASEAN | Association of Southeast Asian Nations |
| CBU | Completely built up |
| CFA | Confirmatory factor analysis |
| CFI | Comparative fit index |
| CI | Customer integration |
| CLMV | Cambodia, Laos, Myanmar, and Vietnam |
| CP | Cost (performance) |
| CKD | Completely knocked down |
| DI | Direct relationship |
| DF | Degrees of freedom |
| EU | European Union |
| EV | Electric vehicle |
| FDI | Foreign direct investment |
| GDP | Gross domestic product |
| H | Hypothesis |
| ICE | Internal combustion engine |
| IFI | Bollen's Incremental Fit Index |
| II | Internal integration |
| IR | Indirect relationship |
| IT | Information technology |
| JAMA | Japan Automobile Manufacturers Association |
| LF | Logistics flexibility |
| MI | Modification index |
| NAFTA | North American Free Trade Agreement |

| | |
|---|---|
| OEM | Original equipment manufacturer |
| OF | Organization flexibility |
| OICA | Organisation Internationale des Constructeurs d'Automobiles |
| PF | Production flexibility |
| RMSEA | Root mean square error of approximation |
| SCI | Supply chain integration |
| SCF | Supply chain flexibility |
| SCM | Supply chain management |
| SCP | Supply chain performance |
| SEM | Structural equation modeling |
| SF | Sourcing Flexibility |
| SI | Supplier Integration |
| SRMP | Standardize rood mean square residual |
| TAI | Thailand Automotive Institution |
| TAIA | Thailand Automotive Industry Association |
| TAPMA | Thai Auto-parts Manufacturers Association |
| TLI | Tucker-Lewis index |
| TP | Time (performance) |

# CHAPTER 1
# INTRODUCTION

Supply chain performance (SCP) defined as the ability of a supply chain to react to any changes, with dynamic collaboration among members (Lai & Cheng, 2003). The outcome of an SCP increment is responsiveness, quality improvement, and cost reduction (Zelbst, Green, & Sower, 2009). Therefore, the influential factors in SCP have been studied (Awais, Tipu, & Fantazy, 2014; A Gunasekaran, C Patel, & Ronald E McGaughey, 2004; C. W. Lee, Kwon, & Severance, 2007). However, there are limited numbers of studies that focus on the construction of the performance measurement index for measuring the level of firm's performance in a supply chain. The traditional analytical tools are unable to respond to managerial issues that involve real-world dynamic supply chain problems (H. Min & Zhou, 2002). Moreover, the new generation of supply chain models should focus on relationships and interactions among partners (H. Min & Zhou, 2002). This research overcomes this gap by developing a customizable index that measures SCP based on empirical data with the structural equation model (SEM) and comprehensive factors from the literature review. The constructed SCP index can be applied as an indicator to identify the performance level of supply chain members, and it can be employed as a benchmark for comparing and improving SCP.

The adoption of the SCP index requires an empirical measurement to indicate the SCP in a dynamic environment. This paper develops an index to measure the performance of a firm in a supply chain. The factors for evaluating the SCP cover supply chain flexibility (SCF) and supply chain integration (SCI) which are two main dimensions of supply chain management (SCM) (Arnold, Benford, Canada, & Sutton, 2015; Beamon, 1999; Duclos, Vokurka, & Lummus, 2003; Huo, Ye, Zhao, & Shou, 2016; S. Kumar, Garg, & Makkar, 2012; Laosirihongthong, Tan, & Adebanjo, 2011; Merschmann & Thonemann, 2011; Moon, Ying, & Ngai, 2012; Nagarajan, Savitskie, Ranganathan, Sen, & Alexandrov, 2013; Stevenson & Spring, 2007; Antonio Márcio T Thoméa, Luiz Felipe Scavarda, Sílvio R I Pires, Paula Ceryno, & Katja Klingebiel, 2014; Wong, Lai, & Bernroider, 2015). Respondents (210) in the Thai automotive supply chain were asked to develop the SCP index. The results from the empirical study provided the influence level of the individual factors in the SCI and SCF on the SCP index. Furthermore, the influential weights from structural equation modeling (SEM) are applied to construct an SCP index, to measure the performance level of automotive firms.

### 1.1 Introduction to supply chain management

Supply chain management (SCM) has been concerning as an important topic to increase the productivity and profitability of an organization (Beamon, 1999; A. Gunasekaran, C. Patel, & Ronald E. McGaughey, 2004). The SCM is considered to be a system of three or more entities that pass materials, products, services, finances, information between upstream and downstream, and deliver to their end customers (Mentzer et al., 2001). It is complex systems within dynamic environments (Defee, Stank, & Esper, 2010). In the globalization era, business entities are mainly concerned with performance improvement rather than focusing on the isolated organization (Zailani & Rajagopal, 2005). Therefore, SCM directly influences the ability of a business and competitive advantage (Craighead, Hult, & Ketchen, 2009; Khattab, Abu-rumman, & Massad, 2015).

SCM facilitates the efficiency and effectiveness of whole processes, from sourcing to the end-consumers. It is the flow of goods, services, finance, and information (Vijayasarathy, 2010). Efficiency (cost reduction) and efficient (customer service) are concerned as an important output for supply chain improvement (Mentzer et al., 2001). It helps to increase quality, and reduce overall costs by managing issues in a supply chain system, including warehousing, stock and inventory management, purchasing, transportation, manufacturing, supplier management, and negotiations (Dawson, 2002).

The main goal of SCM is to create seamless coordination across members in a chain (Zailani & Rajagopal, 2005). A higher level of SCM results in higher levels of supply chain performance (SCP) (Sukati, Hamid, Baharun, & Yusoff, 2012). SCP is the capability of a supply chain to handle with any uncertain situation, with the dynamic collaboration of the members. Likewise, it is directly related to any activities within a supply chain, including manufacturing, logistics, materials handling, distributing, and transporting functions (Ibrahim & Hamid, 2014). The higher performance in an effective supply chain can be measured by many factors, including customer and supplier relationships, redundant process reduction, an increase of information flow and material, (Zailani & Rajagopal, 2005), and flexibility (Antonio Márcio T Thoméa et al., 2014).

Since a supply chain is a network that aim to delivers materials, products, services, finances, and information among upstream and downstream members within a system, with delivery to the end customer (Mentzer et al., 2001), the partnership is considered as the essence of SCM (Gallear, Ghobadian, & Chen, 2012; Hea, Ghobadian, & Gallear, 2013). Before the establishment of a supply chain partnership, each firm is individually operated, and suppliers

act as providers. The critical phases of supply chain partnership can be separated into three main phases.

### 1.1.1 Pre-partnership

In the initial phase, a firm mainly focuses on internal operation; suppliers are seen as raw material sellers. The relationship between supply chain members in this phase is shown in Figure 1.1. They are aiming at individual profit rather than sharing higher profits. In the literature, the internal operational processes are always defined as a part of supply chain performance. Internal integration, collaboration, communication, information sharing, and flexibility are mentioned as the influential factors in SCM (Beheshti, Oghazi, Mostaghel, & Hultman, 2014; Chang, Lin, Chang, & Chen, 2007; Huo, 2012b). Therefore, the individual operation of a firm in the supply chain is imperative to construct a competitive advantage and it is referred to as antecedent factors of SCP. When the firm achieves higher business performance, it is likely to concern more on buyer-customer relationships to create better responsiveness within supply chain members (Robert B. Handfield & Bechtel, 2002).


**Figure 1.1** Relationship of pre-partnership phase

### 1.1.2 Partnership

The partnership is a stage that members of the supply chain are working together to achieve higher responsiveness and customer satisfaction (Gallear et al., 2012; Zailani & Rajagopal, 2005) (Figure 1.2). The members are working together, sharing information, risk, and strategies. A closer relationship with supply chain members is essential for creating higher SCP and competitive advantage (Panayides & Venus Lun, 2009). Thus, the critical factors for creating performance are dramatically different from the pre-partnership phase. According to Ryu, So, and Koo (2009), Abdullah & Musa (2014), components of the partnership are a commitment, trust, and collaboration among supply chain members. The firm is mostly concerned more about suppliers to achieve higher SCP. However, the firm with a higher internal integration level mostly employs integrative methods to handle relationships with members of the supply chain (Willis, Genchev, & Chen, 2016).


**Figure 1.2** Relationship of partnership phase

### 1.1.3 Post-partnership (Fully integrated)

In this phase, buyer-supplier relationships are shifting from transaction-oriented to relationship-oriented (Ku, Wu, & Chen, 2016). The customers become an important part of SCM. They can co-create value by providing information about the requirements, operations, and environmental contexts to the firms (M. Zhang, Zhao, Voss, & Zhu, 2016) as shown in Figure 1.3. When firms become a partnership, they need to maintain and create long-term benefits for the suppliers (Ku et al., 2016). According to Usha Ramanathan and Angappa Gunasekaran (2014), the success of collaboration among partners influences on future collaboration and long-term partnership. In this phase, trust and commitment are created through engagement in strategic alliances (Ryu et al., 2009). Moreover, knowledge and integration among suppliers, firms, and customers are needed for constructing SCF (Ku et al., 2016; M. Zhang et al., 2016) and SCP.

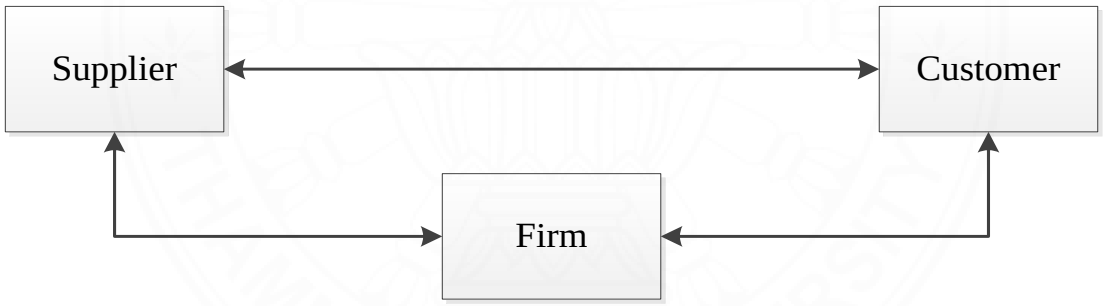


**Figure 1.3** Relationship of post-partnership phase

The need for performance measurement is an essence of a SCP improvement (S. D. Singh & Bhandari, 2015). Though vast studies have been studied on the suppliers selection (Galankashi, Helmi, & Hashemzahi, 2016; Punniyamoorty, Mathiyalagan, & Lakshmi, 2012) and the influential factors in supply chain performance (SCP) (Awais et al., 2014; A Gunasekaran et al., 2004; C. W. Lee et al., 2007), there are limited studies that focus on a construction of SCP index for measuring performance of supply chain members. The constructed SCP index can be applied as an indicator for measuring firm's performance and it can be employed as a benchmark for comparing and improving SCP.

A supply chain is a large system that is influenced by many factors. Thus, its performance is driven by various factors.

The first is a pre-partnership phase; in which a critical factor is created by a willingness of the firm to create a higher performance to serve the customer and assist in business management without any contribution from inter-organization. The critical factors in this phase are internal integration and flexibility with supporting factors of technology and innovation.

The second phase occurs when the firm interacts with inter-organization and creates a buyer-customer relationship to achieve higher performance through the supply chain. This phase called partnership phase; it is a beginning phase of the partnership. The firms start working together to achieve a higher profitability. However, the focus of the firm in this phase is a benefit for itself.

The third phase is a post-partnership phase, in which a group of firms is working together for a period of time for sharing the profit and risk together. The firms are most likely sharing the same objectives and helping each other to achieve the same goal. The knowledge and information freely flow among the partnership and strategies are developed together. The keys factors in this phase are trust and integration among the partnership to create supply chain flexibility. Trust occurs only when supply chain members are confident and willing to share the information among each other (Panayides & Venus Lun, 2009; Yeung et al., 2009). Technology is concerned with an infrastructure to support the overall supply chain processes. In this phase, the firms maintain and tighten a good relationship among partners in order to achieve flexibility, responsiveness, and reliability of a supply chain.

## 1.2 Problem statement

The supply chain is a complex system of a firm that collaboratively working together and provide value to the customers. It consists of countless materials and tons of information flow among a group of buyers and sellers. Therefore, it is influenced by various factors and dynamic environment. Supply chain itself also dynamic and difficult to measure due to the fluctuation of factors to response with the ecosystem. The relationships of a set of influential factors that drive a SCP are differently appear in each situation and supply chain system. Performance indexes were employed to measure the capability of a specific system and to identify the strength and weakness of a system. However, there are no more one size fit all for the measurement index in a supply chain. To measure the performance of a specific supply chain, a standard or general measurement is unable to distract the core value of indicating the

true SCP. The weight and influential factors that impact on SCP should be measured by the supply chain member and stakeholder. Since the different influential factors and dynamic environment. It is imperative to develop an index based on the stakeholder in a supply chain. The relationships of the influential factors of a supply chain are also needed to be identify as an initial concept of the index development. Hence, the index needed to be customizable to serve the multi-dimension and different aspects of a supply chain.

Automotive industry is a major industry driving economy of the nation and contributing to the global economy. Since the the global automotive industry is a complex network, it is viewed as the industry of industries (Bhattacharya, Mukhopadhyay, & Giri, 2014; Wad, 2009). The automotive supply chain becomes more and more complex due to globalization. Auto industry has a significant influence on many industries because a car requires more than ten thousand components from many manufacturing industries such as plastic, steel, and gasoline that lead to a high complexity in a supply chain system (Liu, Srai, & Evans, 2016). SCM is a key theory to manage the flow of material, product, finances, information, and services (Mentzer et al., 2001). The study of Chandak, Chandak, and Sharma (2014) has present many challenges among a supply chain of the automotive industry including long lead times, unpredictable production schedules, unnecessary inventory, and suppliers' visibility. Moreover, the global automotive industry is shifting from the Internal Combustion Engine (ICE) to Electric Vehicle (EV). According to the advanced transportation consortium in California, the component of EV and ICE are around 70 percent different. Therefore, component parts for producing a car are changing and it leads to changes in a supply chain. The supply chain members need to adjust themselves to react on the change environment and maintain competitiveness as a hub of automotive supply chain.

Besides the change of automotive components, a competitive supply chain is needed to maintain the SCP to serve the global automotive supply chain. Hence, complexity of the automotive supply chain is a perfect example of a complex and dynamic supply chain. This research aims to develop an SCP index of automotive-based in the empirical model. Synthesis of literature reviews SCP was reviewed to identify key components for developing a questionnaire. The empirical survey is conducted among domestic tier 1, tier 2, and other tier suppliers of an automobile company. The result expected to revile the development of an adjustable SCP index that can be adjusted to complete with the different characteristics and ecosystem.

## 1.3 Research objectives

The purpose of the research is to develop an index for measuring SCP. Since SCP is influenced by various factors and resources, the influential factors needed to be identify as the indicators of SCP. Then the influential weights, and relationships are measured to reflect the perception of supply chain members. This dissertation aims to emphasis the processes of an SCP index development with the benefits from the adjustable factors, weights, and relationships to reflect stakeholder perception. The SEM approach is apply as a tool to measure the weights, and relationships of influential factors of SCP.

The major research objective is to develop an adjustable index that can measure SCP in different characteristics and dynamic environments. To achieve the main goal of the research, subsidiary objectives are

- To identify the influential factors on SCP.
- To measure the weights and relationships of those influential factors on SCP by using SEM technique.
- To develop an index based on weights and relationships of the influential factor.

First, the related literature are reviewed to founded the fundamental concept of the supply chain and to identify the influential factor of SCP. The literature review influential factors in SCM are conducted to construct a research framework and questionnaire. The survey-based on the literature studies developed and completed by automobile companies and component producers in Thailand in the form of mail surveys and online surveys, field, and in-depth interviews. The survey is distributed among domestic 1st tier, 2nd tier, and other tier suppliers of an automobile company to measure the influential level of the individual factor SCP based on perception from supply chain members.

The results from the empirical surveys are employed as fundamental of the conceptual model. Then, to identify influential weights and relationships among selected factors in the automotive supply chain, the structural equation modeling (SEM) is employed as a key tool for analyze the data. Then the conceptual model from SEM is applied for developing a SCP index to measure the level of SCP for automotive firms. Therefore, the index is technically developed by the respondents in a supply chain. The result is expected to identify and real situation of a supply chain rather than general and theoretical index.

These results expected to explore the relationship among the automotive supply chain based on the literature review. The employment of empirical study on the members of Thai's automobile industry will point out the relationship and influence rate. The result will represent

two major different aspects of the automotive industry. Firstly, previous supply chain researches will be considered to conclude the factors influencing on the SCP of the automobile industry. Secondly, the conceptual model of the SCP of the automotive industry will be suggested. Thirdly, the development of an index for SCP. The results are expected to support the development of the supply chain in ensuring and improve their performance and it is possible for government agencies and private sectors to develop policies or strategies to overcome weakness and take a competitive advantage in automotive industry.

# CHAPTER 2
# REVIEW OF LITERATURE

SCP is influenced by many factors and considered by different research areas. In develop the SCP index, the components of SCP needed to be review for conducting a primary method to define the SCP. However, supply chain terminologies mentioned in supply chain research are overlapped due to different purposes and areas of study .This leads to unclear definitions and overlapped meanings in supply chain research. Chapter 2 aims to achieve two issues, the first issue is to understand the situation of Thai's automotive industry. The knowledge of an industry is considered as an important fundamental of the idea and conceptual development. Then the second issue is to identify the influential factors that contribute to SCP development by a substantial literature review of supply chain terminologies in SCM. Then framework for constructing a SCP index is purposed to support the growth of a supply chain.

Since the evaluation of SCP which involves various criteria is a complicated decision-making problem in SCM (Shafiee et al., 2014), a number of techniques and approaches have been developed to evaluate SCP (Shafiee et al., 2014). The well-known models that frequently serve this purpose are the balanced scorecard (Kaplan & Norton, 1992), and the Supply Chain Operations Reference (SCOR) model by the Supply Chain Council (Stewart, 1995). The SCOR model has an advantage in operational processes and performance evaluation. However, interfaces between trading partners are excluded in the SCOR model so the adoption and application are limited (Zhang et al., 2015). The supply chain model has been unable to respond to a dynamic environment in a real-world situation, to support decision making and performance improvement in SCM (Min & Zhou, 2002; Chan & Qi, 2003).

Currently, manufacturers are facing higher competition in the real world situation. The pressure from customer expectations, competitive markets, globalization, and technology development shape a supply chain (Chan & Qi, 2003). Likewise, SCP is directly related to any activities within organizations including manufacturing, logistics, materials handling, distributing, and transporting functions (Ibrahim & Hamid, 2014). Therefore, different companies emphasis different aspects and elements of SCM. According to the literature, SCM is two or more members in a supply chain working together to provide value in term of both product or service to the end customers. The key concept of SCM focuses on the flow of tangible and intangible including finance, goods, and information to respond to the customer demand (Ibrahim & Hamid, 2014, Sánchez & Pérez, 2005; Merschmann & Thonemann, 2011; Nagarajan et al., 2013). SCP depends on the ability of a group of firms to respond to the

demand. A supply chain has an ultimate goal to ensure profitability by increasing its performance and customer responsiveness (Chan & Qi, 2003). Therefore, SCF and SCI are important factors to measure SCP (Huo et al., 2016; Wong et al., 2015; Duclos et al., 2003; Kumar et al., 2012; Thoméa et al., 2014b; Arnold et al., 2015; Moon et al., 2012; Merschmann & Thonemann, 2011; Beamon, 1999; Stevenson & Spring, 2007; Nagarajan et al., 2013; Laosirihongthong et al., 2011). Integration of the supply chain is an important source of SCF and leads to better responses for customers (Duclos et al., 2003; Gunasekaran et al., 2004; Boon-itt & Paul, 2006; Kohli & Jensen, 2010; Lii & Kuo, 2016; Mentzer et al., 2001; Awais et al., 2014).

## 2.1 Overview of Thai's automotive industry

The automotive industry is a major industry driving economy of the nation and contributing to the global economy and it is viewed as the industry of industries (Bhattacharya et al., 2014). This industry has a significant influence on many industries because a car requires more than ten thousand components from many manufacturing industries such as plastic, steel, gasoline, and etc. that lead to a high level of complexity (Liu et al., 2016). Thus, SCM is very significant for this industry and it can be a partial improvement of this overall economic performance of the nation. According to (Pérez & Sánchez, 2001), the development of supply chain networks and clusters of suppliers in automotive industry is continuously active due to the dynamic environment. In the automotive supply chain, reduce cost is a main goal. Therefore, automotive manufacturers try to reduce the cost of inventories and frequent deliveries by transfer those costs to the suppliers. Therefore, many suppliers have established factories near the assembly plants of the automotive makers to minimize the cost as well. The supply chain management of this industry significantly influences on every process. Therefore, automotive supply chain members are mostly located in the central and eastern parts of Thailand (Figure 1.4).

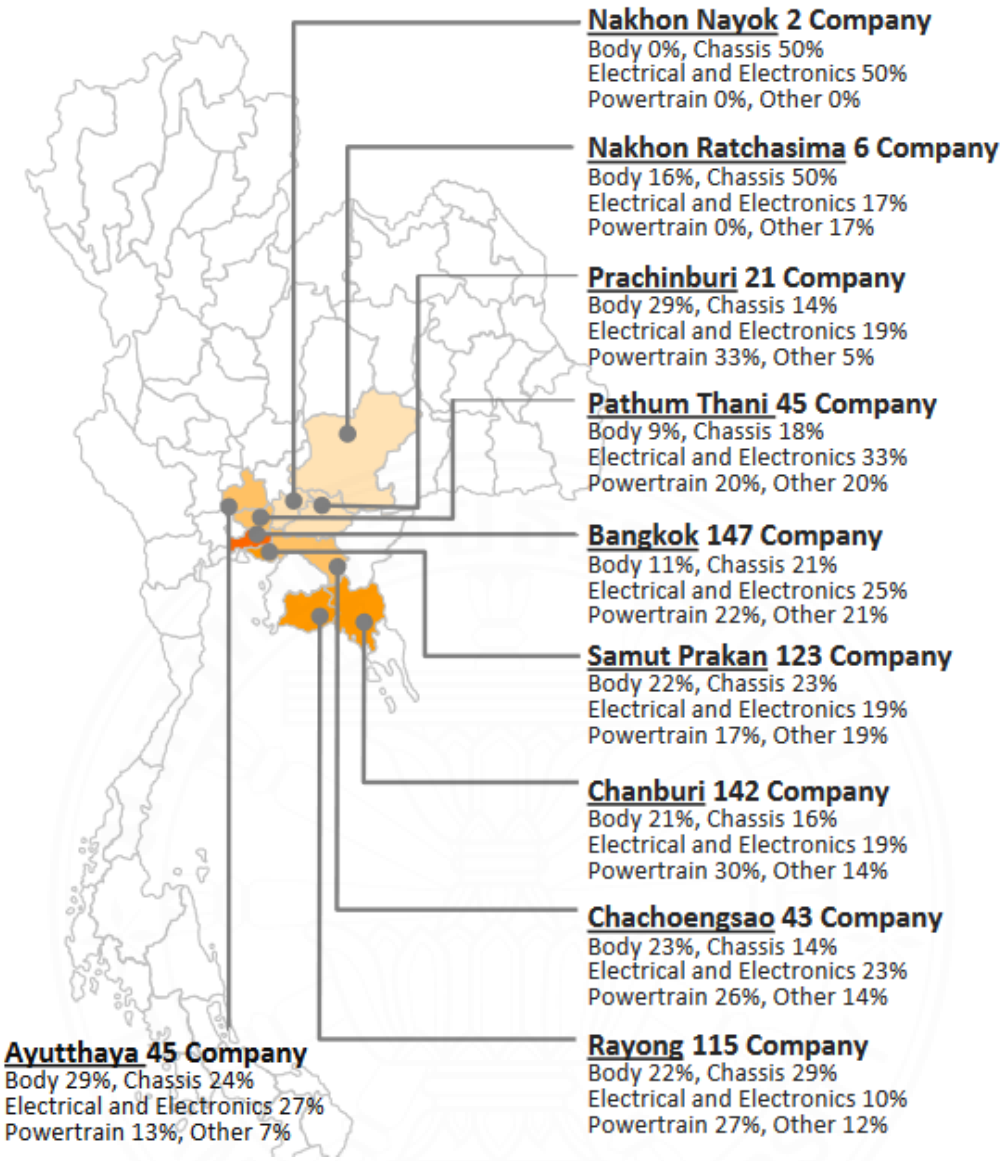


**Figure 2.1** Map of auto parts companies in Thailand

Source: Krungsri research, 2018 and Thai automotive institute, 2018

### 2.1.1 Value chain of Thai automotive

In Thailand, the automotive supply chain has been established over in 1960s. This industry is supported with import substitution policy by the government and it is becoming an export-oriented production base of automotive industry in Asia (Jeerapaet, 2012). Thailand has policies to support the automobile sector since the beginning of the 60s century, for imported automobile components from Europe and Japan for assembling in Thailand (Complete Knock Down). In the second phase, in the 70s century, the automotive industry in Thailand is growing continuously because of the government's policies that encourage domestic production and in-house components instead of imported. At the beginning of twenty century, the automotive

industry in Thailand has more than 1800 companies. In the past decade, the number of suppliers in Thailand has increased to approximately 2400 companies including first-tier auto parts 720 suppliers (Foreign majority 47 percent, Thai majority 30 percent, and wholly Thai 23 percent) and second-tier and third-tier about 1,100 suppliers (Krunsri, 2018) (BOI, 2014). First-tier is the firms that deliver finished goods direct to the automotive companies (Nopprach, 2006). Second-tier is the supplier of first-tier. The firms that supplied raw materials to the company above the supply chain are considered as third-tier (Automotive Team, 2005).

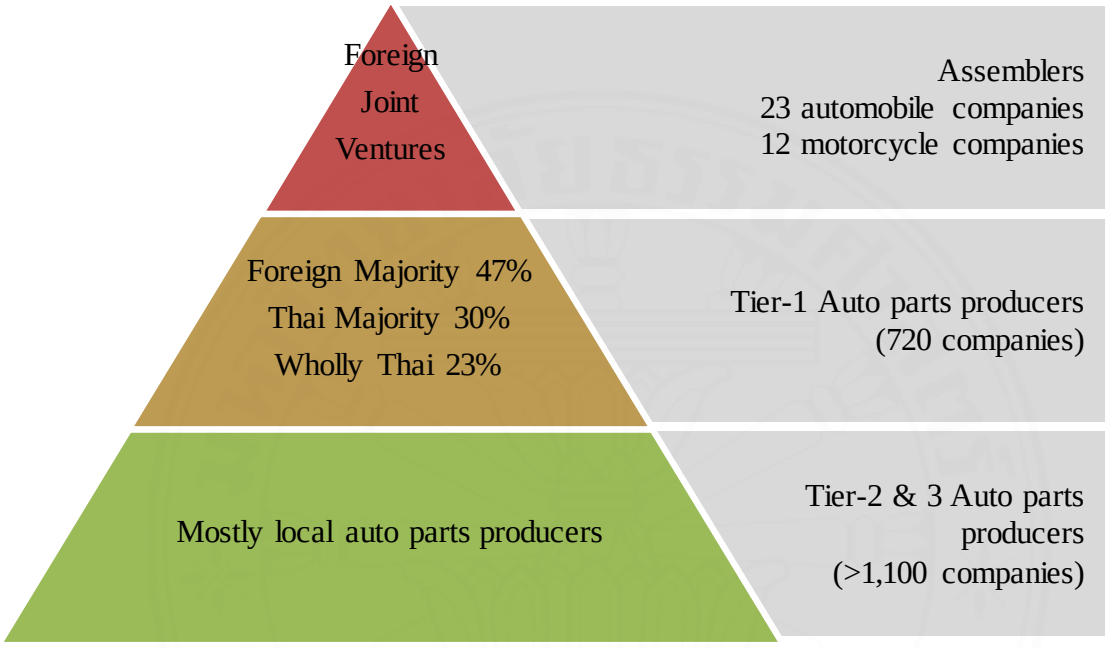


**Figure 2.2** Structure of Thai automotive industry

Source: Krungsri research, 2018 and Thai automotive institute, 2018

### 2.1.2 Value of Thai's automotive industry

The automotive industry considered as knowledge (Piyanaraporn, 2012) resource- and labor-intensive based industry (Eric D Ramstetter, 2015). Thai's automotive industry was started in early 1960s with well support from the government, it became an important production hub of Southeast Asia. Thailand became an export-oriented plant for automotive firms from both Europe and Japan (Jeerapaet, 2012; Patarapong Intarakumnerd & Charoenporn, 2015). Since the growth of global demand for automobile, Thai's automotive industry is continuously growth as a automotive hub, both local parts and components producers and Complete Knock Down (CKD) product are significantly progress in Thailand (Patarapong Intarakumnerd & Charoenporn, 2015). Besides, the government also encourages and supports domestic firms in terms of policies and trade facilitation. In 1990s with the trade liberalization era, Thailand is recognized as an automotive production base in ASEAN since

supply chains of automobile production, parts, and components are fully located in Thailand. Since more than a half of the finished products (car and components) are exported, automotive industry is an export base industry for Thailand and it can create bulky income for Thailand (Patarapong Intarakumnerd & Charoenporn, 2015).

Thailand has become Asian Detroit because of a major production base and supply chain network of automotive industry. Thus, it attracts foreign direct investment in the automotive industry in Thailand (Piyanaraporn, 2012). Besides the automobile companies, component parts producers or Tier 1 &2 part suppliers are interested in international and domestic companies. In addition, the parts and components of automobile is one of the important industry that can create value that contribute to growth in Thai economics (Napolpong Sorsomboon, 2015). However, trade liberalization among the global economy leads to the increment of competition in the automobile industry. Automotive producers may recognize the benefit from the establishment of production bases in Asia such as Malaysia, Indonesia, and Thailand. The establishment of a production base in Asia can create total trade value of 78,241.1 million dollars which is the top five trade value among ASEAN (as shown in table 1.1) and it can provide numerous jobs opportunities and generate a large amount of revenue for ASEAN countries (Piyanaraporn, 2012). According to Organisation Internationale des Constructeurs d'Automobiles (OICA) in 2015 automotive industry can create 182,300 employments in Thailand. The vehicles are the top-five of the total trade value in ASEAN. Nevertheless, automobile production also creates demand in many industries such as electronics, steel, plastic, etc. This industry can consider as an important industry in ASEAN. However, the situation can be changed due to the development of the business environment and economic development from the influences of AEC, the investor may reconsider other countries within the region.

