# DETERMINANTS OF LOW CARBON SUPPLY CHAIN IN MALAYSIAN MANUFACTURING INDUSTRY: PRACTICES AND ITS RELATIONSHIP ON GREEN SUPPLY CHAIN OPERATIONAL PERFORMANCE AND LOW CARBON PERFORMANCE

MUHAMMAD SHABIR SHAHARUDIN

DOCTOR OF PHILOSOPHY

UNIVERSITI MALAYSIA PAHANG

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MUHAMMAD SHABIR SHAHARUDIN

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# ABSTRAK

Perubahan iklim semasa merupakan penyumbang utama kepada kelestarian alam. Penyumbang utama perubahan iklim ini adalah kerana pelepasan karbon yang tinggi. Oleh itu, sarjana dan pengamal industi telah memberi tumpuan kepada pengurangan pelepasan karbon di dalam rantaian bekalan dan operasi syarikat pembuatan. Ini adalah kerana syarikat di sektor pembuatan mempunyai kadar pencemaran karbon yang tinggi. Walau bagaimanapun, model rantaian bekalan sedia ada tidak mampu mengurangi pelepasan karbon kerana ketiadaan langkah amalan pengurangan karbon yang menyeluruh. Justeru, penyelidikan ini adalah bertujuan untuk membangunkan model pengurangan karbon didalam rantaian bekalan yang berlandaskan teori. Selain itu, kajian ini juga bertujuan untuk menganalisa hubungkait antara penentu dengan amalan pengurangan karbon rantaian bekalan serta hubungkait antara amalan pengurangan karbon rantaian bekalan dengan prestasi karbon rendah. Selain itu, penyelidikan ini juga telah memperkenalkan pembolehubah pengantara prestasi operasi rantaian bekalan hijau. Metodologi kuantitatif telah digunapakai oleh kajian ini bagi menjawab kajian objektif. Sebanyak 700 kajian soal selidik telah dihantar kepada syarikat pembuatan yang berdaftar dibawah Persekutuan Perkilangan Malaysia dan sebanyak 143 soal selidik telah diterima lengkap untuk tujuan analisa. Analisa kajian dilakukan dengan menggunakan perisian IBM SPSS versi 24 dan SmartPLS versi 3.2.8. Hasil kajian mendapati amalan pengurangan karbon rantaian bekalan mempunyai hubungan positif dan penting kepada prestasi karbon rendah oleh syarikat pembuatan. Selain itu, kajian menunjukkan prestasi operasi rantaian bekalan hijau mampu menjadi pengantara dan meningkatkan hubungan antara amalan pengurangan karbon rantaian bekalan dengan prestasi karbon rendah. Tambahan pula, tekanan dari pelanggan didapati mempunyai pengaruh lebih memaksa berbanding peraturan kerajaan didalam amalan pengurangan karbon rantaian bekalan. Keseluruhan hasil kajian ini menyumbang kepada pembangunan teori institusi dan kajian literatur rantaian bekalan dan operasi. Hasil penyelidikan juga dapat membantu syarikat untuk meningkatkan prestasi penjagaan alam sekitar dan prestasi operasi syarikat.

# ABSTRACT

Climate change has become one of the most critical sustainability challenges. One of the most evident contributor of climate change is carbon emissions. Therefore, academia and firms are focusing on carbon emissions reduction in both the supply chain and operations as manufacturing and supply chain activities emit high carbon emissions. Nevertheless, the current supply chain model lack of carbon emissions abatement. Thus, this study's objectives are to develop a theoretical model for low carbon supply chain and to examine the relationship between determinants on low carbon supply chain practices and the practices with low carbon performance. In addition, this study also investigates the mediating effect of green supply chain operational performance. The methodology adopted in this study is of a quantitative method. 700 survey questionnaires were sent out to manufacturing firms registered with Federal of Manufacturers Malaysia and 143 completed questionnaires were collected and analyzed. This study uses IBM SPPS version 24 and SmartPLS version 3.2.8 software to analyze the data. Based on the finding, it shows that low carbon supply chain practices have positive effect on low carbon performance of firms. In addition, the mediating effect of green supply chain operational performance was found to mediate the relationship and improve low carbon supply chain practices of manufacturing firms. It was further found that customer pressure has a coercive nature compared to government regulations. These findings have contributed to the extension of Institutional theory knowledge and the literature of supply chain and operations. The comprehensive low carbon supply chain model has also been proven valid and reliable to help manufacturing firms meet environmental performance and operational performance. The introduction of mediating effect to improve low carbon performance has also contributed to the literature as currently firms are split in decision whether to achieve environmental performance or operational performance. The finding shows that manufacturing firms achieved better results with both performances. Practically, manufacturing firms are recommended to adopt green supply chain operational performance in order to achieve better low carbon performance.

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# INTRODUCTION

## 1.1 Introduction

This study is to investigate carbon emissions reduction in manufacturing industry. This chapter will begin with introducing the issues of carbon emissions in general before relating to manufacturing industry. Then, the section will continue with problem statement with regard to carbon emissions reduction that this study will focus on its investigation. After that, the proposed research objectives and research questions for the investigation of carbon emissions reduction will be presented before explaining the significance of the study. Additionally, key terms that will be used throughout the study, scope of the study and structure of thesis will be discussed to guide the study.

## 1.2 Background of study

Carbon emissions has become a threat to sustainability. This is because carbon emission that produces carbon dioxide gas traps heat and stay on Earth's atmosphere for more than 100 years (Juniper, 2007). Due increasing carbon emissions, world's temperature has increased exponentially resulting in global warming and changing of Earth's ecosystem. This leads to sustainability issues such as environmental impacts, social repercussion and economic downturn (Luthra & Kumar, 2018; Atanda, 2018; Wang, Zhao, & He, 2016). As such, the world has seen an increase of natural disaster taking place more often, human migration from climate-affected places to urban areas and changing people's way of life that includes consuming more energy and resources. As a result, scholars and firms have focus on investigation to reduce carbon emissions (Shaharudin, Fernando, Jabbour, Sroufe, & Jasmi, 2019).

Rich research findings have found that one of the heaviest polluters of carbon emissions are manufacturing firms (Chowdhury et al., 2018; Griffin, 2017; Salim et al., 2018; Santibanez-Gonzalez, 2016). All over the world including Malaysia, the manufacturing industry focuses on environmental budget to stimulate manufacturing firms in reducing carbon emissions. In addition, incentives on low carbon technology adoption is provided. This is due to the fact that manufacturing firms do not only produce products but the layers of processes and numerous supply chain partners too plays a role in the production of a product (Bastas & Liyanage, 2019; Tseng et al., 2019). For example, manufacturing firms need to get its supplies of energy and materials from suppliers, design, manufacture, distribute and transport the product. These processes and multiple supply chain partners contribute to an increase in carbon emissions emitted from the manufacturing activities of a product. As a result, managing supply chain has become a critical issue for firms to reduce carbon emissions.

Attention by scholars have directed the investigation of carbon emissions reduction towards the supply chain process of a firm (Denham, Biswas, Solah, & Howieson, 2016; He, Xiong, & Lin, 2016; Ji, Zhang, & Yang, 2017a; Kaur & Singh, 2017b; Luo, Gunasekaran, Dubey, Childe, & Papadopoulos, 2017; Mao, Zhang, & Li, 2016). Furthermore, many scholars are beginning to focus on the management aspect of how to reduce carbon emissions due to its contribution to the literature, industry and firms (Bastas & Liyanage, 2018; Long & Young, 2016; Scur & Barbosa, 2017). The reason as to why scholars focuses on the investigation of carbon emissions reduction practices in manufacturing firms is because logistics activities in the supply chain contributes 5.5 percent (2800 mega-tonnes) of world carbon emissions (Tacken, Sanchez Rodrigues, & Mason, 2014) and another study found that the operations of producing cement contributed five percent of global carbon emissions (Ishak & Hashim, 2015). Furthermore, Nishitani, Kokubu, and Kajiwara (2013) found that the upstream process in a supply chain greatly produce carbon emissions per unit of output while overall carbon emissions are very high in downstream of supply chain process. This shows that the existing supply chain and theoretical model are lacking carbon abatement initiatives. Therefore, scholars and firms need to focus on conceptualizing and practicing Low Carbon Supply Chain (LCSC) to reduce carbon emissions (Huisingh, Zhang, Moore, Qiao, & Li, 2015; Kaur & Singh, 2017; Urata, Yamada, Itsubo, & Inoue, 2015).

LCSC can be outlined as carbon emissions reduction throughout the activities of a supply chain. Taking into consideration of both supply chain and operations concern with carbon emissions reduction (Alves, de Sousa Jabbour, Kannan, & Jabbour, 2017; Santibanez-Gonzalez et al., 2016; Wang et al., 2017; Zhou, Bao, Chen, & Xu, 2016), a holistic study on implementation of LCSC practices to achieve carbon emissions reduction is recommended (Hong, Su, Chu, & Yen, 2018; Jervis, 2015; Schanes, Giljum, & Hertwich, 2016). There are several factors that impact firms' strategies to reduce carbon emissions. For example, compliance with environmental regulations (Wahyuni & Ratnatunga, 2015) and image of the firm and its relationship with stakeholders (Long & Young, 2016) are important elements for decision making to reduce carbon emissions. Stakeholders such as governments, customers, employees, shareholders and environmental Non-Governmental Organizations (NGOs) are all found to have interest in firms' carbon emissions reduction (Böttcher & Müller, 2015). The question is not whether firms should adopt or abandon carbon emissions practices (Liu, 2014) but the question is how firms can effectively achieve carbon emissions reduction without losing the trust of its stakeholders. This shows that a study of determinants and outcomes of LCSC is critical for the manufacturing industry.

In order to drive firms to practice LCSC, previous studies have recognized that government, customers and environmental NGOs are pressuring firms to practice carbon emissions reduction (Böttcher & Müller, 2015; Talbot & Boiral, 2015). Internal pressures such as top management support and technological advancement and external pressures such as governmental regulations, customer pressure and environmental NGOs have significant influence on firms response towards carbon emissions reduction and practicing LCSC (Luo et al., 2017). Due to the pressure to produce low carbon products, manufacturing firms in supply chains have to change strategies from conventional supply chain practices to implement LCSC practices. The reason for LCSC adoption is to reduce total costs of supply chain and improve supply chain performance (Zhou et al., 2016). This is the missing part of conventional supply chain that looks "business as usual". The conventional supply chain activities do not include environmental management practices (Subramanian & Gunasekaran, 2015) where environment including low carbon emissions become a focal point in the supply chain and operations. Furthermore, conventional supply chain concept does not take into consideration latest requirements of dynamic business environment. In current industry climate, firms need to take a proactive approach due to fast changing operating environment such as political, economy, social, technology and environment wellness. Firms that remain static and unable to strategize for low carbon environment will lose its capabilities and competitive advantage resulting in low performance. Thus, firms that are not practicing carbon emissions reduction have not able to achieve its potential and performance maximization.

Traditionally, economic performance is the most sought after objective by manufacturing firms but operational and environmental performances (Balfaqih, Nopiah, Saibani, & Al-Nory, 2016) are now gaining attention to meet customer and societal demands. Firms practicing environmental friendliness strive to ensure the manufacturing of product meet the environmental and societal demands by stakeholders. Thus, in the literature, environmental friendliness has become an interest for both scholars and firms (Ahi & Searcy, 2015; Balfaqih et al., 2016; Bhattacharya et al., 2014; Chardine-Baumann & Botta-Genoulaz, 2014; Subramanian & Gunasekaran, 2015). Environmental friendliness can be outlined as supply chain achieving better performance without harming the environment through less energy consumption and process and the usage of clean energy in the production (Gunasekaran & Ngai, 2012). As environmental friendliness can help in carbon emissions reduction, it has been widely adopted by manufacturing firms (Beske & Seuring, 2014; Wahyuni & Ratnatunga, 2015). Even though environmental friendliness has been adopted by manufacturing firms, the industry itself is still preferring operational excellence in terms of flexibility, responsiveness and cost reduction without emphasising on environmental friendliness. This means that firms are voluntarily measuring their performance on environmental friendliness just to appease stakeholders rather than to meet the requirement of low carbon industry. On the other hand, it shows that scholars are partially correct in exaggerating environmental friendliness adoption in the industry. Scholars investigation into operational excellence should undertake the inclusion of LCSC as an important criteria for operational performance as firms nowadays need to achieve not only operational performance but economic, social and environment (Fernando, Jasmi, & Shaharudin, 2019).

Practicing LCSC enable manufacturing firms to reduce carbon emissions and achieve environmental performance. Environmental performance has been a concern by stakeholders especially the government and customers. This led manufacturing firms to reduce air emissions such as carbon emission, effluent waste and solid waste as well as decrease consumption of hazardous materials (Zhu et al., 2013). Since carbon emission comes from generating energy for manufacturing and supply chain process, statistics have shown that energy is one of the largest contributors of carbon emissions for United States of America (International Energy Agency, 2015b), European Union (Benjaafar, Li, & Daskin, 2013), Japan (Nishitani et al., 2013) and Malaysia (Department of Statistics Malaysia, 2016a). Therefore, to reduce carbon emissions, manufacturing firms need to focus on air emission more than other environmental emissions and waste. Yet, scholars failed to imprint the importance of energy due to lack of literature on the difference between Green Supply Chain Management (GSCM) and LCSC. Nishitani et al. (2013) distinguished LCSC as a special type of GSCM aimed at improving GHGs emissions performance through energy management throughout entire supply chain. By reducing GHGs emissions through energy management, firms will be able to achieve Low Carbon Performance (LCP). To do so, firms need to record carbon emissions throughout its supply chain process and network. LCP can be defined as firm's commitment to reduce carbon emissions.

## 1.3 Problem Statement

The commitment of reducing carbon emissions is important because numerous studies have shown the significant impact of firms achieving LCP (He, Chen, Liu, & Guo, 2017; Kellner & Igl, 2015; Lee & Choe, 2019; Makridou, Doumpos, & Galariotis, 2019). Firms reduce carbon emissions not only to achieve performance but also to reduce fines or taxes on carbon emission discharge (Fernando & Hor, 2017). As global market has more stringent carbon requirements, more firms are beginning to measure its carbon footprint. Similarly, source of energy and energy used have been monitored and measured together with carbon emissions due to its contribution to carbon emissions (Fernando, Bee, Jabbour, & Thomé, 2018). An investigation by Benjaafar et al. (2013) has found that in terms of country-level carbon emissions, 50 percent of European Union countries carbon emissions come from energy generation. In addition, another investigation by Matthews, Hendrickson, and Weber (2008) found that in terms of carbon emissions from firm-level, 40 percent of carbon emissions comes from source of energy and energy used. These findings show close-relatedness of energy with carbon emissions. Thus, manufacturing firms that are heavily dependent on energy need to measure and reduce energy consumption on top of carbon emissions reduction. Simultaneously, manufacturing firms also need to reduce the use of carbon-intensive materials in product development and production. Several studies in the literature have shown the impact of carbon-intensive materials on firm's LCP (Kis, Pandya, & Koppelaar, 2018; Millward-Hopkins et al., 2018; Schandl et al., 2016) and how substituting to less carbon-intensive materials help firms to achieve LCP (Arena, Lee, & Clift, 2016; Chiriacò, Grossi, Castaldi, & Valentini, 2017; Kumar et al., 2017; Neamhom, Polprasert, & Englande, 2016). However, reduction in emitting carbon emissions, energy use and carbon-intensive materials depend on accurate measurement of carbon emissions that remain unclear until firms report carbon emissions data and disclose LCSC practices.

Nevertheless, the extend that LCSC practices contribute to firm's performance is unclear (Zhu et al., 2013) because LCSC practices has to be linked with measurement of LCP. The inconsistent current findings on LCP is due to scholars are currently still developing the low carbon measurement in management. For example, LCP indicators developed by Böttcher and Müller (2015) for German manufacturing firms focus on three measurement items to record carbon emissions that focus on operations and quantifying per output carbon emissions that are difficult to obtained as carbon reporting is voluntary. On the other hand, Fernando and Hor (2017) have five measurement items for recording carbon emissions in Malaysian manufacturing firms that are based on perception of top management. While these measurement items are easier to be collected by firms, it failed to distinguish between carbon emissions reduction and energy performance. Overall, both scholarly measurement items were not tested on supply chain of manufacturing firms. On the other hand, other scholars include carbon emissions reduction indicators as general environmental indicators (Mao et al., 2016; Sambasivan et al., 2013; Zhu & Geng, 2013). Yet, these measurements have not been standardized that would allow generalizability with other industries. A more specific indicator for LCP will help to establish more concrete understanding of how manufacturing firms can achieve carbon emissions reduction.

The main problem with various supply chain performance measures is that firms find it difficult to measure supply chain due to complexity of supply chain networks. Due to this complexity, there are different terminologies adopted by scholars and unstandardized performance measures for supply chain performance. Due to these issues, specific industry-related supply chain performance measures is suggested (Balfaqih et al., 2016). For example, important indicators to measure supply chain performance in manufacturing industry are flexibility, responsiveness and cost reduction (Balfaqih & Yunus, 2014). Yet, with 34 percent of data collected from manufacturing industry for studies of supply chain practices (Gorane & Kant, 2015b), there is lack of uniformed measures (Balfaqih et al., 2016) because firms in the supply chain networks have different performance measures. In that regard, scholars have identified key supply chain performance measures such as cost, quality, flexibility, responsiveness, reliability and asset management (Balfaqih et al., 2016) but other scholars argued that manufacturing industry is changing and current performance measures are insufficient to address latest trends in the industry. As such, latest performance measure need to be included for firms to achieve performance such as risk (Heckmann, Comes, & Nickel, 2014; Leat & Revoredo-Giha, 2013) and environmental friendliness (Garg, Kannan, Diabat, & Jha, 2015; Kushwaha & Sharma, 2016).

In a systematic review study of Wang, Zhao, Mao, Zuo and Du (2017) on low carbon studies found that low carbon studies on management approach only accounted for 11.6 percent from overall LCP investigations. Scholars investigating LCP on management approach uses multidisciplinary study but places more emphasis on economics perspective. This shows the need for a new development of LCP investigation from management perspective that covers multiple performance measures. The engineering approach on the other hand has contribute great number of studies with more studies being done with regard to energy and fuels (25.5%) and environmental sciences (23%) (Wang et al., 2017). While, an engineering approach contributes to measurement of carbon emissions, it offers limited knowledge for managers to understand without the help from technical specialists. Therefore, this study of LCP uses a management approach essentially to help firms understand the importance of carbon emissions reduction by integrating both management and engineering approach.

## 1.4 Summary of Literature Gaps

This section will discuss on summary of literature gaps. Further details can be found in Chapter 2 research debate section. This section however will summarize overall literature gaps found in regard to determinants of LCSC, LCSC practices, GSCOP, LCP and theory that are still lacking in the literature.