Key automotive products in ASEAN can obviously consist of two main products. First is the Mid-size pickup (body on frame), this product has been very popular in Thailand and many ASEAN countries. Since the automotive trend is shifting to more environmentally friendly and fuel efficiency, another key product is a small car. This product is considered as a new segment of this market. Especially after 2010, the small cars were promoted by the government in many countries in order to encourage market demand, reduce the value of fuel imported and reduce overall emissions from the vehicle.

Major automotive companies are considering ASEAN as a major investment destination, due to the increasing of the potential market and beneficial in the manufacturing and assembling. It is expected that in 2020, Thailand, Indonesia, and Malaysia will have a major

contribute to automobile production in ASEAN (about 96 percent of ASEAN production capacity) (Autofact, 2015). Due to the AEC development, it is not focusing only on the improvement of intra-ASEAN trade, but it largely involved in ASEAN external trade partners and the enhancement of global production networks. The full implement of AEC2015 can predispose the automotive producers to invest in ASEAN countries due to the trade liberalization within the region. Many companies are evaluating the business opportunities and benefits of establishing a production base within ASEAN.

**Table 2.1** Value of import and export divided by Harmonized System (HS code) year 2015

| Commodity group | | Value | | |
|---|---|---|---|---|
| 2-digit HS code | Description | Exports | Imports | Total trade |
| 85 | Electrical machinery and equipment | 290,529.2 | 248,021.9 | 538,551.1 |
| 27 | Mineral fuels, mineral oils and products of their | 207,505.6 | 268,423.2 | 475,928.7 |
| 84 | Nuclear reactors, boilers, machinery and mechanical appliances | 139,847.6 | 154,010.2 | 293,857.8 |
| 39 | Plastics and articles thereof | 43,376.6 | 43,924.4 | 87,301.0 |
| 87 | Vehicles other than railway or tramway | 41,008.7 | 37,232.5 | 78,241.1 |
| 90 | Optical, photographic, cinematographic, | 34,121.1 | 27,911.6 | 62,032.6 |
| 29 | Organic chemicals | 33,411.0 | 27,139.1 | 60,550.1 |
| 71 | Natural or cultured pearls jewelry, coin | 28,027.9 | 25,654.2 | 53,682.1 |
| 72 | Iron and steel | 8,903.5 | 42,538.5 | 51,442.0 |
| 40 | Rubber and articles thereof | 32,975.7 | 11,559.1 | 44,534.7 |
| | **Top Ten Commodities** | **859,706.8** | **886,414.6** | **1,746,121.4** |
| Others | | 432,926.8 | 349,869.3 | 782,796.1 |
| **Total** | | **1,292,633.6** | **1,236,283.8** | **2,528,917.4** |

Source: ASEAN Trade Database (compiled from data submission and/or websites of ASEAN Member Countries' national statistical offices and other relevant government agencies)

Thailand is an industry-based economy, which export value from the industry section is around 6.4 trillion baht or around 80 percent of the total export value of Thailand. Moreover, the automobile industry is accounted for 927,501 million Baht in 2018 (http://www2.ops3.moc.go.th/) or 14 percent of total industry value in Thailand and it has grown annually.

**Table 2.2** Top ten of Thailand's export products in 2018

| No. | Lists | Value (million Baht) |
|---|---|---|
| 1 | Automotive and components | 927,501.3 |
| 2 | Computer and components | 633,150.2 |
| 3 | Jewelry and accessory | 383,976.7 |
| 4 | Rubber and latex products | 353,442.9 |
| 5 | Polymer | 330,156.1 |
| 6 | Refined oil | 298,921.3 |
| 7 | Chemical products | 294,215.4 |
| 8 | Electronic board | 267,101.0 |
| 9 | Machine and components | 262,831.5 |
| 10 | Steel products | 201,010.9 |

Thailand is an export-dependent country, where export value is accounting for more than two-thirds of gross domestic product (GDP) (CIB, 2013). Due to the geographic location and incentive in Thailand, many major producers in the automotive industry have been using Thailand as a production hub of ASEAN. According to automobile production statistics in 2017 (Table 2.3), Thailand is the twelfth automotive producer of the world with a total number of 1,988,823 units including both cars and commercial vehicles.

**Table 2.3** World's automobile production statistics in 2017

| Country | Cars | Commercial vehicles | Total | % change |
|---|---|---|---|---|
| **China** | 24,806,687 | 4,208,747 | 29,015,434 | 3.19% |
| **USA** | 3,033,216 | 8,156,769 | 11,189,985 | -8.13% |
| **Japan** | 8,347,836 | 1,345,910 | 9,693,746 | 5.31% |
| **Germany** | 5,645,581 | 0 | 5,645,581 | -1.76% |
| **India** | 3,952,550 | 830,346 | 4,782,896 | 5.83% |
| **South Korea** | 3,735,399 | 379,514 | 4,114,913 | -2.69% |
| **Mexico** | 1,900,029 | 2,168,386 | 4,068,415 | 13.00% |
| **Spain** | 2,291,492 | 556,843 | 2,848,335 | -1.30% |
| **Brazil** | 2,269,468 | 430,204 | 2,699,672 | 25.20% |
| **France** | 1,748,000 | 479,000 | 2,227,000 | 6.54% |
| **Canada** | 749,458 | 1,450,331 | 2,199,789 | -7.21% |
| **Thailand** | 818,440 | 1,170,383 | 1,988,823 | 2.28% |

Source: http://www.oica.net

The total value of automotive, parts, components, and accessories export is increasing annually. In 2014, the total export value from this industry is equal to 789,234.78 million baht. The highest proportion export destination is Australia (127,594.13 million baht), following by Indonesia, Saudi Arabia, Malaysia, and Philippine respectively. As the Asian Detroit, most of the export destinations are in Asia.

**Table 2.4** Motor cars, parts and accessories export value of Thailand

| No. | Export Destination | Export Value (Million Baht) | | | |
|---|---|---|---|---|---|
| | | 2011 | 2012 | 2013 | 2014 |
| 1 | AUSTRALIA | 77,797.14 | 115,203.80 | 133,642.39 | 127,594.12 |
| 2 | INDONESIA | 61,428.37 | 92,714.78 | 74,163.63 | 64,533.76 |
| 3 | SAUDI ARABIA | 25,742.18 | 38,654.04 | 45,978.41 | 51,796.56 |
| 4 | MALAYSIA | 33,639.29 | 48,795.67 | 46,172.14 | 51,062.92 |
| 5 | PHILIPPINES | 21,782.84 | 30,743.21 | 36,598.37 | 49,528.25 |
| 6 | JAPAN | 37,832.09 | 51,231.66 | 40,520.45 | 42,224.29 |
| 7 | U. ARAB EMIRATES | 12,958.30 | 20,641.46 | 24,155.63 | 25,148.98 |
| 8 | SOUTH AFRICA | 15,701.20 | 19,104.22 | 24,620.86 | 21,756.59 |
| 9 | U.S.A. | 9,381.17 | 10,848.90 | 13,238.41 | 20,216.30 |
| 10 | VIETNAM | 9,384.14 | 7,672.12 | 11,480.55 | 16,776.53 |
| 11 | NEW ZEALAND | 5,669.68 | 10,809.16 | 14,202.44 | 16,747.70 |
| 12 | LAOS | 7,795.03 | 12,613.32 | 14,377.40 | 15,476.46 |
| 13 | CHILE | 9,531.30 | 13,676.79 | 13,517.28 | 15,008.07 |
| 14 | OMAN | 9,523.98 | 16,115.47 | 15,917.03 | 14,860.76 |
| 15 | MEXICO | 4,388.47 | 10,391.00 | 9,843.61 | 13,195.10 |
| 16 | UNITED KINGDOM | 8,624.14 | 11,036.32 | 7,915.94 | 11,916.89 |
| 17 | BRAZIL | 9,464.49 | 14,461.21 | 13,015.44 | 11,222.65 |
| 18 | INDIA | 8,049.28 | 9,204.01 | 8,304.99 | 9,975.50 |
| 19 | RUSSIAN FEDERATION | 11,875.19 | 12,713.89 | 9,446.70 | 9,378.87 |
| 20 | EGYPT | 2,535.82 | 5,333.89 | 6,467.86 | 9,357.83 |
| Total 20 records | | **383,104.1** | **551,964.9** | **563,579.5** | **597,778.1** |
| Other | | 128,399.5 | 155,747.2 | 174,533.9 | 191,456.6 |
| Total | | 511,503.62 | 707,712.15 | 738,113.38 | 789,234.78 |

Source: Information and Communication Technology Center with Cooperation of Customs Department

Total production of automotive in Thailand is an upward trend, it is reached to its peak in 2012 and 2013 around 2.4 million units due to the "first car policy". Therefore, the extra car produced between 2012 and 2013 are sold in Thailand. According to this policy, the demand for new car dramatically drops after 2013 and rebounded in 2016.

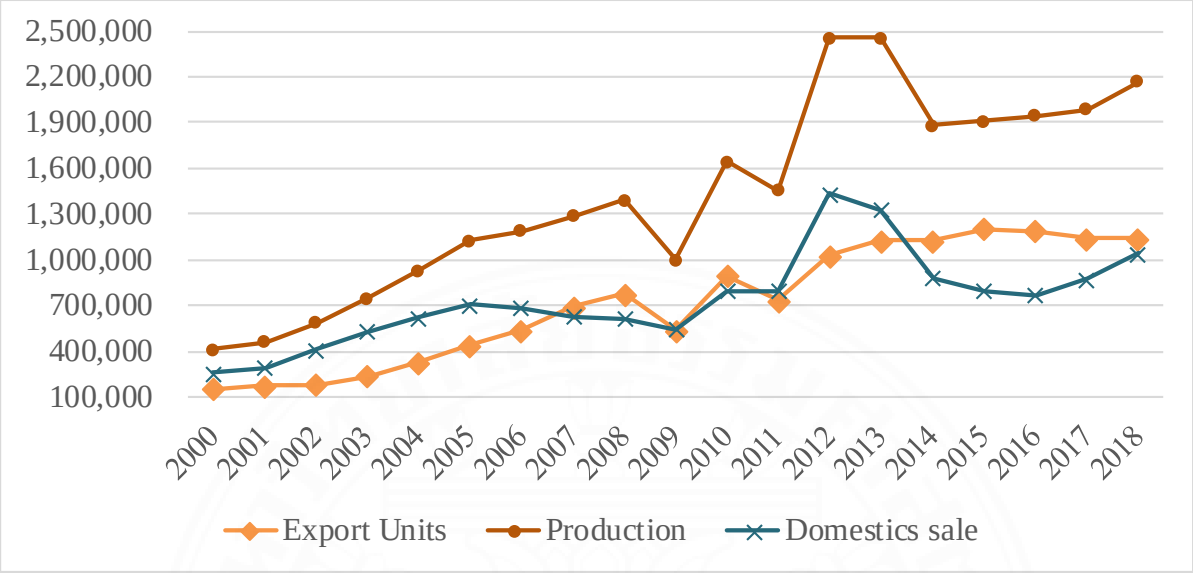


**Figure 2.3** Automotive production and sale units from 2000 to 2018

Source: https://www.fti.or.th

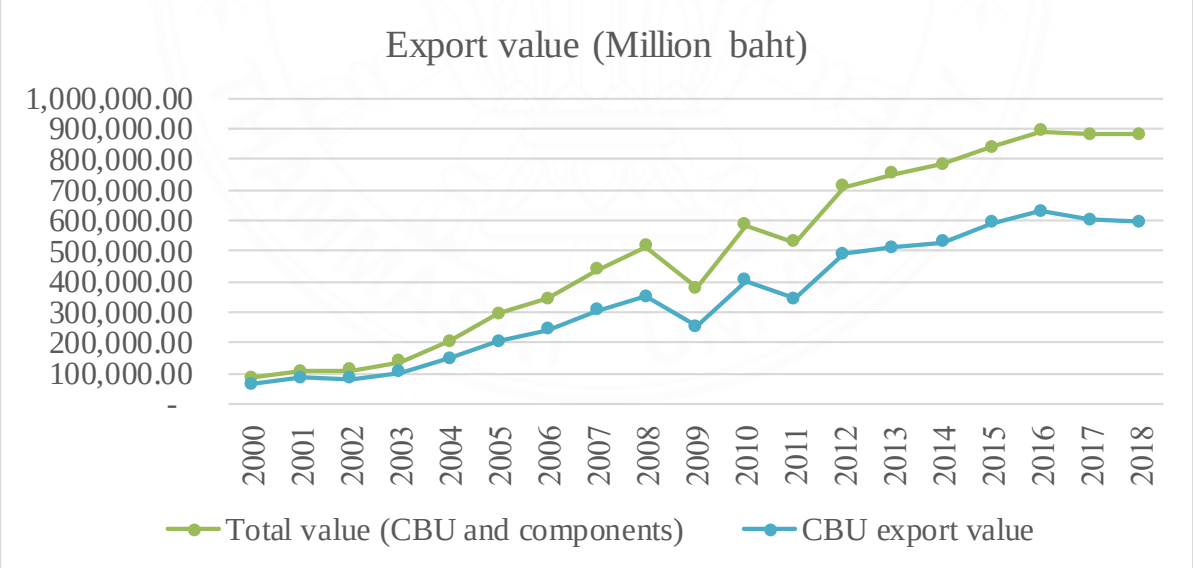


**Figure 2.4** Automotive export trend from 2000 to 2018

Figure 2.4 shows the export value of automotive industry in Thailand from the year 2000 to 2018. The export value is increasing from 83,044 million in 2010 to 822,083 million baht in 2018 or about 10 times grow rate for 18 years. The export value is increasing due to the

increase in economic development and investment support. The foreign companies were supported in terms of government policies. Then this sector had become an important area for the national economy in Thailand. Nevertheless, the export values are significantly dropped in the year 2009 and 2011 due to political issue and protestors and massive flooding in the year 2009 and 2011 respectively.

In the current stage, the automotive supply chain should not concern only on growth rate in term of sale and market but it is needed to be sustainable as well (Chandak et al., 2014). Since the environment and sustainable are major driven of the global market demand, an effective tool is needed for improve organization's competitiveness. A supply chain aims to be in a good global market position with an improvement of effective and efficient to earn profits in the dynamic environment. Therefore, the critical element of a supply chain is to develop themselves to be different from the competition (Sumit Chandak, 2014).

### 2.1.3 Characteristic Thai's automotive supply chain

Thailand has been pursuing the role of "Asian Detroit" with many automotive markers are establish production factories within Thailand. Nowadays, Thailand is the ASEAN production hub of two key products namely one-ton pickup truck and eco-car or small passenger cars with highly efficient. Moreover, Thailand also is a leader in a product, design, engineering, and production process development in Asia (Jeerapaet, 2012). The growth of global and Thai automotive market and service parts attracts enormous investment from foreign companies, especially Japanese firms which are joint development as the joint venture companies. Therefore, Thailand is an industry base country that has a strong potential to produce all necessary components for serving the demand from automobile producers including engine parts to the interior and body parts. According to the data from BOI in 2013, more than a half of the first-tier suppliers are the world auto parts producers. Moreover, 50 percent of the leading global parts makers have factories in Thailand (BOI, 2014) such as Delphi, Denso, Robert Bosch, TRW, and Visteon. Many Thai-Japanese joint ventures and few local companies also compete in this latter market. Parts manufactured include engines, suspension controls, and springs, axles, hubs, propeller shafts, brakes, clutches, steering systems, body parts, electronic parts, air conditioning systems, tires, wheels, internal and external trim components and glass (OIE, 2004). Major multinational automotive industry leaders with presence in Thailand include Toyota Motors, Isuzu Motors, Honda Automobile, Nissan Motors, Suzuki Motor, Mitsubishi Motors, Auto Alliance Thailand (Ford and Mazda),

Hino Motor, General Motors, BMW Manufacturing, Volvo Car Thailand, Mercedes-Benz Thailand and Tata Motors (BOI, 2014). In 2020, General Motors design to discontinue on Thai market and many other right-handed market and Morris Garage (MG) is enter Thai market.

Thai automotive industry is mostly constituted by brand owner, and first-tier and second-tier suppliers. Suppliers of carmakers in Thailand are mostly invested by multinational companies. Beside the automotive supply chain, manufacturing of service parts of automotive is another value-added industries that significantly drive the growth of Thai's economy (Thailand Automotive Institute: TAI, 2007) (Napolpong Sorsomboon, 2015). The Thai automotive supply chain is leading by automobile brands (e.g. Toyota, Honda, etc.), called a supply chain leader. A company is seeking flexibility to respond the customer demand. The supply chain followers are first-tier, second-tier, and other tier suppliers. The suppliers of a company are concern about their profits by keeping a long-term relationship with the leader.

In Thai's automotive industry, automobile companies (brand owner) play a leader role in SCM, called a supply chain leader. They take control of management, strategies, and innovation over a supply chain. Automobile companies have been a concern as a major source of profits for the followers (first-tier, second-tier, and other tire suppliers). Since the leading company is seeking flexibility to respond to the customer demand, the followers are an important part that contributes to the SCP. Hence, they need to adapt themselves to maintain a high level of SCP and keeping a long-term relationship with the supply chain leaders.

The concept of supply chain leadership and follower-ship are explained in the study of Defee et al. (2010). Supply chain leader is a member with the capability to influence another members in a supply chain. Their vision can drive and create a better future for a supply chain. They are the one who identify need of a supply chain for changing and creates better performance. Leadership plays key role in a supply chain, but the majority of output and overall SCP are a direct result of the contributions of supply chain followers.

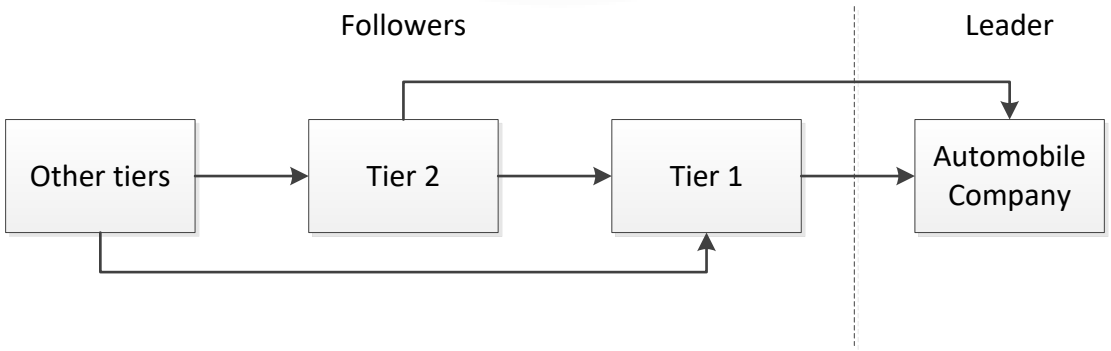


**Figure 2.5** Leader and Follower in Thai Automotive Supply Chain

A strong channel leader of a chain will dominant and drive the direction of a supply chain chain. Supply chain leader can be one or two firms in most chains. The lack of thereof of any member can affect the supply chain performance and commitment among other members (Lambert & Cooper, 2000). Therefore, the leader needs encourage and given the opportunity to the followers to quickly respond to the action.

### 2.1.4 Impact of AEC development on Thai's automotive industry

The primary Improving the efficiency of customs processes by single window and online custom is one of the purposes of AEC (Eric D Ramstetter, 2015). Even though the main purpose of AEC is the improvement of export rate to third markets outside ASEAN, it also influenced the increase of intra-regional trade. The purpose of free trade agreement was focused on investment more than trade (Joseph A. Mckinney, 2005). However, the effects of an economic agreement implementation are significantly diverse based on the characteristics, situation, environment, and ecosystem of each country. Therefore, it is unable to isolate the effects of an economic agreement on the business environment (Mary E. Burfisher, Robinson, & Thierfelder, 2001). The key macroeconomic variables that were important to consider in trade liberalization agreements are trade and employment (Mary E. Burfisher et al., 2001). This economic agreement can generate the benefit for manufacturing sectors by two components including the removal of Non-tariff barriers (NTBs) and improvements in the investment climate. Beside intra-regional economic development and integration of AFTA and AEC, an integration of intra-regional economic cooperation among ASEAN will be significant for not only members of ASEAN, but also influencing the investment and trade between ASEAN and partners. Although AEC can integrate ten countries and create a single economic region, many ASEAN countries have major trade partners outside ASEAN which will gain comparative advantages from AEC development. The study of Ramstetter (2015) is mention that elimination of tariff and trade barriers among the region can lead to increasing of extra-regional trading but it could decrease intra-regional trade because ASEAN region is an important supplier and partner of well-developed countries such as Europe, Japan, and North America. In short, AEC can lead to low intra-regional shares because the major trade partners of ASEAN are not located within the region. Nevertheless, trade is influenced by many factors. Thus, it unable to assume that the increased trade value among the region is a primary result of an economic agreement (Joseph A. Mckinney, 2005). Employment or labor is one of the key topics that should be considered in economic agreement implementation. Free flow of labor is one of the agreements

of AEC2015, Labor usually displaces due to the difference wages. However, trade liberalization generally increases in long-run productivity, but in the short-run, it can influences on labor displacement (Joseph A. Mckinney, 2005). The AEC implementation aims to eliminate tariffs among ASEAN, it can dramatically imparted on ASEAN industry especially the labor-intensive industries (Peter A. Petri, Plummer, & Zhai, 2012). Fortunately, cooperation and integration among ASEAN members must be tightened (Kazushi Shimizu, 2010).

The study of other trade liberalization agreements is required for measuring the effect of trade agreements that may occur in the development of AEC. Thus, the study of the North American Free Trade Agreement (NAFTA) and European Union (EU) are considered because these agreements highly represent trade integration among many countries within the region. Burfisher (2001) has studied the effect of NAFTA since implementing in 1994 for the automotive industry in U.S. and Mexico. Researchers mention that trade liberalization can increase trade with respect to comparative advantage and grow of GDP in the region can significantly general the demand within the region. The study is expected that investment, production, and employment are shifting from the United States to Mexico due to the lower operating cost. According to the assumption, the development of NAFTA effect on the automotive industry in many aspects. High skill workers with lower wages are attracting automotive producers from U.S. to expand their production based in Mexico. It is expected to increase automobiles and parts exports from U.S. to Mexico. However, it tends to create smaller increases in U.S. import rate because Mexico had higher tariffs barriers. The export rates from Mexican to U.S. are expected to increase because Mexican automotive factories are the suppliers of U.S. producers with higher demand. In consequence, after the implementation of NAFTA, integration of the North American auto industry has improved, which are allow the producer of automobiles and parts to reach a higher level of efficiency. NAFTA has significantly influenced on intra-industry trade in autos and parts. According to the data from 1994 to 1996, the employment rate in the American automotive industry including both auto parts sector and vehicle assembly sector has grown by 14.1 percent. In 1993 to 1996, U.S. automobile companies including General Motor (GM), Ford Motor, and Fiat Chrysler Automobiles (FCA US) have invested $39.1 billion in establishing and improving factories in the United States, while investing in Mexico only $3 billion (Mary E. Burfisher et al., 2001). However, Mexico required improvement in capital and technology that generally occur by an increase in foreign investment (Joseph A. Mckinney, 2005). It was evident that after NAFTA, FDI in Mexico has increased, but when comparing to other Latin American countries it is not

significantly different. Researchers found only a few relationships between an increase in exports and the productivity rate in Mexico (Cruz, Riker, & Voorhees, 2013). Trade and labor force also be interested factors in the study of European Union integration. The study of OECD (2000) in 2000, presenting that trade can influence the growth of capital and investment in the region. Additionally, low wages always effect of labor displacement and raised the competition. According to the case of Hungary, many economic indicators such as FDI, productivities, trade value, disinflation, and labor force increase due to EU agreement. However, the study from Anna Shaleva (2007) concluded that only the development of EU accession has not brought an economic miracle all of sudden. Government action including policies and strategies are important to handle the challenge of economic development and increase the capability of economic and social development among free trade network situations.

The development of ASEAN countries from the past two decades are incurred the shift of imports and export value from natural resource or agriculture intensive to manufacturers including electronics and other relatively manufactures (Peter A. Petri et al., 2012). It is influenced by the growth of the automotive industry in ASEAN countries since the demand are increasing and establishing export bases in South East Asia (Pei-Lee Teh, Tritos, & Dotun, 2012). An implementation of AEC is resulting in an increase of flexibility and marginal trade among ASEAN members (Sabhasri, 2013) and creates benefit in many aspects for the automotive industry. The fully integrated AEC can be a potential development for improvements in the manufacturing sector. With ACE agreement, ten countries became a single market, therefore, automotive producers with production base in ASEAN can create a benefit in term of economies of scale (Peter A. Petri et al., 2012). The AEC agreement is expected to be able to provide a seamless business operation and harmonized among the region. Likewise, it can provide opportunities and support the automotive industries in terms of market integration (Datuk Aishah Ahmad & Ike, 2015). ASEAN can categorize as one of the important partners for Japanese companies especially in the automotive industry, this region is considered a major market and invests for Japanese automobile manufacturers in terms of both markets and production bases (Kazushi Shimizu, 2010). To be more specific, Japan has the highest value of invest in Thailand among ASEAN (Oizumi & Soejima, 2015). It will be able to improve the capability of production and performance for the Japan Automobile Manufacturers Association (JAMA). Automotive producers from Japan are expected to further strengthen the production network in ASEAN and driven economic development of the automotive industries within the region in the future (JAMA, 2014). In general, an increase in manufacturing

productivity is resulting in an enhancement of ASEAN's comparative advantage (Peter A. Petri et al., 2012). The manufacturing sector in Thailand has contributed about one-quarter of the total sale value of ASEAN-6. It means the effects of AEC implementation will be the largest in the manufacturing sector especially in automotive goods and logistics (Eric D Ramstetter, 2015). Thus, Thailand can receive benefits from AEC in the manufacturing section rather than agriculture goods (Sombun Meadhapithakwong, 2013). Manufacturing sectors directly related with capital and technology (Peter A. Petri et al., 2012) which leads to an incremental of inward investment and technological development from foreign direct investment (FDI) in the nation.

Thus, the competitive environment from AEC establishment, it has some factors that needed to be considering the development of AEC 2015. In order to increase flexibility and collaboration among ASEAN, communication among members through the information center is required for sharing information among members. Labor knowledge and skill also significantly increase productivity and knowledge of the firm. The study of Sabhasri (2013) suggested that infrastructure, information sharing center and labor training programs should be implemented as soon as possible. Furthermore, financial support is also important for CLVM countries in order to create well development and beneficial among AEC. Additionally, capital, technological capabilities, and managerial skills are important for domestic firms for surviving in a global dynamic environment (Nguyen Tien Dung, 2010). The study of Meadhapithakwong (2013) has mentioned AEC2015 impacted on Thai industry in terms of investment, production, and labor. Labors are required in this industry even robotic technology has an influence in the production line. In the developing countries, the labor force still have more efficient than the developed countries when comparing with the price of advance robotic technology. Thus, the firm should concern on the opportunities from regional integration because import and export facilitation are directly related to tariffs, the reduction of tariff collection can incur competitive pressures within the region (Nguyen Tien Dung, 2010). The study of Oizumi and Soejima (2015) is mentioned about the importance of SCM to improve the manufacturing industry in the AEC era. Thailand is located in the center of the ASEAN with strong supply chain, supportive infrastructure, and border development. Neighboring countries of Thailand including Cambodia, Laos, and Myanmar are growing in term of economic, market, and demand of goods and service. With all those reasons, Thailand can became a competitive production based for automotive industry. However, there are four ASEAN countries that can consider as competitors including Indonesia, Malaysia, Philippine, and Vietnam. These five countries (including Thailand) are viewed as key players in the Asia automotive industry (Pei-Lee Teh et al., 2012).

The growth of the economy in neighboring countries including Cambodia, Laos, and Myanmar led to an increase in customer demand and expansion of customer markets. Thus, an enhancement of supply chain competitiveness in ASEAN is required for increasing the value of production bases in Thailand. In the automotive industry,

According to literature reviews, the implementation of AEC can be a source of a significant effect on the economic situation within the region. Trade and employment are frequently discussed in the literature. However, the effects of the economic agreement are far beyond the trade but it is including market demand, trends, and competitiveness of each country because it is difficult to distinguish the effects of trade among economic development. Then, labor is the sensitive factors that elastic with respect to wages. AEC can allow the free flow of labor which is directly related to the industrial input that directly effects to Thai automotive industry. In summary, those effects can be classified into three categories as shown in table 2.5. First, many studies are focused on industrial input such as financial support, foreign investment, immigration of labor force, and infrastructure development in members of ASEAN. Second, AEC is clearly related to the current economic situation in both the supply and demand side, SCM is another area that affected by AEC, communication among suppliers, information sharing across countries, and flexibility are including in the area of the SCM. AEC is expected seamless the supply chain among firms in different countries. Thirdly, the economic growth in developing countries within ASEAN resulted in the expansion of the market within the region and increasing customer demand. However, it is also leading to an increase in competitiveness among ASEAN.

**Table 2.5** Summary of influence factors based on literature

| Factors | Description |
|---|---|
| Industrial Input (Supporting sectors) | Factors that consider as an input for business development such as labor cost, labor skill, foreign investment, etc. Those factors directly effect to Thai's automotive industry |
| Supply Chain | The relationship among suppliers within the supply chain is reflecting the performance of an industry. An improvement in communication and integration can occur by AEC development. |
| Economic Situation (Customer) | External factors that related to a business situation such as market demand, trends, and competitiveness among ASEAN countries. The change in this business environment is influencing in the automotive industry. |

Many studies have discussed the AEC implementation topic; the effects of trade agreement were measured from a different perspective. Trade liberalization can create opportunities and challenges for any industry. Thus, the firms and relative government agencies should heavily consider that effect. Especially in Thai's automotive industry, this sector is an important industry that creates benefits to Thai economy. However, the current situations that occur in Thai's automotive sector are unable to identify and detail of impact for the firms is unmeasurable. Since effects of AEC2015 on the automotive industry in Thailand still not being identified, the policies recommendation and strategic plan are unknown. In order to determine the solutions to maintain and increase the competitiveness of Thai automotive industry, it is essential to concern the current situation and detailing of AEC affects.

## 2.2 Identify factors and relationship of SCP: A systematic literature review

A systematic literature review technique is employed to investigate and extract the relevant research literature on SCP from credible published journals .The literature review aims to classify the definition of related terminologies of SCP. The research methodology is divided into two phases as follows: (i) planning and searching and (ii) analysis.