In the literature, there is still lack of complete investigations on pressures of firms to adopt LCSC practices. Currently scholars look at internal pressure and there has been wide investigations on external pressures (Böttcher & Müller, 2015; Luo et al., 2017;

Zhang, Wang, Yin, & Su, 2012; Zhu et al., 2013). This is due to lack of integration of theory in scholarly works. In addition, there are some studies by scholars that have overlapping theories that results in inconsistent findings (Geng, Mansouri, & Aktas, 2017). Therefore, investigation of internal and external pressures is required to understand what pressure firms to adopt LCSC practices.

Inconsistent findings in the literature due to overlapping theory will results in low robustness of the LCSC model development. Current supply chain model lack of carbon reduction practices (Benjaafar et al., 2013) while some LCSC model developed in the literature failed to take into consideration of overall performance of the firm's supply chain (Wang et al., 2017). Thus, there is a need to extend current LCSC model to improve the robustness of the model.

In order to improve the robustness of the LCSC model, there is a need to link between practices and performances (Zhu et al., 2013). Studies by Böttcher and Müller (2015) and Nishitani et al. (2013) found that meeting the operational goals are critical for manufacturing firms to reduce carbon emissions. Similarly, Zhu et al. (2013) found that manufacturing firms that focus on operational performance are able to achieve environmental performance. Therefore, in order to reduce carbon emissions, manufacturing firms need to be allowed to achieve GSCOP as it will help to improve firms' LCP.

Improvement of LCP for firms require firms to record and measure carbon emissions across the supply chain (Mao et al., 2016). However, current measurement of LCP is unstandardized and therefore measuring carbon emissions is challenging. There are scholars proposing LCP measurement based on output of carbon emissions (Böttcher & Müller, 2015; Matthews et al., 2008; Nishitani, Kokubu, & Kajiwara, 2016), but this measurement is not widely accepted as carbon reporting is still a voluntary act for firms. On the other hand, there are also scholars measuring LCP with actions taken by firms to reduce carbon emissions (Fernando & Hor, 2017; Luo et al., 2017; Shaharudin & Fernando, 2017), but this measurement has failed to differentiate between energy measurement and carbon emissions measurement. Thus, an investigation of LCP with wide acceptance and ease of use measurement is recommended.

On the other hand, organizational theory that is used to explain firm's practices is insufficiently in the literature in discussing the relationship and providing empirical evidence. This is due to organizational theory has just now getting attention by scholars to contribute to the new area of multidisciplinary such as supply chain (Sarkis, Zhu, & Lai, 2011). Therefore, LCSC model development and investigation of its relationship supporting by organizational theory is able to provide empirical justification, extending the theory understanding and improve the robustness of the model.

## 1.5 Research Objectives

In this section, the research objective is discussed. To do so, this study will discuss the proposed theoretical framework in the literature review chapter based on the following research objectives:

1. To develop a theoretical framework of LCSC based on Malaysian manufacturing industry practices by examining determinants of LCSC practices, determinants of GSCOP and determinants of LCP and its relationship
2. To investigate the relationship between determinants and LCSC practices
3. To investigate the relationship between LCSC practices and GSCOP
4. To investigate the relationship between GSCOP and LCP
5. To investigate the mediating effect of GSCOP to leverage the link of LCSC practices and firm outcomes in Malaysian manufacturing industry

## 1.6 Research Questions

Manufacturing industry is one of the highest contributor of carbon emissions in the world after transportation and energy generation (Huisingh et al., 2015; Ishak & Hashim, 2015). To reduce carbon emissions, manufacturing firms need to achieve LCP by practicing LCSC in procurement, product development, production process, distribution and logistics. This study can be used as a guideline by the industry to overcome environmental issues and to reduce operational costs. In addition, other scholars can adopt this study's findings in other countries within the same industry. The research questions posed by this study are as follows:

6. What is the theoretical framework of LCSC practices in Malaysian manufacturing industry, determinants of LCSC, LCSC practices, determinants of GSCOP, determinants of LCP and its relationship?
7. What is the relationship between determinants and LCSC Practices?
8. What is the relationship between LCSC practices and GSCOP?
9. What is the relationship between GSCOP and LCP?
10. Does GSCOP mediate between LCSC practices and firm outcomes in Malaysian manufacturing industry?

## 1.7 Significance of Study

This section will discuss the significance of this study. By undertaking this study, practically it will contribute to firms and the society such as consumers. Consequentially, this study will also fill the gaps in the literature through theoretical contributions.

### 1.7.1 Theoretical Contribution

The study of LCSC is critical to reduce negative outcomes of manufacturing activities in developing countries (Geng et al., 2017). In the literature, scholars have proposed theoretical framework for LCSC, but it is not comprehensive. There are scholars proposing theoretical framework for LCSC such as Böttcher and Müller (2015) but their studies limit their investigation to individual supply chain activities and not the whole supply chain process. In addition, low carbon procurement was not a consideration whereas other scholars such as Nishitani, Kokubu and Kajiwara (2016) and Mao et al. (2016) stressed on the importance of low carbon procurement activity in their LCSC framework. However, those scholars failed to differentiate each supply chain process in their studies. Therefore, this study will propose a comprehensive LCSC theoretical framework for manufacturing firms.

A theoretical framework development needs to be and should be supported by a theory. The theory that will be used in this study is an institutional theory as this study tries to investigate LCSC in manufacturing firms. Institutional theory is used to explain the behaviour of an organization as in this case it relates to manufacturing firms. In the literature, it was found that many studies on LCSC and Green Supply Chain Management (GSCM) have not disclosed or explain the theory that governs their theoretical framework. For example, a study by Geng et al. (2017) on meta-analysis of empirical evidences for GSCM studies in Asian emerging countries found that almost half of scholarly work did not specify their theoretical approach. Other than the issue of theoretical approach, the literature shows that scholars have not fully understood the underpinning theory for their theoretical framework (Dubey et al., 2017). Scholars that understand underpinning theory use mostly institutional theory, contingency theory and resource based view to explain the pressure of firms to adopt LCSC practices (Geng et al., 2017). Even though institutional theory is widely used in scholarly work, there are still gaps in the knowledge that can be filled. For example, scholars are divided whether institutional theory can be used to explain the internal pressure of firm. Furthermore, institutional theory is regarded as a theory that can explain why and how firms adopt LCSC practices. Yet, there are no concrete evidences that were supported by empirical data. Thus, this study will contribute to the literature by explaining LCSC framework with institutional theory and provide empirical data to further expand the knowledge of the theory.

In the literature, theoretical framework development and underpinning theory are not the only gaps that need to be addressed. As the literature pointed out, scholars are divided in their school of thoughts. Some view LCSC as extension of GSCM (Nawrocka, 2008) and some view LCSC as different from GSCM (Nishitani et al., 2013). Due to different school of thoughts regarding LCSC, there are several LCSC measurement indicators provided in the literature. For example, scholars such as Böttcher and Müller (2015) and Fernando and Hor (2017) contributed to LCP indicators while other scholars such as Mao et al. (2016) and Zhang, Wang, Yin and Su (2012) measure LCP using environmental performance indicators that are widely used in the investigation of GSCM. In this study, LCP indicators are adopted from Böttcher and Müller (2015) because it is suitable for manufacturing firms. In addition, this study's empirical result of LCP can be adopted by other scholars in other countries or industries.

More studies on LCSC with evidence of empirical data will help scholars to extend the understanding of how manufacturing firms can reduce carbon emissions. Empirical data is needed to test the relationship between LCSC practices and LCP. Testing the link between practices and performance will help scholars to understand more of LCSC. In this study, the relationship of LCSC practices with GSCOP and LCP will be tested to contribute to the empirical findings and relationship result.

### 1.7.2 Practical Contribution

Due to Malaysia's manufacturing industry being one of the most developed industry in ASEAN, it is relevant for firms within the industry to reduce carbon emissions. As Malaysia ratified the carbon emissions plan in Paris Climate Change Agreement (United Nations Convention on Climate Change, 2015), the Malaysian government needs to balance the trade-off between economic and environmental effects. Thus, this industry will receive more attention from regulatory bodies as this industry is important and releases high carbon emissions. This study can help firms understand what and how manufacturing firms can achieve operational performance and environmental performance by meeting governmental regulations, customer pressure and environmental NGOs requirements. Furthermore, manufacturing firms also will understand how their upper echelon management's support and green technology can help achieve GSCOP and LCP.

Government incentives for energy efficiency and renewable energy are part of low carbon emissions strategies that manufacturing firms can adopt in their supply chain (Ahi, Searcy, & Jaber, 2016). Additionally, the government is still developing and improving current policies to reduce carbon emissions so that Malaysia can achieve 40 percent GHGs reduction by 2020 (United Nations Development Programe Malaysia, 2014) via increasing carbon emissions knowledge in the Malaysian industry. Developing knowledge on carbon emissions in the manufacturing industry through incentives will motivate manufacturing firms to focus more on energy use, cost reduction (Böttcher & Müller, 2015) and reduce carbon emissions in the supply chain. Thus, adoption of low carbon practices with suppliers (Kaur & Singh, 2017), product development (Wang, Zhao, & He, 2016), energy efficiency (Fernando & Hor, 2017) and green technology (Fernando, Wah, & Shaharudin, 2016) in the production process, distribution and logistics (Du, Tang, & Song, 2016) will help firms achieve GSCOP and LCP.

This study proposed supply chain performance measures to highlight LCSC practices that impact GSCOP. These measures are taken from the literature and based from "best practice" (Chardine-Baumann & Botta-Genoulaz, 2014) that can be used by manufacturing firms to achieve its objectives. As low carbon manufacturing performance measurement is not yet established in the literature, this study will contribute to the development of low carbon manufacturing performance through GSCOP.

Lastly, as measurement of LCP are available in the literature for manufacturing firms to record carbon emissions and reduce the emissions, variety of measurements adds to the confusion as to what to measure and how to reduce carbon emissions. Therefore, this study's adoption of the LCP measurement will help manufacturing firms to quantify carbon emissions and contribute to the carbon emissions reduction.

## 1.8 Scope of Study

This study focuses on the management aspect of LCSC practices towards achieving LCP for manufacturing firms in Malaysia. The management aspect of this study ensures that the relevant theoretical contribution and practical contribution are geared towards organizational theory and management's or policymakers' contributions respectively. Therefore, this study will investigate determinants or push factors for manufacturing firms to adopt LCSC practices and its relationship on how LCSC practices help manufacturing firms to achieve both operational performance and LCP. In this regard, this study proposed the understanding of what pressures firms to adopt LCSC practices, what LCSC practices help firms to achieve operational performance and LCP and how firms' achievement in operational performance will lead to realization of LCP.

This study sample is manufacturing firm practicing LCSC and there are many studies on LCSC or GSCM in manufacturing industry in Malaysia that has small sample size or response rate no more than 30 percent. As getting response from firm is difficult, this study still use firm as unit of analysis as manufacturing firms contribute a lot to LCP and information regarding firms' LCSC practices are able to contribute vastly to theoretical and practical contributions even though the sample frame and sample size are small.

This study is based on perception and adoption of LCSC without quantifying carbon emissions data. Therefore, results from this study is suitable for firm's adoption of LCSC and reduction of carbon emissions in a holistic view. Furthermore, this study's empirical results will be suitable to justify findings from engineering approach literature. As a result, empirical evidences and previous studies of engineering approach are suitable for this study as it will contribute to the practices and performance of manufacturing firms.

### 1.9 Definition of Key Terms

In this section, the terminologies used throughout this study will be briefly explained to guide understanding of the study. The more specific and thorough understanding will be further explained in the literature review section.

#### 1.9.1 Determinants of Variables

**Government regulation** is a pressure exert by institutions such as nation's government body and local government where firms operate. In this study, both effects are considered as one, which falls under government regulation. As environmental management is important, government pressures firms to adhere and take responsibility towards the environment through regulations (Zhu et al., 2013).

**Customer pressure** is a power possess by customer that firms need to satisfy. Customer determines the success of firms to sustain in the business. As environmental consciousness and knowledge increases, customers are demanding firms to take more proactive role in preserving the environment while producing environmental friendly products and services (Zhu et al., 2013).

**Green Technology** is considered as an important element in reducing pollutions and the harming of the environment through adoption of technologies. As environmental issues intensify, firms are pressured to invest and adopt more green technology and efficient equipment to ensure fewer waste, lean management, reduce pollution, energy efficiency and low carbon emissions (Fernando et al., 2016a).

**Environmental Non-Governmental Organizations (NGOs)** play a crucial role in helping the government and public to monitor and pressure firms to be more responsible towards the environment. Environmental NGOs pressure firms to adopt environmental management practices, organises industrial activities for firms, monitor firms' environmental activities and take into consideration of firms' carbon emissions reduction practices (Tachizawa, Gimenez, & Sierra, 2015; Zhu et al., 2013).

**Top management support** is crucial in determining the success or failure of firms' green practices. Top management makes decisions on supporting low carbon efforts, while assessing the impact of carbon emissions on the business, preference for natural environment over higher profits and commitment on reducing carbon emissions across supply chain activities (Colwell & Joshi, 2013).

### 1.9.2 Predictor Variables

**Low carbon procurement** is a process of integrating decisions between suppliers and firms in designing a product and suppliers' processing of raw materials into virgin materials that will be used in the production. The concerns of low carbon procurement are low carbon requirements for purchased items, suppliers meeting low carbon objectives, performing environmental audit for suppliers and environmental standards for suppliers (Zhu et al., 2013).

**Low carbon product** is a process where firms make decisions on carbon emissions reduction throughout the life cycle of the product, using recycled materials for the product and reduce carbon intensive materials (Böttcher & Müller, 2015).

**Low carbon production process** is a process where virgin materials are fabricated and assembled during production process. The concerns of low carbon production process are measurement of carbon emissions during production process, the utilization of carbon efficient equipment in the production process , low carbon energy sources and practicing recycling of carbon intensive scrap (Böttcher & Müller, 2015).

**Low carbon distribution** is a process in which firms along the supply chain interact. The interaction among supply chain partners include product movement along the supply chain and inventory storage at the warehouses. This process concerns the packaging policy with customers and suppliers and the use of environmental packaging (Rao, 2006).

**Low carbon logistics** is a process of transferring products to customer. It can be done through third party logistics provider or logistics provider of firm. The concerns of low carbon logistics are measurement of carbon emissions of transportation mode, consolidation of shipments to reduce carbon emissions, the use of carbon efficient technologies for transportation and low carbon transportation mode (Böttcher & Müller, 2015).

### 1.9.3 Mediating Variable

**Green Supply Chain Operational Performance (GSCOP)** is the performance objective for operational performance. GSCOP is used to measure supply chain performance through firms' achievement in operational objectives such as flexibility, responsiveness, cost and environmental friendliness.

**Flexibility** is the firms' ability to offer wide-range of product customization to customers and the offering of a diverse product range (Gunasekaran & Ngai, 2012).

**Responsiveness** is the firms' ability to respond to customers' requirements in a given time frame and the period to achieve customers' satisfaction. This can be done through quick response and the ability to fulfil customers' request as well as good aftersales service (Gunasekaran & Ngai, 2012).

**Cost** is the firms' ability to achieve financial goal through cost reduction while offering quality products and customer satisfaction (Gunasekaran & Ngai, 2012).

**Environmental friendliness** is the firms' ability to perform without harming the environment through less energy consumption and the use of clean energy (Gunasekaran & Ngai, 2012).

### 1.9.4 Criterion Variable

**Low carbon performance (LCP)** objective is to achieve environmental performance through carbon emissions reduction, energy efficiency and carbon-intensive materials reduction (Böttcher & Müller, 2015).

## 1.10 Structure of Thesis

This study has been structured accordingly. In Chapter One, a brief background of the study is presented before the issues related to this study and issues that will be investigated (problem statement) are presented. In order to answer these problems, research objectives and research questions are proposed. Then, the significance of investigation in this study is presented and followed by definitions of key terms and research process to aid the understanding of this study.

Chapter Two starts with overview of manufacturing industry and background of Malaysian manufacturing industry. Following that, concept and previous studies on determinants of LCSC practices and GSCOP, LCSC practices, GSCOP, LCP and institutional theory will be presented. Then, theoretical framework and hypotheses development follows before ending with a summary of that chapter.

Chapter Three starts with research paradigm, justification for choosing the paradigm and research design. The research design explains targeted population of this study, unit of analysis, sample size and sampling technique. After research design, survey instrument design consisting of data collection method, preliminary test and pilot test will be discussed. Then, statistical data analysis after data collection from respondents will be presented. Lastly, the measurement for each determinant, independent variables, dependent variables and mediating variables will be presented before closing with summary of that chapter.

## 1.11 Chapter Summary

LCSC practices is an important climate change mitigation strategy for manufacturing firms. Due to the fact that manufacturing industry emits large amount of carbon emissions, this industry proves to be of significance in achieving LCP. An introduction to determinants of LCSC practices that pressures firms to adopt low carbon practices in their supply chains is presented followed by LCSC practices that leads to performance outcomes of firms such as operational performance and LCP. From those specific problem statements, research objectives and research questions are established to carry out the investigation. This study also introduces practical contributions and theoretical contributions for pursuing this study. The definition of key terms on determinants, predictor variables, mediating variables and criterion variables are discussed before closing with organization of thesis and chapter summary. The next chapter will thoroughly discuss the topic mentioned in this chapter but based on literature review of previous findings and further development on research framework.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

This section will discuss investigative variables related to research title such as determinants of LCSC practices, determinants of operational performance, LCSC practices, operational performance and LCP. Each identified variable will be categorized into section and sub-sections accordingly. In these specific sections and sub-sections, this study will define the investigative variables, present components of those variables and provide justification through scholarly work in the literature. Prior to previous studies in the literature, this study will synthesize studies related to the research topic and the justification for conducting this study.

## 2.2 Low Carbon in Manufacturing Industry

Sustainability requires humankind especially firms to start practicing environmental degradation reduction such as low carbon practice. As a result, governments all over the world have started to impose stricter environmental regulations (Wu, Liu, & Xu, 2017) and pledged to further reduce carbon emissions (Hardin-Ramanan, Chang, & Issa, 2018) in order to achieve sustainability and avoid backlash from stakeholders' of the firms (Barbosa-Póvoa, da Silva, & Carvalho, 2018). Most notably, firms in the manufacturing industry are being regulated and monitored for its contribution to environmental pollution and degradation practices (Li, Qiao, & Shi, 2017; Wang, Jia, Xu, & Xu, 2018). This is being the case is because the manufacturing industry is one of the uppermost contributors to carbon emissions (Huisingh et al., 2015; Ishak & Hashim, 2015). Manufacturing industry requires large amount of energy to manufacture products (Jin, Granda-Marulanda, & Down, 2014). Energy supplies to manufacturing firms mostly come from combustion of fossil fuel and coal, which accounted for 81.6

percent (International Energy Agency, 2015c). The process of combustion to yield energy releases high carbon emissions. In terms of contribution to carbon emissions, international transport is responsible for 33 percent of world carbon emissions and 75 percent of carbon emissions in manufacturing industry (Cristea, Hummels, Puzzello, & Avetisyan, 2013). In addition, manufacturing industry, which is one of the largest carbon emissions polluter consumed 35 percent of world energy (Dubey & Ali, 2015) and over 50 percent of Green House Gasses (GHGs) emissions in the European Union comes from energy generation (Benjaafar et al., 2013). Statistically, a study has found that 224 firms emits more than 72 percent of global carbon emissions (Griffin, 2017).

This study examines LCSC in manufacturing industry. Hence, the understanding of a low carbon manufacturing industry is required. Low carbon manufacturing can be defined as cost saving and carbon emissions reduction connected with production process of product (Zhu, Jiang, Zhang, Tian, & Wang, 2017). It is related to green manufacturing but focuses more on carbon emissions reduction.

As reducing environmental impact in manufacturing industry is important (Cao & Li, 2014; Tian, Chu, Hu, & Li, 2014), scholars have given more attention to energy management, resource management and manufacturing process management (Winter, Li, Kara, & Herrmann, 2014). With regard to management practices, Madu, Kuei and Madu (2002) identified recycling, environmentally supportive equipment design and material selection, manufacturing processes and product design, effective waste collection systems, disassembly and reclamation of scraps, and disposal of hazardous waste as components of low carbon practices in the manufacturing industry.

However, those components of low carbon practices in manufacturing industry does not include current landscape of the manufacturing industry. Gunasekaran and Spalanzani (2012) proposed that low carbon manufacturing industry should include developing low carbon manufacturing, low carbon in supply operations and production operations, low carbon in distribution operations, remanufacturing, recycling and reverse logistics. The understanding of developing low carbon in manufacturing should focus on using energy efficiently, reduce carbon emissions of product and reduction of carbon-intensive materials (Böttcher & Müller, 2015).

The importance of developing low carbon in manufacturing industry is because carbon emission is the largest GHGs emissions. Carbon emissions from fossil fuel and industrial processes accounted for 65 percent and a total of 75 percent with the inclusion of forestry and land use. For industrial processes, carbon emissions come from energy generation (25%), manufacturing (21%) and transportation (14%) (IPCC, 2014). Thus, to reduce carbon emissions in the manufacturing industry, every country is undertaking low carbon practices in their manufacturing industry.

USA and the European Union countries have high carbon emissions per capita while China has a very high total volume of carbon emissions (International Energy Agency, 2015b). In terms of ranking as shown in Figure 2.1, actual data shows that China is the largest contributor of carbon emissions (34%) of global carbon emissions followed by USA (17%), EU countries (10%) and India (6%) (Boden, Marlen, & Andres, 2015). It is to be noted that data of carbon emissions from Boden et al. (2015), IPCC (2014) and World Resources Institute (2017) are actual data not predicted data. The latest available actual data for carbon emissions to date is for year 2013 while for predicted data is for year 2030. Both actual and forecasted data show an alarming trend of carbon emissions that need to be reduced.

Regardless, every country is facing carbon emissions issue that need to be reduced especially in industries such as energy generation and manufacturing. Every country has its own manufacturing industry and in countries where its economy depends largely on the manufacturing industry such as China, India, Indonesia, Thailand and Malaysia, large amount of carbon emissions are produced. Realistically, there is a need to reduce carbon emissions without neglecting manufacturing industry growth and economic growth.

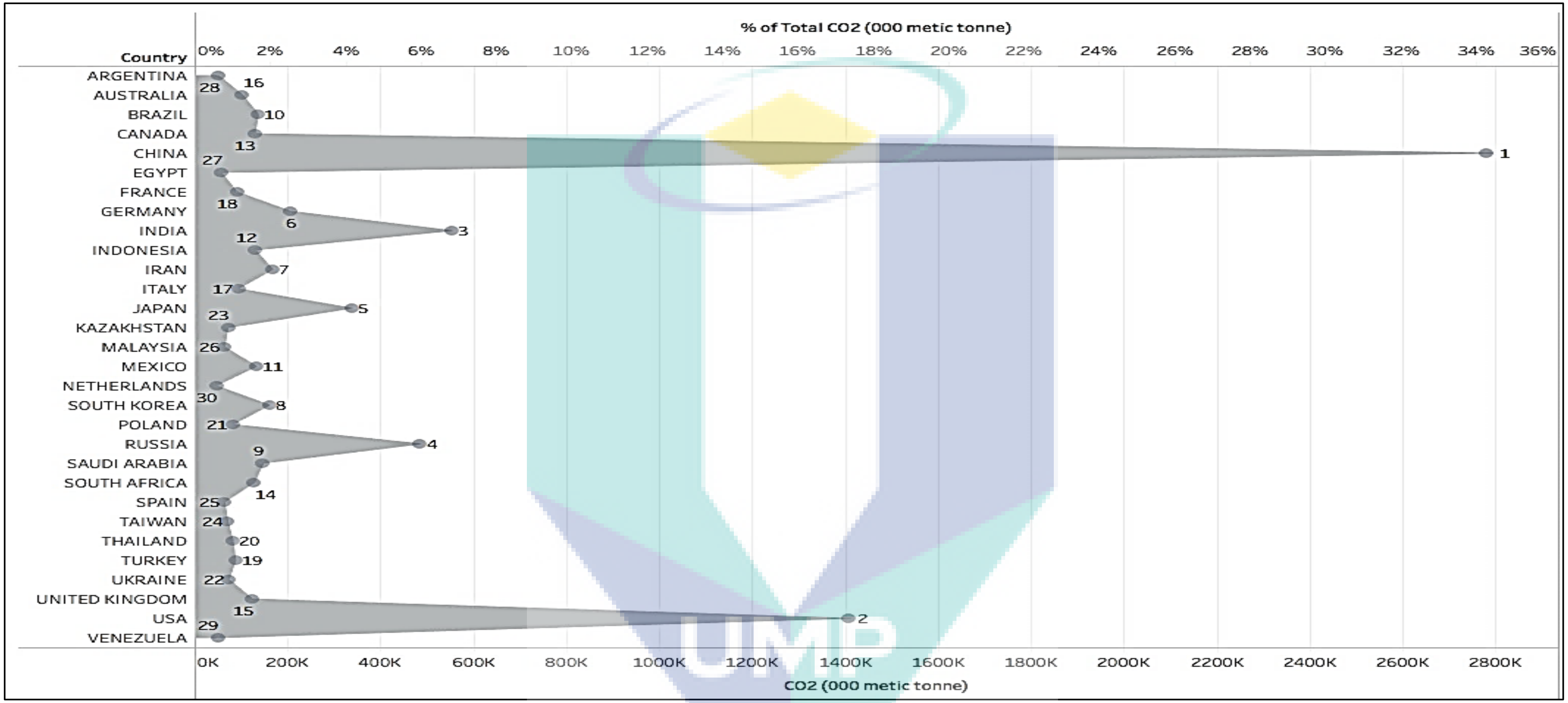


Figure 2.1 Top 30 world carbon emissions polluters

Source: Boden et al. (2015)

Carbon emissions in the manufacturing industry can be reduced by managing energy, overall emission reduction and a reduction in the use of carbon-intensive materials (Böttcher & Müller, 2015). In order to achieve carbon emissions reduction, data from manufacturing industry from each country need to be recorded. Figure 2.2 shows data of every country's carbon emission, energy use for industry, carbon emissions from overall industry, carbon emissions from manufacturing process and transportation. Notably, China ranked first with most of carbon emission it emitted coming from manufacturing process. Due to that, China requires a high amount of energy and as a result produces the highest amount of carbon emissions from energy generation process. Since China is a destination for global product manufacturing, overall industrial emissions and manufacturing waste are also very high. On the other hand, USA produces high carbon emissions more than China in transportation because the global market is in USA. In addition, USA outsources manufacturing of product to other countries and imports the processed product to be assembled in the country. Therefore, carbon emissions from transportation is higher in USA compared to other countries. Data of global carbon emissions for manufacturing industry shows that other than energy, industry and manufacturing process, transportation also plays an important role in the reduction of carbon emissions.

Reduction of carbon emissions in the manufacturing is not only supported by statistical data but scientific community has acknowledged every country and carbon-intensive industry need to further reduce carbon emissions. The literature shows that in the past five years there have been an increase of studies in sustainable manufacturing, which can be interpreted as a sign of high acknowledgement in the scientific community (Beske-Janssen, Johnson, & Schaltegger, 2015) to look into low carbon manufacturing. For example, scholars have already look into customer behaviour towards low carbon product and manufacturing (Jiang & Chen, 2016), green technology adoption strategies for manufacturing firms to reduce carbon emissions (Bi, Huang, & Ye, 2015; Fernando & Wah, 2017), low carbon manufacturing with customer demand (Nouira, Frein, & Hadj-Alouane, 2014), impact of manufacturing activities on environmental performance (Choudhary et al., 2015) and framework of carbon-sensitive demand on manufacturing firms strategies (Jiang & Chen, 2016). However, these studies only look at single dimension of determinants (customer, green technology & manufacturing strategies) and limited scope of supply chain process. Yet, those scholars conclude that low carbon manufacturing is critical to reduce global carbon emissions.

Scholarly work in the literature shows that 88 percent of publications focuses on LCSC or GSCM while the rest discuss other supply chain related issues. Nevertheless, out of that percentage, only 24 percent of those publications are supported by empirical results (Singh & Trivedi, 2012). Another investigation on low carbon manufacturing studies from the literature continued with Gorane and Kant (2015) that performed a systematic review. These scholars found that there are 34 percent of publications that investigated LCSC or GSCM in manufacturing industry with empirical results. Another study by Geng et al. (2017) performed content analysis on LCSC and GSCM literature and found that only 50 publications in the Asian context discussed the linkage between practice and performance. These studies show LCSC and GSCM have impact on economic, environment, operational and social performances while other studies provide inconsistent findings, overlapping theories and LCSC and GSCM model that are not in line with manufacturing firms especially in developing countries. Thus, limited empirical studies on low carbon manufacturing serves as reminder of the importance of this investigation.

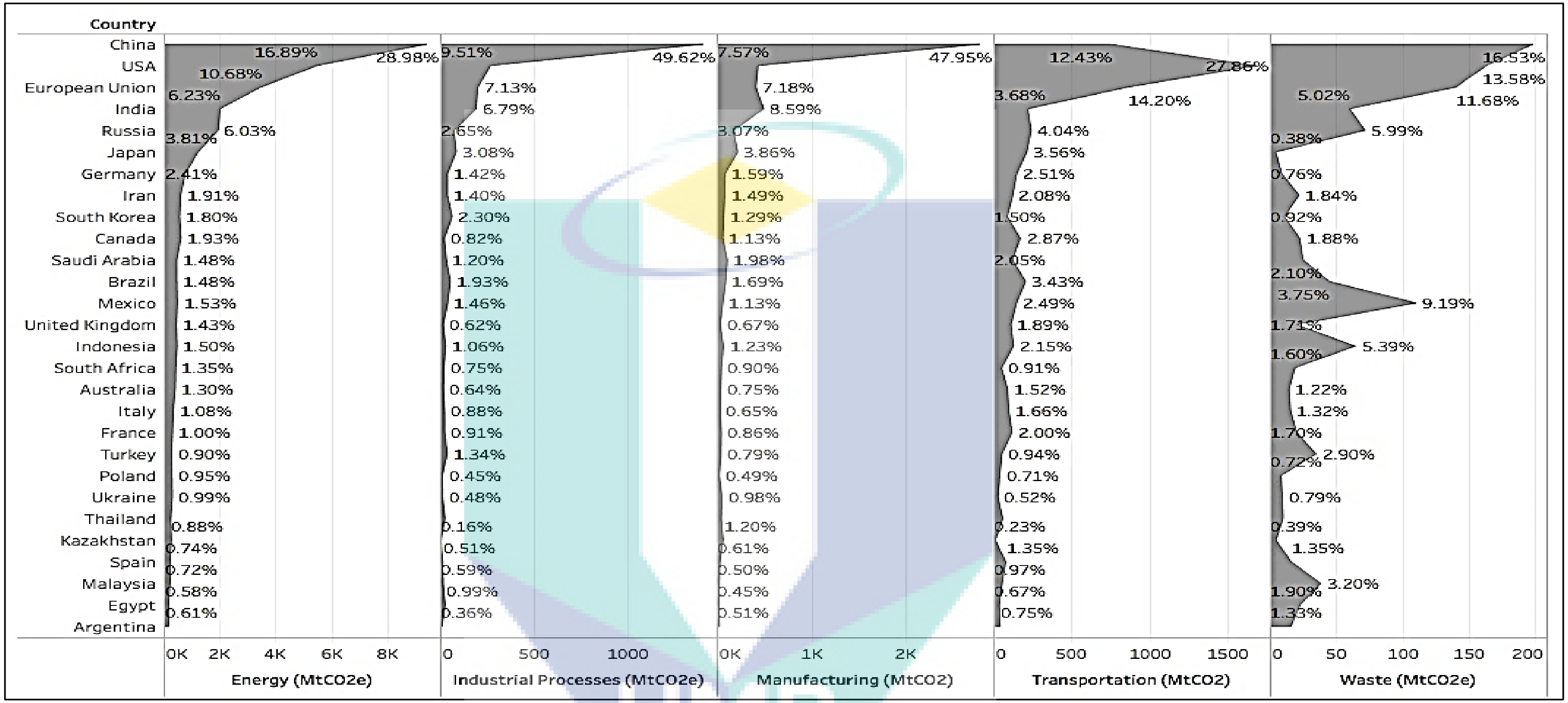


Figure 2.2 World carbon emissions for energy, industrial process and waste year 2013

Source: World Resources Institute (2017)

### 2.2.1 Low Carbon in Malaysian Manufacturing Industry

Malaysia manufacturing industry is one of the most developed in the ASEAN region behind Thailand and Myanmar (World Resources Institute, 2016a). Manufacturing industry contributed 23.5 percent or RM52.3 billion to the Malaysian economy (Department of Statistics Malaysia, 2016e). However, Malaysian manufacturing firms have not yet understood the impact of carbon emissions to the performance of the firm. This is evidenced in a study by Sambasivan, Bah, and Ho (2013) on 291 Malaysian firms stating that firms view carbon emissions reduction practice is only for firms that wanted to achieve LCP but carbon emissions reduction has no impact on other performance measurements. However, all this is about to change because 127 of 197 potential export countries for Malaysian firms have ratified carbon emissions reduction in Paris Climate Agreement (United Nations Convention on Climate Change, 2015). Malaysia has also pledged to reduce 40 percent of carbon emissions by the year 2020 (United Nations Development Programe Malaysia, 2014) through the practice of low carbon emissions. Therefore, Malaysian manufacturing firms must start progressing in LCSC adoption to achieve LCP in their firm as carbon emissions reduction will affect the performance of the firm.

In order to help firms achieve LCP, the Malaysian government established MyCarbon guidelines to set up GHG accounting and reporting program, data centre for local emissions and provide standards, guidance and incentives for firms to reduce carbon emissions (United Nations Development Programe Malaysia, 2014). MyCarbon began with a pilot test targeting 50 voluntary firms but only 26 firms submitted their carbon emissions data. Nevertheless, Malaysian firms are already adopting LCP, but limited evidence are available on the achievement and compliance in the literature. In fact, most of public listed manufacturing firms do not disclose their carbon information in their sustainability report. For example, there are only 468 manufacturing firms that disclosed their green practices and carbon emissions reduction out of 2463 firms (Federation of Malaysian Manufacturing, 2017). There is evidence in the literature that for sustainability and low carbon related studies in a Malaysian context, Malaysia only accounted for 2.24 percent in the literature (Gorane & Kant, 2015b) compared to studies globally. Through incentives and guidelines provided by MyCarbon, it is expected that more firms will start to disclose carbon emissions and enable them to achieve LCP.

Due to development and growth of the Malaysian manufacturing industry, the Malaysian government has spent 73.6 percent of RM2.244 billion for environmental protection (Department of Statistics Malaysia, 2017). In Malaysia, manufacturing is the second largest contributor to Gross Domestic Product (GDP) in Malaysia with 22.7 percent (Department of Statistics Malaysia, 2018) and sales value of RM60.1 billion in 2016 compared to RM55.5 billion in 2015 (Department of Statistics Malaysia, 2016d). Even though contribution of manufacturing industry is second largest after service industry, Malaysian government has put a lot of efforts and outspent 72.1 percent expenditure for environmental protection in manufacturing industry compared to 14.6 percent for the service industry in 2014 (Department of Statistics Malaysia, 2016f). The environmental protection expenditure recorded consisting of three million tonnes from vehicles emissions (70%), power generation emissions (24.3%) and manufacturing emissions (2.8%) respectively (Department of Statistics Malaysia, 2016a).

From the mentioned statistical data, the severity of energy generation and manufacturing are more serious because three million tonnes of vehicles emissions are from all motor vehicles in Malaysia regardless whether these vehicles are used by individuals or firms. Energy generation and manufacturing emissions data on the other hand are specific to both energy sector and all manufacturing sectors in Malaysia. Even though manufacturing is the second largest contributor to GDP of Malaysia, it is the largest contributor to carbon emissions. Spending on environmental expenditure to keep manufacturing industry clean even though service industry contributes more to the economy shows the importance of manufacturing industry to Malaysian economy. High expenditure spending on manufacturing industry also put pressure on the industry to continue its growth within the Malaysian economy. The contribution of manufacturing industry to the economy can be achieved through adopting practices that can reduce environmental expenditure. Thus, low carbon manufacturing practices are advisable.

Developing Malaysia low carbon manufacturing will increase the contribution to the economy and improve the position of the Malaysian manufacturing industry. As shown in Figure 2.3, Malaysia is ranked ninth for manufacturing industry contribution to gross domestic product alongside more developed manufacturing industry countries such as South Korea, China and Thailand. Malaysia deemed manufacturing industry as critical to the Malaysian economy because its contribution to gross domestic product is constantly at an average of 22 percent every year. In order to further improve the contribution and sustain manufacturing, Malaysia need to adopt the latest environmental management practices to ensure that the industry will continue to grow while reducing environmental expenditure.