### 2.2.1 Planning and searching

To scope down the literature review, discussions among authors are done to obtain effective search terms. The searching terms are employed to scope down a tons of literature review to a bearable set of research. Two levels of searching keywords were employed to specify the research papers that contribute to supply chain development. The results from the discussion among authors are summarized in Table 2.1. The first level focuses on SCP, and the second level emphasizes on specific components of SCP. The term "supply chain performance" is a concerned key to extract the critical factors that contribute to supply chain network. In the second level, the key concerned is the factors that contribute to supply chain management. Thus, the literature reviews for "Evaluation", "Measurement", "Framework", "Model", and "Technique" are a major search term for finding related literature. A systematic literature review is conducted, based on the ScienceDirect database .According to the searching results, 1,842 journals were found that are related to SCP from 1996 to the middle of 2016, as shown in Figure 2.6. In addition, other journal databases, for instance, Emerald, SCIRUS, and SCOPUS are utilized, to cover complete research outcomes, in terms of definitions and terminologies.

**Table 2.6** Searching keywords

| Searching Level | Keywords |
|---|---|
| First level | Supply Chain Performance |
| Second level | Evaluation OR Measurement OR Framework OR Model OR Technique |

### 2.2.2 Analysis

According to searching results of 1,842 journals, as shown in Figure 2.6, the relevant research papers in the supply chain, performance measurement, and relevant topics are selected from the quality sources. The reviewed of titles and keywords are considered the first screening process. Then, abstract, introduction, and conclusion were reviewed for selecting the paper for further discussion. Finally classified to papers based on terminology that they mentioned for creating SCP. The review and selection methods are shown in Figure 2.7. Most of the selected articles are discussed as critical factors for developing SCP.

A systematic literature review is employed to synthesize the contents of the existing journals. In the analysis phase, the terminologies in supply chain research are listed. Then, a definition is provided for each term, and terminologies are classified, based on the similarity

of their definitions to purpose relationships among them are determined, based on the literature review.

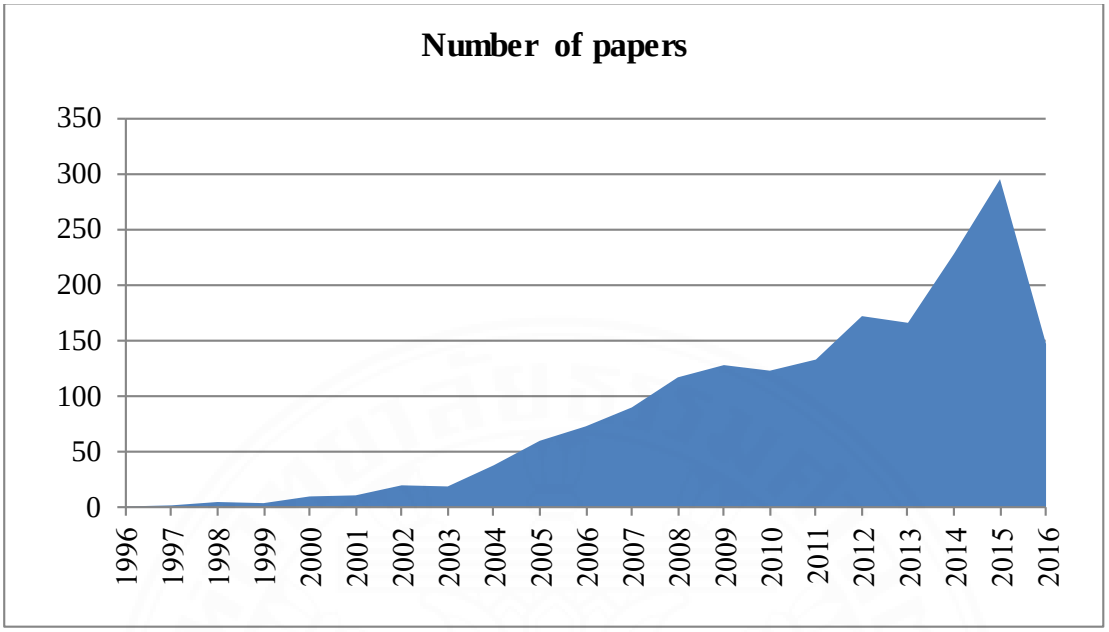


**Figure 2.6** Distribution of number of journals related to SCP, published in ScienceDirect, from 1996 to the middle of 2016

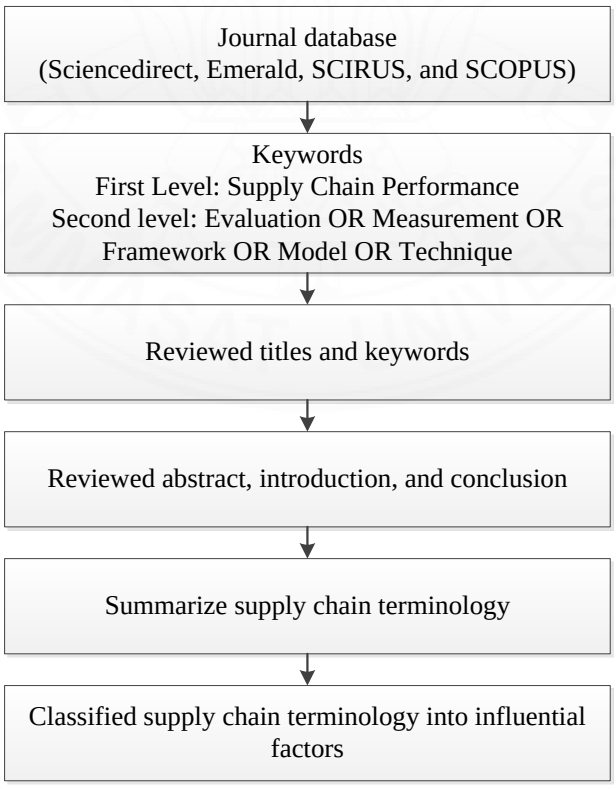


**Figure 2.7** Selecting process

## 2.3 Supply chain management

Due to global economic development and globalization, supply chain management (SCM) has been increasingly focused on by business entities (Craighead et al., 2009). In 1980s, supply chain concept was developed by consultants (Lambert & Cooper, 2000) with the main goal of seamless operation within a supply chain network (Zailani & Rajagopal, 2005) to create quality and reduce costs in all the processes embedded within SCM, including both provider, customers, and third-party activities (Dawson, 2002; Prasetyanti & Simatupang, 2015). In the traditional aspect, productivity and profitability are key focuses of SCM (Beamon, 1999; A. Gunasekaran et al., 2004). It mostly prioritizes the performance of an entire business network rather than an isolated organization (Hamed, El-Bassiouny, & Ternes, 2017; Zailani & Rajagopal, 2005). Therefore, the supply chain is a network of actors who interact, integrate, create, and deliver value through the chain. It consists of activities and processes to satisfy demand (Prasetyanti & Simatupang, 2015). The supply chain is influenced by many criteria and a changeable environment (Xu, Li, & Wu, 2009).

The SCM is considered to be systems of three or more entities that pass materials, products, services, finances, and information upstream and downstream among the members, and deliver to their end customers (Naslund & Williamson, 2010). It is complex system within dynamic environments (Defee et al., 2010). To create an effective partnership among members of a supply chain, the review of influential factors of Supply Chain Performance (SCP) is mandatory. However, SCP is influenced by many factors and considered by different research areas.

In the conventional supply chain, SCP is observed as a critical issue that contributes competitive advantages of an organization; it involves many actors in a supply chain, including suppliers, manufacturers, and related retailers (Cai, Liu, Xiao, & Liu, 2009; Craighead et al., 2009). SCP is cost-containment and performance reliability. Cost-containment refers to cost-related activities, such as holding, transporting, and operating costs (Ibrahim & Hamid, 2014). Reliability is related to satisfaction and serviceability, including order fulfillment rate, inventory turns, and product warranties .These measurements have been recognized as the direct and observable factors of SCM. To improve the performance and competitive advantages of a supply chain, the supply chain activities and techniques including inventory reduction, just-in-time delivering system, safety stock, and improving flexibility are promoted and applied among members (Vijayasarathy, 2010).

SCP allows an organization to measure the source of problems in different procedures and create a better understanding of a supply chain as a whole .Therefore, many industries, including the automotive industry(Azevedo, Carvalho, & Cruz Machado, 2011; Brandenburg, 2013; Hasan, Gao, Wasif, & Iqbal, 2014; Olugu, Wong, & Shaharoun, 2011; Antonio Márcio T Thoméa et al., 2014; Woolliscroft, Caganova, Cambal, Holecek, & Pucikova, 2013), manufacturer (Robert B. Handfield & Bechtel, 2002; He & Lai, 2012; Hwang, Lin, & Lyu, 2008; Lin, Wang, & Yu, 2010; Xu et al., 2009; Zhu, Sarkis, & Lai, 2008), construction industry (Dadhich, Genovese, Kumar, & Acquaye, 2015; Wibowo & Sholeh, 2015), and foods industry (Afonso & Cabrita, 2015; Beske, Land, & Seuring, 2014; Bourlakis, Maglaras, Aktas, Gallear, & Fotopoulos, 2014; Grimm, Hofstetter, & Sarkis, 2014), are interested in SCP measurement. In order to measure an SCP, researchers employ different measuring tools, for instance, the Supply Chain Operations Reference model (Alomar & Pasek, 2014; Clivillé & Berrah, 2006; Ducq & Berrah, 2009; Ganga & Carpinetti, 2011; A Gunasekaran et al., 2004; Hwang et al., 2008; Lambert & Cooper, 2000; Ntabe, Lebel, Munson, & Santa-eulalia, 2015; Okongwu, Lauras, Franc, & Deschamps, 2016; Trkman, McCormack, De Oliveira, & Ladeira, 2010), Balanced Scorecard (Afonso & Cabrita, 2015; Bhagwat & Sharma, 2007; Hon, 2005; Lohman, Fortuin, & Wouters, 2004; Marimin, Adhi, & Darmawan, 2017; Shafiee, Hosseinzadeh Lotfi, & Saleh, 2014; Ukko, Tenhunen, & Rantanen, 2007; Zin, Sulaiman, Ramli, & Nawawi, 2013), Structural Equation Modeling (Avelar-Sosa, García-Alcaraz, & Castrellón-Torres, 2014; Green, Whitten, & Inman, 2012; Hussain, Khan, & Al-Aomar, 2015; S. W. Kim, 2009; Lin et al., 2010; Trkman et al., 2010), and Analytic Hierarchy Process (Adel El-Baz, 2011; Alomar & Pasek, 2014; Badea, Prostean, Goncalves, & Allaoui, 2014; Ganga & Carpinetti, 2011).

The previous research study on the propose of SCP frameworks to describe the relationship and evaluate the performance, for example relationships of supply chain linkages (Zelbst et al., 2009); strategy and flexibility on supply chain performance (Awais et al., 2014; Yusoff, Ashari, & Salleh, 2016); effect of leadership and follower-ship of a supply chain on supply chain efficiency and effectiveness (Defee et al., 2010); relationships between resources, outputs, and flexibility (Beamon, 1999); relationships between supply chain linkages and supply chain performance (C. W. Lee et al., 2007); the role of partnerships in supply chain performance (Ryu et al., 2009); relationships between integration among supply chain and performance (Huang, Yen, & Liu, 2014); and supply chain collaboration enhancing efficiency, effectiveness, and marketing position (S. Min et al., 2005). Thus, an effective supply chain network requires flexibility, responsiveness, reliability, and integration among partners and members of a supply chain.

SCM has many similarities in many terms because a supply chain is a process of exchange and create the value as a "value-creating networks" (Braziotis, Bourlakis, Rogers, & Tannock, 2013). The study of Mentzer et al. (2001) proposed three levels of supply chains. The first level, supply chain, focuses on the core business and direct suppliers (tier 1 supplier) who directly interact with the organization (horizontal relationship) called "direct supply chain" (dyadic relationship). The second level, extended supply chain, includes suppliers of suppliers (tier 2 and 3 suppliers) and indirect customers. This level also concerns the relationships of the actors in different levels (vertical relationship). The third level is the ultimate supply chain or supply chain network (Braziotis et al., 2013). It consists of supporting sectors and actors that contribute to the supply chain system, including financial providers, logistics providers, and information providers. The study of Letaifa (2014) defined the value-creation network as a network of individuals, customers, partners, competitors, and suppliers collaborate with co-creation among multiple actors.

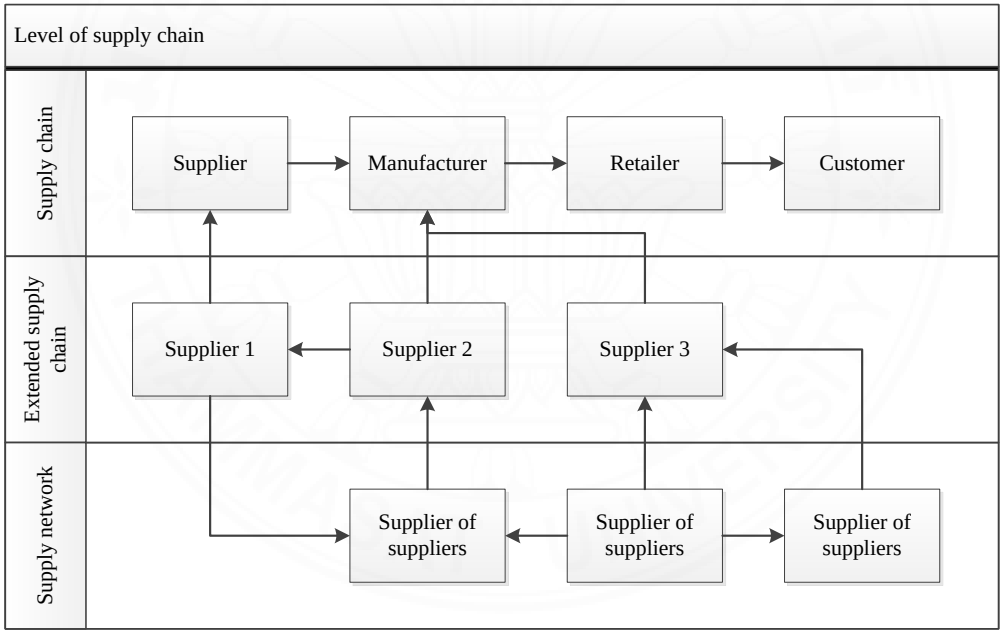


**Figure 2.8** Level of supply chain

**Table 2.7** The definition of each type of supply chain

| Type of supply chain | Definition |
|---|---|
| Supply chain | A direct supply chain is a system that flows of finances, products, services, and information occur among a company, a supplier, and a customer in both upstream and downstream directions (Mentzer et al., 2001).<br>According to Braziotis et al. (2013p.648), supply chain is "a set of primarily collaborative activities and relationships that link companies in the value-creation process, in order to provide the final customer with the appropriate value mix of products and/or services". |
| Extended supply chain | An extended supply chain is a direct supply chain with immediate of supplier and customers aspect. The flows of products, services, finances, and information occur in upstream and/or downstream of both vertical and horizontal direction in a system (Mentzer et al., 2001). |
| Supply network | A supply chain network includes every actor that interacts in flows of products, services, finances, and information in both upstream and downstream directions (Mentzer et al., 2001). In this network, members of a supply chain contribute to each other to achieve the goal (Braziotis et al., 2013) |

Source: Mentzer et al. (2001)

Since a supply chain requires nodes with complex relationships (Cai et al., 2009; Carter, Rogers, & Choi, 2015), it consists of many actors participating in a system, not only the suppliers, manufacturers, distributors, and retailers, but also all the actors that integrate resources (knowledge and skills) into the flow of products, services, finances, and information in both upstream and downstream directions (Mentzer et al., 2001). All members of a supply chain have direct and indirect interaction with the other actors via non-linear and complex relationships. For example, a manufacturer has direct communication with a distributor that buys the finished goods and has an indirect relationship with the distributor who orders and resale the products (Braziotis et al., 2013).

According to SCM development, a supply chain is now focused on the relationships, interactions, and value creation among partners, and value constellation rather than the

movement of tangible materials along with the processes. Therefore, the S-D logic concept possibly provides the benefits in SCM because it relates to the processes of sharing and exchanging information between actors within the supply chain (Prasetyanti & Simatupang, 2015). Therefore, supply chains can be considered value co-creation networks (Maas, Hartmann, & Herb, 2014). According to Braziotis et al. (2013), a supply chain is a set of practices for exchanging and creating value as value-creating networks. The study of Letaifa (2014) defined the value-creation network as a network of individuals actors including customers, suppliers, recipients, competitors, and providers that interact with each other to develop a network in terms of knowledge and competency in the value chain (Letaifa, 2014).

According to the literature, each study differently summarizes the influence factors based on the industry and research methodology. However, the time period of supply chain development is disappeared. To develop a framework for supply chain development, the study of factors influencing SCP in each phase of supply chain development is inevitable.

## 2.4 Supply chain terminology

A supply chain is a large system that is influenced by many factors. Thus, its performance is driven by various factors . In the past decade, the most frequently mentioned factors are summarized in Appendix A

According to the definition provided in Appendix A, there are some factors that are closely related to each other; for instance, collaboration and coordination, and responsiveness and reliability. Since coordination is frequently mentioned in terms of collaboration (Costantino, Di Gravio, Shaban, & Tronci, 2014) and integration (Aryee, Naim, & Lalwani, 2008; Ibrahim & Hamid, 2014; Lotfi, Mukhtar, Sahran, & Zadeh, 2013), coordination is concerned as a sub-topic under collaboration and integration. Responsiveness and reliability are related to the capability of the firm to deliver the product with speed and accuracy (Bourlakis, Maglaras, Aktas, et al., 2014; Ganga & Carpinetti, 2011). Thus, this can consider as a part of supply chain flexibility. The first is a pre-partnership phase; in which a critical factor is created by a willingness of the firm to create a higher performance to serve the customer and assist in business management without any contribution from inter-organization. The critical factors in this phase are internal integration and flexibility with supporting factors of technology and innovation. The second phase occurs when the firm interacts with inter-organization and creates a buyer-customer relationship to achieve higher performance through the supply chain. This phase called the partnership phase; it is a beginning phase of the

partnership. The firms start working together to achieve higher profitability. However, the focus of the firm in this phase is a benefit for itself. The third phase is a post-partnership phase, in which a group of firms is working together for a period of time for sharing the profit and risk together. The firms are most likely sharing the same objectives and helping each other to achieve the same goal. The knowledge and information freely flow among the partnership and strategies are developed together. The keys factors in this phase are trust and integration among the partnership to create supply chain flexibility. Trust occurs only when members of the supply chain are confident and willing to share the information together (Panayides & Venus Lun, 2009; Yeung, Selen, Zhang, & Huo, 2009). Technology is concerned with an infrastructure to support the overall supply chain processes. In this phase, the firms maintain and tighten a good relationship among partners in order to achieve flexibility, responsiveness, and reliability of supply chain.

**Table 2.8** Summarize of critical factors in supply chain management

| Factors | Definitions and their relationships | References |
|---|---|---|
| Collaboration | Collaboration is defined as sharing and exchanging information and planning among two or more independent companies .Its key elements include sharing information (Defee et al., 2010), knowledge (Naslund & Williamson, 2010), risk, and reward among partners in order to achieve mutual goals (Min et al., 2005). | (Beske et al., 2014), (Lohman et al., 2004), (Badea et al., 2014), (Panayides & Venus Lun, 2009), (Costantino et al., 2014), (Min & Zhou, 2002), (Meixell & Gargeya, 2005), (Chen et al., 2007), (Lee et al., 2011), (Naciri et al., 2011), (Fawcett et al., 2012), (Wu et al., 2014) |
| Coordination | Coordination is frequently mentioned in terms of collaboration (Costantino et al., 2014) and integration (Ibrahim & Hamid, 2014, Aryee et al., 2008; Lotfi et al., 2013) of supply chain systems . Coordination among supply chain members reduces various inefficiencies including the bullwhip effect and inventory issues (Costantino et al., 2014). Hence, coordination leads to better SCP in terms of benefits and profit (Lotfi et al., 2013). | (Costantino et al., 2014), (Lotfi et al., 2013), (Lee et al., 2011), (Zhang &Chen, 2013) |

| Factors | Definitions and their relationships | References |
|---|---|---|
| Flexibility | Supply chain flexibility is the ability to be flexible in terms of operation and manufacturing (Duclos et al., 2003), including the ability to respond to the environmental changes (Huang et al., 2014a) to customize the product based on customer requirements .It is generally related to the ability to react to uncertain situations in both internal and external organization (Thoméa et al., 2014). | (Cai et al., 2009), (Sukati et al., 2012), (Thoméa et al., 2014) ,(Hwang et al., 2008), (Xu et al., 2009), (Wibowo & Sholeh, 2015), (Bourlakis et al., 2014a), (Afonso & Cabrita, 2015), (Gunasekaran et al., 2004b), (Ganga & Carpinetti, 2011), (Lohman et al., 2004), (Hon, 2005), (Bhagwat & Sharma, 2007), (Kim, 2009), (Avelar-Sosa et al., 2014), (Adel El-Baz, 2011), (Yu et al., 2010), (Cho et al., 2012), (Fan et al., 2013), (Acar & Uzunlar, 2014), (Bourlakis et al., 2014b), (Qrunfleh & Tarafdar, 2014), (Arnold et al., 2015) |
| Green (Environment) | Green supply chain is focused on integrating environmental issues into a supply chain (Zhu et al., 2016; Uygun & Dede, 2016) with the main purpose to minimize the overall effects from supply chain systems including product design, material sourcing, manufacturing processes, delivering, and disposing of the products on the environment (Uygun & Dede, 2016) (Kumar & Rahman, 2016). | (Zhu et al., 2008), (Azevedo et al., 2011), (Diabat & Govindan, 2011), (Olugu et al., 2011), (Azfar et al., 2014) |

| Factors | Definitions and their relationships | References |
|---|---|---|
| Information sharing | Information sharing, an important part of IT systems, is the availability of information and knowledge sharing among partners within a network . It is considered as an important supply chain tool for a successful SCI, and coordination (Ibrahim & Hamid, 2014), and for improving firm performance (Sukati et al., 2012). | (Cai et al., 2009), (Lambert & Cooper, 2000), (Gunasekaran et al., 2004b), (Trkman et al., 2010), (Badea et al., 2014), (Abdullah & Musa, 2014), (Costantino et al., 2014), (Lotfi et al., 2013), (Yeung et al., 2009), (Min & Zhou, 2002), (Chen et al., 2007), (Naciri et al., 2011), (Wu et al., 2014), (Zhang & Chen, 2013), (Yu et al., 2010), (Fan et al., 2013), (Acar & Uzunlar, 2014), (Qrunfleh & Tarafdar, 2014), (Prajogo & Olhager, 2012), (Chen et al., 2013), (Luo et al., 2013), (Costantino et al., 2015), (Li & Zhang, 2015), (Marinagi et al., 2015), (Wong et al., 2015) |
| Innovation | In SCM, innovation is strongly related to new products or services development that offers greater customer satisfaction. Innovation has been considered as a result of new knowledge and discovery (Craighead et al., 2009). Innovation is a new approach to improve operational efficiency and enhance service effectiveness (Bello et al., 2004) . | (Cai et al., 2009), (Craighead et al., 2009), (Woolliscroft et al., 2013), (Lin et al., 2010), (Beske et al., 2014), (Afonso & Cabrita, 2015), (Bhagwat & Sharma, 2007), (Adel El-Baz, 2011), (Panayides & Venus Lun, 2009), (Min & Zhou, 2002), (Fawcett et al., 2012), (Cho et al., 2012), (Fan et al., 2013), (Bello et al., 2004), (Chan et al., 2014) |

| Factors | Definitions and their relationships | References |
|---|---|---|
| Integration | Integration is resulting in the increase of supply chain capability and the ability to shorten the response time with high quality and reasonable cost (Naslund & Williamson, 2010) . It leads to better coordination of business processes across the members of a chain (Aryee et al., 2008). | (Vijayasarathy, 2010), (Sukati et al., 2012), (Hasan et al., 2014), (Lin et al., 2010), (He & Lai, 2012), (Beske et al., 2014), (Okongwu et al., 2016), (Kim, 2009), (Green et al., 2012), (Lotfi et al., 2013), (Min & Zhou, 2002), (Chen et al., 2007), (Yu et al., 2010), (Acar & Uzunlar, 2014), (Prajogo & Olhager, 2012), (Wong et al., 2015), (Koçoğlu et al., 2011), (Ryoo & Kim, 2015) |
| Knowledge | Knowledge management (KM) is important in organizations and supply chain development. It is the process of collection, distribution, and implementation of knowledge resources (Woolliscroft et al., 2013). KM in a supply chain is reflected by the learning progression, use of knowledge, and knowledge collection (Craighead et al., 2009). Knowledge is a component shared by a supply chain. | (Craighead et al., 2009), (Woolliscroft et al., 2013), (Hasan et al., 2014), (Beske et al., 2014), (Adel El-Baz, 2011), (Min & Zhou, 2002), (Chen et al., 2013), (Luo et al., 2013), (Ryoo & Kim, 2015), (Borjeson et al., 2015) |
| Reliability | Reliability in SCM is mainly related to the capability to respond to customers. Ganga & Carpinetti (2011) mentioned that it is the ability to deliver to the right place, in the right quantity, at the right time, with the correct documentation, to the customers . It is measured as the percentage of correct orders delivered (Hwang et al., 2008). | (Hwang et al., 2008), (Wibowo & Sholeh, 2015), (Ganga & Carpinetti, 2011) |

| Factors | Definitions and their relationships | References |
|---|---|---|
| Responsiveness | Supply chain responsiveness is considered as a primary source of performance (Handfield & Bechtel, 2002). It is the speed of a supply chain systems to respond to customer demand (Ganga & Carpinetti, 2011). Responsiveness is also related to the accuracy and ability to provide the right products in the right place, at the right time (Bourlakis et al., 2014a). Thus, responsiveness within a chain is an element of supply chain flexibility. | (Craighead et al., 2009), (Sukati et al., 2012), (Handfield & Bechtel, 2002), (Hwang et al., 2008), (Wibowo & Sholeh, 2015), (Bourlakis et al., 2014a), (Ganga & Carpinetti, 2011), (Hon, 2005), (Avelar-Sosa et al., 2014), (Fan et al., 2013), (Bourlakis et al., 2014b), (Azfar et al., 2014) |
| Risk | The risk is investigated in many research fields including supply chain management . In a supply chain, the risk is related to unreliable and uncertain processes in both supply and demand sides (Avelar-Sosa et al., 2014). Greater risk in a supply chain results in poorer inventory management, lead-time, flexibility, and responsiveness (Avelar-Sosa et al., 2014). | (Beske et al., 2014), (Avelar-Sosa et al., 2014), (Badea et al., 2014), (Hussain et al., 2015), (Min & Zhou, 2002), (Giannakis & Papadopoulos, 2016) |

| Factors | Definitions and their relationships | References |
|---|---|---|
| Technology | Technologies related and adopted in supply chains vary: for instance, Electronic Data Interchange and point of sale systems, information processing capability, information sharing (Vijayasarathy, 2010), Enterprise Resource Planning (Gunasekaran et al., 2004b), e-procurement and e-commerce, internet and extranets (Marinagi et al., 2014; Karakudilar & Sezen, 2012), and Radio Frequency Identification (Lee et al., 2011). | (Vijayasarathy, 2010), (Woolliscroft et al., 2013), (Gunasekaran et al., 2004b), (Ducq & Berrah, 2009), (Lohman et al., 2004), (Zin et al., 2013), (Badea et al., 2014), (Min & Zhou, 2002), (Chen et al., 2007), (Lee et al., 2011), (Naciri et al., 2011), (Yu et al., 2010), (Cho et al., 2012), (Acar & Uzunlar, 2014), (Qrunfleh & Tarafdar, 2014), (Prajogo & Olhager, 2012), (Bello et al., 2004) |
| Trust | Trust is defined as confidence and willingness among members in exchanging information with each other (Panayides & Venus Lun, 2009, Yeung et al., 2009). This results in an improvement of responsiveness (Handfield & Bechtel, 2002). Trust is an essential element for sustainable development and collaboration of partners (Fawcett et al., 2012). | (Handfield & Bechtel, 2002), (Panayides & Venus Lun, 2009), (Abdullah & Musa, 2014), (Yeung et al., 2009), (Chen et al., 2007), (Fawcett et al., 2012), (Chen et al., 2013), (Ryoo & Kim, 2015), (Capaldo & Giannoccaro, 2015) |

| Factors | Definitions and their relationships | References |
|---|---|---|
| Strategies | Strategies are often considered as the primary method for operating and managing an organization. Supply chain strategies focus on two important aspects which are lean/efficient and agile/responsive (Zhou et al., 2014). The organizational performance is influenced by the relative strategy and developed elements to encourage the strategy (Defee et al., 2010). | (Craighead et al., 2009), (Sukati et al., 2012), (Lin et al., 2010), (Gunasekaran et al., 2004b), (Alomar & Pasek, 2014), (Lohman et al., 2004), (Adel El-Baz, 2011), (Green et al., 2012), (Qrunfleh & Tarafdar, 2014), (Kang et al., 2012) |
| Sustainable | Sustainable development is the development without compromising the ability of future generations (Gopalakrishnan et al., 2012). Sustainability in a supply chain is related to awareness towards environmental. It is often described as an integration of three dimensions namely economic, social, and environmental dimensions for sustainable development (Kumar & Rahman, 2016; Formentini & Taticchi, 2016). | (Lohman et al., 2004), (Hon, 2005), (Azfar et al., 2014), (Beske et al., 2014), (Bourlakis et al., 2014a), (Bourlakis et al., 2014b), (Grimm et al., 2014), (Pedro José Martínez-Jurado & Moyano-Fuentes, 2014), (Dadhich et al., 2015), (Hussain et al., 2015), (Giannakis & Papadopoulos, 2016) |

Since supply chain development has a time frame and each factor influences in each phase of the supply chain with an unequal weight, it is significant to identify the factors influencing a supply chain network in each phase. This research synthesizes and organizes those complex relationships into antecedent and descendent of a supply chain network to develop a framework for supply chain development.

## 2.5 Framework of SCM development

According to the research literature review, SCP is influenced by many factors in supply chain systems. The factors influencing SCP can be divided into three different time frames namely pre-partnership (antecedent factors), partnership, and post-partnership (descendent factors) as shown in three critical phases in Figure 2.9. This proposed framework is classified into four aspects; supporting factors, resources, interaction, and capability of SCM. Supporting factors is an infrastructure of the supply chain while information and knowledge are referred to as the resource of the supply chain for interacting and integrating among members. Interaction plays an important role in the resource integration process and leads to the higher supply chain capability which is considered as the ability of the firm and supply chain to respond to the demand and the environmental changes. Since supply chain development has a time frame and each factor influences in each phase of the supply chain with an unequal weight, it is important to identify the factors influencing a supply chain network in each phase. This section synthesizes and organizes those complex relationships into antecedent and descendent of a supply chain network to develop a framework for supply chain development.

In the pre-partnership phase, each member of the supply chain focuses on the individual business process to respond to customer demand. The suppliers or customers are components of higher achievement at the firm level. However, when the individual firm perceives the value of partnership collaboration among members, they aim at a higher level of responsiveness, thus, creating a partnership. A partnership is a key concern for improving SCP. After members become partners, members will work together to achieve the goals of the supply chain. Then, they have the ability to create a flexible supply chain to respond to uncertain demand.

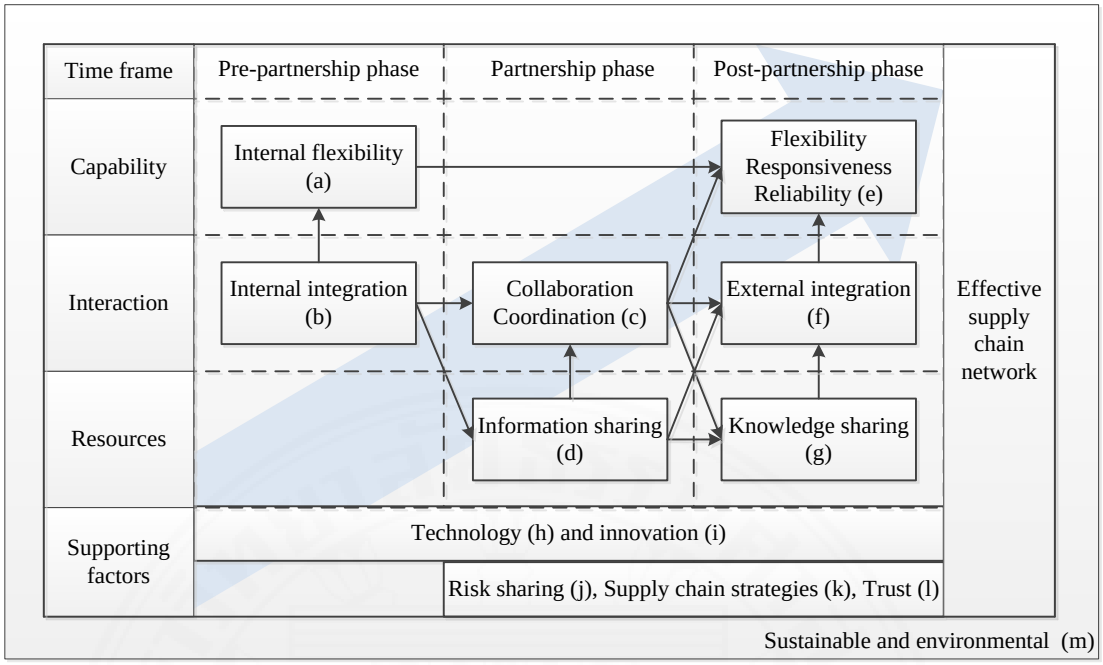


**Figure 2.9** Framework of effective supply chain network

### 2.5.1 Pre-partnership phase (Antecedent factors)

In the pre-partnership phase, antecedent factors are considered as sources of supply chain partnership or primary factors in SCM .The purpose of antecedent factors is to maximize organization profit with less support by inter-organization. The key factors in this phase consist of an internally business approach including flexibility and integration within the organization. The main purpose of this phase is to generate profit for the organization.

***(a) Internal flexibility***

Internal flexibility or agility of the firm is considered as a key factor in performance improvement, resulting in competitive advantage (Awais et al., 2014; Azfar, Khan, & Gabriel, 2014; Ganga & Carpinetti, 2011). It is the ability of supply chains to adjust sourcing and production planning for optimizing operations (Chandak et al., 2014). The need for flexibility initiates from demand side since they require variety, specific quality, competitive prices, and faster delivery (Sukati et al., 2012). The performance of a supplier also influences on internal flexibility (Ndubisi, Jantan, Hing, & Ayub, 2005). Thus, the firm should consider the supplier selection process since the pre-partnership phase.

Increasing flexibility provides a better ability to respond to unpredictable events, including a variety of demand, poor manufacturing, late delivery, and supplier performance. Flexibility leads to a reduction in backorders, lost sales, and late orders (Beamon, 1999). Internal flexibility is all internal operations that support external flexibility (Antonio Márcio T Thoméa et al., 2014). Therefore, the flexibility and performance of a supply chain have a positive relationship with each other because they allow firms to better respond to customer demand with less cost and time. However, flexibility requires many supporting factors such as information sharing and integration within the organization.

***(b) Internal integration***

Integration supports participating firms to better identify problems and reduce the complexity of projects (Naslund & Williamson, 2010). Internal integration is a dimension of SCI (Beheshti et al., 2014; Boon-itt & Paul, 2006; Huo, 2012b; Huo et al., 2016; C. W. Lee et al., 2007; Lii & Kuo, 2016; M. Zhang et al., 2016). In this phase, the firm needs to focus on internal integration. It is the degree of collaborative work among the business functions in a firm. It also includes linkages and relationships within a single organization. At the operational level, a goal of the collaborative work is to create better management for operating and controlling inventory (S. Min et al., 2005), such as minimizing safety stock requirements and increasing information availability (Defee et al., 2010). Internal integration supports product design, procurement, production, marketing, and distribution, in order to meet customer requirements with cost minimization and the effectiveness of the value chain (B. G. Kim, Hwang, Shin, Choi, & Leem, 2008).

### 2.5.2 Partnership phase

The core competency of a supply chain relies on the flow of goods, services, information, and finances among members .Thus, the essence of supply chain systems is the relationships, interaction, and cooperation among members to achieve a mutual goal .Relationships between the members or inter-relationships have become a core consideration by many organizations that aim to create a higher response level in systems. A supply chain partnership allows each entity to focus on core competencies

and outsource noncore activities to other entities in the supply chain (Robert B. Handfield & Bechtel, 2002). Communication and interactions between members are primary activities in every supply chain system, but collaboration, integration, risk and award sharing, and trust among the members are not generally found in every supply chain system .Therefore, a closer relationship among members is a core consideration, in order to achieve higher performance (Panayides & Venus Lun, 2009), and faster responses for customers (Robert B. Handfield & Bechtel, 2002). A close supply chain partnership results in goal sharing among firms and seamless activities. Consequently, it helps unite cooperation in supply chain systems and, hence, increases flexibility in the management system (Wiengarten, Humphreys, Gimenez, & Mcivor, 2016).

***(c) Collaboration and coordination***

Collaboration is defined as sharing information and planning among two or more independent companies (P. J. Singh & Power, 2009). It is an expectation of a supply chain leader and followers (Defee et al., 2010). It directly influences the formation of a supply chain partnership (Lotfi et al., 2013). The key purpose of supply chain collaboration is to create a competitive advantage and improve performance (M. C. Chen, Yang, & Li, 2007; Kohli & Jensen, 2010; Naslund & Williamson, 2010; Simatupang & Sridharan, 2002). Collaboration among supply chain members allows firms to deal with uncertain demand and requirements from customers (Defee et al., 2010). Hence, collaboration plays an important role in the success of SCM (S. Min et al., 2005).

External collaboration is the relationship between suppliers and customers that generate a positive impact on the process and product innovation (Ibrahim & Hamid, 2014). Collaboration is achieved if the firms are able to develop themselves in terms of standard business operation and information sharing .Effective information sharing improves decision- making and supply chain efficiency (S. Min et al., 2005). IT influences successful collaboration among organizations (Naslund & Williamson, 2010). However, the collaboration factor cannot solely improve SCP (Kache & Seuring, 2014; Kohli & Jensen, 2010).

***(d) Information sharing***

Information sharing is concerned as a part of inter-organization collaboration and coordination (Wu, Chuang, & Hsu, 2014). Real-time information sharing among upstream and downstream in a supply chain leads to an optimization operation of the supply chain including minimizing lead time and bullwhip effect (C. W. Lee et al., 2007). Generally, information sharing is frequently mentioned in the inter-organization approach and considered an issue in SCM. This is related to trust and integration among partners (Ibrahim & Hamid, 2014; Wu et al., 2014). However, when firms are willing to share information, they require appropriate technological support for transmitting the information among partners (Li & Zhang, 2015).

### 2.5.3 Descendent factors

When antecedent factors are implemented among partners and a partnership was created, partners possess the ability to respond to unpredictable situations. The related factors (descendent factors) consist of flexibility and integration along with a supply chain. Descendent factors help members of a supply chain to maintain good relationships with each other. A better relationship with supply chain members means members integrate together in supply chain processes and support each other to achieve the same goals. Thus, risk sharing, supply chain strategies, and trust among members are needed to maintain and extend from the partnership phase. A better relationship with supply chain partners creates more flexibility in any aspect of the supply chain and leads to SCP.

***(e) Supply chain flexibility***

The definition of supply chain flexibility is "the ability of supply chain partners to restructure their operations, align their strategies, and share the responsibility, to respond rapidly to customers' demand at each link of the chain, to produce a variety of products in the quantities, costs, and qualities that customers expect, while still maintaining high performance" (V. Kumar, Fantazy, Kumar, & Boyle, 2006 p.305). Another definition of flexibility is responsiveness (Ibrahim & Hamid, 2014), which is defined as the availability of responsive and flexible partners in both upstream and downstream supply chains. In order to create supply chain

flexibility, effective partnership and collaboration are required in both upstream and downstream supply chains (Awais et al., 2014; Antonio Márcio T Thoméa et al., 2014).

Flexibility results in an improvement of service performance for unpredictable customer requirements, better demand planning, inventory visibility (Awais et al., 2014), increasing customer satisfaction (Beamon, 1999), shorter cycle time, and lower overall levels of inventory (Leavy, 2006), eliminating bottlenecks, and creating a higher level of performance (Antonio Márcio T Thoméa et al., 2014). Flexibility includes the management of supply chain members, and the coordination of resources, information, and technology (Awais et al., 2014; Mentzer et al., 2001). Due to an uncertain environment with unpredictable changes, an organization with the ability to respond and adapt itself tends to be a successful organization (V. Kumar et al., 2006). More flexibility and responsive systems allow an organization has advantages in a competitive environment. However, it is a fact that cost, uncertainty, and controllability are the trade-off for creating SCF (Tiwari, Tiwari, & Samuel, 2015). Therefore, the supply chain needs to balance the flexibility among supply chain partners to create a sustainable partnership.

***(f) External integration***

In supply chain studies, integration is considered as an important factor for surviving in the current economy and improving the competitiveness of supply chains (S. W. Kim, 2009; Lotfi et al., 2013). Supply Chain Integration (SCI) is the ability of the supply chain members to better prepare for environmental uncertainties, improve responsiveness, and create more flexibility (Wonga & Boon-itt, 2008). External integration is classified into customer and supplier integrations (Beheshti et al., 2014; Boon-itt & Paul, 2006; Huo, 2012b; Huo et al., 2016; C. W. Lee et al., 2007; Lii & Kuo, 2016; M. Zhang et al., 2016). Customer integration is the ability of a firm to collaborate with its key customers in terms of demand and customer requirements. The main idea of customer integration is a close customer relationship that enables firms to respond faster to customers (Sukati et al., 2012). This leads to improved customer service, lower costs, and higher profits by closely integrating internal functions and external functions from other members (S. W. Kim, 2009). Supplier integration is the ability of a firm to collaborate with the suppliers in a supply chain. The integration of a supply chain occurs

when two or more independent supply chain members work together for planning and executing production (Simatupang & Sridharan, 2002). SCI is a seamless operation among members within a supply chain. Integration among companies within supply chains usually leads to the highest levels of performance improvement (Naslund & Williamson, 2010; Zailani & Rajagopal, 2005). Some literature distinguishes the integration into (1) physical flows among suppliers, manufacturers, and customers, and (2) information flows within a supply chain (Naslund & Williamson, 2010; Zailani & Rajagopal, 2005). Thus, information sharing is considered as components of SCI.

Integration is also a source of partnership that is needed for companies to gain a competitive advantage (Lotfi et al., 2013). This results in overall cost reduction, better quality, and dependability (A Gunasekaran et al., 2004; Kohli & Jensen, 2010). A high degree of integration with suppliers and customers through a supply chain contributes measurable benefits for an organization's performance and the overall chain (Kache & Seuring, 2014; Zailani & Rajagopal, 2005). The goal of SCI is to integrate all supply chain partners into a single network to share common goals in developing a supply chain network. Thus, a supply chain partnership directly participates in SCI (M. Zhang et al., 2016). SCI is also related to the efficiency and effectiveness of IT including diffusion and adaptation of IT support and information sharing, interdependence, and the relationship among members of a supply chain (Huang et al., 2014; Woolliscroft et al., 2013).

***(g) Knowledge exchange***

Knowledge is one of the key contributions of SCP (Craighead et al., 2009; S. Lee, Hong, & Suh, 2016). It is considered as the critical resource of a firm (Ryoo & Kim, 2015). Sharing knowledge with other members in the supply chain requires communication, information sharing, supply chain strategies, and trust among the partner (Beske et al., 2014; Craighead et al., 2009; Luo, Sha, & Huang, 2013; Ryoo & Kim, 2015). In order to build and maintain a relationship with partners, members required not only information sharing but knowledge transferring (Borjeson, Gilek, & Karlsson, 2015). On the other hand, knowledge transfer among organizations and supply chains is required trust and a strong relationship with each other (Ensign, Lin, Chreim, & Persaud, 2014). Explicit and tacit knowledge often lead to value creation

and competitive advantage (Robert B. Handfield, Cousins, Lawson, & Petersen, 2015). According to Borjeson et al. (2015), the effects of both intra-organization and inter-organization depend on knowledge sharing to achieve higher SCP. Moreover, knowledge sharing often leads to better production in a supply chain (Beske et al., 2014; Craighead et al., 2009) and supports the construction of buyer-customer relationship and results in SCP improvement (Luo et al., 2013).

### 2.5.4 Supporting factors

Other than influential factors in three phases of supply chain development, there are other supporting factors that contribute to the success of each phase. Technology, trust, risk sharing, supply chain strategies, and innovation are critical factors for supporting the supply chain development.

***(h) Information Technology (IT)***

Due to the globalization era, IT has become increasingly important (Naslund & Williamson, 2010) in all phases of supply chain development. The seamless flow of information among members results in an improvement of information visibility, communication, commitments, and cooperation. IT is related to many parts of SCM, including information/knowledge sharing, systems integration, and communication among upstream and downstream suppliers (Kim et al., 2008). Implementation of IT creates capabilities to achieve better management in supply chain systems, creates new business model (Muegge and Mezen, 2017), supporting SCI and enabling the integration of both internal and external business functions (Vijayasarathy, 2010, Marinagi et al., 2014, Karakudilar and Sezen, 2012, Kim et al., 2008, Hamed et al., 2017a).

IT is a tool to create real-time information networks among organizations and their partners to create supply chain visibility and improve productivity and customer satisfaction (Dawson, 2002). Moreover, IT helps suppliers and buyers to better respond to customer demand (Marinagi et al., 2014). This leads to lead-time reduction and overall performance improvement with costs and inventory reductions (Zailani & Rajagopal, 2005, Lee et al., 2007). In addition, IT in a supply chain assists in transferring product ideas, product support, training aids, and technical knowledge

(Zailani & Rajagopal, 2005). IT plays an important role in KM as a tool for collecting, distributing and transferring knowledge. IT supports all business activities in supply chain systems in terms of speed and agility, improvement of decision-making, responsiveness, and productivity (Marinagi et al., 2014, Kohli & Jensen, 2010). Significantly, IT allows a supply chain to improve overall performance, increase responsiveness, and reduce uncertainties among members within a supply chain (Kache & Seuring, 2014).

***(i) Innovation***

Due to the improvement of the competitiveness of global supply chains, the differentiation of products, services, and/or processes in SCM is increasingly important. Innovation is the improvement or fundamental development of products, services, and processes, including a change in value activities of the organization (Panayides & Venus Lun, 2009). Innovation supports an increasing of organizational competitive advantage (Craighead et al., 2009). It is defined as the development and adaptation of a new idea or behavior. Supply chain innovation covers many aspects, such as novel products, services, processes, policies, and programs implemented in a supply chain system (Panayides & Venus Lun, 2009). The essence of innovation is strongly influenced by the knowledge which supports the development of information and technology (Craighead et al., 2009, Bello et al., 2004). Coordination and collaboration among members of a supply chain are also necessary for developing innovative supply chain processes (Hwang et al., 2008). Since new processes in supply chain systems are considered as innovations that lead to an increase in mutual profits and decrease of cost (Bello et al., 2004), they are critical influential factors of SCP (Lin et al., 2010). Companies place much attention on innovativeness since it is considered as an important linkage to organization performance improvement and sustainable development (Panayides & Venus Lun, 2009, Shrivastava et al., 2016).

***(j) Risk sharing***

The study of Giannakis & Papadopoulos (2016) classified risks in a supply chain into two main categories: risks that are caused by the organizations among a supply chain, and risks that are caused by the surrounding environment .Uncertainty is defined as a risk among members in supply chain processes (Avelar-Sosa et al., 2014). The uncertainty influences global supply chains in managing the risk that affects SCP (Meixell & Gargeya, 2005). A goal of SCM is to manage uncertainty within a system. Hence, risk management is a major part of SCM (Giannakis & Papadopoulos, 2016). The risk is generally interpreted as unreliability and uncertainty of a supply chain process, including the instability of the business environment. Moreover, risk causes a negative impact on inventory, lead-time, flexibility, and responsiveness (Avelar-Sosa et al., 2014). Risks are also considered as a cause of supply chain disruption .Therefore, sharing risk along a supply chain significantly influences long-term commitment and supply chain partnership (Lambert & Cooper, 2000).

***(k) Supply chain strategies***

The strategy is a primary concept in an organization and SCM. The study of Lin et al. (2010) defined supply chain strategy as market and resource orientations .Market orientation is related to an organization's culture, including coordination and information sharing, systematic information collection among customers and competitors, and responsiveness to market change and competitor action .Resource orientation strategy is mainly related to the resources in supply chain systems including knowledge, organization, and physical resources. Due to the changing business environment, the strategy needs to be developed and adjusted regularly in order to maintain competitiveness and achieve a high level of customer requirements (Awais et al., 2014). On the other hand, strategy plays an important role in a business management. Supply chain strategy is an important source of a successful alliance (Awais et al., 2014). Strategy orientations and innovations influence the enhancement of SCP (Yusoff et al., 2016). By this reason, companies should focus on the relationships among members to create better processes, coordination systems, and strategic partners (Lin et al., 2010). Hence, the collaboration, information sharing, and

integration of strategies among the members are key influences for establishing value in a supply chain partnership (Awais et al., 2014).

***(l) Trust***

Trust is an essential element to establish and support a partnership in SCM (Ryu et al., 2009). It is defined as the confidence of other members for collaborating and achieving a specific purpose .Trust plays an important role in collaboration, innovation capability, strategic development among partners (Yeung et al., 2009; Fawcett et al., 2012), and sustainability and innovation development (Rohrbeck et al., 2013). When trust is created among members, firms are willing to exchange information and collaborate among themselves .

In order to create a high level of trust in an alliance, companies need to "do as they promise" (Fawcett et al., 2012). In addition, collaboration and innovation generate a positive effect on trust in a supply chain network, which results in performance improvement in a supply chain (Panayides & Venus Lun, 2009). According to Panayides & Venus Lun (2009), trust among organizations can be accomplished by the willingness to achieve the requirements of a relationship to increase mutual benefits. Moreover, an improvement in responsiveness critically affects the trust in an alliance (Handfield & Bechtel, 2002) and is considered as a critical part of sustainability and collaborative partnership (Fawcett et al., 2012).

***(m) Sustainable and environmental aspects***

Since SCP require sustainable supply chain development (Uysal, 2012), sustainable and environmental aspects are key factors in a supply chain. Sustainability is the degree of the organization that concern on the impact of three main dimensions namely society, economy, and natural environment ( Kumar & Rahman, 2016, Formentini & Taticchi, 2016) . The study on Giannakis & Papadopoulos (2016) concludes that the sustainability in supply chain leads to cost reduction and an increase of organization long-term profitability. However, sustainable development generally creates a trade-off between costs and environmental degradation in short-run for supporting the sustainable development (Uygun & Dede, 2016). Since sustainable development is a result of environmental and social consideration in supply chain operation, green supply chain is considered as a part of the development of supply chain

sustainability (Formentini & Taticchi, 2016). It motivates technological innovation to improve the environmental impacts of products and operation processes (Uygun & Dede, 2016).

Apart from the consideration of environmental impact, sustainability influences on many parts of a supply chain including risks, products development, knowledge, and organizational culture, materials, information, and capital (Grimm et al., 2014, Formentini & Taticchi, 2016). The communication and cooperation among supply chain members are important to supply chain systems. Hence, strong buyer-supplier relationship significantly influences on supply chain sustainability (Kumar & Rahman, 2016) with the key goal of improving the competitiveness of the organization (Formentini & Taticchi, 2016). After the partnership is created, the alliance got the benefits of flexibility, integration, and sustainability of the entire system. Sustainability is the final result from flexibility and integration of a supply chain system.

### 2.5.5 Supply chain as an ecosystem

The supply chain also considers on activities and relationships among the network, the related activities and influence on the organizations including manufacturing, logistics, materials, distribution, and transportation (Ibrahim & Hamid, 2014). The relationship and interaction of internal processes, suppliers, and customers in the supply chains are leading to the performance improvement of the system (Zailani & Rajagopal, 2005). The key element of supply chain collaborative includes sharing information (Defee et al., 2010), knowledge (Naslund & Williamson, 2010), risk and reward among the partners in order to achieve the mutual goal (Min et al., 2005). Supply chain management is not focused only on supply chains, but also the overall networks of the system (Schaltegger & Burritt, 2014). Thus, the actors within the supply ecosystem consist of suppliers, lead producers, competitors, and other stakeholders including institutions (value proposing social, economic actors, and technology) (Lusch, 2011). The term ecosystem is appropriated for implementing in a supply chain system because it includes the flows of both human, nature, and energy among each actor (Vargo & Lusch, 2015). A set of active and inactive members within a supply chains are all related and could be contributing to a system at anytime (Schaltegger & Burritt, 2014).

The term "ecosystem" is used to identify the supply chain because it represents a system consisting of humans and other non-human actors such as the environment (Vargo & Lusch, 2015, Lusch et al., 2016). Thus, the integration of both human and non-human interaction in the supply chain is significant in terms of supply chain development. Each actor in the supply chain has direct and indirect relationships that influence the performance of the other actors in the supply chain system (Mentzer et al., 2001). Both active and inactive members of the supply chain contribute in SCM (Schaltegger & Burritt, 2014). According to Lusch et al. (2016), the network of organizations with resource integration and service exchanges among actors influenced by shared institutional arrangements can be viewed as ecosystems. In supply chain research, they consider the geographical markets, including domestic and international cultures and laws as a part of service ecosystems studies (Lusch et al., 2016). A service ecosystem is a large system with loose relationships among the actors and institutions for co-creating and offering value. Therefore, a supply chain is a part of the service ecosystem (Lusch, 2011).

## 2.6 Supply chain performance (SCP)

SCM attempt to increase the quality of outputs and reduce overall costs among a supply chain (Dawson, 2002). SCP is the ability to react to any changes, with the dynamic collaboration among members within a supply chain (Lai & Cheng, 2003). Likewise, it is directly related to any activities within organizations including manufacturing, logistics, materials handling, distributing, and transporting functions (Ibrahim & Hamid, 2014). Since SCP is measured by the quality and cost of overall supply chain activities (Zelbst et al., 2009), SCP is a result of supply chain activities.

According to the definition provided by the previous research, there are some factors that are closely related to each other; for instance, collaboration and coordination, and responsiveness and reliability. Since coordination is frequently mentioned in terms of collaboration (Costantino et al., 2014) and integration (Ibrahim & Hamid, 2014; Aryee et al., 2008; Lotfi et al., 2013) coordination is concerned as a sub-topic under collaboration and integration. Responsiveness and reliability are related to the capability of the firm to deliver the product with speed and accuracy (Bourlakis

et al., 2014a; Ganga & Carpinetti, 2011). Thus, this can be considered as a part of supply chain flexibility. According to Warren H. Hausman (2002), quality is excluded in a supply chain management. "The diagnosis and improvement of quality involves factors which are quite separate from factors used to improve SCM". Since quality is an output for manufacturing process rather than the whole supply chain, the quality of the output or error in production process is excluded in SCP.

Resource-based view (RBV) is a distinctive method for create competitive advantage based on the assets and resources t (Barney, 1991; McIvor, 2009). The potential resource can create competitive advantage to the organization and supply chain system. It is important to identify the organization activities that related with the achievement of supply chain performance and competitive advantage. Therefore, the RBV emphasis on the organization's capabilities that influence on competitive position and performance (McIvor, 2009). According to RBV concept, resources or inputs of the firms that enable their activities can create competitive advantages and performance (Bridoux, 2004). However, the resources can be broadly defined to cover all tangible and intangible inputs of the organization (Pankaj, 2009). Brumagin (1994), defined four levels of corporate resources; production/maintenance, administrative, organization learning, and strategic vision resources. Since, SCM is a management concept of two or more members in a supply chain working together for delivering the product or service to the end customers. The key concept of SCM focuses on the flow of resources in term of goods and information to respond to the demand (Ibrahim & Hamid, 2014; Merschmann & Thonemann, 2011; Nagarajan et al., 2013; Sánchez & Pérez, 2005). On the other hand, the SCP depends on the ability of a group of firms for responding to the demand. The capability and ability of a supply chain can considered as resources of a supply chain in RBV concept. Therefore SCF and SCI are important resources that drive SCP (Arnold et al., 2015; Beamon, 1999; Duclos et al., 2003; Huo et al., 2016; S. Kumar et al., 2012; Laosirihongthong et al., 2011; Merschmann & Thonemann, 2011; Moon et al., 2012; Nagarajan et al., 2013; Stevenson & Spring, 2007; Antonio Márcio T Thoméa et al., 2014; Wong et al., 2015).

SCF and SCI are defined as the important resources of SCP (Arnold et al., 2015; Awais et al., 2014; Duclos et al., 2003; Huo et al., 2016; V. Kumar et al., 2006; Antonio Márcio T. Thoméa, Luiz Felipe Scavarda, Sílvio R.I. Pires, Paula Ceryno, & Katja

Klingebiel, 2014; Wong et al., 2015). The study of Awais et al. (2014), concluded that flexibility is a major driver of firm's performance and supply chain. Integration is and ingredient of SCP, the higher collaboration and communication within and between organizations are a source of competitive advantage and smoothen the activities of a supply chain (Kohli & Jensen, 2010; Montoya-Torres & Ortiz-Vargas, 2014; Usha Ramanathan & Angappa Gunasekaran, 2014; Simatupang & Sridharan, 2005). Moreover, internal and external integration also create flexible ability of a supply chain that leads to better response to customers (Awais et al., 2014; Boon-itt & Paul, 2006; Duclos et al., 2003; A Gunasekaran et al., 2004; Kohli & Jensen, 2010; Lii & Kuo, 2016; Mentzer et al., 2001). Therefore, the various terms of flexibility and integration in the automotive supply chain needed to clarify for evaluating the critical impact on SCP. Thus, three main hypotheses of this study is set to measure the relationship between SCI, SCF, and SCP as shown in Figure 2.10.

*H1.* SCI influence on SCP

*H2.* SCI influence on SCF

*H3.* SCF influence on SCP

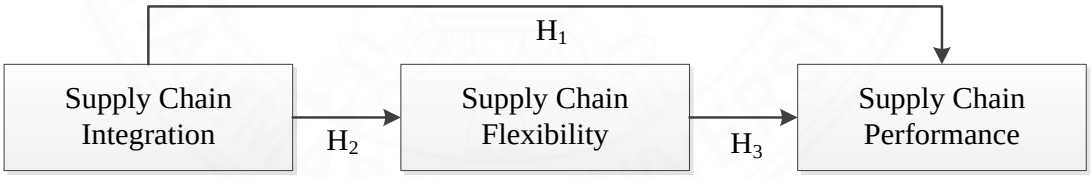


**Figure 2.10** Theoretical framework

Source: Kamel Aissa Fantazy, Kumar, and Kumar (2009)

### 2.6.2 Supply chain integration (SCI)

Integration is one of the important aspects of SCM (Huo et al., 2016; Wong et al., 2015). The main goal of SCI is to integrate supply chain partners into a single union network that shares the same common goals for developing a supply chain network. Thus, the firms require the integration of both product and processes flow between the supply chain (Huang et al., 2014). The integration of key business processes from the

customer through the suppliers can create more value for both customers and the suppliers side (Okongwu et al., 2016). Integration among the members of a supply chain is an important source of SCF (A Gunasekaran et al., 2004; Kohli & Jensen, 2010). and achieve a better response to customers (Zailani & Rajagopal, 2005)(Duclos et al., 2003)(Boon-itt & Paul, 2006) Therefore, SCI requires both integrations from upstream suppliers and downstream customers (Lii & Kuo, 2016).

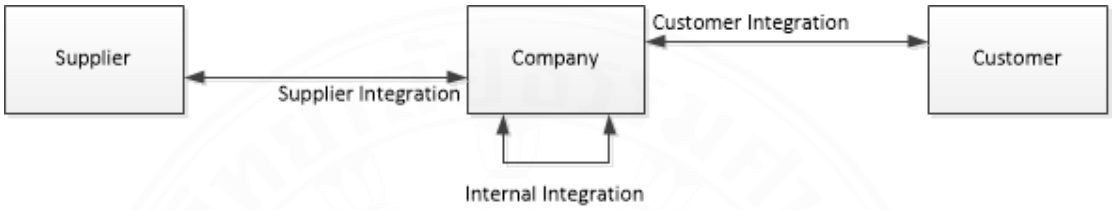


**Figure 2.11** Framework of SCI

Integration in a supply chain can be divided into internal and external integration (Boon-itt & Paul, 2006)(C. W. Lee et al., 2007)(Wonga & Boon-itt, 2008). Internal integration is the ability of the department within the firm for working together. Internal integration plays an important role in cost-containment (Wonga & Boon-itt, 2008), quality, and dependability (A Gunasekaran et al., 2004; Kohli & Jensen, 2010) of a supply chain. External integration is a degree of the firm working with suppliers and customer within the supply chain (Huo et al., 2016; Lii & Kuo, 2016). Therefore, both types of SCI are supported by integrated information technology for information sharing, communication, and collaboration within a supply chain (Aryee et al., 2008; Sukati et al., 2012).