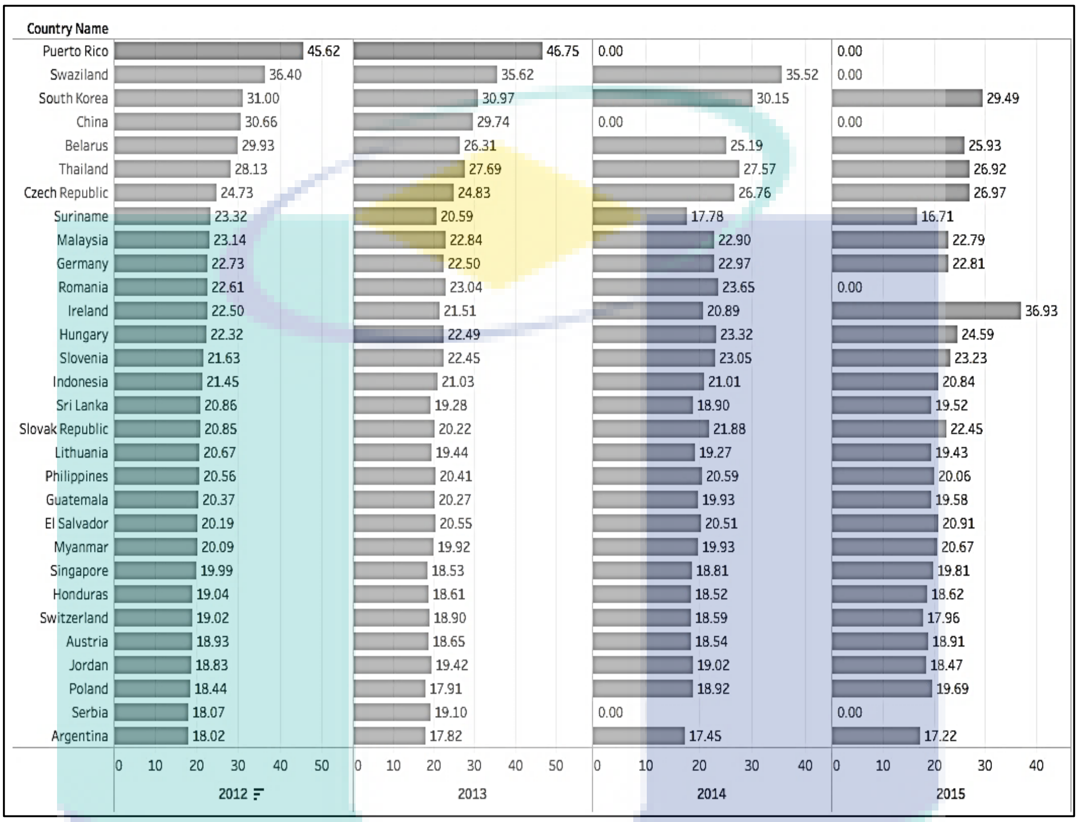


Figure 2.3 Top 30 manufacturing contribution to GDP year 2012 to year 2015
Source: World Resources Institute (2016b)

Statistical data shows that Malaysia is ranked 26th highest globally in carbon emissions emitter (Boden et al., 2015) with government spending as much as RM763.5 million on pollution prevention, RM642.8 million on waste management, in which Malaysian industrial waste contributes 3.20 percent of global carbon emissions (World Resources Institute, 2017) and RM504.5 million for pollution control and reduction (Department of Statistics Malaysia, 2016b). Out of all emissions, the Malaysian government spent RM838 million on air emission, which is more than 50 percent from the total expenditure for environmental protection (Department of Statistics Malaysia, 2016b). In the ASEAN region, Malaysia is the second largest GHGs emitters behind Indonesia contributing 0.52 percent of the world's carbon emissions (Boden et al., 2015). Malaysia's largest carbon emissions as much as 70 percent come from transportation. Transportation consists of all motor vehicles used in the country whether for personal use or for firms use. In terms of single industry emissions, power plant contributes 24.3 percent and industrial emissions contributes 2.8 percent out of 3.1 million metric tonnes (Department of Statistics Malaysia, 2016a). The reason for higher air emission compares to water emission and waste emission is because subsectors in manufacturing industry continue to grow. For example petroleum, chemical, rubber and plastic (6.1%), electric and electronics (8.9%) and food, beverages and tobacco (10.4%) (Department of Statistics Malaysia, 2016c) are growing compared to the previous year. Those are sectors that contribute to higher carbon emissions in Malaysia. Thus, an investigation of carbon emissions in the manufacturing industry is critical.

Studies of low carbon in the literature is shifting to the Asian region from developed countries. As a result, low carbon manufacturing studies in Asia are rising in the literature (Chang, Li, Zhao, Liu, & Wu, 2017; Chen, Luo, & Wang, 2017a; Ishak & Hashim, 2015; Jiang & Chen, 2016; Shaharudin & Fernando, 2015; Urata, Yamada, Itsubo, & Inoue, 2017; Xu, Xu, & He, 2016). As shown in Table 2.1, it was found that five out of 50 articles published in the Asian context that relates to LCSC or GSCM are investigating the Malaysian manufacturing industry (Geng et al., 2017). Yet, there are still more studies needed for LCSC in Malaysian manufacturing industry.

Table 2.1 Reviewed articles on Malaysian manufacturing industry

| No | Author | Sample | Investigation |
|---|---|---|---|
| 1 | (Ann, Zailani, & Wahid, 2006) | 159 Manufacturing firms | Impact of EMS certification on the performance of firms, including economic and environmental aspects and perceived customer satisfaction |
| 2 | (Zailani et al., 2012) | 132 Manufacturing firms | Implementation of sustainable supply chain management practices (environmental purchasing and sustainable packaging and the outcomes of these practices on sustainable supply chain performance |
| 3 | (Abdullah & Yaakub, 2014) | 101 Manufacturing firms | Current level of reverse logistics adoption among manufacturers in Malaysia and to identify the influence of customer/stakeholder pressure, regulatory pressure, financial and competitive pressure, and corporate citizenship pressure on the level of reverse logistics adoption |
| 4 | (Lee, Ooi, Chong, & Lin, 2015) | 119 Manufacturing firms | Relationships between greening the supplier, enhanced environmental performance and improved competitive advantage, to provide an impetus for firms to green their suppliers |
| 5 | (Zailani, Govindan, Iranmanesh, & Rizaimy, 2015) | 153 Manufacturing firms | Determinants of green innovation adoption and its effect on firm performance |

Source: Geng et al. (2017)

## 2.3 Low Carbon Supply Chain Overview

To understand the concept of LCSC, the understanding and definition of Supply Chain Management (SCM) has to come first. The concept of SCM was evidenced in management and technical literature in the early 20th century (Askarany, Yazdifar, & Askary, 2010). SCM can be defined as integrative practices to manage the total flow of distribution channel from supplier to ultimate user (Cooper, Ellram, Gardner, & Hanks, 1997), which involved flows of products, services, finances and information from a source (supplier) to customer (Mentzer et al., 2001). Some of the best practices of SCM are lean management and Just-in-Time (JIT) manufacturing, which can be traced to Henry Ford's integration of automotive supply chain and firms' practices. These concepts focus on enhancing operational efficiency and minimizing waste (Bornholt, 1913; Faurote, 1928). At that time, carbon emissions and industrial pollution were not major topic of investigation for management scholars. One of the earliest issues related to LCSC and GSCM can be traced to Ayres and Kneese (1969) study relates to SCM balancing economics with solid and water pollutions and climate change.

### 2.3.1 Low Carbon Supply Chain and Green Supply Chain Differences

As concerns about environment increases, society begin to demand more responsibility from firms to practice environmental management. As a result, GSCM concept was introduced. This concept can be defined as integration of environmental management and reverse logistics into supply chain management concept (Sarkis et al., 2011). GSCM encompasses practices such as procurement, product, production process, distribution and logistics (Chin, Tat, & Sulaiman, 2015). GSCM help firms to reduce overall impact on environment such as air emission, water emission and land waste (Zhu et al., 2013). As more environmental issues are being linked with increasing carbon emissions, firms are required to focus more on LCSC.

In the literature, LCSC is viewed as an extension of GSCM (Nawrocka, 2008) but specifically at reducing carbon emissions (Nishitani et al., 2013). Figure 2.4 represented SCM practices but with the emphasis on GSCM and LCSC. However, reverse logistics is yet to be found as significant as LCSC practice due to cost considerations in adopting this practice (Garg et al., 2015). In addition, government support policies and product return policies by firms are required to develop reverse logistics (Abdulrahman, Gunasekaran, & Subramanian, 2014). Thus, for LCSC it is concerned with energy and carbon emissions coming from supply chain processes while GSCM is concerned with general waste and emissions from supply chain processes. Therefore, LCSC practices can be viewed as GSCM practices but not all GSCM practices can reduce carbon emissions.

All carbon emissions reduction practices can be categorized according to the process of supply chain. Table 2.2 shows low carbon practices that has been adopted by countries to reduce carbon emissions. These practices are related to energy, green technology adoption, regulations, incentives, transportation and research and development. In order to identify which low carbon practices is more critical, these practices are categorized into supply chain process as shown in Figure 2.4. When low carbon practices are being investigated according to the process of supply chain, firms are able to reduce overall firm's carbon emissions.

Table 2.2 Low carbon practices

| Sectors | Policies & Measures | China | India | Japan | Australia | Singapore | Korea | Indonesia | Thailand | Vietnam | Malaysia |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Energy Supply | Advanced fossil generation technologies | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | |
| | Transition/distribution grid improvements | ✓ | ✓ | | | | | ✓ | | ✓ | |
| | Retiring old, inefficient plants | ✓ | | | | | | | | | |
| | Feed-in tariff | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ |
| | Renewable portfolio standards | ✓ | ✓ | ✓ | ✓ | | | | | | ✓ |
| | Subsidies grants and rebates | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | ✓ |
| | Investment excise and other tax credits | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | | ✓ |
| | Public investment and loans | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ |
| Energy Demand | Efficiency labels | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Sales tax, energy tax, VAT reduction | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Transport | Mass transit goals | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | |
| | Control of individual ownership | | | | | ✓ | | | | | |
| | Vehicle fuel efficiency goals | ✓ | ✓ | ✓ | | ✓ | | | | ✓ | |
| | Vehicle Emission Standards | ✓ | ✓ | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Biofuel standards | ✓ | ✓ | | | ✓ | ✓ | ✓ | ✓ | | |
| R&D | Clean energy efficiency programs | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | ✓ |
| | Carbon sink programs | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ |
| Financing | Climate funds | | | ✓ | ✓ | | | ✓ | | | |
| Capacity Building | Public awareness campaigns | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Institutional capacity | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | |
| | Human resources development | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

Table 2.2 Continued

| Sectors | Policies & Measures | China | India | Japan | Australia | Singapore | Korea | Indonesia | Thailand | Vietnam | Malaysia |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **City Level Measures** | Demand side energy | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Net metering | | | ✓ | ✓ | | | | ✓ | | |
| | Sustainable transport systems | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ |
| | Compact cities | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ | ✓ | |
| | Low carbon lifestyle | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ |
| | Sift of energy intensive industries | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ |
| | Use of MBI, such as C&T | ✓ | | ✓ | ✓ | | | | | | |

Source: Asian Development Bank Institute (2012, 2013); Shaharudin & Fernando (2015)

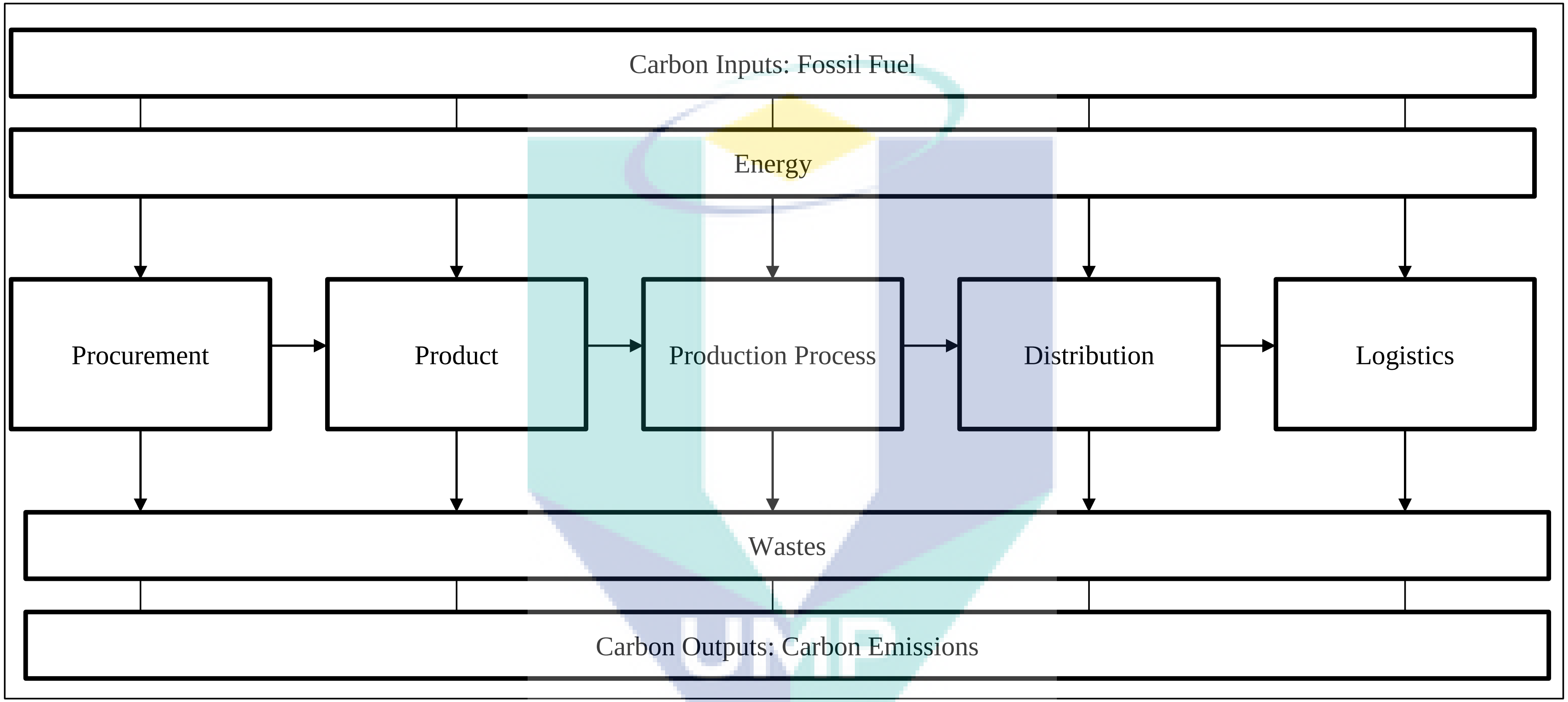


Figure 2.4 Low carbon supply chain practices

Source: Lee (2011) and Sarkis (2003)

Scholars have established that energy management, reduction of emissions from products and use of carbon-intensive materials are indicators of low carbon emissions (Böttcher & Müller, 2015; Fernando & Hor, 2017). Energy significantly contributes to increasing GHGs in the atmosphere with as much as 68 percent and 90 percent of GHGs produced are carbon emission. High carbon emissions produced are results of electricity and heat generation (42%), transportation (23%) and manufacturing industry (19%) (International Energy Agency, 2015a). As a result, the ,government is encouraging firms to invest in renewable energy and energy efficiency (Shaharudin & Fernando, 2015).

Other than energy management, low carbon practice that can impact the reduction of carbon emissions is product development and production. Product will go through supply chain process starting with design and development and production process. All these processes will emit carbon emissions. Therefore, having low carbon practice in product design and development and production process will improve carbon emissions reduction. Carbon emissions reduction can also come from substituting carbon-intensive materials with environmental friendly and recycle materials (Mao et al., 2016). A study by McKinnon (2010) found that identifying carbon emissions of product is a "wasteful distraction" and firm should focus substituting carbon-intensive materials. On the other hand, Böttcher and Müller (2015) found that carbon emissions reduction for product is important. However, both scholars are looking at different perspective, where McKinnon (2010) looked at carbon auditing and Böttcher and Müller (2015) looked at carbon operations. That is the reason why both scholars have different result for LCSC. Nevertheless, it shows that product plays an important role for firms to achieve LCP. In a study by Jiang and Chen (2016), it was proven that customer demand for firm's product depends on firm's carbon-sensitivity and pricing strategy. Thus, energy management, emission from product and carbon-intensive materials are all related to carbon emissions reduction. Therefore, by practicing LCSC, firms will be able to reduce carbon emissions and achieve LCP.

### 2.3.2 Low Carbon Supply Chain in Malaysia

In Malaysia there is a program called MyCarbon that was introduced by the Malaysian government with NGOs in 2013 in order to help develop a policy of carbon emissions reduction. Nevertheless, Malaysia has long undertaken initiatives and policies to reduce carbon emissions. Due to high carbon emissions from energy generation, which accounted for 7.43 million tonnes and from manufacturing of 1.02 million tonnes (Department of Statistics Malaysia, 2015), many Malaysian policies starting in 2001 were specifically tailored to reduce energy generation from fossil fuel and reducing carbon emissions (Economic Planning Unit, 2011). In Table 2.3, several environmental policies since 1975 were established by the Malaysian government to reduce environmental degradation and reduce dependency on fossil fuel as a source of energy. Starting from 2001 onwards, Malaysia ventured into diversification of energy sources and renewable energy and by the year 2009, carbon emissions reduction strategies through renewable energy, green technology, low carbon cities, carbon reporting and automotive policy were implemented by the Malaysian government throughout its industries. These are low carbon policies that will impact the business of firms and supply chain.