SCM is a result of the successful coordination and integration of all activities in a supply chain since the raw material stage until deliver to the final customer (Lii & Kuo, 2016). SCI is a situation that two or more companies in a supply chain interact and collaborate for conducting supply chain activities together (Simatupang & Sridharan, 2002, Wonga & Boon-itt, 2008). SCI can be a seamless operation among members to achieve a higher level of SCP (Zailani & Rajagopal, 2005). It is an important component to manage any environmental uncertainty and the effects on competitive capability. To achieve the goal of SCI, information sharing, collaboration,

and cooperation among supply chain members are required (Hung et al., 2011). A majority of SCI research classifies integration into internal and external integration (Boon-itt & Paul, 2006; Lee et al., 2007; Huo, 2012; Beheshti et al., 2014; Zhang et al., 2016; Huo et al., 2016; Lii & Kuo, 2016)

To achieve the goal of SCI, information sharing, collaboration, and cooperation among supply chain members are required (Hung, Ho, Jou, & Tai, 2011). Majority of SCI research classifies integration into internal and external integrations (Beheshti et al., 2014; Boon-itt & Paul, 2006; Huo, 2012a; Huo et al., 2016; C. W. Lee et al., 2007; Lii & Kuo, 2016; M. Zhang et al., 2016) as demonstrated in Table 2.9. Supplier integration always related to the total operating cost of a supply chain (Punniyamoorty et al., 2012). Therefore, effective SCM requires the integration of internal business processes and external activities among suppliers and customers (Wonga & Boon-itt, 2008). The higher the degree of integration with suppliers and customers, the greater the measurable benefit on an organization's performance and overall chain (Kache & Seuring, 2014; Zailani & Rajagopal, 2005). Integration among members of a supply chain is a source of competitive advantage (Zailani & Rajagopal, 2005), and create SCF (A Gunasekaran et al., 2004; Kohli & Jensen, 2010). The hypotheses of intra-relationship within SCI are shown as the following.

$H_{1a.}$ Internal integration positively affects the supplier integration

$H_{1b.}$ Internal integration positively affects the customer integration

$H_{1c.}$ Supplier integration positively affects the customer integration

**Table 2.9** Type of integration

| Type of integration | Definition | Publication |
|---|---|---|
| Internal integration | Internal integration is the degree of the firm to synchronize and collaborate with internal business functions. It is related to information sharing, cross-functional strategy, and working together across the business function. Internal integration involves in product design, procurement, production, marketing, | (Boon-itt & Paul, 2006) (C. W. Lee et al., 2007) (Wonga & Boon-itt, 2008) ( Huo, 2012b) (Beheshti et al., 2014) (M. Zhang et |

| | | |
|---|---|---|
| | and distribution to meet the customer requirement with cost minimization. | al., 2016) ( Huo et al. , 2016) (Lii & Kuo, 2016) |
| External integration | External integration is a degree of the firm to collaborate with external actors in a supply chain including upstream (supplier integration) and downstream (customer integration).<br>• Supplier integration is occurred through information sharing and involved in planning and decision making.<br>• Customer integration is the information flow provided by customers to the supplier.<br>External integration helps firms to manage and execute among partners and members of a supply chain to enhance their competitive advantages. | (Boon-itt & Paul, 2006) (C. W. Lee et al., 2007) (Wonga & Boon-itt, 2008) ( Huo, 2012b) (Beheshti et al., 2014) (M. Zhang et al., 2016) (Wiengarten et al., 2016) ( Huo et al. , 2016) (Lii & Kuo, 2016) |

Supplier integration is related to the total operating cost of a supply chain (Punniyamoorty et al., 2012) .Therefore, effective SCM requires the integration of internal business processes and external activities among suppliers and customers (Wonga & Boon-itt, 2008). The higher the degree of integration with suppliers and customers, the greater the measurable benefits for an organization's performance and overall supply chain (Zailani & Rajagopal, 2005; Kache & Seuring, 2014). Integration among members of a supply chain is a source of competitive advantage (Zailani & Rajagopal, 2005), and creates SCF (Gunasekaran et al., 2004; Kohli & Jensen, 2010).

SCI cover the following activities in SCM;

- Collaboration – Collaboration is defined as sharing and exchanging information and planning among two or more independent companies. Its key elements include sharing information, knowledge, risk, and reward among partners in order to achieve mutual goals. Therefore, the collaborative strategic

development across functions within a supply chain is an important part of SCI (Wonga & Boon-itt, 2008) (Huang et al., 2014) (Ibrahim & Hamid, 2014)

- Communication – It is represent the ability of the firm to communicate among each other in exchange data, procurement, and solve the problem in a supply chain. Therefore, communication infrastructure within a company and supply chain needed to be appropriate and can be function across partners (Wonga & Boon-itt, 2008) (Huo et al., 2016) (Zhang et al., 2016)
- Cross-functional cooperation - Cross-functional is how well the worker across the business function can working together to achieve a production plan and overcome the fluctuation in a supply chain. (Wonga & Boon-itt, 2008) (Fayezi & Maryam Zomorrodi, 2015) (Huo et al., 2016)
- Information sharing - Information sharing the availability of information and knowledge sharing among partners within a network. It is considered as an important supply chain tool for a successful SC, and coordination, and for improving firm performance. Information sharing is considered an issue in SCM. This is related to trust and integration among partners (Ibrahim & Hamid, 2014; Wu et al., 2014) to share their information. When members in a supply chain are willing to share information, they require appropriate technological support for transmitting the information among partners (Li & Zhang, 2015). (Zhao, Xie, & Leung, 2002) (Zailani & Rajagopal, 2005) (Wonga & Boon-itt, 2008) (Naslund & Williamson, 2010) (Wong et al., 2015).

SCI is divided into two aspects; which are a hard issues (technology) and soft issues (collaborative strategies) (Naslund & Williamson, 2010; Zailani & Rajagopal, 2005). SCI represents a high-level collaboration and longer-term perspective compared to supply chain collaboration (Naslund & Williamson, 2010). Collaboration and technology can assist supply chain members to reduce the gap and create people networks across the chains. In the study of Karakudilar and Sezen (2012), supply chain collaboration, information technology (IT) and conflict avoidance are studied as influence variables on the Turkish auto part suppliers and their major customers.

***Strategic Aspect in SCI***

Integration has been defining by the higher level of interaction and collaboration across firms, customers, and suppliers (Huang et al., 2014). According to Huang et al. (2014) information, sharing and communication between members are considered as important factors on SCI. Boon-itt & Paul (2006) study on supply chain integration in the Thai automotive industry, they are mentioned that supply chain integration (internal, supply, and customer integration) is an important component to manage environmental uncertainty and effect on competitive capability.

According to Aryee et al. (2008), they have divided collaboration into internal and external collaboration. Internal is representing linkages and relationships within a single organization. While external collaboration includes the relationship with suppliers and customers. Cooperation means complementary, coordinated activities among the supply chain member, it is necessary for effective supply chain.
Coordination among the supply chain is related to collaboration between internal department of the organization as well as an external collaborate across company (Ibrahim & Hamid, 2014).

***Information Technology (IT) Aspect in SCI***

Due to the globalization era, the information technology (IT) has become increasingly important (Naslund & Williamson, 2010). IT is a key factor for supporting SCI (Huang et al., 2014; Catherine Marinagi, Trivellas, & Sakas, 2014; Sukati et al., 2012; Wong et al., 2015). Information technology is one of the important factors for manufacturing companies to obtain a competitiveness of speediness, flexibility, collaboration (B. G. Kim et al., 2008). Information sharing is mentioned as a part of SCI (Wong et al., 2015) since adaptation of technology and information sharing and interdependence in a supply chain are influenced by SCI (Huang et al., 2014).

Implementing information technology is required for the firms for enhancing supply chain integration (Sukati et al., 2012). IT is a primary factor in creating integration and flexibility. The most critical roles of the IT function is to support the flow of transactions among users within a supply chain to response the business needs (Arnold et al., 2015). Information technology and relationship among a supply chain members are a key variable of SCI (Leavy, 2006). IT system can support the integration

in term of electronic information sharing support to enabling mechanism of information interchange and coordination among members of a supply chain (Wong et al., 2015). Technical requirements and arrangements between partner firm they serve the common purpose of facilitating coordination among partner firms by managing information processing and organizing information distribution in support of their respective activities and responsibilities

### 2.6.1 Supply chain flexibility (SCF)

Due to the change in uncertain environment, a successful organization needed to be more responsive and adaptive (V. Kumar et al., 2006) Therefore, flexibility is obviously considered as a key influential factor on the improvement of SCP (Awais et al., 2014). SCF refers to the ability of the supply chain to response on the change such as customer demand, environmental change, global trends, and crisis (Huang et al., 2014). It is generally related to the ability to react due to the uncertain situation (Antonio Márcio T. Thoméa et al., 2014). Moreover, it can allow supply chains to adjust its activities including source and planning to maximize the operation efficiency (Chandak et al., 2014). More flexibility and responsive allow an organization to take advantage in a competitive environment. SCF consists of the internal ability to be flexible in terms of operation and manufacturing (Duclos et al., 2003) and external ability to adjust the processes in a supply chain (Ndubisi et al., 2005). Production volume, transportation schedule, manufacturing processes, and deliverability are used for measuring the level of flexibility (Beamon, 1999).

Flexible in a supply chain aim to react on uncertain of the demand and unpredictable event with the shortest time at least cost (Yasushi Ueki, 2013). Flexibility among the automotive supply chain is considered as a major effect on customer satisfaction (Antonio Márcio T. Thoméa et al., 2014). The practical research of flexibility in the automotive industry can become a reference for other industries to better respond to the customers. The need for improvement of SCF in the automotive industry has been mentioned by many researchers (Pérez & Sánchez, 2001) (Sánchez & Pérez, 2005) (Boon-itt & Paul, 2006). The majority of automotive components supplied by suppliers, a only limited parts are produced by the automobile assemblers (Pérez & Sánchez, 2001). Moreover, the study of (Mentzer et al., 2001)(Awais et al.,

2014) concluded that level of integration among supply chain members is a critical source for creeating SCF.

Flexibility is a major component of SCP since it contributes to operating cost and response time of a supply chain (Duclos et al., 2003; Kumar et al., 2006; Thoméa et al., 2014a; Arnold et al., 2015; Awais et al., 2014; Moon et al., 2012; Merschmann & Thonemann, 2011; Beamon, 1999). SCF is mentioned in many studies as an important component of SCM (Duclos et al., 2003; Kumar et al., 2006; Thoméa et al., 2014a; Arnold et al., 2015; Awais et al., 2014). The main goal of flexibility is to handle the variations and uncertainty and maintain profitability (Kara & Kayis, 2004). Flexibility refers to the capability of a firm or system to respond on the changing environmental by customizing the products, adjusting production planning, and managing sources to meet customer requirements (Punniyamoorty et al., 2012; Huang et al., 2014; Thoméa et al., 2014a; Chandak et al., 2014). The definition of SCF from Kumar et al. (2006) is "the ability of supply chain partners to restructure their operations, align their strategies, and share the responsibility to respond to customers' demand at each link of the chain, to produce a variety of products in the quantities, costs, and qualities that customers expect, while still maintaining high performance". According to the previous supply chain research, SCF is a multi-dimensional factor consists of various aspects based on the research direction. In this paper, we summarize the flexibility concept as shown in Table 2.10.

Since flexibility is important to determine financial and market performances, it is vital to understand its antecedents. Flexibility requires both internal and external collaboration of the members within a system (Ndubisi et al., 2005). According to Table 2.4, the components of SCF can be divided into four main categories: Production related flexibility, organization related flexibility, logistics related flexibility, and supplier-related flexibility. Therefore, flexibility requires coordination between the manufacturer and its suppliers (Ndubisi et al., 2005). SCI is a significant component to create flexibility among the entire supply chain to achieve a better response for customers (Duclos et al., 2003; Gunasekaran et al., 2004; Boon-itt & Paul, 2006; Kohli & Jensen, 2010; Lii & Kuo, 2016).

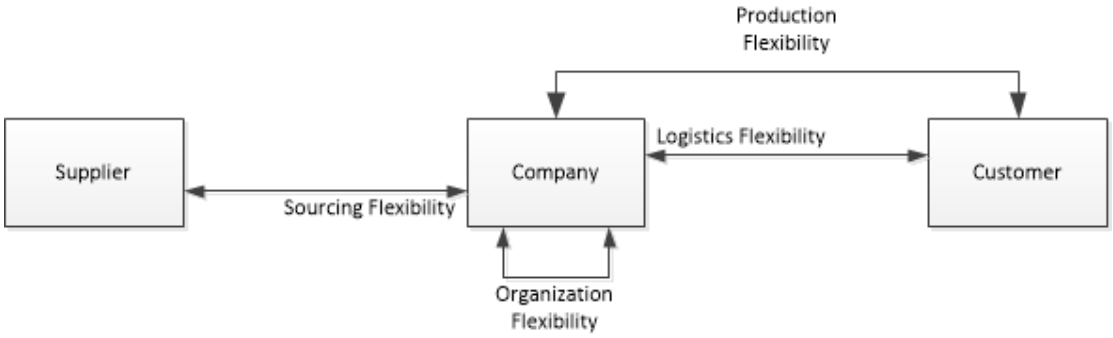


**Figure 2.12** Framework of SCF

Flexibility is the key function of SCM, created by a collaboration of supply chain members, coordination of resources, and integration of information and technology (Awais et al., 2014; Mentzer et al., 2001). SCF including the internal ability to be flexible in terms of operation and manufacturing (Duclos et al., 2003) and the availability of responsive and flexibility partner in both upstream and downstream supply chains (Ibrahim & Hamid, 2014). Thus, SCI is necessary to make the entire SCF (Duclos et al., 2003; A Gunasekaran et al., 2004; Kohli & Jensen, 2010). SCF creates the ability to respond to the variation of demand. SCF is influenced in many dimension of SCM, the increase of flexibility supports on supply chain management in many aspects; including the reducing of backorders, lost sales, late order (Beamon, 1999), bottlenecks (S. W. Kim, 2009), cycle time, overall inventory's level (Leavy, 2006), and increasing of demand planning, inventory visibility (Awais et al., 2014), and create higher level of supply chain performance (S. W. Kim, 2009; Antonio Márcio T. Thoméa et al., 2014).

**Table 2.10** Type of flexibility in supply chain

| Area | Type of flexibility | Definition | Publication |
|---|---|---|---|
| Product | Product flexibility | The ability of a supply chain to change a product specification based on customer requirements with low additional time and cost. | (V. Kumar et al., 2006) (Sánchez & Pérez, 2005) |
| | New product flexibility/ Launch flexibility | The ability to produce new products to meet the market demand with low additional time and cost. | (V. Kumar et al., 2006) (Sánchez & Pérez, 2005) |
| | Customer service flexibility | The ability to support the additional requirement from the customer. | (Zailani & Rajagopal, 2005) |
| | Market flexibility/ Response flexibility | The ability to create or modify new or existing products (mass customize) to serve customer demand. | (Duclos et al., 2003) (Sánchez & Pérez, 2005) |
| Organization | Organizational flexibility | The ability to manage the labor force and skills to respond service/demand requirements. | (Duclos et al., 2003) |
| | Operation system flexibility | Manufacturing facilities and processes adjustability to vary volumes, modify the product, change products and services output to response emerging customer trends at each department of organization and supply chain. | (Duclos et al., 2003) (Moon et al., 2012) |

| | | | |
|---|---|---|---|
| | Order flexibility | The ability to change or rearrange order size and volume during logistics operation. | (Zailani & Rajagopal, 2005) |
| | Volume Flexibility | The ability to effectively rise or drop the production output to refect the unstable demand | (Sánchez & Pérez, 2005) |
| Logistics | Logistics flexibility | Ability to change the location and/or postpone receive and deliver a product with cost-effective. | (Duclos et al., 2003) |
| | Location flexibility | The ability to change the service location to respond to customers. | (Zailani & Rajagopal, 2005) |
| | Routing flexibility | According to the research, routing flexibility cover many parts in a supply chain. It is represent the various routes of the production to the customer (eg. machines, material handling, and transportation). | (Sánchez & Pérez, 2005) |
| | Delivery time flexibility | The ability to chagen the delivery schedule for responding the customer requirements. | (Zailani & Rajagopal, 2005) |
| | Distribution flexibility | Distribution flexibility related to the availability of warehouses, inventory, and other distribution/logistics facilities to delicery goods among a supply chain. | (Moon et al., 2012) |
| | Delivery flexibility | The ability of the members in a supply chain to deliver the product with less additional cost and time sinceraw material sourcing process to deliver to final customers. | (V. Kumar et al., 2006) (Sánchez & Pérez, 2005) |

| | | | |
|---|---|---|---|
| Sourcing | Sourcing flexibility | The ability of the members in a supply chain to adjust supply level with less additional cost and time to meet customer demand. It also including the ability to manage suppliers and influence them to provide quality materials and services. | (V. Kumar et al., 2006) (Moon et al., 2012) (Sánchez & Pérez, 2005) |
| | Responsive flexibility | The capability of members in a supply chain to respond on market change with low additional time and cost to satisfy customer demand | (V. Kumar et al., 2006) |
| | Supply flexibility | Ability to adjust the products supply to meet the demand or add/remove suppliers to complete a task. | (Duclos et al., 2003) |

**Table 2.11** Summary of supply chain flexibility component

| Publication | Narain, Yadav, | Mohamed, | Petroni and | F T S Chan | Duclos et al. | Kara & Kayis | Chang, Lin, | Ndubisi et al. | Sánchez and | Zailani & | V. Kumar et al. | P. Kumar, | Kamel Aissa | Larso, Doolen, | Esturilho and | Moon et al. | K. a. Yu, | Tiwari et al. | Rojo, Llorens- | Jafari, Nyberg, |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Production flexibility (PF)** | | | | | | | | | | | | | | | | | | | | |
| Product flexibility | | | | | | | | ● | ● | | ● | | ● | | | | ● | | | |
| New product flexibility/ Launch flexibility | | | | ● | | | ● | ● | ● | | ● | | ● | ● | | | ● | ● | | |
| Volume Flexibility | | | ● | ● | | ● | ● | ● | ● | | | ● | | ● | | | ● | ● | | |
| Market flexibility/ Response flexibility/Modification flexibility | | | | | ● | | | | ● | | | | | ● | | | | ● | | |
| **Operation flexibility (OF)** | | | | | | | | | | | | | | | | | | | | |
| Process flexibility | ● | | ● | | | ● | | | | | | ● | | | | | | ● | | |
| Machine flexibility | | ● | | ● | | ● | | | | | | | | ● | ● | | | ● | | |
| Material handling flexibility | ● | | | ● | | ● | | | | | | | | ● | ● | | ● | | | |

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Organizational flexibility/labor flexibility | | | | ● | ● | ● | | | | | | | | ● | ● | | | ● | | |
| Operation system flexibility | | | | ● | ● | | | | | | | | | ● | | ● | | | ● | |
| Routing flexibility | ● | ● | ● | ● | | | | | ● | | | ● | ● | | ● | | | ● | | |

| Publication | Narain et al. | Mohamed et | Petroni and | F T S Chan | Duclos et al. | Kara & Kayis | Chang et al. | Ndubisi et al. | Sánchez and | Zailani & | V. Kumar et | P. Kumar et | Kamel Aissa | Larso et al. | Esturilho and | Moon et al. | K. a. Yu et al. | Tiwari et al. | Rojo et al. | Jafari et al. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Logistics flexibility (LF)** | | | | | | | | | | | | | | | | | | | | |
| Order flexibility | | | | | | | | | | ● | | | | | | | | | | |
| Logistics flexibility | | | | | ● | | | | | | | ● | | | | | | | | ● |
| Location flexibility | | | | | | | | | | ● | | ● | | | | | | | | |
| Delivery time flexibility | | | | | | | | | | ● | | | | | | | | | | |
| Distribution flexibility | | | | | | | | | | | | | | | | ● | | | ● | |
| Inventory flexibility | | ● | | | | | | | | | | | | | | | ● | | ● | |
| **Sourcing flexibility (SF)** | | | | | | | | | | | | | | | | | | | | |
| Sourcing flexibility | | | | | | | | | ● | | ● | ● | ● | | | ● | | | ● | |
| Delivery flexibility | | | | ● | | | | | ● | | ● | ● | ● | | | | | | | |
| Responsive flexibility | | | | | | | | | | | ● | | | | | | | | | |
| Supply flexibility | | | | | ● | | | | | | | | | | | | | | | |
| Supplier flexibility | | | | | | | | | | | | ● | | | | | | | | |

Integration of the supply chain is an important source of SCF and achieves a better response to customers (Boon-itt & Paul, 2006; Duclos et al., 2003; A Gunasekaran et al., 2004; Kohli & Jensen, 2010; Lii & Kuo, 2016). Therefore, flexibility requires coordination between members of a supply chain including manufacturer and suppliers (Ndubisi et al., 2005), SCI is a significant component to create flexibility among the complete supply chain system (Duclos et al., 2003; A Gunasekaran et al., 2004; Kohli & Jensen, 2010). The following hypothesizes are tested to define the relationships between SCI and SCF.

$H_{2a.}$ Internal integration positively affects production flexibility
$H_{2b.}$ Internal integration positively affects organization flexibility
$H_{2c.}$ Internal integration positively affects logistics flexibility
$H_{2d.}$ Internal integration positively affects Sourcing flexibility
$H_{2e.}$ Supplier integration positively affects production flexibility
$H_{2f.}$ Supplier integration positively affects organization flexibility
$H_{2g.}$ Supplier integration positively affects logistics flexibility
$H_{2h.}$ Supplier integration positively affects Sourcing flexibility
$H_{2i.}$ Customer integration positively affects production flexibility
$H_{2j.}$ Customer integration positively affects organization flexibility
$H_{2k.}$ Customer integration positively affects logistics flexibility
$H_{2l.}$ Customer integration positively affects Sourcing flexibility

Since flexibility is important to determine financial and market performances, it is vital to understand its antecedents. Effective collaboration among internal and external entities is important for creating flexibility in a supply chain (Ndubisi et al., 2005). However, SCF is a multi-dimensional factor consists of a various aspect based on the research direction (Beamon, 1999; Nagarajan et al., 2013; Stevenson & Spring, 2007). The summary of the flexibility concepts is classified into sub-factors shown in Table 2.11.

Flexibility is a major component of SCP since it contributes to operating cost and response time of a supply chain (Arnold et al., 2015; Awais et al., 2014; Beamon, 1999; Duclos et al., 2003; V. Kumar et al., 2006; Merschmann & Thonemann, 2011; Moon et al., 2012; Antonio Márcio T. Thoméa et al., 2014). Moreover, many literatures claim that higher SCF leads to higher level of SCP (S. W. Kim, 2009; Antonio Márcio T. Thoméa et al., 2014). Therefore, the following hypothesizes are imperative to identify the relationship between flexibility and SCP.

$H_{3a.}$ Production flexibility positively affects organization flexibility
$H_{3b.}$ Production flexibility positively affects logistics flexibility
$H_{3c.}$ Production flexibility positively affects sourcing flexibility
$H_{3d.}$ Production flexibility positively affects supply chain performance
$H_{3e.}$ Organization flexibility positively affects production flexibility
$H_{3f.}$ Organization flexibility positively affects logistics flexibility
$H_{3g.}$ Organization flexibility positively affects sourcing flexibility
$H_{3h.}$ Organization flexibility positively affects supply chain performance
$H_{3g.}$ Logistics flexibility positively affects production flexibility
$H_{3h.}$ Logistics flexibility positively affects organization flexibility
$H_{3i.}$ Logistics flexibility positively affects sourcing flexibility
$H_{3j.}$ Logistics flexibility positively affects supply chain performance
$H_{3k.}$ Sourcing flexibility positively affects production flexibility
$H_{3l.}$ Sourcing flexibility positively affects organization flexibility
$H_{3m.}$ Sourcing flexibility positively affects logistics flexibility
$H_{3n.}$ Sourcing flexibility positively affects supply chain performance

However, the relationships among the different types of SCF are unidentified. Before analyzing a structural model in SEM, the directions of each sub-factor have to be identified. The literature review of SCI and SCF were analyzed to obtain the relationship and the impact of one sub-factor variable to another sub-factor. In SCI research, internal integration is frequently mentioned as a source of external integration including both supplier and customer integrations (Huo, 2012a; Willis et al., 2016; W. Yu, Jacobs, Salisbury, & Enns, 2013). The relationships of SCF are shown in Table 2.12.

**Table 2.12** Relationship of sub-factors in SCF

| No | Authors | PF to LF | PF to OF | LF to OF | SF to LF | SF to PF | SF to OF |
|---|---|---|---|---|---|---|---|
| **1** | Hill and Chambers (1991) | ● | | | | | |
| **2** | Primrose (1996) | ● | | | | | |
| **3** | Lau (1999) | | | | | ● | |
| **4** | Pérez and Sánchez (2001) | ● | | | | | |
| **5** | Chang, Yang, Cheng, and Sheu (2003) | | ● | | | | |
| **6** | Kara & Kayis (2004) | ● | | | | | |
| **7** | Narasimhan, Talluri, and Das (2004) | | | | | ● | |
| **8** | Oke (2005) | ● | ● | | | | |
| **9** | Avittathur and Swamidass (2007) | | | | | | ● |
| **10** | Stevenson and Spring (2007) | | | | | ● | ● |
| **11** | P. Kumar et al. (2008) | | | | ● | ● | |
| **12** | Cousens, Szwejczewski, and Sweeney (2009) | | | | | ● | |
| **13** | Fredriksson and Wänström (2014) | | | | | ● | |
| **14** | Scherrer-Rathje, Deflorin, and Anand (2014) | | | | | ● | |
| **15** | Antonio Márcio T Thoméa et al. (2014) | | | | | ● | |
| **16** | Kamel A Fantazy and Salem (2016) | | ● | | | | |
| **17** | Jafari et al. (2016) | ● | | | ● | | |
| **18** | Ku et al. (2016) | | ● | ● | | | |
| | Total | 6 | 4 | 1 | 2 | 8 | 2 |

# CHAPTER 3
# METHODOLOGY

An index is a useful tool for measuring and comparing a performance score to enhance and address the system (Latif, Gopalakrishnan, Nimbarte, & Currie, 2017). The first step is a literature review process; the related literature of SCP is reviewed as mentioned in the previous section. In the second step, a questionnaire is developed to gather the primary opinion of firms on the effects of SCI and SCF on SCP. After the pilot test and questionnaire distribution, the data analysis part consists of confirmatory factor analysis (CFA), and structural equation modeling (SEM) are conducted. SEM is employed to identify the weight of each influential factor on SCP. Then the direct and indirect influential weights of each factor on SCP are accounted to construct a performance index. The aim of this index is to measure the SCP and its members.

The empirical study is important to identify the existent situation among the firms based on the definite resources. The questionnaire is constructed by the critical components in SCM with the key purpose to collect the opinion from automotive and parts producers by focusing on supply chain manager.

The flowchart in Figure 3.1 demonstrates steps in constructing an SCP index for evaluating the SCP performance of each automotive firm. An index is a useful tool for measuring and comparing a performance score to enhance and address the system (Latif et al., 2017). In an index construction process, the first step is to scope the latent variable and the domain of the context (Diamantopoulos & Winklhofer, 2001). Therefore, the first step is a literature review process; the related literature of SCP is reviewed to scope down the domain of the context. Then, in the second step, a questionnaire is developed as latent variables to gather the primary opinion of firms on the effects of SCI and SCF on SCP. After the pilot test and questionnaire distribution, the data analysis part consists of CFA and SEM techniques. CFA is employed to identify the fitness of each questionnaire item with the data and model. Then SEM is employed to identify and explain the weight and relationships of each factor in a model. After that, the direct and indirect influential weights of each factor on SCP are employed to construct an index for evaluating the SCP.

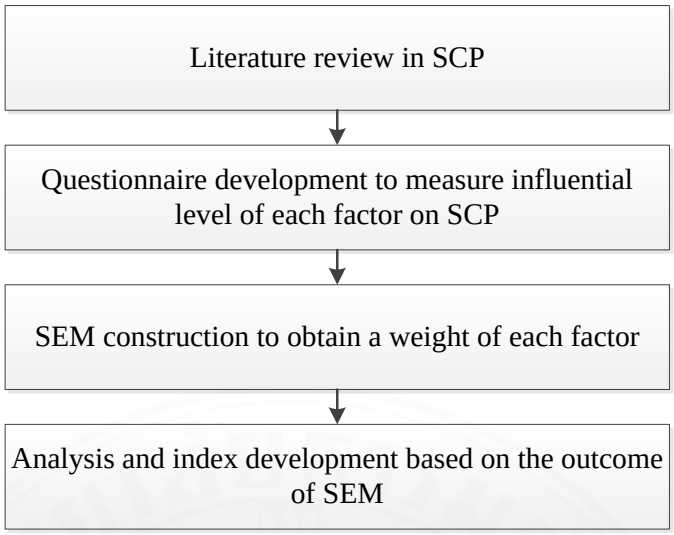


**Figure 3.1** Method of approach

In summary, the procedure for the research consist of four interrelated steps (Simatupang & Sridharan, 2005), (1) conceptualization – literature review process is employed to identify the concept of SCP. (2) develop measurement instrument – the questionnaire development based on the concept and domain for index development. (3) data collection – in this research, the questionnaire and interview are the main technique for data collection. (4) statistical analysis – SEM is employed for data analysis, factor analysis also employed for validate the relationship of observable variable and latent variable of the model. Then, the measurement and structural model are validated by the goodness-of-fit index.

## 3.1 Questionnaire development

This empirical study identifies the existent situations among the firms based on the actual resources. The measurement items in SCP, SCF, and SCI were constructed from the relevant literature to simulate the relationships of supply chain factors from the real situations. A questionnaire was developed to estimate the effects of integration and flexibility among the supply chain members on SCP of the automotive industry in Thailand. This questionnaire of SCI, SCF, and SCP consists of 13, 15, and 7 questions respectively. To minimize the bias among sub-factors in SCI, SCF, and SCP, the number of questions in each sub-factors are ranging from three to the maximum of five questions. A five-point Likert scale (1 = no relationship; 5 = strong relationship) is employed in the questionnaire to measure the level of agreement in each of the

statements in Table 3.1. In-depth interviews with the selected automotive suppliers are used as a pilot study to validate the items in the questionnaire.

**Table 3.1** Questionnaire topics and questions

| Topic | Sub-factor | Questionnaire item | |
|---|---|---|---|
| Supply Chain Integration (SCI) | Internal Integration (II) | $II_1$ | Strategic development across functions within a company. |
| | | $II_2$ | Communication infrastructure within a company. |
| | | $II_3$ | Cross- functional working between departments to develop a production plan. |
| | | $II_4$ | Information sharing across functions within a company. |
| | Supplier Integration (SI) | $SI_1$ | Strategic development cooperation with suppliers. |
| | | $SI_2$ | Communication infrastructure between company and suppliers. |
| | | $SI_3$ | Collaboration with suppliers to develop a production plan. |
| | | $SI_4$ | Information sharing with suppliers. |
| | Customer Integration (CI) | $CI_1$ | Strategic development cooperation with customers. |
| | | $CI_2$ | Communication infrastructure with between company and customers. |
| | | $CI_3$ | Collaboration with customers to develop a production plan. |
| | | $CI_4$ | Information sharing from customers. |
| | | $CI_5$ | Customer's opinion in quality and efficiency of your company. |

| Topic | Sub-factor | Questionnaire item | |
|---|---|---|---|
| Supply Chain Flexibility (SCF) | Production Flexibility (PF) | $PF_1$ | Ability to produce new products according to customer preference. |
| | | $PF_2$ | Ability to change a product specification (Minor Change) according to customer preference. |
| | | $PF_3$ | Ability to adjust a production capacity according to customer preference. |
| | Organization Flexibility (OF) | $OF_1$ | Ability to adjust manufacturing process ( production plan) according to customer preference. |
| | | $OF_2$ | Ability to adjust a machine to perform different operations required. |
| | | $OF_3$ | Ability of a material handling system to handle a production of different product types. |
| | | $OF_4$ | Ability to support the job rotation. |
| | Logistics Flexibility (LF) | $LF_1$ | Ability to reschedule the delivery time according to customer preference. |
| | | $LF_2$ | Ability to change a transportation route according to customer preference. |
| | | $LF_3$ | Ability to change a warehouse location. |
| | | $LF_4$ | Ability to adjust inventory levels to serve customer demand. |
| | Sourcing Flexibility (SF) | $SF_1$ | Ability to substitute the main supplier with another supplier. |
| | | $SF_2$ | Ability to increase suppliers to complete production to serve customer demand. |
| | | $SF_3$ | The ability of suppliers to adjust a delivery service according to a company requirement. |
| | | $SF_4$ | The ability of suppliers to adjust a product according to a company requirement. |

| | | | |
|---|---|---|---|
| Supply Chain Performance (SCP) | Cost (CP) | $CP_1$ | Ability to reduce manufacturing cost. |
| | | $CP_2$ | Ability to reduce holding costs. |
| | | $CP_3$ | Ability to reduce logistics cost. |
| | Time (TP) | $TP_1$ | Ability to reduce manufacturing time. |
| | | $TP_2$ | Ability to reduce lead time. |
| | | $TP_3$ | Ability to reduce product development time. |
| | | $TP_4$ | Ability to reduce defected product. |

### 3.2 Data collection

As the world 11th automotive producer (OICA, 2017), Thai automotive supply chain considered an important player in the global automotive industry. The population of this study is Thai and foreign automotive and parts producer companies that operate in Thailand to produce automotive components to fulfill the global demand. In order to effectively collect the data from the suppliers in Thai automotive supply chain, the purposive sampling method is employed for collecting the desired information from the specific automotive companies with the manufacturing activities (Ndubisi et al., 2005) for minimize bias of the collected data. The 3,000 sets of the questionnaire are contributed to the automotive suppliers by three methods. (1) The questionnaires are contributed to main institutions that involve in Thai's automotive industry including Thailand Automotive Institution (TAI), Thailand Automotive Industry Association (TAIA), and Thai Auto-parts Manufacturers Association (TAMPA). The respondents are including both Thai and foreign companies that produce the components for fulfilling the demand of the automotive industry. The research distributed survey paper during the monthly meeting of those institutions. (2) Mail surveys and an online surveys are employed to collect the data directly from the companies. This methods accounted for more than 60 percent of the total data collection. The paper survey were distribute to the company by postal mail. Online survey is available upon request. (3) The field survey method is conducted at the automotive and manufacturing exhibition. Paper survey is main method for data collection process.

### 3.3 Factor Analysis

To ensure the measurements, convergent and discriminant were validated by CFA. It is applied to confirm the questionnaire items in each factor. The principal component analysis was performed by SPSS program version 17 to determine the factor loading in each factor. The questionnaire has 35 questions with a sample size of 210 respondents. The variable-ratio is equal to 6.00, which is above the acceptable range of 5:1 (Arrindell & Van Der Ende, 1985). Principal axis factoring with varimax rotation is employed for effectively measuring the dimension reduction and interpreting the factor loading (Chinda & Mohamed, 2008). The items with a factor loading less than 0. 40 are eliminated (Velicer & Fava, 1998). Based on Table 3.2, the principal component analysis shows eight sub- factors as expected. Since all factor loadings are above 0. 40, none of the observed variables are eliminated. However, the result show three items with less than 0.50 factor loading. Information sharing among suppliers (SI4) has factor loading of 0.465, the firms need not to share all those information among supply chain and they still need to keep some trade secret and confidential information. Internal strategic development (II1) has 0.445 factor loading, the firm itself driven by its strategy. Therefore, it has less effect on the flexibility and integration along a supply chain because supply chain need more strategic development with downstream and upstream members. Labor force and skills rotation (OF4) has factor loading of 0.469, according to the interview, job rotation within the production process is an option to increase flexibility. However, it can lead to delay and defect within the process due to the lack of skill and expertise in a production line. It creates cost of training and production cost as well. The firm did not expected that all the worker can be rotated but a few worker with skill and expertise is more important for organization flexibility. The factor loading of OF1 is 0. 513 for the PF factor. Thus, OF1 is a better fit with the PF variable than OF.

**Table 3.2** Reliability and validity tests

| Latent variable | Observed variable | Cronbach's α | Loading |
|---|---|---|---|
| Supplier integration (SI) | SI1 | 0.905 | 0.619 |
| | SI2 | | 0.709 |
| | SI3 | | 0.667 |
| | SI4 | | 0.465 |
| Internal integration (II) | II1 | 0.864 | 0.445 |
| | II2 | | 0.678 |
| | II3 | | 0.641 |
| | II4 | | 0.511 |
| Customer integration (CI) | CI1 | 0.918 | 0.714 |
| | CI2 | | 0.752 |
| | CI3 | | 0.691 |
| | CI4 | | 0.692 |
| | CI5 | | 0.691 |
| Production flexibility (PF) | PF1 | 0.919 | 0.654 |
| | PF2 | | 0.615 |
| | PF3 | | 0.615 |
| | OF1 | | 0.513 |
| Operational flexibility (OF) | OF2 | 0.884 | 0.650 |
| | OF3 | | 0.762 |
| | OF4 | | 0.469 |
| Logistics flexibility (LF) | LF1 | 0.896 | 0.602 |
| | LF2 | | 0.743 |
| | LF3 | | 0.827 |
| | LF4 | | 0.700 |
| Sourcing flexibility (SF) | SF1 | 0.927 | 0.556 |
| | SF2 | | 0.726 |
| | SF3 | | 0.690 |
| | SF4 | | 0.694 |
| Supply chain performance (SCP) | CP1 | 0.941 | 0.795 |
| | CP2 | | 0.763 |
| | CP3 | | 0.651 |
| | TP1 | | 0.792 |
| | TP2 | | 0.809 |
| | TP3 | | 0.651 |
| | TP4 | | 0.582 |

### 3.4 Structural Equation Modelling (SEM)

SEM is widely employed in supply chain research (Avelar-Sosa et al., 2014; Green et al., 2012; Hussain et al., 2015; S. W. Kim, 2009; Lin et al., 2010; Trkman et al., 2010). SEM has been used as an influential tool in theoretical testing (Martínez-López, Gázquez-Abad, & Sousa, 2013). It is a statistical technique that undertakes a multivariate analysis of multi-causal relationships among different and independent phenomena (Davcik, 2014). This method allows researchers to test measurement and structural theories against the real world, captured by covariance matrices (Babin & Svensson, 2012). From the study of Babin and Svensson (2012), SEM can explore a higher level of understanding of the research theory and enlighten human perception and phenomena based on empirical data. This method has been frequently employed to measure the relationships among performance indicators such as export performance (Racela, Chaikittisilpa, & Thoumrungroje, 2007), importer distribution performance (Obadia, 2008), and measurement of logistics strategy (Kohn, McGinnis, & Kara, 2011). This method is also applied in social science research (Babin & Svensson, 2012), marketing, and business research (Martínez-López et al., 2013). SEM is employed to explain the optimal behavior of agents and to predict future behavior and performances (Davcik, 2014). The advantages of SEM are more powerful ways of assessing the reliability and correcting structural relationships for error variance. Therefore, the measurement and structural models are crucial in creating valid and reliable SEM applications and research findings (Babin & Svensson, 2012). To achieve the objective of this research, SEM is employed to analyze the data .

To explore the intra- and inter-relationships of eight latent variables, the Amos 22 software package was employed to conduct the SEM. The measurement and structural framework are developed based on the literature and the results of factor analysis. To achieve an acceptable goodness-of-fit index, non-significant paths are (Goodboy & Kline, 2017). The eliminated paths in this model are SI → SCP, SI → PF, SI → OF, SI → LF, II → SCP, CI → SF, and PF → SCP. Then the path with a high modification index (MI) within the same latent variable and approved by the theory of evidence is added to the model (Goodboy & Kline, 2017). Therefore, the framework consists of eight latent variables and 35 observed variables.

The connection strength (path coefficient) represents the response of the dependent variable to a unit change in an explanatory variable when other variables in the model are held constant (Bollen, 1989). The path coefficients of a structural equation model are similar to correlation or regression coefficients and are interpreted as follows (McIntosh and Gonzalez-Lima, 1994):

- A positive coefficient means that a unit increase in the activity measure of one structure leads to a direct increase in the activity measure of structures it is projected at with proportional to the size of the coefficient.
- A negative coefficient means that an increase in the activity measure in one structure leads to a direct, proportional decrease in the activity measure of structures its projected at.

### 3.5 Goodness-of-Fit

In order to measures the fitness of SEM model, the research model illustrated in Fig. 4-1 presents good results for measuring the model fit. The parameters Chi-square or CMIN/DF = 1.786 ($\chi 2$ = 946.365, the degree of freedom df. = 530), which fall in an acceptable range of below 3 (Ryu et al., 2009). The guidelines for model fit from the study of Hooper, Coughlan, and Mullen (2008) recommended to employ the root mean square error of approximation (RMSEA), comparative fit index (CFI), Standardize Rood Mean Square Residual (SRMR) as the parameters. In this model, RMSEA = 0.061, CFI = 0.937, and SRMR = 0.049 are presented the general consensus of a good model fit (Hooper et al., 2008). Other goodness-of-fit indices are, for instance, IFI = 0.938, and TLI = 0.930; they fall in an acceptable range of at least 0.9 (Hooper et al., 2008; Hu & Bentler, 1998; Sharma, Mukherjee, Kumar, & Dillon, 2005), The goodness-of-fit indices represent an acceptable model fit as shown in Table 3.3. It is still revealed sufficient breath of coverage for capturing the content of the construct model by inspect of four out of nine indicators (Diamantopoulos & Winklhofer, 2001). Moreover, RMSEA and SRMR of this model are equal to 0.06 and below 0.09 respectively. Therefore, it effectively presents the model fit according to two-index presentation strategy of Hu and Bentler (1999).

**Table 3.3** Results of goodness-of-fit indices for the structural model

| Goodness-of-fit indices | Recommended range | Results |
|---|---|---|
| Chi square (CMIN/DF)* | < 2 Good fit (Cangur & Ercan, 2015)<br>< 3 Good (Ryu et al., 2009)<br>< 5 Acceptable (Hooper et al., 2008) | 1.786 |
| Root Mean Square Error of Approximation (RMSEA)* | < 0.05 Indicative fit (Hu & Bentler, 1998)<br>0.05 to 0.08 fair fit (Hu & Bentler, 1998)<br>0.08 to 0.10 Mediocre fit (Hu & Bentler, 1998) (Hooper et al., 2008) | 0.061 |
| Standardize Rood Mean Square Residual (SRMR)* | < 0.05 Good fit (Cangur & Ercan, 2015)<br>< 0.09 Acceptable fit (Hu & Bentler, 1999; Iacobucci, 2010) | 0.049 |
| Comparative Fit Index (CFI)** | > 0.9 Good fit (Iacobucci, 2010) | 0.937 |
| Tucker- Lewis Index (TLI)** | > 0.9 Good fit (Sharma et al., 2005) | 0.930 |

*Closer to 0 is a better fit, **Closer to 1 is a better fit

## 3.6 Development of an SCP index

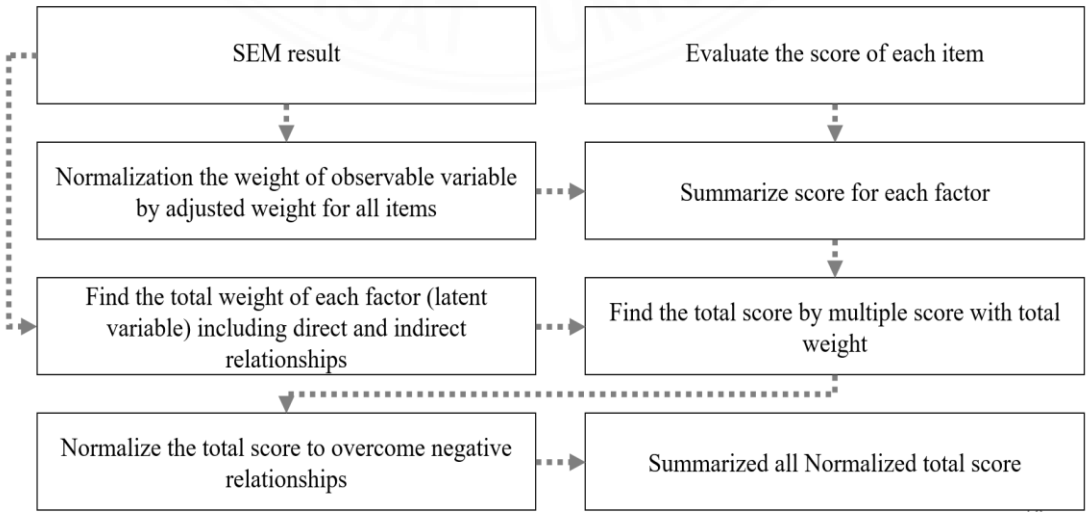


**Figure 3.2** Index development process

The influential weights obtained from the results of SEM are employed to calculate the supply chain performance index. The following steps are used to develop the index.

Let $w_{ij}$ be the weight of latent variable $i$ obtained from an observed variable $j$. In this study, there are seven latent variables, so $i = 1, 2, 3, \ldots, 7$. For each latent variable $i$, a proportion of each $w_{ij}$ is calculated, where $j = 1, 2, \ldots,$ and $n_i$ and $n_i$ are the number of observed variables in each latent variable $i$. The proportion is referred to as an adjusted weight or $\widehat{w}_{ij}$, where for each $i$:

$$\widehat{w}_{ij} = \frac{w_{ij}}{\sum_{j=1}^{n_i} w_{ij}} \times 100\% \quad (3.1)$$

Suppose $x_j$ is the performance score of a firm in each category based on an observed variable, where $j = 1, 2, \ldots, n_i$. The factor score of each latent variable $i$ is defined as

$$F_i = \sum_{j=1}^{n_i} \left(\widehat{w}_{ij} \times x_j\right) \text{ for each } i = 1, 2, \ldots, 7 \quad (3.2)$$

The model, indicated in Figure 4.10, demonstrates both direct and indirect paths from each latent variable $i$ to SCP. A latent variable is also referred to as a factor. A direct relationship refers to a direct path from factor $i$ to SCP ($D_i$), and an indirect relationship is when at least two paths from factor $i$ to SCP existed. The weights of paths from each factor to SCP are the product of each weight along the path from the initial latent variable to SCP, denoted as $IR_i$.

The total weight ($TW$) of each factor from factor $i$ to factor $j$ is normalized by the following formula:

$$\widehat{TW}_{ij} = \frac{IR_{ij} + D_{ij}}{\sum_{j=1}^{n_i} (IR_{ij} + D_{ij})} \times 100\% \quad (3.3)$$

Hence, the total score ($TS$) for each factor $i$ is:

$$TS_i = F_i (TW_i) \quad (3.4)$$

Since the index is employ SEM result, the relationship weights could be negative value. In order to prevent this issue. All the TS needed to be normalize. The total score or $\widehat{TS}_i$ is normalized by the following formula:

$$\widehat{TS}_\iota = \frac{TS_i}{\sum_{i=1}^{7} TS_i} \times 100 \quad (3.5)$$

The SCP index is:

$$SCP\ index = \sum_{i=1}^{7} \widehat{TS}_\iota \quad (3.6)$$

The SCP index shows the performance of the organization, based on flexibility and integration ability. The index can be used to evaluate the performance of an individual firm and a whole supply chain.

# CHAPTER 4
# ANALYSES AND RESULTS

## 4.1 Demographic results

The questionnaires were distributed to the suppliers of automotive firm who operating in Thailand. The 3,000 sets of the questionnaire are contributed to the automotive suppliers. Moreover, the selected respondents were in-depth interviewed to validate the questionnaire by the purposive sampling method. The returned rate is 8.16 percent, where 245 sets of the questionnaire are returned. The exclusion of 35 sets with missing data resulted in 210 valid questionnaires for data analysis. The presented results are exclude that missing data from the respondents.

Based on 210 valid questionnaires, as we aimed to collect the data from at least manager level. The 39 percent of valid questionnaire are manger following by managing director (20 percent), executive (15 percent), owner/president (8 percent), and chef of a department (7 percent). Therefore, the respondents of this survey are appropriate and understand the automotive supply chain.

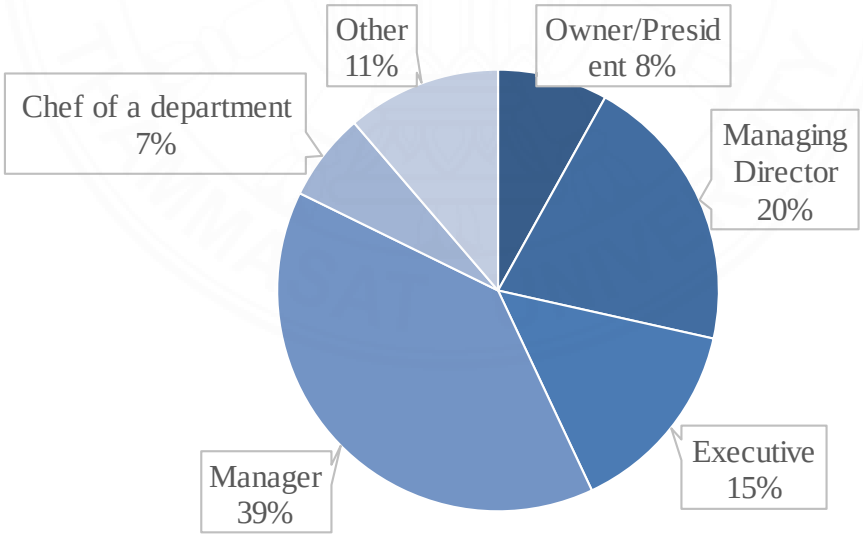


**Figure 4.1** Percentage of respondent working position

In order to ensure the quality of collected data, the experiences of respondent on current position and automotive industry are asked. Then the company experience

also filled to verify the expertise of the company in automotive industry. Figure 4.2 shows that the highest proportion of respondent are rely in 1 to 5 years of experience following by 6 to 10, 11 to 15, and 16 to 20 respectively. However, if we focus on company experience, the highest proportion is 1 to 5 following by 6 to 10, and more than 20 years of experience in automotive industry. The lowest proposition is less than 1 year experience. Therefore, the surveys are going to the right respondents and company.

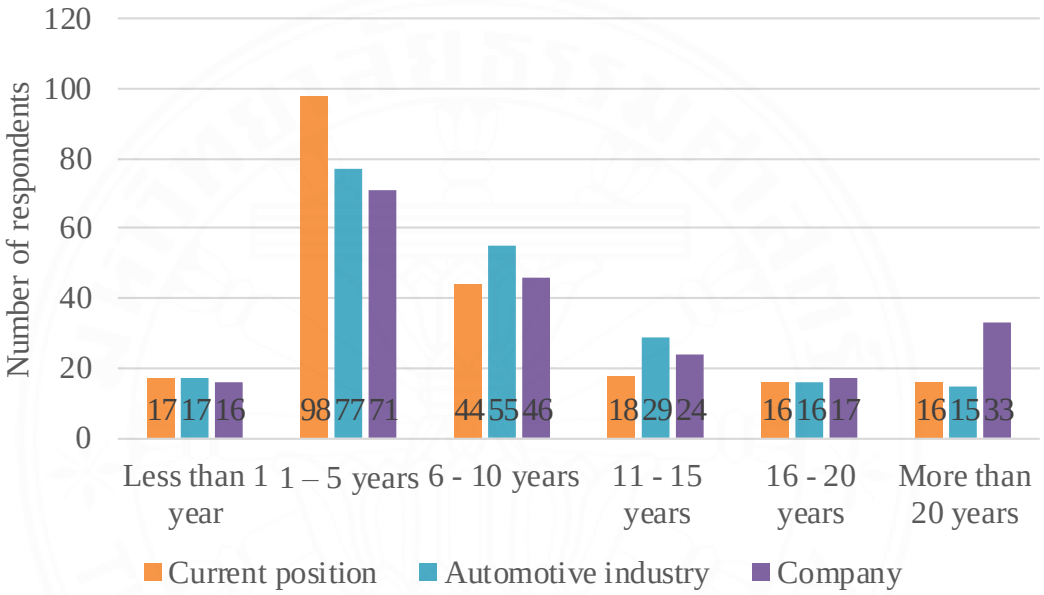


**Figure 4.2** Experiences of respondents and companies

For the type of ownership of the company, more than a half of respondent are owned by the foreigner and 14 percent has more than 50% foreign ownership. As we known that the automotive industry in Thailand drive by the supply chain leader which are foreign company. Therefore, they are mostly develop a supply chain based on they origin chain from oversea. However, we also got 17 percent from Thai ownership and 11 percent from the respondents are Thai majority. Hence, this data can be a good sample to represent the real situation of Thai auto industry.

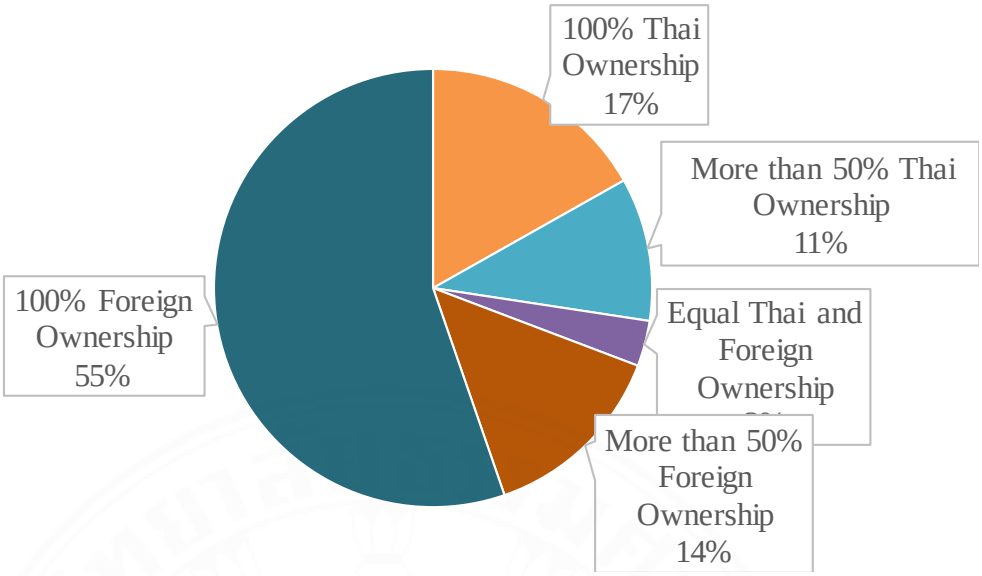


**Figure 4.3** Type of company ownership

Beside the ownership of the responded company, the company position in supply chain is another data that the survey are collected. Based on the survey, we got 39 percent of Tier 1 who directly supply the product to the automotive brands. Therefore, the large proposition of this survey is came from the 2nd, 3rd, and other tier suppliers.

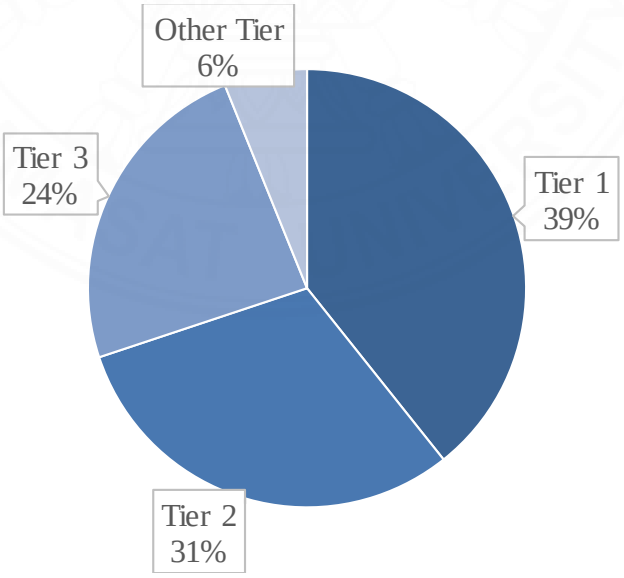


**Figure 4.4** company position in supply chain

The collected data are reflect the structure of Thai automotive industry since the data from TAI 2019 (figure 4-5) presented that Thailand has 18 car assembler, 476 Tier 1 suppliers, and 1,210 companies in 2nd and other tier suppliers. The majority of assemble and 1st tier are foreign companies, while the lower tier and mostly Thai and Thai majority.

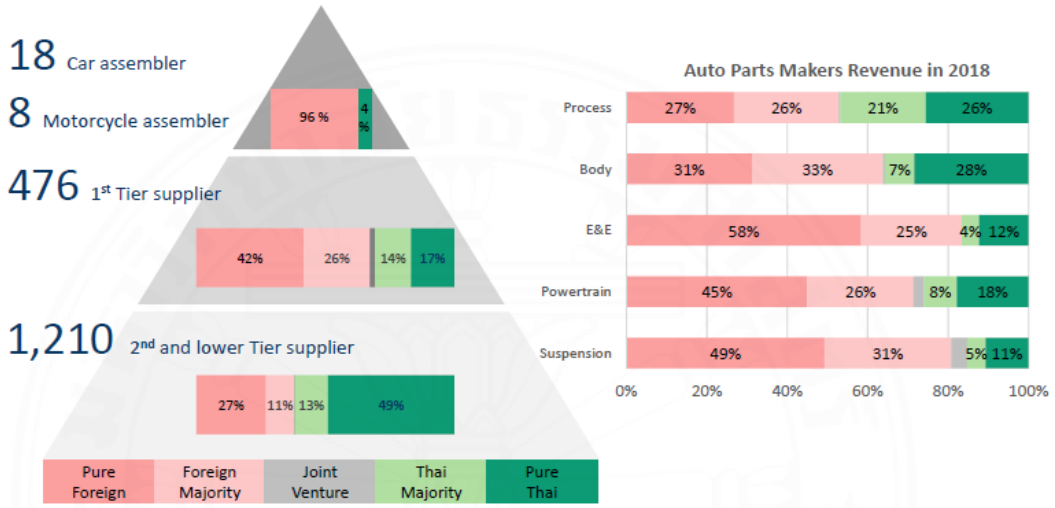


**Figure 4.5** Structure of Thai automotive industry

Source: Thai automotive institution

For the size of company, the survey collected almost equal proportion of the company size defined by number of employees. The respondents are 38 percent working in the companies with more than 200 employees and other groups are equally came from companies with more than 51 to 200 employees and companies with less than 51 employees.

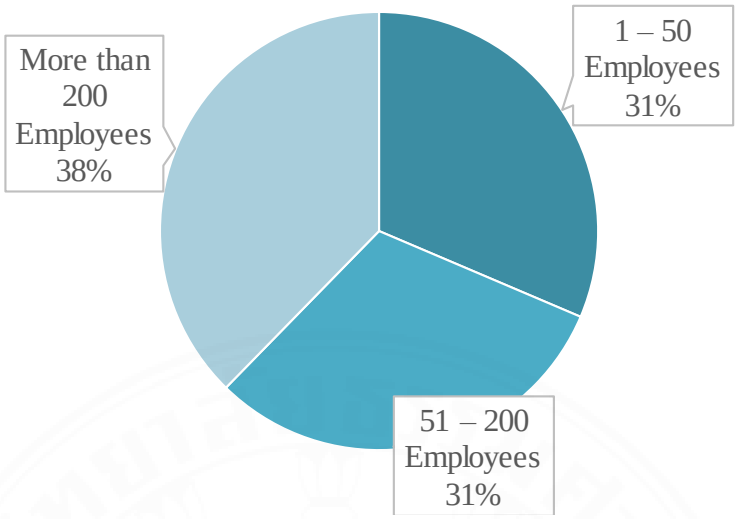


**Figure 4.6** number of employees

According to the survey, the majority of respondents (84 percent) is currently support the production of internal combustion engine. It reflects the result in figure 4.7 and 4.8 that mostly of the respondent are produce engine parts and raw material is steel. They have 13 and 3 percent of the respondent that filled in the questionnaire that their product can be components for producing hybrid and electric vehicle.

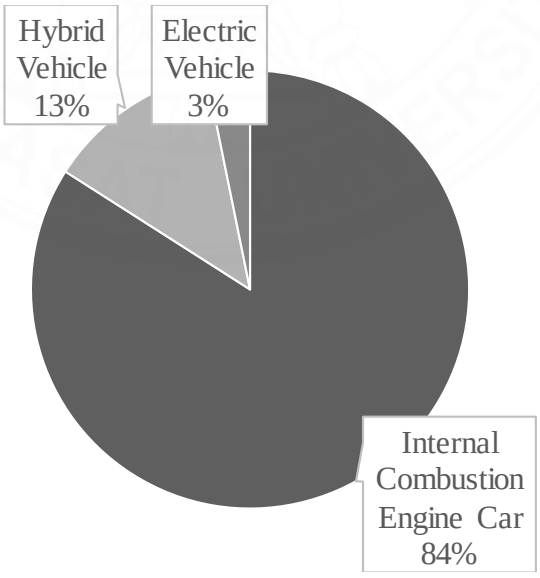


**Figure 4.7** type of car that suits with company products

Since majority of the products from respondents are engine parts, interior part, suspension, and powertrain (figure 4.8), the important raw material is steel following by plastic and rubber.