Table 2.3 Malaysian environmental policies

| No | Policy | Description | Year | Source |
|---|---|---|---|---|
| **1** | National Petroleum Policy | Efficient utilization of petroleum resources | 1975 | (Department of Energy Green Technology and Water Malaysia, 2011) |
| **2** | National Energy Policy | To promote efficient utilization of energy and eliminate wasteful and non-productive usage | 1979 | (Jalal & Bodger, 2009) |
| **3** | National Depletion Policy | To prolong the life span of the nation's oil and gas reserves | 1980 | (Department of Energy Green Technology and Water Malaysia, 2011) |
| **4** | Four-Fuel Diversification Policy | Diversification of fuel through oil, gas, hydro and coal | 1981 | (Department of Energy Green Technology and Water Malaysia, 2011) |
| **5** | National Forestry Policy | Conservation and sustainable utilization of natural resources, local communities and forest development | 1978; 1992 | (Oon, Orini, Weng Chuen Woon, & Norini, 2002) |
| **6** | National Policy on Biological Diversity | To protect biodiversity of Malaysia, promote sustainable use and ensure biodiversity benefits are equitably shared | 1998 | (Ministry of Natural Resources and Environment, 2015) |

Table 2.3 Continued

| No | Policy | Description | Year | Source |
|---|---|---|---|---|
| **7** | Five-Fuel Policy | Recognizing biomass, solar, biogas and other renewable energy | 2001 | (Economic Planning Unit, 2011) |
| 8 | Small Renewable Energy Power Program | To promote renewable energy utilization | 2001 | (UNFCCC, 2015) |
| 9 | National Policy on Environment | To achieve sustainable development, enhancing quality of life and the environment and achieving economic, social and cultural progress | 2002 | (Department of Energy Green Technology and Water Malaysia, 2002) |
| 10 | Biomass-based Power Generation | To promote biomass as source of power | 2003 | (UNFCCC, 2015) |
| 11 | National Strategic Plan for Solid Waste Management | To guide in planning and allocation resources of solid waste to achieve a developed country status | 2005 | (Ministry of Housing and Local Government Malaysia, 2005) |
| 12 | Malaysia Building Integrated Photovoltaic Technology Project | To promote development of solar technology | 2005 | (Gan, Komiyama, & Li, 2013) |
| 13 | National Biofuel Policy | To increase awareness of biomass, capacity building, financial assistance program, power generation and technology development program through several strategies of using biofuel for transport, industry export and cleaner environment | 2006 | (Abdul-Manan, Baharuddin, & Chang, 2015) |
| 14 | National Policy on Climate Change | To reduce carbon emissions through energy management | 2009 | (Gan et al., 2013) |
| 15 | National Green Technology Policy | To promote efficient utilization of energy, minimized the impact on the environment, national development through the use of technology and quality of life | 2009 | (Green Technology Agencies, 2009) |
| 16 | National Energy Policy | Addresses energy supply, energy pricing and energy efficiency | 2010 | (Economic Planning Unit, 2011) |
| 17 | New Economic Model | To achieve better quality of life through high income per capita, enables communities to fully benefit from the wealth of the country and sustainable development | 2010 | (National Economic Advisory Council, 2009) |
| 18 | Renewable Energy Policy and Action Plan | To promote renewable energy in the country such as Feed-in-Tariff (FiT) mechanism | 2010 | (Yahaya, 2014) |

Table 2.3 Continued

| No | Policy | Description | Year | Source |
|---|---|---|---|---|
| 19 | Second National Physical Plan | Set guidelines for federal and state governments to tackle climate change and conserve natural resources by establishing carbon sinks, sustainable forest and water management | 2010 | (Ahmad, Mohammad, Maidin, Zainol, & Noor, 2013) |
| 20 | Low Carbon Cities Framework | To promote low carbon cities, transportation, product and green growth in Malaysia | 2011 | (M.S. Shaharudin & Fernando, 2015) |
| 21 | National Agro-Food Policy | Modernization of agriculture industry to combat climate change | 2011 | (Bakar, Hashim, Wan, Mohamed, & Songan, 2012) |
| 22 | National Water Resources Policy | To ensure water resources security and water resources sustainability to meet the demand of man and nature | 2012 | (Jais, 2012) |
| 23 | MyCarbon | To set up globally recognized GHG guidelines and encourage more carbon reporting | 2013 | (United Nations Development Programe Malaysia, 2014) |
| 24 | National Automotive Policy | To increase value-added activities in a sustainable way while continuously developing domestic capabilities | 2014 | (National Automotive Industry, 2014) |
| 25 | Economic Planning | Improving sustainability through green growth by lowering dependency on fossil fuel and coal | 2017 | (Economic Planning Unit, 2017) |

Environmental policies implemented by the Malaysian government to reduce carbon emissions were enforced and have been adopted by Malaysian manufacturing firms. This is evident from the various studies of GSCM and LCSC in Malaysian firms that exist in the literature. Table 2.4 illustrates several studies on GSCM and LCSC in Malaysia to reduce carbon emissions and environmental degradation. For example, the early studies of GSCM in Malaysia focused on drivers and GSCM practices for firms but not until 2013 when the implementation and energy management started to increase. From that year onwards, the term low carbon were used by scholars (Gan et al., 2013; Ishak & Hashim, 2015; Shaharudin & Fernando, 2015). However, investigation on specific LCSC practices is still scarce in Malaysian industries. This gives rise for opportunities to investigate the LCSC model for Malaysia, an indication that a study on LCSC is very much needed to achieve performance.

Due to the fact that energy generation is the highest contributor of carbon emissions in Malaysia, both scholars (Abdul-Manan et al., 2015; Chin et al., 2015; Gan et al., 2013; Jalal & Bodger, 2009; Nizam, Muhammad, Abdullah, & Newaz, 2013) and Malaysian authorities (Abdul-Manan et al., 2015; Economic Planning Unit, 2011; Gan et al., 2013; Green Technology Agencies, 2009; Shaharudin & Fernando, 2015; UNFCCC, 2015; United Nations Development Programe Malaysia, 2014; Yahaya, 2014) are exploring renewable energy and energy efficiency studies to reduce carbon emissions. Therefore, investigation on determinants for adoption of LCSC practices and GSCOP, practices and performance measures are critical for Malaysian industries especially in manufacturing industry.

Table 2.4 Scholarly studies on GSCM and LCSC in Malaysian industries

| No | Author | Investigation |
|---|---|---|
| 1 | (Ann et al., 2006) | Impact of EMS certification on firms' performance |
| 2 | (Eltayeb & Zailani, 2009) | GSCM practices achieving environmental performance |
| 3 | (Jalal & Bodger, 2009) | Energy policies and the electricity sector in Malaysia |
| 4 | (ElTayeb et al., 2010) | Drivers for green purchasing among EMS certified firms |
| 5 | (Lin, Chen, & Nguyen, 2011) | GSCM performance in automotive manufacturing industry |
| 6 | (Ng, Lam, Ng, Kamal, & Lim, 2012) | Waste potential for palm biomass in Malaysia |
| 7 | (Rusli, Rahman, & Ho, 2012) | GSCM drivers and practices in Malaysia |
| 8 | (Zailani et al., 2012) | Implementation of GSCM and outcomes of practices on sustainable supply chain performance |
| 9 | (Ahmad et al., 2013) | Issues in implementation of development planning system in Malaysia |
| 10 | (Gan et al., 2013) | Low carbon energy for Malaysian society |
| 11 | (Hsu, Tan, Zailani, & Jayaraman, 2013) | Drivers and implementations to adopts GSCM practices |
| 12 | (Lee et al., 2013) | Drivers of green practices in food service industry |
| 13 | (Nizam et al., 2013) | Emission sources, policies and development in Malaysia |
| 14 | (Zailani, Eltayeb, Hsu, & Tan, 2013) | Impact of external institutional drivers and internal strategy on environmental performance |
| 15 | (Abdullah & Yaakub, 2014) | Pressure for adoption and impact of reverse logistics on firm's performance |
| 16 | (Thoo, Abdul Hamid, Rasli, & Zhang, 2014) | Moderating effect of enviropreneurship on GSCM practices and sustainable performance |
| 17 | (Abdul-Manan et al., 2015) | Energy policies in Malaysia from 1970 to 2010 |
| 18 | (Al-Amin, Rasiah, & Chenayah, 2015) | Climate change mitigation assessment using Malaysia to reduce carbon emissions in future |
| 19 | (Chin et al., 2015) | GSCM, environmental collaboration and sustainable performance |
| 20 | (Ishak & Hashim, 2015) | Low carbon measures for cement plant |

Table 2.4 Continued

| No | Author | Investigation |
|---|---|---|
| 21 | (Lee et al., 2015) | Structural analysis of greening the supplier, environmental performance and competitive advantage |
| 22 | (Shaharudin & Fernando, 2015) | Low carbon footprint in Malaysian manufacturing industry |
| 23 | (Tan, 2015) | Dynamic interaction between economic growth and energy in Malaysia |
| 24 | (Zailani et al., 2015) | Green innovation adoption in automotive supply chain |
| 25 | (Tan, 2015) | Dynamic Interaction between Economic Growth and Energy in Malaysia |
| 26 | (Fernando et al., 2016a) | Eco-innovation from the lens of Malaysian firms practicing green technology |
| 27 | (Fernando & Hor, 2017) | Impacts of energy management practices on energy efficiency and carbon emissions reduction |
| 28 | (Shaharudin & Fernando, 2017) | Measuring low carbon supply chain |
| 29 | (Fernando & Wah, 2017) | The impact of eco-innovation drivers on environmental performance |
| 30 | (Abdulrazik, Elsholkami, Elkamel, & Simon, 2017) | Analysing economic potentials from the optimal biomass supply chain |
| 31 | (Fernando, Sharon, Wahyuni-Td, & Tundys, 2017) | The effects of reverse logistics on cost control abilities: An insight into manufacturing companies in Malaysia |
| 32 | (Fernando & Saththasivam, 2017) | Green supply chain agility in EMS ISO 14001 manufacturing firms: Empirical justification of social and environmental performance as an organisational outcome |
| 33 | (Jasmi & Fernando, 2018) | Drivers of maritime green supply chain management |
| 34 | (Fernando, Walters, Ismail, Seo, & Kaimasu, 2018) | Managing project success using project risk and green supply chain management |
| 35 | (Fernando, Jasmi, & Shaharudin, 2019) | Maritime Green Supply Chain Management: Its Light and Shadow on the Bottom Line Dimensions of Sustainable Business Performance |
| 36 | (Shaharudin et al., 2019) | Past, Present, and Future Low Carbon Supply Chain Management: A Content Review Using Social Network Analysis |

### 2.3.3 Low Carbon Supply Chain Definition

Scholars view carbon emissions issue as more threatening than other environmental issues and have suggested that LCSC should be different from GSCM and Sustainable Supply Chain Management (SSCM) (Busch & Hoffmann, 2007; Correia, Howard, Hawkins, Pye, & Lamming, 2013; Cucchiella & Koh, 2012; Hardy, 2003). Low carbon supply chain can be defined as the practice of carbon emissions reduction in the supply chain processes. In the literature, there are many definitions of LCSC from the point of view of supply chain and operations management.

From the viewpoint of supply chain literature, LCSC is a special type of GSCM aimed at improving GHG emissions performance but different from GSCM because the effect of LCSC are much broader than GSCM as carbon emissions have a strong correlation with energy consumption. Furthermore, improvement of LCP is relatively voluntary but for GSCM environmental performance is mandatory (Nishitani et al., 2013). On the other hand, Nawrocka (2008) defined LCSC as an extension of GSCM practices but focuses more on energy management methods of individual components of a supply chain rather than the entire value chain.

From the viewpoint of operations management, Bloemhof-Ruwaard, Beek, van Beek, Hordijk and Wassenhove (1995) studied the relationship between environmental management and operations management. They defined LCSC as a decision on production planning, logistics, distribution and inventory control that will change due to legal requirements and consumer pressures to reduce waste and carbon emissions. In addition, Böttcher and Müller (2015) differentiated GSCM and LCSC by defining LCSC as low carbon operations management concept that includes issues pertaining to low carbon, carbon efficiency, business sustainability and competitive advantage. Three main components of low carbon operations management concept are low carbon products, low carbon production process and low carbon logistics (Böttcher & Müller, 2015). For low carbon products, firms have to map carbon emissions for all stages of product development process and during new product design. For the low carbon production process, firms should evaluate carbon emissions in production process of products. For the low carbon logistics, firms have to assess their transport activities' carbon emissions. These are some definitions provided by scholars viewing LCSC within operation management.

Even though there are different point of views on the definition of LCSC, the definition between supply chain perspective and operations management perspective are closely similar. The differences lie on whether LCSC is an extension of GSCM (Nawrocka, 2008), special GSCM practice due to voluntary carbon emission reduction in the supply chain (Nishitani et al., 2013) and different from GSCM (Böttcher & Müller, 2015). In this study, Böttcher and Müller (2015) definition of LCSC is adopted because it is more suitable for the manufacturing industry to achieve LCP, which is environmental performance and GSCOP which is operational performance.

## 2.4 Research Debate

As LCSC study is important and on scholars and firms' agenda, the literature has been widely updated and contributions have been made. However, there are several questions that remain unanswered and research areas that need further attention. Therefore, this section will attempt to identify research gaps that need to be addressed and contribute to LCSC literature.

### 2.4.1 Determinants of Low Carbon Supply Chain

In the literature, only 14 percent of the studies used institutional theory to theorize their studies while 42 percent did not specify any theory that underline their studies (Geng et al., 2017). The remaining 44 percent are split between other organizational theories. Theory is important for conceptualization of scholarly work. As there is a lack of theory-driven studies in the literature, model development was not strongly defined by scholars. Thus, inconsistent findings with regard to determinants of LCSC are evident. For example, top management support is viewed as determinant of LCSC (Böttcher & Müller, 2015) which was criticised because top management support make decisions based on determinants not do not themselves act as a determining factor for a firm to adopt LCSC practices (Colwell & Joshi, 2013; Luo et al., 2017).

Even though there are criteria available to measure supply chain performance, there are inconsistent classification of criteria due to different definition given to performance measure criteria. For example, risk has been identified as a criteria to evaluate the performance of the supply chain (Balfaqih et al., 2016). However, the measurement indicator for risk has not been defined. Moreover, scholars recommend that risks such as risk of terrorist, risk of cyber-attack and carbon emissions reduction to be included as a criterion, it has not been widely tested with empirical study. For example, many scholarly work in the literature still value flexibility, responsiveness, cost reduction and reliability as main performance indicators for manufacturing firms (Galankashi, Memari, Anjomshoae, Ma'aram, & Helmi, 2014; Tavana, Kaviani, Caprio, & Rahpeyma, 2016; Wibowo & Sholeh, 2015) but environmental friendliness that has been suggested by scholars are not yet empirically tested (Gunasekaran & Ngai, 2012; Santiteerakul, Sekhari, Bouras, & Sopadang, 2015).

### 2.4.2 Low Carbon Supply Chain Practices

Stakeholders that are heavily affected by increasing carbon emissions are society such as customers and firms. Customers are pressuring firms to reduce carbon emissions and producing environmental friendly products (Alvarez, Carballo-Penela, Mateo-Mantecón, & Rubio, 2016). However, firms find it difficult to achieve LCP due to complexities in determining the sources and causes of carbon emissions. This is evident in a study by Matthews, Hendrickson and Weber (2008) that found only 40 percent of carbon emissions from tier I (direct emissions) and tier II (purchased energy) are clearly visible while 60 percent of carbon emissions lie in the supply chain. In another example, manufactured products only accounted for 10 percent of total carbon emissions while 90 percent of carbon emissions lie in the other supply chain activities such as procurement, product design, distribution and logistics (He, Xiong, & Lin, 2016). Thus, investigation of LCP in the supply chain by looking into supply chain practices to identify carbon emissions is important. Scholars acknowledge the benefits that can be derived from the implementation of LCSC practices to address LCP (Dong et al., 2017; Griffin, Hammond, & Norman, 2016; Jin et al., 2014). Specifically, previous studies in the literature did not distinguish the effects of both internal and external LCSC practices (Mao et al., 2016). Both internal LCSC practices such as production process and product design might be different from external LCSC practices such as procurement and logistics. There is also an issue of inconsistent findings in the literature where it was found that internal LCSC practices improve LCP while hinder economic performance and external LCSC practices improve both LCP and economic performance (Mao et al., 2016). The contradiction of findings in the literature is due to the conceptualization of LCSC practices.

Furthermore, as LCSC is an extension and upgrade from GSCM, conceptualization of LCSC practices should be closely related to GSCM practices. Sarkis (2003), a renowned GSCM scholar has conceptualized GSCM practices by including procurement, production, distribution and reverse logistics. In an attempt by Böttcher and Müller (2015) to conceptualize the model of LCSC practices for firms to achieve LCP in automotive industry has neglected procurement and distribution because they only interested to study internal individual supply chain practices. Therefore, relationship between LCSC practices comprising of internal and external practices with LCP is required to conceptualize and improve existing LCSC model.

### 2.4.3 Operational Performance (GSCOP)

A study by Younis, Sundarakani and Vel (2016) examining the mediating effects in manufacturing firms found existence of the mediating effects needed for manufacturing firms to synchronize between internal and external LCSC practices to realize LCP. Zhu et al. (2012) also found partial mediating effect of operational performance (GSCOP) on economic performance. In addition, a study by Zhang and Yang (2016) found that LCP has partial mediating effect between LCSC practices with GSCOP. These findings show that it is best for firms that practice LCSC to achieve GSCOP in order to achieve LCP and economic performance. However, there are limited empirical studies testing the combination of performances such as GSCOP and LCP.

In a study by Acquaye et al. (2016), they looked at performance measurement addressing environmental friendliness in the supply chain. Their study found that environmental friendliness is one of the important indicators for operational performance. Yet, the literature has limited empirical study with actual data on environmental friendliness for manufacturing industry. In addition, the performance indicator for supply chain performance for manufacturing firms have not been updated with environmental concerns. For example, popular supply chain performance measures are flexibility, responsiveness and cost reduction (Beamon, 1999).

As firms' objective is to achieve sustainability, firms need to realize economic performance, GSCOP and LCP (Chardine-Baumann & Botta-Genoulaz, 2014). In a study by Laosirihongthong, Adebanjo, and Tan (2013), they argued that manufacturers failed to understand the potential link between LCSC practices and some dimensions of performance. Dimension of performance here is referring to economic, LCP and GSCOP. However, they also found that firms are more likely to invest in LCSC practices when firms wanted to achieve GSCOP. A study on determinants of LCSC practices with LCP and economic performance (Zhang & Yang, 2016) shows that identifying mediating or moderating effect for LCSC practices and performance is needed.

### 2.4.4 Low Carbon Performance

The measurement of carbon emissions through Life Cycle Assessment (LCA), which classified carbon emissions according to scope or tier is widely used in the literature (Acquaye, Genovese, Barrett, & Koh, 2014). LCA divides into several tiers: tier I is for direct emissions resulting from combustion of fuels to generate energy. Tier II is for purchased energy while tier III is for purchased goods and services or emissions in the supply chain up until transportation to end users (United Nations Development Programe Malaysia, 2014). However, LCSC modelling development and calculations across supply chains are still not robust and need improvement (Low, Tjandra, Lu, & Lee, 2016). This is because supply chains are complex due to the nature of multi-tier process and service inputs. Thus, the challenge is to satisfy LCP in the supply chain to address visibility of carbon emissions in the entire supply chain from upstream to downstream. Therefore, any environmental sustainability assessment methodology (for example, LCA) utilized to inform performance measurement must address this complexity (Acquaye et al., 2014).

Lack of insight of the integrated supply chain (Garg et al., 2015) and lack of agreed metrics (Bonilla, Keller, & Schmiele, 2015) to measure LCP are reasons for low carbon improvements. For example, most scholars used environmental performance measures proposed by Zhu et al. (2013) that focus on GSCM practices while Böttcher and Müller (2015) attempted to measure carbon emissions reduction through energy, carbon emissions and carbon materials. Yet, their measurements are still need more empirical study to be considered as LCP measurements. In addition, a recent study by Fernando and Hor (2017) have similar measurement but in addition to carbon on revenue, fines for carbon emissions and carbon in production process. However, both scholarly work measurements have not been widely tested by scholars in the literature.

### 2.4.5 Institutional Theory

Institutional theory is one of the most established theory for firm (Clemens & Douglas, 2006) in environmental management studies (Jennings & Zandbergen, 1995; King & Lenox, 2000; Lounsbury, 2008). Scholars often use institutional theory to explain the relationship between internal and external pressures with LCSC practices to achieve performance outcomes (Esfahbodi, Zhang, Watson, & Zhang, 2016; Fernando & Wah, 2017; Lee, 2015; Zhao, Liu, Zhang, & Huang, 2017). However, for internal pressure, limited scholars use top management support as determinant that pressure firms to adopt LCSC practices (Dubey et al., 2017). Furthermore, there exist a gap in the literature in the area of GSCM and LCSC studies relating to providing theoretical support due to lack of scholars' understanding of theories (Dubey et al., 2017). The lack of knowledge regarding theory used in scholars' work is because organizational theory in multi-disciplinary studies such as LCSC is still expanding (Sarkis et al., 2011). In addition, institutional theory is more capable than justifying the reason why firms adopting or resisting practices due to pressures (Dacin, Goodstein, & Scott, 2002). Institutional theory also can be used to explain firm's changes over time. Thus, by conceptualizing LCSC framework with underpinning institutional theory, new understandings of the affect firm to change will surfaced. Therefore, using institutional theory to support determinants of LCSC practices and LCSC practices achieving GSCOP and LCP is a contribution for the supply chain literature and institutional theory.

There is a recommendation to use determinants from Resource-Based View (RBV) theory to extend the LCSC framework (Böttcher & Müller, 2015). However, due to several recommendations for integration of external determinants (Foerstl, Azadegan, Leppelt, & Hartmann, 2015; Liu, 2015; Ahmad, Rezaei, Sadaghiani, & Tavasszy, 2017) and internal determinants (Ding, Liu, & Zheng, 2016; Lei, Voss, Clegg, & Wu, 2017; Liu, 2015) to extend the framework of LCSC, the use of Institutional theory determinants is more relevant. Institutional theory can be described as internal and external pressures influence firm to adopt certain practices (Hirsch, 1975). For example, using institutional theory, government regulations, customer pressures, technological advancement, top management support and environmental NGOs are found to pressures firms to adopt LCSC practices. Yet, institutional theory is found to have limitation as scholars only use this theory to justify external pressure (Esfahbodi et al., 2016; Glienke & Guenther, 2016) while some scholars attempting to investigate top management support as mediating effect between determinants and practices (Colwell & Joshi, 2013; Luo et al., 2017). There is an opportunity to contribute to institutional theory by investigating internal pressures such as top management support and green technology.

The use of institutional theory to support internal and external pressures for firms to adopt LCSC practices is to avoid overlapping theories. In a content analysis by Dubey et al. (2017) on organizational theories used by scholars in supply chain field found that most of the literature contains overlapping theories, which reflect a lack of understanding regarding GSCM theories and LCSC. They concluded that these areas are relatively new for existing organizational theories as over 70 percent of the contributions come from only 15 percent of first authors. This shows that an urgent need for contributions from scholars with an understanding of theory and methodology (Dubey et al., 2017). Therefore, the use of institutional theory that can support the LCSC framework will help to avoid any overlap with other theories and thus contribute to the literature.

## 2.5 Determinants of Construct

Determinants is a factor that causes firms to adopt a certain practice. In this section, determinants are divided into two sections namely for LCSC practices and operational performance. Even though determinants for both LCSC practices and operational performance are similar, the reason for separation is to easily identify and understand the meaning and purpose of that determinants.

### 2.5.1 Determinants of Low Carbon Supply Chain Practices

There are two sources of determinants for firms to address carbon emissions reduction; literature and theory. According to the literature, the amount of studies on determinants of LCSC originated from scholarly work (Böttcher & Müller, 2015; Glienke & Guenther, 2016; Yu, Li, Qiao, & Shi, 2015; Zhang & Yang, 2016). However, 42 percent of these scholarly work in the literature did not specify any theory in their studies (Geng et al., 2017). On the other hand, determinants also can be identified using organizational theory. For example, (Colwell & Joshi, 2013; Glover et al., 2014; Laosirihongthong et al., 2013; Zailani et al., 2013; Zhu et al., 2013) identified determinants for GSCM practices in manufacturing industry using institutional theory while Böttcher and Müller (2015) used stakeholder theory to explain external determinants for LCSC practices in German automotive manufacturing industry. Specifically, Luo et al. (2016) investigated determinants of LCSC using institutional theory, agency theory and contingency theory in India. In Malaysian manufacturing industry, Zailani et al. (2013) used institutional theory for GSCM practices adoption. In the literature, in the context of Asian emerging countries, most scholars used institutional theory in their studies (Geng et al., 2017).

Even though there are numerous studies in the literature that define determinants for adoption of GSCM and LCSC, there are only 21 percent of those studies with empirical findings (Singh & Trivedi, 2012). Therefore, justification to include determinants in the study can be questioned. In order to identify important determinants for LCSC, this study selected determinant that is supported by theory and has empirical study for justification. This study benchmarks determinant from scholarly work with determinant from institutional theory and select determinants that can be supported using institutional theory. Both survey-based (Damert, Paul, & Baumgartner, 2017) and case study research (Glover et al., 2014) determinants of LCSC and GSCM were considered.

From the literature, governmental regulation (Damert et al., 2017), customer pressure (Zhang & Yang, 2016), green technology (Lee, Hashim, Ho, Fan, & Klemeš, 2017), environmental NGOs (Lei et al., 2017; Rodríguez, Giménez, & Arenas, 2016) and top management support (Luo et al., 2017) have been identified as key determinants for LCSC practices. Table 2.5 illustrate articles in the literature that mentioned and studied on relevant determinants. In the case of LCSC, governmental regulation has been widely investigated because it has been an important driver for carbon emissions reduction. For firms to reduce carbon emissions, top management support is very important as resources and carbon emissions reduction commitment depend on top management of a firm. Pressure from environmental NGOs and customers are also critical (Zhu et al., 2013) to firms in carbon emissions reduction as demand of product depends on the acceptance of environmental NGOSs and customers. In addition, green technology is also important to reduce carbon emissions (Dubey & Ali, 2015) and foster green innovation (Fernando et al., 2016a) especially in energy efficiency and lower carbon emitter.

Table 2.5 Determinants for LCSC practices

| Determinants | Count | Source |
|---|---|---|
| Governmental Regulation | 53 | (Abdulrahman et al., 2014; Alexiades, Kendall, Winans, & Kaffka, 2016; Bamgbade, Kamaruddeen, & Nawi, 2017; Canales-Bustos, Santibañez-González, & Candia-Véjar, 2017; Castillo-Villar, Eksioglu, & Taherkhorsandi, 2017; Chang et al., 2017; Chen & Chen, 2017; Cosimato & Troisi, 2015; Costantini, Crespi, Marin, & Paglialunga, 2017; Densley Tingley, Cooper, & Cullen, 2017; Du, Hu, & Song, 2016; Du et al., 2015; Du, Tang, & Song, 2016; Esteves et al., 2017; Fernando, Shaharudin, & Wahid, 2016b; Fernando et al., 2016a; Fernando & Wah, 2017; Glover et al., 2014; Govindan, Soleimani, & Kannan, 2015; Gruner & Power, 2017; Hafezalkotob, 2017; Hariga, As'ad, & Shamayleh, 2017; Harnesk, Brogaard, & Peck, 2017; He, Zhang, Xu, & Bian, 2015; He, Chen, Liu, & Guo, 2017; Hombach, Cambero, Sowlati, & Walther, 2016; Ji, Zhang, & Yang, 2017; Lei et al., 2017; Li & Haasis, 2017; Li, Su, & Ma, 2017; Li, Qiao, & Shi, 2017; Liu, 2015; Meng et al., 2017; Mohammed, Selim, Hassan, & Naqeebuddin, 2017; Nair et al., 2016; Prakash & Barua, 2016; Qi, Wang, & Bai, 2017; Rodger & George, 2017; Rueda, Garrett, & Lambin, 2017; Schöggl, Fritz, & Baumgartner, 2016; Swallow & Goddard, 2016; Ahmad et al., 2017; Wang, Chen, & Liu, 2017; Wu, Liu, & Xu, 2017; Xia, Yu, Gao, & Cheng, 2017; Xu, Chen, & Bai, 2016; Xu et al., 2016; Yang & Xiao, 2017; Yu, Chavez, Feng, & Wiengarten, 2014; Zailani et al., 2015; Zhou & Zhang, 2017) |
| Customer Pressure | 24 | (Chen et al., 2017a; Chen, Wang, & Chan, 2017b; Chen, Wang, Kumar, & Kumar, 2016; Ding et al., 2016; Dubey et al., 2017; Eisentraut & Brown, 2014; Fernando et al., 2016b; Fernando & Hor, 2017; Fernando, Shaharudin, & Wah, 2015; Foerstl et al., 2015; Geng et al., 2017; Govindan, Seuring, Zhu, & Azevedo, 2016; Grosvold, Hoejmose, & Roehrich, 2014; He et al., 2017; Jiang & Chen, 2016; Kuo, Kremer, Phuong, & Hsu, 2016; Luthra, Govindan, Kannan, Mangla, & Garg, 2017; Rajeev, Pati, Padhi, & Govindan, 2017; Scur & Barbosa, 2017; Talbot & Boiral, 2015; Tiwari, Chang, & Choudhary, 2015; Wang & Sarkis, 2017; Yang & Xiao, 2017; Yu et al., 2014) |
| Green Technology | 43 | (Acquaye et al., 2016; Al-Amin et al., 2015; Anbumozhi, 2015; Chang et al., 2017; Chen, Chan, & Lee, 2015, 2016; Chen et al., 2017a; Chen et al., 2016a; Costantini et al., 2017; Danloup et al., 2015; De Giovanni & Esposito Vinzi, 2014; Dubey et al., 2017; Dubey & Ali, 2015; Fernando et al., 2016b; Fernando et al., 2016a; Fernando et al., 2015; Fernando & Wah, 2017; He et al., 2015; Hong, 2015; Jiang & Chen, 2016; Lai, Liu, & Georgiev, 2016; Lai, Liu, Shi, Georgiev, & Wu, 2017; Lee et al., 2017; Liu & Yi, 2017; Liu, 2014; Meng et al., 2017; Newton, 2017; Pap et al., 2017; Qi et al., 2017; Robertson, 2016; Shaharudin & Fernando, 2015; Shen, Ding, Chen, & Chan, 2017; Subramanian & Gunasekaran, 2015; Vagnoni, Franca, Porqueddu, & Duce, 2017; von der Gracht & Darkow, 2016; Wan, Ng, Ng, Aviso, & Tan, 2016; Ahmad et al., 2017; Alwi, Klemeš, & Varbanov, 2016; Wang et al., 2016; Wang, Zhu, Sun, & Jia, 2017; Wang & Sarkis, 2017; Yang & Xiao, 2017; Zhou et al., 2016) |

Table 2.5 Continued

| Determinants | Count | Source |
|---|---|---|
| Environmental NGOs | 23 | (Abdullah & Yaakub, 2014; Al-Amin et al., 2015; Beske-Janssen et al., 2015; Böttcher & Müller, 2015; Ciccullo, Pero, Caridi, Gosling, & Purvis, 2017; Damert et al., 2017; Foerstl et al., 2015; Geng et al., 2017; Gosling, Jia, Gong, & Brown, 2017; Govindan et al., 2016; Grosvold et al., 2014; Harnesk et al., 2017; Jakhar, 2015; Lei et al., 2017; Liu, 2014; Long & Young, 2016; Rahman, Amran, Ahmad, & Taghizadeh, 2015; Rodríguez et al., 2016; Rueda et al., 2017; Schöggl et al., 2016; Seebauer, Kulmer, Bruckner, & Winkler, 2016; Tachizawa, Gimenez, & Sierra, 2015; Talbot & Boiral, 2015) |
| Top Management Support | 19 | (Abdulrahman et al., 2014; Beske & Seuring, 2014; Bui & de Villiers, 2017; Chin et al., 2015; Dubey et al., 2017; Fernando & Hor, 2017; Franco, 2017; Geng et al., 2017; Govindan, Darbari, Agarwal, & Jha, 2017; Grosvold et al., 2014; Jabbour & de Sousa Jabbour, 2014; Luo et al., 2017; Prakash, Soni, Rathore, & Singh, 2017; Quang et al., 2017; Robinson, Tewkesbury, Kemp, & Williams, 2016; Signori, Flint, & Golicic, 2015; Zailani et al., 2015; Zelbst, Pamela, Green, Sower, & Abshire, 2014; Zhang & Yang, 2016) |

#### 2.5.1.1 Governmental Regulation

Government regulation pressure firms to adopt LCSC through national environmental regulations such as waste emission and cleaner production, national resource saving and conservation regulations, export countries' environmental regulations and products potential conflict with environmental laws (Zhu et al., 2013). It was found that governmental regulation drives the adoption of LCSC practices (Du et al., 2016). Governmental regulation has been an important determinant for GSCM and LCSC. A study by Li et al. (2017) on 18 Chinese manufacturing sectors found that regulation on carbon emissions has helped to reduce carbon emissions and other air emissions because regulation on carbon emissions is able to complement reduction in other air emissions. The effect of regulation also means that it can affect firms' supply chain. For example, a case study by Hombach et al. (2016) on European firms found that regulations on biofuel could reduce total production cost of the energy for firms but would result in less GHGs emissions saving. In addition, a study by Chen and Chen (2017) in China production found that carbon emissions reduction per unit output regulation is more efficient than existing carbon emissions reduction on total production such as carbon tax policy. Similarly, Du et al. (2015) studied on low carbon regulation in China manufacturing industry using mathematical assumptions and found that low carbon regulation will reduce and control carbon emissions as well as promote low carbon production for firms. Therefore, regulations have high impact on firms to adopt LCSC practices.

In Malaysia, Zailani et al. (2015) studied green innovation of 153 automotive manufacturing industry and found that environmental regulation inspire firms to adopt green innovation. A study by Fernando and Wah (2017) on 95 green technology firms in Malaysia found that regulation is the strongest determinant for achieving environmental performance. All in all, scholars that investigate the manufacturing industry found that regulation is an important determinant for LCSC practices because it has high influence on firms' industrial carbon footprint (Liu, 2015). In Table 2.5, there are great evidence that governmental regulation is one of the main drivers that push firms to adopt LCSC practices.

With regard to operations, government intervention on firm's operations will impact performance. Government regulation such as environmental regulations of Kyoto Protocol and its mechanism (carbon trading, CDM and JI), Waste of Electronics and Electrical Equipment (WEEE), Climate Change Act (in the UK), American Clean Energy Bill and Restriction of Hazardous Substance (RoHS) (Laosirihongthong et al., 2013) will affect firms' operations. If firms are able to meet the requirement of the regulations, firms can achieve operational performance while failure to meet the regulations will see firms losing competitive advantage in the industry. The requirement of environmental friendly materials and process has pressured firms to be flexible in the operations. For example, customers have option to purchase product with environmental friendly materials such as RoHS or non-RoHS. Therefore, governmental regulations such as WEEE, Climate Change Act, Clean Bill and CDM are pressuring firms to adopt GSCOP in the operations.

#### 2.5.1.2 Customer Pressure

Due to customer pressure to adopt LCSC practices, firms can increase their green image in the eyes of customers. Furthermore, firms are able to meet export requirements from customers that demand green products, meeting local customers' environmental requirements, increase customer awareness and increase market share in foreign countries (Zhu et al., 2013).

Similar to governmental regulation, customer pressure is also an important determinant of GSCM and LCSC (Foerstl et al., 2015). In China, Yu et al. (2014) studied GSCM practices on operational performance of 126 automotive manufacturing industry and found that customer pressure has positive significant relationship with cost, flexibility, delivery and quality. Also, customer pressure is more important that governmental regulation in China. In addition, a study on a Canadian firm that is responsible for 38 percent of GHGs in Canada by Talbot and Boiral (2015) found that stakeholders such as customers is increasingly aware of climate change issues and tend to pressure firms particularly in carbon-intensive industries. A multiple case study by Foerstl et al. (2015) on drivers of supplier sustainability found that firms' procurement integration between supplier is motivated by customer pressure. A recent study by Dubey et al. (2017) on addressing framework for sustainable supply chain has put customer pressure as one of the main determinants of GSCM and LCSC practices.

In Malaysia, Zailani et al. (2013) studied institutional drivers on environmental performance of 132 Malaysian firms and found that customer pressure motivate firms to adopt green practices that influence environmental performance. Similarly, Lee et al. (2013) studied green drivers based on institutional theory on Malaysian food service firms and found that customer pressure has coercive pressure similar to governmental regulations. In a study by Abdullah and Yaakub (2014) on 101 Malaysian manufacturing firms, they found that customer pressure has an effect but not a significant influence. However, their study is based on firm's performance not operational performance and environmental performance. Therefore, as governmental regulations has been established as important earlier, customer pressure also is another important determinant for adoption of LCSC practices. In Table 2.5, customer pressure was established as one of the important drivers for LCSC practices. However, the lower count of studies related to customer relationship with LCSC practices is due to scholars looking into other determinants that pressure firms to adopt LCSC practices. This is because both governmental regulations and customer pressure are core drivers of institutional theory.

For operational performance, customer pressures manufacturing firms to achieve flexibility, delivery, quality and cost (Yu et al., 2014). Through achieving operational performance, firms are able to meet customer requirements and satisfaction of firm's products and services. For example, due to environmentally friendly products, firms are able to be responsive to customer demand and cater to wider market share.

#### 2.5.1.3 Green Technology

Firms can deploy latest low carbon technology, maximize exploitation of current technology available at firm's disposal and set up Research and Development (R&D) unit (Fernando et al., 2016a) to reduce carbon emissions. Green technology is also part of low carbon practices that has been adopted in production plant (Chen et al., 2015). Green technology as determinant of LCSC practices is associated with low carbon production process (Cao, Xu, Wu, & Zhang, 2018) because it helps to address lowering carbon emissions emitted from a firm's production.

In the literature, there are several studies on LCSC practices with regard to green technology. Jiang and Chen (2016) study of green technology investment under carbon-emissions demand found the significance of green technology to a firm's profit. There is also a study on 100 Indian manufacturing firms that shows firms with green technology investment have superior operational performance in comparison to those which have not successfully implemented (Dubey & Ali, 2015) but the dimension of scholar investigation is limited to green technology to achieve operational performance only. Thus, the usefulness of green technology is only for efficiency in operations and not able to determine the effect of green technology on environmental performance. In an attempt by Munasinghe et al. (2015) to study carbon and energy footprint of garment manufacturing firm in Sri Lanka found that green technology improve both carbon reduction and energy efficiency in production. Therefore, it confirms that green technology is associated with production and in order for firms to achieve operational and environmental performance, firms need to undertake green technology investment.

Fernando et al. (2016a) studied determinants of eco-innovation of 95 Malaysian manufacturing firms and found that firms are able to innovate their product line with green technology. However, in the literature as pointed in Table 2.5, there are plenty of studies on green technology. This is because scholars investigating LCSC practices found that in order for firms to reduce carbon emissions, they need to substitute current machinery and equipment with green technology.

For operational performance, firm's investment in green technology will enable firms to achieve better performance in the operations. This will lead to better improvement in achieving quality product, delivery to customer, cost reduction of product and flexibility in producing the product (Dey, Laguardia, & Srinivasan, 2011; Laosirihongthong et al., 2013). Nowadays, firms are required to reduce carbon emissions. Therefore, firms investing in green technology will be able to minimize risk of environmental fines (Fernando & Hor, 2017).