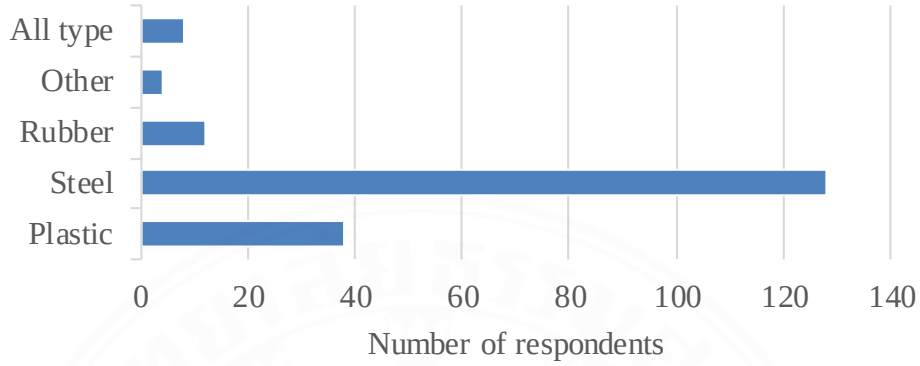


**Figure 4.8** type of raw material for production

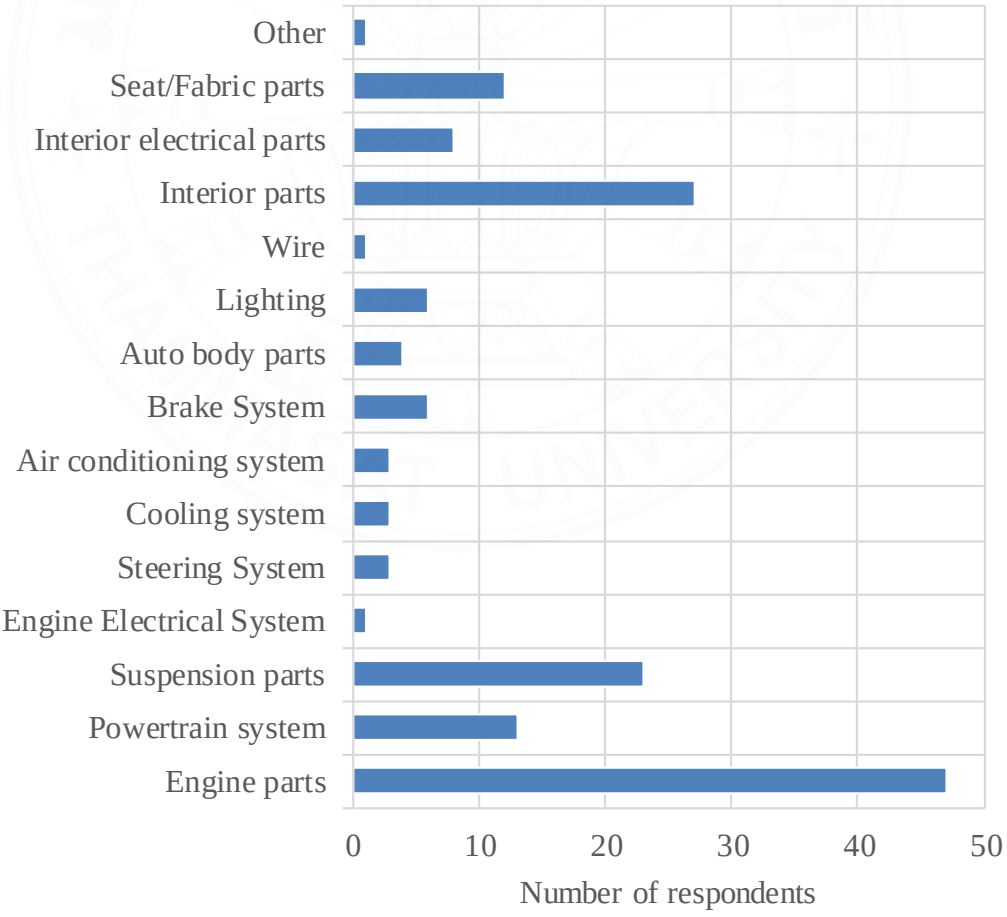


**Figure 4.9** type of company products in automotive industry

### 4.2 Framework of SEM

Figure 4.10 illustrates the best fit model of SEM to identify the relationships among SCI, SCF, and SCP. There are eight latent variables in this model, three factors in SCI, four factors in SCF, and SCP appears as a singer factor. The relationships among factors are shown as an arrow between the boxes. The direction of an arrow is identified by the literature review as represented in section 2 of this paper. The dotted line symbolizes the eliminated path from the initial model. The correlation weight is displayed as a number on the solid line.

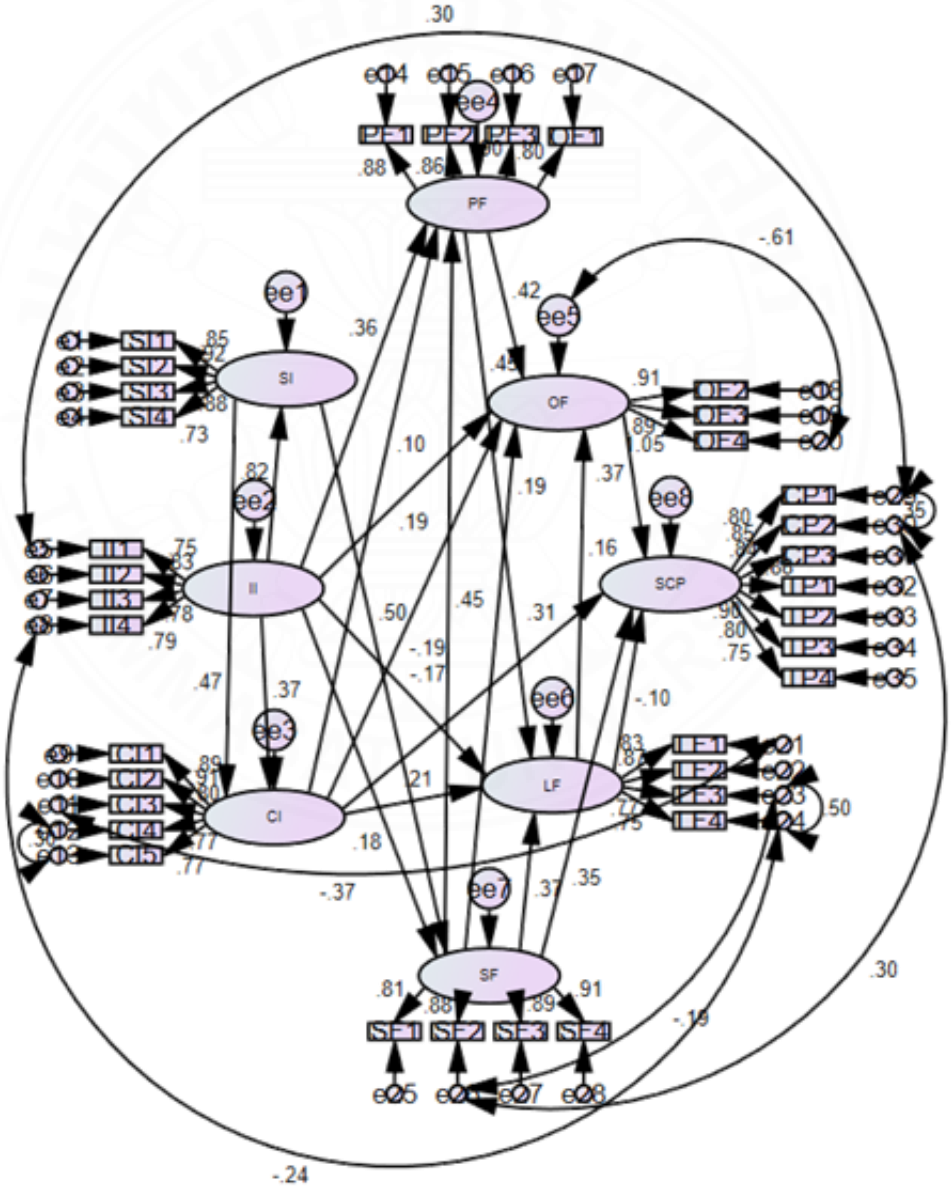


**Figure 4.10** SEM of SCI and SCF of the automotive industry in Thailand

Note: $\chi 2$ = 946.365; *df.* = 530; *p-value* = 0.000; RMSEA = 0.061

**Table 4.1** Weight of each observable variable

| Factor | Obserable variable | Weight | Factor | Observable variable | Weight |
|---|---|---|---|---|---|
| Internal integration | II1 | 0.75 | Production flexibility | PF1 | 0.88 |
| | II2 | 0.83 | | PF2 | 0.86 |
| | II3 | 0.78 | | PF3 | 0.90 |
| | II4 | 0.79 | | OF1 | 0.80 |
| Supplier integration | SI1 | 0.85 | Operation flexibility | OF2 | 0.91 |
| | SI2 | 0.92 | | OF3 | 0.89 |
| | SI3 | 0.88 | | OF4 | 1.05 |
| | SI4 | 0.73 | Logistics flexibility | LF1 | 0.83 |
| Customer integration | CI1 | 0.89 | | LF2 | 0.87 |
| | CI2 | 0.91 | | LF3 | 0.77 |
| | CI3 | 0.80 | | LF4 | 0.75 |
| | CI4 | 0.77 | Sourcing flexibility | SF1 | 0.81 |
| | CI5 | 0.77 | | SF2 | 0.88 |
| | | | | SF3 | 0.89 |
| | | | | SF4 | 0.91 |

### 4.2.1 Hypothesis 1: SCI and SCP relationship

Table 4.2 shows the internal relationship between SCI and relationship with SCP. According to Figure 4.10, II is a primary factor for creating SI and CI. This can confirm that internal integration is the main source of external integration (Huo, 2012a; Willis et al., 2016; W. Yu et al., 2013). Since a correlation between II → SI is 0.82 and II → CI is 0.37, the firms need to have an effective internal integration to create integration among the supply chain. CI is influenced by an improvement of II in both direct and indirect through the improvement of SI. However, they are no direct effects from SI and II to SCP; rather CI is the only factor in SCI that directly influences on SCP with a correlation of 0.31. Since the respondents of this research are the automotive suppliers in Thailand, the customers or downstream suppliers are the automotive brand companies which are the supply chain leader or key player in a supply chain system (Piyanaraporn, 2012). In Thai automotive supply chain, automotive brand companies are dominate the chain. Therefore, it can supports that, SCP of Thai automotive industry is directly influenced by the customer. Since supply chain of automotive industry in Thailand is dominated by the supply chain leader, suppliers of the automotive producers are affiliated companies. Therefore, the II performance is strongly influence on SI.

**Table 4.2** Relationship of SCI and SCP

| Hypothesis | Path | Standardize path coefficients | *t-value* | Result |
|---|---|---|---|---|
| $H_{1a}$ | II→SI | 0.82 | 9.748 | Support |
| $H_{1b}$ | II→CI | 0.37 | 3.481 | Support |
| $H_{1c}$ | SI→CI | 0.47 | 4.368 | Support |
| $H_{1d}$ | II→SCP | - | - | - |
| $H_{1e}$ | SI→SCP | - | - | - |
| $H_{1f}$ | CI→SCP | 0.31 | 4.617 | Support |

Note: *Significant at *t-value* > 1.96

### 4.2.2 Hypothesis 2: SCI and SCF relationship

According to Table 4.3 and Figure 4.10, SI has a strong positive relationship with SF. It is clearly defined the higher integration among suppliers affects to the ability of the firm to manage their suppliers and contribute to supplier production processes such as a change in product specification and delivery schedule. II has a positive relationship with the PF, OF, and SF. The communication, information sharing, and supportive department within the firm moderately support the ability of flexible production with a correlation of 0.36. II has a weak positive relationship to OF with a correlation of 0.19. However, the $H_{2c}$ and $H_{2d}$ are failed to reject the null hypothesis; it means there does not have enough evidence to indicate that II causes a weak negative relationship with LF and weakly influence on SF. $H_{2i}$ and $H_2$j are rejected which indicates the relationship between CI → PF and CI → OF. The results show that CI mainly influences on LF with a correlation of 0.21. The communication between firms and customers leads to a better response in terms of outbound logistics to the customers. On the other hand, SI solely influences SF with a correlation of 0.50. The integration between firm and suppliers have strongly effected the inbound logistics of a firm.

**Table 4.3** Relationship between SCI and SCF

| Hypothesis | Path | Standardize path coefficients | *t-value* | Result |
|---|---|---|---|---|
| $H_{2a}$ | II→PF | 0.36 | 3.745 | Support |
| $H_{2b}$ | II→OF | 0.19 | 2.096 | Support |
| $H_{2c}$ | II→LF | -0.17 | -1.539 | Not support |
| $H_{2d}$ | II→SF | 0.18 | 1.428 | Not support |
| $H_{2e}$ | SI→PF | - | - | - |
| $H_{2f}$ | SI→OF | - | - | - |
| $H_{2g}$ | SI→LF | - | - | - |
| $H_{2h}$ | SI→SF | 0.50 | 3.892 | Support |
| $H_{2i}$ | CI→PF | 0.10 | 1.167 | Not support |
| $H_{2j}$ | CI→OF | -0.19 | -2.395 | Not support |
| $H_{2k}$ | CI→LF | 0.21 | 2.183 | Support |
| $H_{2l}$ | CI→SF | - | - | - |

Note: *Significant at *t-value* > 1.96

### 4.2.3 Hypothesis 3: SCF and SCP relationship

According to Table 4.4 and Figure 4.10, OF and SF are two types of SCF that positively influence on SCP. OF can be considered as a key component of supply chain flexibility since it directly influences on SCP and affected by other types of flexibility. However, according to previous research, PF supposed to have a direct relationship with SCP (Awais et al., 2014; Kamel Aissa Fantazy et al., 2009), nevertheless the results confirm that PF has an indirect influence on SCP through OF. In manager point of view, the ability of the firm to adjust the production plan and product specification is a part of organizational strategies. Thus, PF strongly influences on OF with a correlation of 0.42 which is leading to SCP (0.37).

LF and SF also influence on OF with a correlation of 0.16 and 0.19, it is reasonable since the flexibility in operation processes of an organization is affected by the flexibility of supplier to produce parts and components according to the requirement and logistics ability. Based on the results, SF is a primary factor with contributing to PF (0.45), OF (0.19), LF (0.37), and SCP (0.35). SF is key flexibility in the automotive

supply chain in Thailand that contributes to the cost and time reduction in the supply chain. However, flexibility can often lead to higher costs (Pujawan, 2005) since the result shows a negative correlation from LF to SCP. Therefore, it is important to balance the flexibility to maximize the SCP (Merschmann & Thonemann, 2011).

**Table 4.4** Relationship between SCF and SCP

| Hypothesis | Path | Standardize path coefficients | *t-value* | Result |
|---|---|---|---|---|
| $H_{3a}$ | PF→OF | 0.42 | 4.576 | Support |
| $H_{3b}$ | PF→LF | 0.45 | 4.415 | Support |
| $H_{3c}$ | PF→SF | - | - | - |
| $H_{3d}$ | PF→SCP | - | - | - |
| $H_{3e}$ | OF→PF | - | - | - |
| $H_{3f}$ | OF→LF | - | - | - |
| $H_{3g}$ | OF→SF | - | - | - |
| $H_{3h}$ | OF→SCP | 0.37 | 4.836 | Support |
| $H_{3i}$ | LF→PF | - | - | - |
| $H_{3j}$ | LF→OF | 0.16 | 2.003 | Support |
| $H_{3k}$ | LF→SF | - | - | - |
| $H_{3l}$ | LF→SCP | -0.10 | -1.121 | Not support |
| $H_{3m}$ | SF→PF | 0.45 | 6.789 | Support |
| $H_{3n}$ | SF→OF | 0.19 | 2.612 | Support |
| $H_{3o}$ | SF→LF | 0.37 | 4.301 | Support |
| $H_{3p}$ | SF→SCP | 0.35 | 4.008 | Support |

Note: *Significant at *t-value* > 1.96

### 4.3 Supply Chain Performance Index of the Thai Automotive Industry

According to the result of SEM, Table 4.1 shows the weight of each observable variable from SEM model. Figure 4.10 shows direct and indirect relationships between a factor and SCP. The first step is to adjusted the weight to normalize and make it come the same standard through all variable as show in table 4.5.

**Table 4.5** Adjusted weight for each observable variable

| Factor | Obserable variable | Weight | Adjusted Weight | Factor | Observable variable | Weight | Adjusted Weight |
|---|---|---|---|---|---|---|---|
| Internal integration | II1 | 0.75 | 0.238 | Production flexibility | PF1 | 0.88 | 0.256 |
| | II2 | 0.83 | 0.263 | | PF2 | 0.86 | 0.250 |
| | II3 | 0.78 | 0.248 | | PF3 | 0.90 | 0.262 |
| | II4 | 0.79 | 0.251 | | OF1 | 0.80 | 0.233 |
| | Sum | 3.15 | | | Sum | 3.44 | |
| Supplier integration | SI1 | 0.85 | 0.251 | Operation flexibility | OF2 | 0.91 | 0.319 |
| | SI2 | 0.92 | 0.272 | | OF3 | 0.89 | 0.312 |
| | SI3 | 0.88 | 0.260 | | OF4 | 1.05 | 0.368 |
| | SI4 | 0.73 | 0.216 | | Sum | 2.85 | |
| | Sum | 3.38 | | Logistics flexibility | LF1 | 0.83 | 0.258 |
| Customer integration | CI1 | 0.89 | 0.215 | | LF2 | 0.87 | 0.270 |
| | CI2 | 0.91 | 0.220 | | LF3 | 0.77 | 0.239 |
| | CI3 | 0.80 | 0.193 | | LF4 | 0.75 | 0.233 |
| | CI4 | 0.77 | 0.186 | | Sum | 3.22 | |
| | CI5 | 0.77 | 0.186 | Sourcing flexibility | SF1 | 0.81 | 0.232 |
| | Sum | 4.14 | | | SF2 | 0.88 | 0.252 |
| | | | | | SF3 | 0.89 | 0.255 |
| | | | | | SF4 | 0.91 | 0.261 |
| | | | | | Sum | 3.49 | |

Then, the aim of constructing an index is to identify the performance level based on the strength of the relationship of SCI and SCF, both direct and indirect relationships are included in the construction process as demonstrated in Table 4.5 (only supported hypothesis are show in table). Furthermore, the developed SCP index is influenced by seven factors; three factors are from SCI and the remaining is from SCF.

**Table 4.6** Correlation of among seven factors and SCP

| From/To | SCI | | | SCF | | | | SCP |
|---|---|---|---|---|---|---|---|---|
| | II | SI | CI | PF | OF | LF | SF | |
| II | - | 0.82 | 0.37 | 0.36 | 0.19 | -0.17 | 0.18 | - |
| SI | - | - | 0.47 | - | - | - | 0.50 | - |
| CI | - | - | - | 0.10 | -0.19 | 0.21 | - | 0.31 |
| PF | - | - | - | - | 0.42 | 0.45 | - | - |
| OF | - | - | - | - | - | - | - | 0.37 |
| LF | - | - | - | - | 0.16 | - | - | -0.10 |
| SF | - | - | - | 0.45 | 0.19 | 0.37 | - | 0.35 |
| SCP | - | - | - | - | - | - | - | - |

According to table 4.6, there are four direct relationship (DR) to SCP namely $DR_{CI} = 0.31$, $DR_{OF} = 0.37$, $DR_{LF} = -0.10$, and $DR_{SF} = 0.35$. In indirect relationship (IR), every possible outcome from the initial latent variable to SCP is calculated to measure the indirect relationship to SCP. A path with the weight less than 0.10 will be excluded from the index development. The results of IR's are demonstrated in Table 4.7. There are three factors, II, SI, and PF, which indirectly influence SCP with a weight of 0.378, 0.321, and 0.155 respectively.

**Table 4.7** Calculation of indirect relationship of latent variables

| Initial | Path | Equation | Outcome |
|---|---|---|---|
| II | SI→CI→SCP | 0.82 × 0.47 × 0.31 | 0.119 |
| | SI→CI→PF→OF→SCP | 0.82 × 0.47 × 0.10 × 0.42 × 0.37 | 0.006 |
| | SI→CI→PF→LF→SCP | 0.82 × 0.47 × 0.10 × 0.45 × -0.10 | -0.002 |
| | SI→CI→PF→LF→OF→SCP | 0.82 × 0.47 × 0.10 × 0.45 × 0.16 × 0.37 | 0.001 |
| | SI→CI→OF→SCP | 0.82 × 0.47 × -0.19 × 0.37 | -0.0027 |
| | SI→CI→LF→SCP | 0.82 × 0.47 × 0.21 × -0.10 | -0.008 |

| Initial | Path | Equation | Outcome |
|---|---|---|---|
| | SI→CI→LF→ OF→SCP | 0.82 × 0.47 × 0.21 × 0.16 × 0.37 | 0.005 |
| | SI→SF→SCP | 0.82 × 0.50 × 0.35 | 0.144 |
| | SI→SF→OF→SCP | 0.82 × 0.50 × 0.19 × 0.37 | 0.029 |
| | SI→SF→LF→SCP | 0.82 × 0.50 × 0.37 × -0.10 | -0.015 |
| | SI→SF→LF→ OF→SCP | 0.82 × 0.50 × 0.37 × 0.16 × 0.37 | 0.008 |
| | CI→SCP | 0.37 × 0.31 | 0.115 |
| | CI→PF→OF→SCP | 0.37 × 0.10 × 0.42 × 0.37 | 0.006 |
| | CI→PF→LF→SCP | 0.37 × 0.10 × 0.45 × -0.10 | -0.002 |
| | CI→PF→LF→ OF→SCP | 0.37 × 0.10 × 0.45 × 0.16 × 0.37 | 0.001 |
| | CI→OF→SCP | 0.37 × -0.19 × 0.37 | -0.026 |
| | CI→LF→SCP | 0.37 × 0.21 × -0.10 | -0.008 |
| | CI→LF→ OF→SCP | 0.37 × 0.21 × 0.16 × 0.37 | 0.005 |
| | PF→OF→SCP | 0.36 × 0.42 × 0.37 | 0.056 |
| | PF→LF→SCP | 0.36 × 0.45 × -0.10 | -0.016 |
| | PF→LF→ OF→SCP | 0.36 × 0.45 × 0.16 × 0.37 | 0.010 |
| | OF→SCP | 0.19 × 0.37 | 0.070 |
| | LF→SCP | -0.17 × -0.10 | -0.010 |
| | LF→OF→SCP | -0.17 × 0.16 × 0.37 | 0.017 |
| | SF→SCP | 0.18 × 0.35 | 0.063 |
| | SF→PF→OF→SCP | 0.18 × 0.45 × 0.42 × 0.37 | 0.013 |
| | SF→PF→LF→SCP | 0.18 × 0.45 × 0.45 × -0.10 | -0.004 |
| | SF→PF→LF→ OF→SCP | 0.18 × 0.45 × 0.45 × 0.16 × 0.37 | 0.002 |
| | SF→OF→SCP | 0.18 × 0.19 × 0.37 | 0.013 |
| | SF→LF→SCP | 0.18 × 0.37 × -0.10 | -0.007 |
| | SF→LF→ OF→SCP | 0.18 × 0.37 × 0.16 × 0.37 | 0.004 |
| | | $IR_{II}$ | 0.378 |

| Initial | Path | Equation | Outcome |
|---|---|---|---|
| SI | CI→SCP | 0.47 × 0.31 | 0.146 |
| | CI→PF→OF→SCP | 0.47 × 0.10 × 0.42 × 0.37 | 0.007 |
| | CI→PF→LF→SCP | 0.47 × 0.10 × 0.45 × -0.10 | -0.002 |
| | CI→PF→LF→ OF→SCP | 0.47 × 0.10 × 0.45 × 0.16 × 0.37 | 0.001 |
| | CI→OF→SCP | 0.47 × -0.19 × 0.37 | -0.033 |
| | CI→LF→SCP | 0.47 × 0.21 × -0.10 | -0.010 |
| | CI→LF→ OF→SCP | 0.47 × 0.21 × 0.16 × 0.37 | 0.006 |
| | SF→SCP | 0.50 × 0.35 | 0.175 |
| | SF→OF→SCP | 0.50 × 0.19 × 0.37 | 0.035 |
| | SF→LF→SCP | 0.50 × 0.37 × -0.10 | -0.019 |
| | SF→LF→ OF→SCP | 0.50 × 0.37 × 0.16 × 0.37 | 0.010 |
| | | $IR_{SI}$ | 0.321 |
| CI | PF→OF→SCP | 0.10 × 0.42 × 0.37 | 0.016 |
| | PF→LF→SCP | 0.10 × 0.45 × -0.10 | -0.005 |
| | PF→LF→ OF→SCP | 0.10 × 0.45 × 0.16 × 0.37 | 0.003 |
| | OF→SCP | -0.19 × 0.37 | -0.070 |
| | LF→SCP | 0.21 × -0.10 | -0.021 |
| | LF→ OF→SCP | 0.21 × 0.16 × 0.37 | 0.012 |
| PF | OF→SCP | 0.42 × 0.37 | 0.155 |
| | LF→SCP | 0.45 × -0.10 | -0.045 |
| | LF→ OF→SCP | 0.45 × 0.16 × 0.37 | 0.027 |
| | | $IR_{PF}$ | 0.155 |
| LF | OF→SCP | 0.16 × 0.37 | 0.059 |
| SF | PF→OF→SCP | 0.45 × 0.42 × 0.37 | 0.070 |
| | PF→LF→SCP | 0.45 × 0.45 × -0.10 | -0.020 |
| | PF→LF→ OF→SCP | 0.45 × 0.45 × 0.16 × 0.37 | 0.012 |
| | OF→SCP | 0.19 × 0.37 | 0.070 |
| | LF→SCP | 0.37 × -0.10 | -0.037 |
| | LF→ OF→SCP | 0.37 × 0.16 × 0.37 | 0.022 |

After the DR and IR calculation, the results of DI and IR are employed to calculate the total weight of each factor and presented as TW as shown in table 4.8. The highest influential rate is II with indirect influence on SCP though II and CI with a total weight of 0.212. The SCI's factors mostly have indirect relationships with the SCP and they also impact the flexibility level of the supply chain. However, the direct relationships on SCF are incurred from OF and SF with influential weights of 0.207 and 0.196 respectively. The given score must be multiply by the adjusted weight from table 4.7 as shows in table 4.8. After the evaluation of the observed variable, the score ($F_i$) of each factor is multiplied by the total weight ($TW_{ij}$) to represent the firm performance in each factor as a total score ($TS_i$). Then the outcome needed to be normalize to overcome negative relationships that might occur in the SEM result. Finally, all normalized total score are sum up to get the index score of a supply chain. It presents the performance level in supply chain evaluated by the selected audit. Then, the result appears as a score with a same scale as the given score.

**Table 4.8** Adjusted total score

| Factors | Total weight ($TW_{ij}$) | Score ($F_i$) |
|---|---|---|
| II | 0.212 | $0.238II_1+0.263II_2+0.248II_3+0.251II_4$ |
| SI | 0.180 | $0.251SI_1+0.272SI_2+0.260SI_3+0.216SI_4$ |
| CI | 0.174 | $0.215CI_1+0.220CI_2+0.193CI_3+0.186CI_4+0.186CI_5$ |
| PF | 0.087 | $0.256PF_1+0.250PF_2+0.262PF_3+0.233OF_1$ |
| OF | 0.207 | $0.319OF_1+0.312OF_2+0.368OF_3$ |
| LF | -0.056 | $0.258LF_1+0.270LF_2+0.239LF_3+0.233LF_4$ |
| SF | 0.196 | $0.232SF_1+0.252SF_2+0.255SFII_3+0.261SF_4$ |

This technique is designed to transform the SEM result to a measurement index. Therefore, the benefits of SEM that can interpret the higher level of perception and phenomena based on empirical data is still be existent. To employed this technique, an important input to the construction of the SCP index is the performance evaluation of

each firm in each factor. An observed variable in each latent variable is needed to be evaluated either by an internal or external auditor of a supply chain. For example, $II_1$ is referred to strategic development across functions within a company; an internal or external evaluator of a firm would recommend a score for the firm according it is current performance. The scores can be any scale based on the evaluators but it is need to be on the same scale and standard though all the measurement processes. The final index score will be the same scale as the given score.

# CHAPTER 5
# DISCUSSION AND IMPLICATION

## 5.1 Discussions

In the developing processes of the adjustable index, they are two main critical parts that significantly effect the overall model development. The first part is identify influential factors, it is needed to scope down the research area because performance of a system can be viewed in various dimension. Therefore, this research focuses on SCI, SCF, and SCP which are key factors in SCM. Another point is identify the relationships of each factor in a model. In this research, the literature review is a primary source for identifying those relationships. The industry, culture, situation are considered as filters to identify the relationships. Then model was approved by the selected respondents to ensure the developed model. Therefore, the selected literature review needed to related with environment that we need to evaluate.

The results from the developed model indicate three positive direct effects on SCP of the Thai automotive industry including two types of supply chain flexibility namely OF and SF with correlations of 0.370 and 0.350 respectively. Integration is a source of SCP, Internal integration (II) strongly influences on SI which is a key component of SF that directly influences on SCF. The model presents that SCI contributes to many types of SCF in the automotive industry in Thailand. Hence, an increase in SCI influences both SCP and SCF.

Besides the influential level of SCI, SCF, and SCP, the sub-factors in SCI and SCF are also influenced by other sub-factors within the main factors (SCF and SCI). In SCI, II is a primary factor of supplier and customer integration. The firms with higher communication and cooperation within the organization appear to be better in external integration between upstream and downstream members of the supply chain. Hence, better flexibility and performance among the supply chain are initially occurring within the organization. The results also confirmed that the root of integration among the supply chain is firstly occurring at the firm level, then expand to upstream and downstream members.