#### 2.5.1.4 Environmental Non-Governmental Organizations (NGOs)

Manufacturing firms are pressured to adopt LCSC practices by environmental NGOs and community activists (Tachizawa et al., 2015). This is because firms' practices are known and closely monitored by environmental NGOs and community activists. Thus, firms are encouraged to be involve in industrial activities organized by environmental NGOs and community activists (Zhu et al., 2013).

There is a greater risk for firms if environmental NGOs do not agree with the way firms operate its business. The influence of environmental NGOs could force firms to review its supply chain practices to comply with social and environmental norms. For example, a study by Böttcher and Müller (2015) regarding drivers and outcomes of low carbon operations of 159 German automotive manufacturing firms investigated stakeholder pressure on LCSC practices and found that stakeholders such as governments, financial institutions, investors and insurance firms, customers, general public, NGOs, suppliers, business associations and competitors have influence on manufacturing firms' LCP. A case study by Rodríguez et al. (2016) on NGO-led international project in Ecuador, Peru, Guatemala, and El Salvador found that NGOs have the power to exert pressure on firms to implement practices.  A study by Boiral et al. (2012) on impact of corporate commitment of climate change in 319 Canadian manufacturing firms found that environmental NGOs are primary stakeholders that influence to push firms to reduce carbon emissions. In a study by Sprengel and Busch (2011) on stakeholder engagement and environmental strategy regarding climate change of 141 firms across eight GHGs-intensive industries found that environmental NGOs and media are consistently exerting maximum pressure on firms to reduce carbon emissions. This has made supply chain more complex with environmental NGOs.

Due to involvement of environmental NGOs, firms might adopt all sorts of "voluntary" programs including ISO 14001 and LCSC practices (Arimura, Darnall, & Katayama, 2011). Furthermore, there are not many parties are aware that International

Organization Standardization (ISO) is actually a NGO. When firms adopting ISO standards, it means that it is conforming with NGOs or committed to reduce environmental impacts. For example, firms that adopt ISO 14001 environmental management means that it requires external third-party verification to ensure that firms practice environmental management to achieve performance.

In Malaysia, environmental NGOs are actively working with government agencies to educate the Malaysian public and firms on the issues of environment and sustainability especially on carbon offset program. As an example, environmental NGOs in Malaysia are involved in enhancing public awareness and educating firms on carbon measures and green technology through seminars and projects such as Mobilizing Malaysians on Climate Change, Green Hunts using public transportation and Voluntary Carbon Offset Scheme (VCOS) (Ministry of Natural Resources and Environment Malaysia, 2011). A study by Nizam et al. (2013) on sources and policies development of emissions highlight importance of environmental NGOs for 43 of Malaysia key action plans for carbon emissions reduction. In Table 2.5, the evidence shows that environmental NGOs has been thoroughly studied for LCSC adoption.

For operational performance, since carbon emissions emitted by firms are largely coming from production of products, improving firms' operations will lead to lower carbon emissions. Therefore, environmental NGOs are pressuring and working closely with governmental agencies to ensure firms' operations have less harmful effect on the environment. The introduction of GSCOP especially environmental friendliness criterion is one of the push factors that environmental NGOs are demanding firms to adopt in order to reduce carbon emissions and environmental degradations.

#### 2.5.1.5 Top Management Support

Top management support is an important enabler for GSCM and LCSC practices (Green et al., 2012). Top management is critical because LCSC practices to reduce carbon emissions need full support from top management and that need consistent effort by top management to assess the impact of business on the environment (Colwell & Joshi, 2013).

Low carbon practices across supply chain are higher when support from top management is evident as found in empirical study by Colwell and Joshi (2013) on 199 Canadian manufacturing firms. This is because each supply chain process is integrated and for smooth integration of processes as well as reducing carbon emissions in the supply chain, it requires top management support. Similarly, Grosvold et al. (2014) investigation of management practices, measurement and performance of SSCM using multiple case study found that top management and employee determine the success of practices, measurement and performance of SSCM. A recent study by Quang et al. (2017) on 246 Vietnamese garment firms found that top management support only have direct and indirect effect on operational performance. However, a study by Zhang and Yang (2016) on 124 Chinese manufacturing firms found top management has significant positive pressure on firm's decision to adopt LCSC practices. The fact that there exist inconsistent findings regarding top management's support, convinced scholars that they could use it as a determinant (Zhang & Yang, 2016) and mediator to achieve performance (Luo et al., 2017). In Malaysia, Fernando's and Hor's (2017) study on ISO 14001 manufacturing firms found that top management support is important for LCSC. In Table 2.5, it can be seen that top management support has been widely used by scholars investigating determinants for GSCM and LCSC practices.

With regard to operations, top management support of operational excellence will enable firms to gain competitive advantage in terms of time, resources, cost (Dey, Laguardia, & Srinivasan, 2011) and achieving significant improvement in the dimension of performance (Laosirihongthong et al., 2013). As firms need to achieve performance such as GSCOP and LCP, support from top management to meet stakeholders' demand is important. As such, firms adopt flexibility, responsiveness, cost reduction and environmental friendliness to ensure they are able to achieve both operational and environmental performance (Yu et al., 2014).

## 2.6 Low Carbon Supply Chain Practices

As previously discussed, firms' practice of reducing carbon emissions in the supply chain process is called LCSC practices. The concern of LCSC practices is reducing carbon emissions from total emissions, energy and carbon-intensive materials across supply chain process such as procurement, product development, production process, distribution and logistics.

In the literature, the definition that constitutes LCSC practices are divided. There are understanding that LCSC practices is an extension of GSCM practices (Nawrocka, 2008). Thus, several studies linking carbon emissions reduction as part of GSCM practices in the literature is evident. For example, Kushwaha and Sharma (2016) in their systematic review for automobile manufacturing industry used Green initiative and GSCM as practices to reduce carbon emissions. Chin et al. (2015) who investigated GSCM practices in manufacturing firms in Malaysia defined GSCM as practice to reduce air emissions such as carbon monoxide emission. Cosimato and Troisi (2015) investigated GSCM in logistics firms defined that green production need to replace questionable materials with green technology and equipment to reduce carbon emissions and energy consumption. Lee (2015) remarked in his study on effect of GSCM on supplier's performance that carbon footprint is part of green procurement practice where firms require its suppliers to submit material composition data on each product including carbon emissions. The reason for various studies linking carbon emissions with GSCM practices is because the goal of environmental performance as defined by Zhu et al., 2013) is to reduce air emission, reduce waste water, reduce solid waste, reduce consumption of hazardous materials, reduce environmental accidents and improve firm's environmental situation. These measurement is widely used to measure firm's GSCM practices (Younis et al., 2016).

On the other hand, LCSC practices is also found to be different from GSCM practices (Nishitani et al., 2013). This is due to LCSC is more concerned with carbon emissions, which is the most serious environmental issues (von der Gracht & Darkow, 2016). As a result, scholars have differentiated LCSC practices with GSCM practices by clearly defining low carbon practices such as reducing carbon emissions, reducing energy consumption and reducing carbon-intensive materials as measurement (Böttcher & Müller, 2015). A specific study in low carbon such as Nishitani et al. (2013) defined GSCM practice of reducing carbon emissions and energy consumption as LCSC practices. Zhang et al. (2012) investigated low carbon practices that include innovation, recycling, carbon credit, energy saving on drivers, barriers of low carbon such as regulations, supply chain, competitor, cost and capacity. Luo et al. (2016) investigated antecedents of LCSC practices and found that top management support is important for Indian manufacturing firms to achieve LCP. Even though their studies focused on LCSC practices, the measurement for environmental performance is still similar to Zhu et al.

(2013). Ishak and Hashim (2015) investigated low carbon measures for cement plant and found that 90 percent of carbon emissions came from energy generation. They suggested that low carbon measurements such as energy management, green technology, low carbon production and low distribution and storage. However, their study has no empirical findings. Thus, generalization of these measurements is not possible for other manufacturing firms.

A study by Böttcher and Müller (2015) on LCSC practices on LCP started to introduce low carbon measurements such as carbon emissions reduction per output of product, energy consumption per output of product and carbon-intensive materials reduction per output of product. These measurements are aligned with the findings of Nishitani et al. (2013) where reduction of carbon emissions per output and total carbon emissions are different. For example, in their study, upper stream industries such as energy generation has higher per unit of carbon emissions than lower stream industries. Thus, the upper stream industries that implement LCSC practices should reduce carbon emissions. On the other hand, the total carbon emissions in lower stream industries such as manufacturing firms is lower compared to upper stream industries. Lower stream industries tend to maintain LCSC practices to lower the cost and carbon emissions by improving energy efficiency, green technology and efficient production. This show that LCSC practices have different influence on different industries because the scope for low carbon emissions is different. Therefore, an investigation of carbon emissions reduction in each supply chain process is essential to understand which process is important for manufacturing firms to reduce carbon emissions.

Table 2.6 shows studies related to practices of LCSC. Low carbon procurement is the highest LCSC practice investigated by scholars. This is justifiable as the highest contributor of carbon emissions is energy generation, which is generated by the upper stream industries such as suppliers (Nishitani et al., 2013). Furthermore, procurement explains the relationship between firms and suppliers with regard to materials for producing products. Material used is found to be the major contributor to reducing carbon emissions practice (Urata et al., 2017). Hence, the reason why and how low carbon procurement is the highest LCSC practices been investigated by scholars.

The second highest LCSC practice is low carbon logistics that relates to transportation mode. Logistics is also statistically proven to be one of the highest contributor of carbon emissions (Tacken et al., 2014). Even though there are scholars that combined low carbon distribution with low carbon logistics, the differentiation between both processes are evident. Proven by empirical study, transportation mode, which is the concerns of low carbon logistics emits 5.5 percent of world carbon emissions (Tacken et al., 2014) and low carbon distribution is found to emit 26 percent carbon emissions from energy used for warehousing (Munasinghe et al., 2015). Low Carbon production is also widely studied by scholars because production processes involve carbon-intensive materials, energy and equipment that produces carbon emissions (Böttcher & Müller, 2015).

The third largest LCSC practice that has been widely covered by scholars is low carbon manufacturing. This is because manufacturing process is closely related to a firm's product. Furthermore, low carbon manufacturing is the centre stage between product development and distribution and storing of product at warehouse. Thus, low carbon manufacturing is viewed as important practice to reduce carbon emissions in the supply chain. Moreover, production processes rely heavily on energy and technology. Therefore, this practice is found to be an important LCSC component in the literature.

Table 2.6 LCSC practices

| Practice | Count | Source |
|---|---|---|
| Low Carbon Procurement | 56 | (Ahi et al., 2016; Aljazzar, Gurtu, & Jaber, 2018; Arampantzi & Minis, 2017; Bai, Sarkis, & Dou, 2017; Bechtsis, Tsolakis, Vlachos, & Iakovou, 2017; Beitzen-Heineke, Balta-Ozkan, & Reefke, 2017; Beske & Seuring, 2014; Chin et al., 2015; Cho, Lee, Ahn, & Hwang, 2014; Danloup et al., 2015; Fuente, Athanassiadis, González-García, & Nordfjell, 2017; Tingley et al., 2017; Dubey et al., 2017; Dubey & Ali, 2015; Esfahbodi et al., 2016; Foerstl et al., 2015; Fujii et al., 2016; Garg et al., 2015; Gorane & Kant, 2015a; Gosling et al., 2017; Govindan et al., 2016; Hafezalkotob, 2017; Harangozo & Szigeti, 2017; Hariga et al., 2017; He et al., 2015; He et al., 2016; Herrmann & Guenther, 2017; Kaur & Singh, 2017; Kawasaki, Yamada, Itsubo, & Inoue, 2015; Krantz, Lu, Johansson, & Olofsson, 2017; Kuo, Hong, & Lin, 2016; Kushwaha & Sharma, 2016; Lei et al., 2017; Liu & Song, 2017; Liu & Cui, 2016; Mao et al., 2016a; Mao, Zhang, & Li, 2016b; Martí, Tancrez, & Seifert, 2015; Mohammed et al., 2017; Nejati, Rabiei, & Jabbour, 2017; Roscoe, Cousins, & Lamming, 2016; Shaw, Irfan, Shankar, & Yadav, 2016; Shen et al., 2017; Su et al., 2016; Subramanian & Gunasekaran, 2015; Urata et al., 2015, 2017; Validi, Bhattacharya, & Byrne, 2015; Wang, He, Zhang, & Wang, 2018; Xing, Qian, & Zaman, 2016; Xu et al., 2016; Xu et al., 2017; Yamada, Yoshizaki, Itsubo, & Inoue, 2015; Younis et al., 2016; Zhou et al., 2016; Zohal & Soleimani, 2016) |

Table 2.6 Continued

| Practice | Count | Source |
|---|---|---|
| Low Carbon Product | 33 | (Acquaye et al., 2014; Bai et al., 2017; Beske & Seuring, 2014; Bui & de Villiers, 2017; Busch, Dawson, & Roelich, 2017; Chen & Chen, 2017; Chen et al., 2016b; Chen et al., 2016a; Garg et al., 2015; He et al., 2016; Holmström, Liotta, & Chaudhuri, 2018; Huang, Wang, Zhang, & Pang, 2016; Jin et al., 2017; Kulak, Nemecek, Frossard, & Gaillard, 2016; Li & Haasis, 2017; Liu & Yi, 2017; Mao et al., 2016b; Martí et al., 2015; Nejati et al., 2017; Ribeiro et al., 2016; Ruiz-Benitez, López, & Real, 2018; Scott & Barrett, 2015; Seebauer et al., 2016; Subramanian & Gunasekaran, 2015; Tachizawa et al., 2015; Talaei, Moghaddam, Pishvaee, Bozorgi-Amiri, & Gholamnejad, 2016; Tapia, Promentilla, Tseng, & Tan, 2017; Tsao, Lee, Chen, & Liao, 2017; Wang et al., 2016; Wang et al., 2017; Wang et al., 2018; Zailani et al., 2015; Zou et al., 2017) |
| Low Carbon Production Process | 48 | (Abdulrazik et al., 2017; Agyemang, Zhu, & Tian, 2016; Al-Amin et al., 2015; Bonilla et al., 2015; Böttcher & Müller, 2015; Bracke, Inoue, Ulutas, & Yamada, 2014; Busch et al., 2017; Camanzi, Alikadic, Compagnoni, & Merloni, 2017; Canales-Bustos et al., 2017; Cao & Li, 2014; Chen et al., 2016b; Geng et al., 2017; He et al., 2015; Herrmann & Guenther, 2017; Holmström et al., 2018; Huisingh et al., 2015; Ishak & Hashim, 2015; Jabbour & de Sousa Jabbour, 2014; Ji et al., 2017; Jin et al., 2017; Jin, Shi, Emrouznejad, & Yang, 2018; Krantz et al., 2017; Kuo, Hong, et al., 2016; Kushwaha & Sharma, 2016; Lai et al., 2016; Lei et al., 2017; Li et al., 2017; Liu, Yang, Lu, & Zhang, 2016; Liu, Klemeš, Varbanov, Čuček, & Qian, 2017; Liu, 2014; Mujica, Blanco, & Santalla, 2016; Neamhom, Polprasert, & Englande, 2016; Nouira et al., 2014; Ribeiro et al., 2016; Santibanez-Gonzalez et al., 2016; Santiteerakul, Sekhari, Bouras, & Sopadang, 2015; Sel, Soysal, & Çimen, 2018; Shen et al., 2017; Tachizawa et al., 2015; Tian, Dai, et al., 2017a; Tian, Wu, Geng, Bleischwitz, & Chen, 2017b; Vasilaki, Katsou, Ponsá, & Colón, 2016; Wang et al., 2017; Wang et al., 2018; Xu et al., 2016; Yang, Zhang, & Ji, 2017; Yunus, Elijido-Ten, & Abhayawansa, 2016; Zhao, Zhou, Jin, Wang, & Liu, 2017) |
| Low Carbon Distribution | 14 | (Ahi, Jaber, & Searcy, 2016; Danloup et al., 2015; de Sousa Jabbour et al., 2015; He et al., 2016; Ishak & Hashim, 2015; Kaur & Singh, 2017; Li & Haasis, 2017; Li, Tan, & Sha, 2016; Luthra et al., 2017; Mohammed et al., 2017; Munasinghe et al., 2015; Nejati et al., 2017; Sel et al., 2018; Wainstein & Bumpus, 2016) |
| Low Carbon Logistics | 51 | (Aivazidou, Tsolakis, Iakovou, & Vlachos, 2016; Aljazzar et al., 2018; Bechtsis et al., 2017; Beitzen-Heineke et al., 2017; Bonilla et al., 2015; Böttcher & Müller, 2015; Chen et al., 2016b; Chen et al., 2016a; Chin et al., 2015; Danloup et al., 2015; Giovanni & Esposito Vinzi, 2014; de Sousa Jabbour et al., 2015; Dubey et al., 2017; Feitó-Cespón, Sarache, Piedra-Jimenez, & Cespón-Castro, 2017; Alves et al., 2017; Garg et al., 2015; Geng et al., 2017; Glienke & Guenther, 2016; Gorane & Kant, 2015a; Gosling et al., 2017; Govindan et al., 2017; Gruner & Power, 2017; Gurtu, Searcy, & Jaber, 2017; Harangozo & Szigeti, 2017; Hariga et al., 2017; He et al., 2015; He et al., 2016; He et al., 2017; Holmström et al., 2018; How, Tan, & Lam, 2016; Huang et al., 2016; Ivascu, Mocan, Draghici, Turi, & Rus, 2015; Jakhar, 2015; Ji et al., 2017; Jin et al., 2014; Kaur & Singh, 2017; Kellner & Igl, 2015; Kushwaha & Sharma, 2016; Li et al., 2017; Li et al., 2016; Manandhar & Shah, 2017; Martí et al., 2015; Prosman & Sacchi, 2017; Sánchez-García et al., 2017; Shaharudin & Fernando, 2017; Shaw et al., 2016; Signori et al., 2015; Tacken et al., 2014; Tiwari et al., 2015; Urata et al., 2015, 2017) |

### 2.6.1 Low Carbon Procurement

Low carbon procurement can be defined as procuring of goods, services, works and utilities with a low CF throughout their life cycle and leads to the reduction of overall firm CF (Correia et al., 2013). This definition is specifically for procurement activity with regard to carbon emissions reduction. The early definition of low carbon procurement come from sustainable procurement where it focuses on cooperation with suppliers for the purpose of developing products that are environmentally sustainable (Carter & Carter, 1998; Zhu et al., 2012).

Low carbon procurement consists of supplier-buyer (firm) relationship on providing design specification that includes low carbon requirements for purchased items, cooperation to achieve carbon emissions reduction objectives, environmental auditing of suppliers' internal management, selecting suppliers with environmental management standards such as ISO14001 and selection of suppliers that meet low carbon practices of firms (Zhu et al., 2013).