In SCF, OF is a descendent factor and directly influence on SCP. In addition, OF is influenced by other sub-factors in SCF. Since the automotive supply chain is

mostly relying on the manufacturing, increasing manufacturing flexibility lead to the increase of a supply chain ability to response with the uncertain environment (Wonga & Boon-itt, 2008). According to the characteristics of the flexibility in automotive supply chain, flexibility in terms of machine, material handling, and labor are important because the manufacturing process is a key component of the automotive supply chain. The results show that SF is an important factor in creating SCP. SF also influences in another types of flexibility namely PF, OF, and LF. Hence, the integration among members significantly improves the overall flexibility of a supply chain. However, the model indicates a negative correlation between LF and SCP. According to Kramer, A.K. and Kramer, J. (2010), LSP who offers the higher delivery frequency because of its ability to keep average inventory holding costs low. On the other hand, for the LSPs it is more costly to offer a higher delivery frequency. The increase of SCF can lead to the cost influence, a shorter lead time incur the increase in operating costs (Kuo, Yang, Parker, & Sung, 2016). In the automotive supply chain, the flexibility in terms of delivery time, schedule, and safety stock can be a detriment for SCP. Therefore, to maximize the profit, a supply chain needs to balance between flexibility and operating cost.

In summary, according to the SCP index, both direct and indirect effects are significant to improve SCP. Based on the weight of each factor, if an organization needs to improve the SCP, then II is going to be the first factor for consideration because it is an internal factor that has the highest weight influence on SCP and influence on the increase of SCF. This index can be implemented as a tool to evaluate the organization's performance in areas of SCI, SCF, and SCP especially in the automotive or manufacturing environment.

## 5.2 Contribution and implication

The outcomes provide a constructive parameter for both academia and industry. In the academic viewpoint, this research contributes two critical sections; the first section is an SCP measurement. This research studies the influential factors on SCP based on the empirical data from Thai's automotive industry. Therefore, the model can be used as a reference or guideline for developing an SCP model in other contexts. The

second section is the implementation of the SEM technique to develop an index. SEM is mainly employed as a tool for confirming and exploring the complex relationships among latent variables. This research develops an index that adopts the advantages of SEM for defining the influential weight of each variable on SCP. In practice, the factors under SCI and SCF were reviewed and classified into key elements of integration and flexibility. Then, these factors are validated by the firms in the automotive supply chain. Therefore, the factors mentioned in this framework should contribute to supply chain research. Furthermore, the relationship of each element is identified for enhancing SCP. Practitioners should consider the influential weights and direction, to build an effective supply chain and further support the key elements of SCP .

In managerial aspect, this method can be implemented as a tool to develop an index for a specific situation. Most of the measurement indexes are unable to be adjust, the same index is employed with different situation, country, culture, industry, and etc. Therefore, it cannot present the actual state of a measured system. This index development method is developed to overcome this issue.

In theoretical implication, the research provides the concept for implementing an advantage statistical model (SEM) for develop an index based on the primary data. The developed index provides a platform for automotive firms to apply, as an indicator of their SCP levels. Based on the SEM results, this study supports the relationship of supply chain integration and flexibility on SCP (Awais et al., 2014; Sánchez & Pérez, 2005; Sundram, Chandran, & Bhatti, 2016; Tseng & Liao, 2015; M. Zhang, 2013). This research also considers the internal correlation in supply chain integration and flexibility. The developed index expected to provide the accurate measurement tool with respect to the actual perception of the staekholders in a supply chain.

Beside the index development, this research highlighted that both flexibility and integration among members of the automotive supply chain appear to be critical elements to enhance SCP. Flexibility in machines, material handling, and labor are the main required flexibility for the manufacturing industry. Internal integration leads to SCP through customer integration. This dramatically affects supplier integration, which influences SCP through sourcing flexibility. A key consideration of integration in the supply chain is internal integration. Then, better integration performance within the organization can lead to a higher level of external integration among members of the

supply chain. In SCF, OF is a dependent factor that is influenced by other types of SCF. SF is considered as an antecedent of SCF that affects other types of SCF. Thus, the relationships among SCI, SCF, and SCP are dyadic relationships. An increase in one factor leads in an increase of SCP.

This research focuses on the flexibility and performance of a supply chain in terms of operating cost and time. According to the results, flexibility leads to both positive and negative effects on SCP. Therefore, both the integration and flexibility of a supply chain can incur a higher operating cost and time. Future research should focus on balancing integration and flexibility in a supply chain to maximize SCP. Customer satisfaction is another important factor that affects the performance. Further studies should be concerned with the influence of flexibility on customer satisfaction.

# CHAPTER 6
# CONCLUSIONS, LIMITATION AND FUTURE RESEARCH

## 6.1 Conclusion

The ultimate goal of this research is to construct an SCP index based on the perception of members and stakeholders in a supply chain. Thai automotive industry case was employed as a benchmark for the index development. The first stage of an index development is to identify the influential factor on SCP. In this case we focus on the flexibility and integration capability. Therefore, it is possible to focus on any part of a supply chain. Then, the questionnaire was developed to capture the perception of the supply chain members. The pilot test of key actors or the experts in a field is imperative in this stage. The third stage is the data analysis; SEM is employed to measure the complex relationship of the influential factors on a single dependent variable. Then the weights of SEM were used as an indicator in the developed index.

Furthermore, the results of this index show the significant elements of SCF that firms should be focusing on in order to enhance SCP. Based on the SEM results, this study supports the relationship of integration and flexibility on SCP (Awais et al., 2014; Sánchez & Pérez, 2005; Sundram et al., 2016; Tseng & Liao, 2015; M. Zhang, 2013). The index also highlights the internal correlation within supply chain integration and flexibility. Both flexibility and integration among members of automotive supply chain appear to be critical elements to enhance SCP. Flexibility in term of the machine, material handling, and labor are the main required flexibility for the manufacturing industry. Internal integration leads to SCP through customer integration and dramatic effect to supplier integration which influences on SCP through sourcing flexibility. The key consideration of SCI is initially started with internal integration. Then the better integration performance within the organization can lead to the higher level of external integration among the supply chain members. In SCF, OF is a dependent factor that influences by another type of SCF. SF is considered as an antecedent of SCF that affects another type of SCF. Thus, the change of a factor in supply chain management can effect the SCP.

## 6.2 Limitation and future research

This research aims to propose innovative method for developing an index to indicate status of the existing system. Since automotive industry is significantly important for the industry development, the case of supply chain performance index of automotive industry in Thailand is employed as a pioneer case for developing an effective index. However, the research have some limitation, (1) the samples of the empirical study are rely in tier 1, 2, 3, and other tier supplier. The supply chain leader was interviewed to validate the results. (2) the influential factors on SCP are limited. This research focuses on SCI and SCF, sub-factors under this two type are developed based on the literature review. (3) SCP is cover only cost and time aspects which are two main important components of SCP. However, quality and number of error are excluded because it is mostly rely on the manufacturing process in a supply chain.

As we know that supply chain system is complex systems within dynamic environments (Defee et al., 2010). Therefore, the influential factors in a supply chain is vary and different in each industry. In this research the factors concerning in the index development are limited to SCF and SCI due to the majority of research mentioned SCF and SCI as keys indicator of SCP. The influential factors can be explain greatly to cover all the aspect in a supply chain system to measure the actual situation as an ecosystem. However, it will consume a lot of research and time to identify all those factors. Another critical point is the relationships identified by SEM. According to this research, the relationship among sub-factors in the model are pre-defined by the literature review. More factors may lead to multicollinearity issue because most of the factors are influence on each other. Hence, it is imperative to pre-identify the relationship before conduct an SEM. It can be benefit in both time consumption and accuracy. For the further study, the benefit-cost analysis should be employed as a supporting technique to measure the overall value for money to increase the performance in each factor. In this research, the index clearly presents the impact of an individual factor in SCI and SCF on the performance of the automotive supply chain in Thailand. However, the customization of the index such as the change of dependent, independent factors can be made for implementing the index with another context.

In the future research, influential factors of a system can be adjusted to be compatible with specific characteristic of each system. This methodology can be implemented to smaller system, for example it can employed as an index for measuring integration performance based on the online and offline communication to identify the different and influential weight of each factor. However, it is possible to implemented with the larger system and more complex factors, for example it can cover all those influential factors from literature review but the relationships and weights needed to be extremely concerned and validated. Moreover, this research also confirm the relationships of SCI, SCF, and SCP. The further research can implement this developed model in other industry to measure the different weights and relationships. This model can present that flexibility might be less important on SCP in some industry. Then it can highlight the advantages of the adjustable index for measuring a specific situation. Since the index can be adjusted and improved to be complete with a supply chain system, it will be major improvement after the model being implement in a supply chain.

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# APPENDICES

# APPENDIX A
# SUMMARIZE OF CRITICAL FACTORS IN SUPPLY CHAIN MANAGEMENT

| Factors | Definitions and their relationships | References |
|---|---|---|
| Collaboration | Collaboration is defined as sharing and exchanging information and planning among two or more independent companies .Its key elements include sharing information (Defee et al., 2010), knowledge (Naslund & Williamson, 2010), risk, and reward among partners in order to achieve mutual goals (Min et al., 2005). | (Beske et al., 2014), (Lohman et al., 2004), (Badea et al., 2014), (Panayides & Venus Lun, 2009), (Costantino et al., 2014), (Min & Zhou, 2002), (Meixell & Gargeya, 2005), (Chen et al., 2007), (Lee et al., 2011), (Naciri et al., 2011), (Fawcett et al., 2012), (Wu et al., 2014) |
| Coordination | Coordination is frequently mentioned in terms of collaboration (Costantino et al., 2014) and integration (Ibrahim & Hamid, 2014, Aryee et al., 2008, Lotfi et al., 2013) of supply chain systems . Coordination among supply chain members reduces various inefficiencies including the bullwhip effect and inventory issues (Costantino et al., 2014). Hence, coordination leads to better SCP in terms of benefits and profit (Lotfi et al., 2013). | (Costantino et al., 2014), (Lotfi et al., 2013), (Lee et al., 2011), (Zhang & Chen, 2013) |

| | | |
|---|---|---|
| Flexibility | Supply chain flexibility is the ability to be flexible in terms of operation and manufacturing (Duclos et al., 2003), including the ability to respond to the environmental changes (Huang et al., 2014a) to customize the product based on customer requirements .It is generally related to the ability to react to uncertain situations in both internal and external organization (Thoméa et al., 2014). | (Cai et al., 2009), (Sukati et al., 2012), (Thoméa et al., 2014) ,(Hwang et al., 2008), (Xu et al., 2009), (Wibowo & Sholeh, 2015), (Bourlakis et al., 2014a), (Afonso & Cabrita, 2015), (Gunasekaran et al., 2004b), (Ganga & Carpinetti, 2011), (Lohman et al., 2004), (Hon, 2005), (Bhagwat & Sharma, 2007), (Kim, 2009), (Avelar-Sosa et al., 2014), (Adel El-Baz, 2011), (Yu et al., 2010), (Cho et al., 2012), (Fan et al., 2013), (Acar & Uzunlar, 2014), (Bourlakis et al., 2014b), (Qrunfleh & Tarafdar, 2014), (Arnold et al., 2015) |
| Green (Environment) | Green supply chain is focused on integrating environmental issues into a supply chain (Zhu et al., 2016, Uygun & Dede, 2016) with the main purpose to minimize the overall effects from supply chain systems including product design, material sourcing, manufacturing processes, delivering, and disposing of the products on the environment (Uygun & Dede, 2016) (Kumar & Rahman, 2016). | (Zhu et al., 2008), (Azevedo et al., 2011), (Diabat & Govindan, 2011), (Olugu et al., 2011), (Azfar et al., 2014) |

| | | |
|---|---|---|
| Information sharing | Information sharing, an important part of IT systems, is the availability of information and knowledge sharing among partners within a network . It is considered as an important supply chain tool for a successful SCI, and coordination (Ibrahim & Hamid, 2014), and for improving firm performance (Sukati et al., 2012). | (Cai et al., 2009), (Lambert & Cooper, 2000), (Gunasekaran et al., 2004b), (Trkman et al., 2010), (Badea et al., 2014), (Abdullah & Musa, 2014), (Costantino et al., 2014), (Lotfi et al., 2013), (Yeung et al., 2009), (Min & Zhou, 2002), (Chen et al., 2007), (Naciri et al., 2011), (Wu et al., 2014), (Zhang & Chen, 2013), (Yu et al., 2010), (Fan et al., 2013), (Acar & Uzunlar, 2014), (Qrunfleh & Tarafdar, 2014), (Prajogo & Olhager, 2012), (Chen et al., 2013), (Luo et al., 2013), (Costantino et al., 2015), (Li & Zhang, 2015), (Marinagi et al., 2015), (Wong et al., 2015) |

| | | |
|---|---|---|
| Innovation | In SCM, innovation is strongly related to new products or services development that offers greater customer satisfaction. Innovation has been considered as a result of new knowledge and discovery (Craighead et al., 2009). Innovation is a new approach to improve operational efficiency and enhance service effectiveness (Bello et al., 2004) . | (Cai et al., 2009), (Craighead et al., 2009), (Woolliscroft et al., 2013), (Lin et al., 2010), (Beske et al., 2014), (Afonso & Cabrita, 2015), (Bhagwat & Sharma, 2007), (Adel El-Baz, 2011), (Panayides & Venus Lun, 2009), (Min & Zhou, 2002), (Fawcett et al., 2012), (Cho et al., 2012), (Fan et al., 2013), (Bello et al., 2004), (Chan et al., 2014) |
| Integration | Integration is resulting in the increase of supply chain capability and the ability to shorten the response time with high quality and reasonable cost (Naslund & Williamson, 2010) . It leads to better coordination of business processes across the members of a chain (Aryee et al., 2008). | (Vijayasarathy, 2010), (Sukati et al., 2012), (Hasan et al., 2014), (Lin et al., 2010), (He & Lai, 2012), (Beske et al., 2014), (Okongwu et al., 2016), (Kim, 2009), (Green et al., 2012), (Lotfi et al., 2013), (Min & Zhou, 2002), (Chen et al., 2007), (Yu et al., 2010), (Acar & Uzunlar, 2014), (Prajogo & Olhager, 2012), (Wong et al., 2015), (Koçoğlu et al., 2011), (Ryoo & Kim, 2015) |

| | | |
|---|---|---|
| Knowledge | Knowledge management (KM) is important in organizations and supply chain development. It is the process of collection, distribution, and implementation of knowledge resources (Woolliscroft et al., 2013). KM in a supply chain is reflected by the learning progression, use of knowledge, and knowledge collection (Craighead et al., 2009). Knowledge is a component shared by a supply chain. | (Craighead et al., 2009), (Woolliscroft et al., 2013), (Hasan et al., 2014), (Beske et al., 2014), (Adel El-Baz, 2011), (Min & Zhou, 2002), (Chen et al., 2013), (Luo et al., 2013), (Ryoo & Kim, 2015), (Borjeson et al., 2015) |
| Reliability | Reliability in SCM is mainly related to the capability to respond to customers. Ganga & Carpinetti (2011) mentioned that it is the ability to deliver to the right place, in the right quantity, at the right time, with the correct documentation, to the customers . It is measured as the percentage of correct orders delivered (Hwang et al., 2008). | (Hwang et al., 2008), (Wibowo & Sholeh, 2015), (Ganga & Carpinetti, 2011) |
| Responsiveness | Supply chain responsiveness is considered as a primary source of performance (Handfield & Bechtel, 2002). It is the speed of a supply chain systems to respond to customer demand (Ganga & Carpinetti, 2011). Responsiveness is also related to the accuracy and ability to provide the right products in the right place, at the right time (Bourlakis et al., 2014a). Thus, responsiveness within a chain is an element of supply chain flexibility. | (Craighead et al., 2009), (Sukati et al., 2012), (Handfield & Bechtel, 2002), (Hwang et al., 2008), (Wibowo & Sholeh, 2015), (Bourlakis et al., 2014a), (Ganga & Carpinetti, 2011), (Hon, 2005), (Avelar-Sosa et al., 2014), (Fan et al., 2013), (Bourlakis et al., 2014b), (Azfar et al., 2014) |

| | | |
|---|---|---|
| Risk | The risk is investigated in many research fields including supply chain management . In a supply chain, the risk is related to unreliable and uncertain processes in both supply and demand sides (Avelar-Sosa et al., 2014). Greater risk in a supply chain results in poorer inventory management, lead-time, flexibility, and responsiveness (Avelar-Sosa et al., 2014). | (Beske et al., 2014), (Avelar-Sosa et al., 2014), (Badea et al., 2014), (Hussain et al., 2015), (Min & Zhou, 2002), (Giannakis & Papadopoulos, 2016) |
| Technology | Technologies related and adopted in supply chains vary: for instance, Electronic Data Interchange and point of sale systems, information processing capability, information sharing (Vijayasarathy, 2010), Enterprise Resource Planning (Gunasekaran et al., 2004b), e-procurement and e-commerce, internet and extranets (Marinagi et al., 2014, Karakudilar and Sezen, 2012), and Radio Frequency Identification (Lee et al., 2011). | (Vijayasarathy, 2010), (Woolliscroft et al., 2013), (Gunasekaran et al., 2004b), (Ducq & Berrah, 2009), (Lohman et al., 2004), (Zin et al., 2013), (Badea et al., 2014), (Min & Zhou, 2002), (Chen et al., 2007), (Lee et al., 2011), (Naciri et al., 2011), (Yu et al., 2010), (Cho et al., 2012), (Acar & Uzunlar, 2014), (Qrunfleh & Tarafdar, 2014), (Prajogo & Olhager, 2012), (Bello et al., 2004) |

| | | |
|---|---|---|
| Trust | Trust is defined as confidence and willingness among members in exchanging information with each other (Panayides & Venus Lun, 2009, Yeung et al., 2009). This results in an improvement of responsiveness (Handfield & Bechtel, 2002). Trust is an essential element for sustainable development and collaboration of partners (Fawcett et al., 2012). | (Handfield & Bechtel, 2002), (Panayides & Venus Lun, 2009), (Abdullah & Musa, 2014), (Yeung et al., 2009), (Chen et al., 2007), (Fawcett et al., 2012), (Chen et al., 2013), (Ryoo & Kim, 2015), (Capaldo & Giannoccaro, 2015) |
| Strategies | Strategies are often considered as the primary method for operating and managing an organization. Supply chain strategies focus on two important aspects which are lean/efficient and agile/responsive (Zhou et al., 2014). The organizational performance is influenced by the relative strategy and developed elements to encourage the strategy (Defee et al., 2010). | (Craighead et al., 2009), (Sukati et al., 2012), (Lin et al., 2010), (Gunasekaran et al., 2004b), (Alomar & Pasek, 2014), (Lohman et al., 2004), (Adel El-Baz, 2011), (Green et al., 2012), (Qrunfleh & Tarafdar, 2014), (Kang et al., 2012) |
| Sustainable | Sustainable development is the development without compromising the ability of future generations (Gopalakrishnan et al., 2012). Sustainability in a supply chain is related to awareness towards environmental. It is often described as an integration of three dimensions namely economic, social, and environmental dimensions for sustainable development (Kumar & Rahman, 2016, Formentini & Taticchi, 2016). | (Lohman et al., 2004), (Hon, 2005), (Azfar et al., 2014), (Beske et al., 2014), (Bourlakis et al., 2014a), (Bourlakis et al., 2014b), (Grimm et al., 2014), (Pedro José Martínez-Jurado & Moyano-Fuentes, 2014), (Dadhich et al., 2015), (Hussain et al., 2015), (Giannakis & Papadopoulos, 2016) |

# APPENDIX B
# QUESTIONNAIRE SURVEY
# THE IMPACT OF SUPPLY CHAIN INTEGRATION ON FLEXIBILITY IN SUPPLY CHAIN PERFORMANCE: A CASE STUDY OF THAI AUTOMOTIVE INDUSTRY

This survey examines Supply Chain Integration factors affecting the Supply Chain Flexibility of Thai automotive industry. This study will support the integration between automotive manufacturers and supply chain partners.

All responses will be kept confidential and will not traceable to individual respondent. There is no right or wrong answer to the following questions. I am only interested in your assessment of your organization's activities. The questionnaire will take about 10 minutes to complete. The questionnaire survey is divided into 2 parts, including:

- Part I: Demographic information about the respondents.
- Part II: Ability of company in Supply Chain Integration 13 questions, Supply Chain Flexibility 15 questions, and Supply Chain Performance 7 questions.

**Part I: Demographic information about the respondents.**

**Please kindly identify the appropriate characteristics of your company.**

1. Please choose your position in company (Please choose only 1 answer).

   ☐ Owner/President ☐ Managing Director
   ☐ Executive ☐ Manager
   ☐ Chief (Department of…….) ☐ Other (Please specify.....)

2. Please choose your work experience in current company.

   ☐ Less than 1 year ☐ 1 – 5 years ☐ 6 - 10 years
   ☐ 11 - 15 years ☐ 16 - 20 years ☐ More than 20 years

3. Please choose your work experience in automotive industry.

   ☐ Less than 1 year ☐ 1 – 5 years ☐ 6 - 10 years
   ☐ 11 - 15 years ☐ 16 - 20 years ☐ More than 20 years

4. Please choose an experience of your company in Thai automotive industry.

   ☐ Less than 1 year ☐ 1 – 5 years ☐ 6 - 10 years
   ☐ 11 - 15 years ☐ 16 - 20 years ☐ More than 20 years

5. Please choose a type of company ownership.
   - ☐ 100% Thai Ownership
   - ☐ More than 50% Thai Ownership
   - ☐ Equal Thai and Foreign Ownership
   - ☐ More than 50% Foreign Ownership
   - ☐ 100% Foreign Ownership

6. Please choose type of car that suits with your products (You can choose more than 1 answer).

   ☐ Internal Combustion Engine Car ☐ Hybrid Car ☐ Electric Vehicle (EV)

7. Please choose your main raw material.

   ☐ Plastic ☐ Steel ☐ Rubber
   ☐ Other (Please specify.....)

8. Please choose your company product type (You can choose more than 1 answer).

   ☐ Engine parts ☐ Powertrain system ☐ Suspension parts
   ☐ Engine Electrical System
   ☐ Steering System ☐ Cooling system ☐ Air conditioning system
   ☐ Brake System ☐ Auto body parts ☐ Glass
   ☐ Lighting ☐ Wire ☐ Interior parts
   ☐ Interior electrical parts ☐ Seat/Fabric parts
   ☐Other (Please specify.....)

9. Please choose your company position in Supply Chain (Please choose only 1 answer).
   - ☐ Tier 1 (Directly supply the product to the automotive assembly company).
   - ☐ Tier 2 (Supply the product to tier 1 company).
   - ☐ Tier 3 (Supply the product to tier 2 company).
   - ☐ Other Tier (Raw material producer, such as plastic, steel, and rubber).

10. Number of employees.

    ☐ 1 – 50 Employees ☐ 51 – 200 Employees ☐ More than 200 Employees

**Part II: Supply Chain Integration, Supply Chain Flexibility, and Supply Chain Performance.**

Please indicate your level of agreement on the following statements based on your experience working in this company. The rating is from 1 = Extremely Disagree to 5=Extremely Agree

| No. | Do these Supply Chain Integration factors affect the Supply Chain Flexibility in Thai automotive industry? | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| *Integration in your company.* | | | | | | |
| 1 | Strategies development across functions within a company. | | | | | |
| 2 | Communication infrastructure within a company. | | | | | |
| 3 | Cross-functional working between departments to develop a production plan. | | | | | |
| 4 | Information sharing across functions within a company. | | | | | |
| *Integration between suppliers and your company.* | | | | | | |
| 1 | Strategies development cooperation with suppliers. | | | | | |
| 2 | Communication infrastructure between company and suppliers. | | | | | |
| 3 | Collaboration with suppliers to develop a production plan. | | | | | |
| 4 | Information sharing with suppliers. | | | | | |
| *Integration between customers and your company.* | | | | | | |
| 1 | Strategies development cooperation with customers. | | | | | |
| 2 | Communication infrastructure with between company and customers. | | | | | |
| 3 | Collaboration with customers to develop a production plan. | | | | | |
| 4 | Information sharing from customers. | | | | | |
| 5 | Customer opinion in quality and efficiency of your company. | | | | | |

1=Extremely Disagree to 5=Extremely Agree

| No. | Do these Supply Chain Flexibility factors affecting the Supply Chain Performance in Thai automotive industry? | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| *Flexibility in production process.* | | | | | | |
| 1 | Ability to produce new products according to customer preference. | | | | | |
| 2 | Ability to change a product specification (Minor Change) according to customer preference. | | | | | |
| 3 | Ability to adjust a production capacity according to customer preference. | | | | | |
| *Flexibility in company.* | | | | | | |
| 1 | Ability to adjust manufacturing process (production plan) according to customer preference. | | | | | |
| 2 | Ability to adjust a machine to perform different operations required. | | | | | |
| 3 | Ability of a material handling system to handle a production of different product types. | | | | | |
| 4 | Ability to support the job rotation. | | | | | |
| *Flexibility in product delivery.* | | | | | | |
| 1 | Ability to reschedule the delivery time according to customer preference. | | | | | |
| 2 | Ability to change a transportation route according to customer preference. | | | | | |
| 3 | Ability to change a warehouse location. | | | | | |
| 4 | Ability to adjust inventory level to serve the customer demand. | | | | | |
| *Flexibility of suppliers.* | | | | | | |
| 1 | Ability to substitute a main supplier with another supplier. | | | | | |
| 2 | Ability to increase suppliers to complete a production to serve the customer demand. | | | | | |
| 3 | Ability of suppliers to adjust a delivery service according to a company requirement. | | | | | |
| 4 | Ability of suppliers to adjust a product according to a company requirement. | | | | | |

| No. | Do these factors help increase the Supply Chain Performance in Thai automotive industry? | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| 1 | Ability to reduce manufacturing cost. | | | | | |
| 2 | Ability to reduce holding cost. | | | | | |
| 3 | Ability to reduce logistics cost. | | | | | |
| 4 | Ability to reduce manufacturing time. | | | | | |
| 5 | Ability to reduce lead time. | | | | | |
| 6 | Ability to reduce product development time. | | | | | |
| 7 | Ability to reduce defected product. | | | | | |

Suggestion

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**********Thank you for your cooperation**********

# APPENDIX C
# RAW DATA FOR INDEX DEVELOPMENT

| FROM/TO | II | SI | CI | PF | OF | LF | SF | SCP |
|---|---|---|---|---|---|---|---|---|
| II | - | 0.82 | 0.37 | 0.36 | 0.19 | -0.17 | 0.18 | - |
| SI | - | - | 0.47 | - | - | - | 0.5 | - |
| CI | - | - | - | 0.1 | -0.19 | 0.21 | - | 0.31 |
| PF | - | - | - | - | 0.42 | 0.45 | - | - |
| OF | - | - | - | - | - | - | - | 0.37 |
| LF | - | - | - | - | 0.16 | - | - | -0.1 |
| SF | - | - | - | 0.45 | 0.19 | 0.37 | - | 0.35 |
| SCP | - | - | - | - | - | - | - | - |

| SCI | Weight | Adjust weight | Raw score | Score |
|---|---|---|---|---|
| II | 3.15 | | | 100 |
| II1 | 0.75 | 0.238 | 100 | |
| II2 | 0.83 | 0.263 | 100 | |
| II3 | 0.78 | 0.248 | 100 | |
| II4 | 0.79 | 0.251 | 100 | |
| SI | 3.38 | | | 100 |
| SI1 | 0.85 | 0.251 | 100 | |
| SI2 | 0.92 | 0.272 | 100 | |
| SI3 | 0.88 | 0.260 | 100 | |
| SI4 | 0.73 | 0.216 | 100 | |
| CI | 4.14 | | | 100 |
| CI1 | 0.89 | 0.215 | 100 | |
| CI2 | 0.91 | 0.220 | 100 | |
| CI3 | 0.8 | 0.193 | 100 | |
| CI4 | 0.77 | 0.186 | 100 | |
| CI5 | 0.77 | 0.186 | 100 | |

| SI | CI | PF | OF | LF | SF | SCP | Total score |
|---|---|---|---|---|---|---|---|
| 0.119 | 0.115 | 0.056 | 0.070 | -0.010 | 0.063 | | 21.173 |
| 0.006 | 0.006 | -0.016 | | 0.017 | 0.013 | | |
| -0.002 | -0.002 | 0.010 | | | 0.002 | | |
| 0.001 | 0.001 | | | | -0.004 | | |
| -0.027 | -0.026 | | | | 0.013 | | |
| -0.008 | -0.008 | | | | 0.004 | | |
| 0.005 | 0.005 | | | | -0.007 | | |
| 0.144 | | | | | | | |
| 0.029 | | | | | | | |
| -0.015 | | | | | | | |
| 0.008 | | | | | | | |
| | 0.146 | | | | 0.175 | | 17.979 |
| | 0.007 | | | | 0.035 | | |
| | -0.002 | | | | -0.019 | | |
| | 0.001 | | | | 0.010 | | |
| | -0.033 | | | | | | |
| | -0.010 | | | | | | |
| | 0.006 | | | | | | |
| | | 0.016 | -0.070 | -0.021 | | 0.310 | 17.379 |
| | | -0.005 | | 0.012 | | | |
| | | 0.003 | | | | | |

| SCF | Weight | Adjust weight | Raw score | Score |
|---|---|---|---|---|
| PF | 3.44 | | | 100 |
| PF1 | 0.88 | 0.256 | 100 | |
| PF2 | 0.86 | 0.250 | 100 | |
| PF3 | 0.9 | 0.262 | 100 | |
| OF1 | 0.8 | 0.233 | 100 | |
| OF | 2.85 | | | 100 |
| OF2 | 0.91 | 0.319 | 100 | |
| OF3 | 0.89 | 0.312 | 100 | |
| OF4 | 1.05 | 0.368 | 100 | |
| LF | 3.22 | | | 100 |
| LF1 | 0.83 | 0.258 | 100 | |
| LF2 | 0.87 | 0.270 | 100 | |
| LF3 | 0.77 | 0.239 | 100 | |
| LF4 | 0.75 | 0.233 | 100 | |
| SF | 3.49 | | | 100 |
| SF1 | 0.81 | 0.232 | 100 | |
| SF2 | 0.88 | 0.252 | 100 | |
| SF3 | 0.89 | 0.255 | 100 | |
| SF4 | 0.91 | 0.261 | 100 | |

| SI | CI | PF | OF | LF | SF | SCP | Total score |
|---|---|---|---|---|---|---|---|
| | | | 0.155 | -0.045 | | | 8.712 |

| | | | | |
|---|---|---|---|---|
| | | 0.027 | | |
| | | | 0.370 | 20.743 |
| | 0.059 | | -0.100 | -5.606 |
| 0.070<br>0.012<br>-0.020 | 0.070 | 0.022<br>-0.037 | 0.350 | 19.621 |

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| | |
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