Low carbon procurement is essential because upstream industries such as suppliers are carbon-intensive. For example, in a study by Nishitani et al. (2013) on upstream industries such as suppliers and downstream industries such as manufacturing firms found that different regulations and policies are needed to reduce carbon emissions because the upper stream industries are the heaviest polluter of carbon emission. This is justifiable because suppliers activities range from energy generation (Zhang et al., 2012) and processing of raw materials to virgin materials (Sarkis, 2003). In a study by Correia et al. (2013) on low carbon procurement in UK, discussed that low carbon procurement play a role in reducing carbon emissions. For example, in tier I and tier II of direct emission and indirect emission respectively, purchasing of more energy efficient and renewable energy can reduce carbon emissions. In tier III of supply chain, it helps to highly reduce carbon emissions because mainly suppliers carry out the most carbon-intensive activities in the supply chain. However, their study focused on public policies and not on manufacturing firms. Similarly, Esfahbodi et al. (2016) study of SSCM in 146 UK manufacturing firms found out that out of four major SSCM practices: sustainable procurement, sustainable design, sustainable distribution and investment recovery, only sustainable procurement has a positive effect on cost reductions. However, in a study by Nakajima et al. (2013) on challenges of constructing a LCSC to promote resource efficiency of 356 Japanese manufacturing firms found that only 0.8 percent of respondents are concerned with materials used for products that might have negative impact on the environment. Furthermore, 55 percent of manufacturing firms are not informed about material yield from the supplier's side. Nevertheless, even though their study is on procurement of manufacturing firms, it is specifically for adoption of Material Flow Cost Accounting (MFCA), which is an environmental management accounting method that simultaneously pursues the reduction of environmental impact and reduction of cost (Nakajima et al., 2013) not on the source of materials for environmental product.

In Malaysia, Chin et al. (2015) examining GSCM, environmental collaboration and sustainability conceptualized GSCM practices with green procurement because of its significance in Malaysia. Nevertheless, their study has no empirical data to justify only conceptual. Previous research in Malaysia on green procurement in Malaysia were done by Eltayeb and Zailani (2009) on 138 manufacturing firms and found that firms with larger supplier base will have significantly higher level of GSCM practices. In addition, ElTayeb, Zailani and Jayaraman (2010) study on drivers for green procurement using the same sample and found that green procurement in Malaysia reacts to regulations pressure. Zailani et al. (2012) investigated green procurement and green distribution in 109 manufacturing firms and found that green procurement has a positive effect on environmental, economic, social and operational performances. Hsu et al. (2013) study of green procurement and reverse logistics in 132 manufacturing firms found that the determinants such as regulations, customers pressure, competitors and social responsibility pressure manufacturing firms to adopt green procurement. Yet, the study of low carbon procurement in Malaysia is still very rare. As green procurement measurements (Zhu et al., 2013) does not directly specify carbon emissions reduction, a study on low carbon procurement in Malaysian manufacturing firms is essential.

### 2.6.2 Low Carbon Product

Low carbon product can be defined as reducing carbon emissions during new product development at different stages in product's life (Kleindorfer et al., 2005; Lee et al., 2012). The definition of low carbon product comes from green product definition of implanting eco-design process into the product design components, to maximize resource and energy efficiency and to minimize pollutants (Pratt, 2008). While green product focus on eco-design, low carbon product focus on carbon emissions reduction in product's design components.

The development of low carbon product can be assessed using Life Cycle Analysis (LCA) to identify carbon emissions (Baumann, Boons, & Bragd, 2002; Scipioni, Manzardo, Mazzi, & Mastrobuono, 2012). LCA is an assessment tool to evaluate carbon emissions over life cycle. For example, if LCA is used for low carbon product, it is to assess carbon emissions over entire life cycle of product (Scipioni et al., 2012) while assessment of CF using LCA is to assess entire source of carbon emissions such as in tier I for direct source, in tier II for indirect source and in tier III for entire supply chain (United Nations Development Programe Malaysia, 2014). Furthermore, renewable or recycled materials, reduction of carbon-intensive raw materials and overall reduction of carbon emissions during product development are low carbon product characteristics (Böttcher & Müller, 2015).

In the literature, there are various studies of low carbon associated with low carbon product. In a study by Alvarez, Carballo-Penela, Mateo-Mantecón and Rubio (2016) on carbon footprint indicator, they highlighted that carbon emissions from products and firms need to be integrated to achieve more standardized and consistent approach to measuring carbon emissions. Attempting to contribute to methodology of carbon footprint of product, Scipioni et al. (2012) analysed international organizational standards (ISO) for GHGs and found that by following ISO standards guidelines, the issue of carbon emissions of product and corporate carbon emissions can be integrated. Their study also contributes to the measurement of low carbon product adopted by Böttcher and Müller (2015). In their study on LCSC practices with LCP, low carbon product measurement based on conceptualization of available carbon emissions assessment tools such as ISO and LCA are developed and the result of their study on 159 German automotive manufacturing industry shows that low carbon product is expected by manufacturing firms to be the main competitive edge and product differentiation (Böttcher & Müller, 2015). This is due to the fact that 80 percent of carbon emissions come from automobile development (Böttcher & Müller, 2015) and manufacturers that are able to reduce carbon emissions can therefore achieve competitive advantage and tap on low carbon transportation market. Manufacturing firms are motivated to pursue competitive advantage of producing low carbon product when economic feasibility is available and when firms reduce carbon emissions during product development. A study by Ding et al. (2016) investigating assessment of economic performance of SSCM in reducing environmental externalities suggested that incentives by stakeholders especially government play an important role for supply chain firms to produce low carbon product. Another study by Yalabik and Fairchild (2011) confirmed that statement where they found that manufacturing firms invested in green technology when demand for low carbon product is visible from customers.

In Malaysia, a study of low carbon product specifically is limited. A similar investigation of external and internal pressures on environmental performance of 132 Malaysian manufacturing firms by Zailani et al. (2013) found that institutional and internal pressures will push firms to consider low carbon products as a main strategy to achieve environmental performance.

### 2.6.3 Low Carbon Production Process

Low carbon production process can be defined as adoption of production process enhancement in an attempt to reduce carbon emissions (Böttcher & Müller, 2015). On the other hand, green manufacturing addresses process redundancy, ergonomics and cost implications due to faulty methods of producing goods by taking into consideration materials used in manufacture, elimination of waste and treatment of the product after its useful life (Balan, 2008). The difference of low carbon production process is that it eliminates waste and pollution through reduction of energy used carbon emissions, adoption of green technology and efficiency equipment and overall carbon emissions reduction in entire production process.

In order to reduce carbon emissions in entire production process, manufacturers have to measure carbon emissions along production process. This can be done through collecting carbon information so that firms can improve carbon efficiency (Wong et al., 2012). Consequentially, firms need to use energy efficient equipment that produces less carbon emissions, adopting low carbon energy sources and recycling of carbon-intensive scrap (Böttcher & Müller, 2015). This is because managing energy sources and equipment and recycling of carbon-intensive materials can reduce carbon emissions and wastes in the production (Sangle, 2011; Weinhofer & Hoffmann, 2010).

In the literature, Anbumozhi (2015) study of low carbon in Asia highlighted that green technology is important for developing countries' manufacturing firms because it can reduce carbon emissions in the production process. In addition, scholars also listed several studies in Asia on low carbon that focuses on production process. Böttcher and Müller (2015) study on LCSC practices in 159 German automotive manufacturing firms is one of the important studies done because they investigated determinants, practices and performance of firms practicing LCSC. The finding that low carbon production is driven by pressure from stakeholders and firms' competitiveness expectations on low carbon production is low due to low exposure to benefits of reducing carbon emissions in the production process such as cost savings (Boiral et al., 2012; Liu, Niu, Bao, Suk, & Shishime, 2012) and lack of resources to implement low carbon production process such as experts and funds (Böttcher & Müller, 2015). This is because production is energy-intensive, and energy is provided by firm's suppliers. Therefore, firms will try to reduce carbon emissions and production cost more through low carbon procurement, which is the source of energy. However, their study findings can be challenged because they did not differentiate between low carbon product and low carbon manufacturing. In a study by Du et al. (2015) stated that firms are reluctant to reduce carbon emissions through low carbon production because it incurs additional costs to alter and improve production process compared to investing in green technology. Furthermore, there are many incentives given by governments to invest in green technology than low carbon production (Asian Development Bank Institute, 2012) that includes financial incentives and tax reduction and exemption (Shaharudin & Fernando, 2015). Yet, low carbon production process is important because this single process alone produces a lot of carbon emissions as recorded by country's statistical data (Department of Statistics Malaysia, 2016a, 2016b) and scholarly work (Jiang & Chen, 2016; Nishitani et al., 2013).

Since low carbon production process is related to energy consumption, Ahi et al. (2016) provided a systematic review investigating energy-related performance measures in firms practicing GSCM and LCSC. Their study shows three energy metrics that were often used by scholars to measure GSCM and LCSC, which are energy use, energy consumption and energy efficiency. These three are related to low carbon production rather than low carbon procurement because low carbon procurement is more related to energy source. From their study, it can be concluded that in order for firms to achieve LCP, practice of energy management by having reduction in energy use, consumption and energy efficiency are important. Similarly, copious amount of articles on carbon emissions reduction in the supply chain explore energy as determinants of low carbon practices (Zhang et al., 2012), energy saving practices in manufacturing firms (Liu, Niu, Bao, Suk, & Shishime, 2012), energy analysis with carbon accounting (Burritt, Schaltegger, & Zvezdov, 2011; Griffin, Hammond, & Norman, 2016; Lee, 2012; Nakajima et al., 2013; Schaltegger & Csutora, 2012; Vesty, Telgenkamp, & Roscoe, 2015), relationship between finance and energy access (Gujba, Horne, Mulugetta, Rai, & Sokona, 2012), energy efficiency in production (Bunse, Vodicka, Schönsleben, Brülhart, & Ernst, 2011) and energy efficiency in supply chain (Halldórsson & Kovács, 2010; Munasinghe et al., 2015; von der Gracht & Darkow, 2016). These studies show that energy and green technology are the main criteria for GSCM and LCSC practice especially low carbon production process.

In Malaysia, Ishak and Hashim (2015) investigated low carbon measurement in one of the highest contributor to world carbon emissions sector, which is cement production. Their findings concluded that 90 percent of carbon emissions come from production process of cement. Therefore, low carbon production process is deemed as an important LCSC practice to reduce carbon emissions.

### 2.6.4 Low Carbon Distribution

Low carbon distribution can be defined as carbon emissions reduction practice with regard to downsizing of packaging, usage of low carbon materials for packaging, promotion of recycling and reuse programs, standardization of packaging with suppliers, encouragement of returnable packaging methods, minimize material uses and time to unpack, the use of recyclable pallet and an energy efficient system at warehouse (Holt & Ghobadian, 2009). Low carbon distribution and green distribution have similar understanding as both practices are consist of low carbon packaging and green packaging (Chin et al., 2015).

To reduce carbon emissions in packaging, firms need to use environmental improvement packaging, adopting take-back packaging policy with customers (Rao & Holt, 2005), collaboration with suppliers to reduce packaging and requiring suppliers to use environmental packaging (Zhu et al., 2013).

In the literature, there are scholars who combined low carbon distribution with low carbon logistics and coined it as green distribution. The reason for this combination is because measurements for green distribution includes both packaging and transportation (Green et al., 2012; Zhu et al., 2005). For example, a study by Esfahbodi et al. (2016) constructed their framework by defining distribution channel quoting Zhu et al. (2005) and Green et al. (2012) as any means of transportation of products or services from suppliers to manufacturers to final customers with the purpose of having the least possible negative environmental impact. However, this is partially true as scholars such as Zhu et al. (2005) used green packaging and transportation as collaboration with customer without mentioning distribution nor logistics. Similarly, Green et al. (2012) used measurement from Zhu et al. (2005) without any changes as the focus of their study is to investigate impact of GSCM on performance. There are also scholars that defined distribution and logistics under logistics practice. This is because it relates very much with delivery to customers. For example, Holt and Ghobadian (2009) measures logistics with both packaging and transportation mode. Combination of distribution and logistics is not adequate to determine which LCSC practices contribute to lower carbon emissions. For example, in a study by Böttcher and Müller (2015) on 159 German automotive manufacturing firms found that low carbon logistics has low effect on competitiveness expectations of firms that it will reduce carbon emissions. However, their study could not identify whether it is related to packaging or transportation. Therefore, a conceptualization of GSCM like Chin et al. (2015) where green distribution is differentiated with green logistics is required to identify which of the LCSC practices help firms to LCP. Other scholars that separate distribution and logistics are Keebler and Plank (2009).

In the literature, investigations on specific termed low carbon distribution is rare (Subramanian & Gunasekaran, 2015). A study by Youn et al. (2012) on responsive supply chain frameworks of two global Korean firms investigated green practice in distribution channel of those firms. However, their study did not specifically investigate carbon emissions reduction. A low carbon distribution and low carbon logistics study by Harris, Naim, Palmer, Potter and Mumford (2011) investigated cost optimization of distribution and logistics carbon emissions found that cost is not necessarily an important factor for distribution and logistics but the practice of reducing carbon emissions to help firms achieve performance is important. Yet, their study did not differentiate between low carbon distribution and low carbon logistics.

In Malaysia, study on low carbon distribution is still lacking with study such of Zailani et al. (2013) and Chin et al. (2015) that investigated green distribution. However, their studies have not look into specific distribution channel while Chin et al. (2015) has no empirical findings to support the concept.

### 2.6.5 Low Carbon Logistics

Low carbon logistics can be defined as carbon emissions reduction with regard to transportation of materials and goods (Scholtens & Kleinsmann, 2011). On the other hand, green logistics is about delivering goods directly to user site, using alternative fuel vehicles and orders grouping (Ninlawan, Seksan, Tossapol, & Pilada, 2010), investing in vehicles with low impact on the environment and planning vehicle routes (Holt & Ghobadian, 2009). The focus of low carbon logistics is to reduce carbon emissions while green logistics is generally to reduce impact on environment without specific scope of carbon emissions reduction.

Similarly, low carbon logistics aims to reduce carbon emissions by measuring carbon emissions of transportations processes, consolidating of shipments of materials and goods, using low carbon technologies for transportation and using low carbon transportation modes (Böttcher & Müller, 2015).

Low carbon logistics and low carbon distribution studies are plenty. This study followed the separation between distribution and logistics processes adopted by scholar like Chin et al. (2015). In the literature, Jin et al. (2014) developed a model to determine impact of carbon policies on supply chain and logistics cost in USA because the consumption of energy that emits carbon emissions is highly increasing. A study by Tacken et al. (2014) attempted to contribute to the model of developing carbon emissions reduction but focusing on German logistics sector. They recommended that low carbon logistics to be included in firm's long-term planning because of its importance regardless of different evolutionary stages of firms. To confirm carbon emissions reduction model for low carbon logistics, Cosimato and Troisi (2015) in their case study of DHL logistics provider found that green technologies helped firm to achieve logistics innovation that resulted in the firm saving cost , improving quality, reliability performance and energy efficiency. Therefore, not only the firm achieved operational performance but also environmental performance. Another case study by Danloup et al. (2015) investigating low carbon logistics in UK food products to retail stores found that collaboration and consolidation of shipments are able to help firms reduce 26 percent of carbon emissions from transportation alone. In addition, a study by Kellner and Igl (2015) on carbon emissions reduction in different freight forwarders using secondary data found that consolidation of shipments is the best method to reduce carbon emissions.

In Malaysia, a study by Shaharudin and Fernando (2015) compiled various LCSC practices by Malaysian manufacturing firms and highlighted that low carbon logistics is practiced by Toyota Malaysia and Perodua, which is the second national automobile manufacturer. Furthermore, firms working with Toyota are also required to adopt other green practices. On the other hand, Chin et al. (2015) investigated GSCM practices on performance. Both studies however have no empirical data.

## 2.7 Green Supply Chain Operational Performance (GSCOP)

GSCOP is an operational outcome (performance) of improving supply chain performance. It helps supply chain achieve better performance without harming the environment through less energy consumption and process, clean energy (Gunasekaran & Ngai, 2012) and low carbon emissions. In order to help supply chain achieve better performance, firms must meet operational objectives in the supply chain. For example, firms can achieve better performance when firms are able to respond to customers in shorter time and have a flexible suppliers' selection.

There are various operational performance criteria for supply chain. For example, Gunasekaran and Ngai (2012) highlighted several supply chain performance objectives for future operations management such as responsiveness, flexibility, dependability, quality and environmental friendliness. Zhu et al. (2013) measured operational performance of supply chain on delivery time, inventory levels, scrap in production, quality of products, increase in product lines and capacity utilization in production. On the other hand, Ageron et al. (2012) measured supply chain performance on flexibility, quality, customer satisfaction, fill rate, costs, supplier lead-time, suppliers' capabilities to innovate, risk management and inventory levels. The reason for different operational performance measurements is because there are various approaches, techniques and criteria to measure supply chain performance (operational performance) (Balfaqih et al., 2016).

In the literature, there are several attempts to systematically categorize supply chain performance measurements (Balfaqih et al., 2016). For example, supply chain performance measures can be based on (Gunasekaran & Kobu, 2007):

11. Balanced Scorecard (BSC) perspective (financial, customer, internal business process and growth)
12. Components of performance measures (resource, output and flexibility)
13. Location of measures in supply chain (plan, source, make and deliver)
14. Decision-making levels (strategic, tactical and operational), nature of measures (financial and non-financial)
15. Measurement base (quantitative and non-quantitative)
16. Traditional versus modern measures (function-based or value-based)

A systematic review on supply chain performance measurements by Balfaqih et al. (2016) categorized those performance measures based on major trends in the literature of supply chain performance measurement. According to these scholars, supply chain performance measures can be classified as perspective-based approach, process-based approach and hierarchical-based approach. A perspective-based approach is where selection of supply chain performance measures criteria based on the perspective of investigation in use to measure supply chain performance. For example, Beamon (1999) proposed a framework of supply chain performance measures for manufacturing industry. However, that framework does not follow the latest trend such as inclusion of environmental objective, risk and technology. There are 63 percent of articles that applied this approach in the literature (Balfaqih et al., 2016). This is the most popular approach that scholars used to measure operational performance in their study.

A process-based approach is where criteria for supply chain performance measures are from key processes in the supply chain. For example, the Supply Chain Operations Reference (SCOR) model evaluate supply chain processes that includes plan, source, make, deliver and return (Liepina & Kirikova, 2011). There are 41 percent of articles that applied this approach in the literature (Balfaqih et al., 2016). This is the existing operational performance measures that has been established, which scholars can adopt to measure operational performance.

A hierarchical-based approach is where supply chain performance is measure according to level of decision making. For example, strategic level, tactical level and operational level. In addition, it can be categorized according to financial and non-financial so that proper strategy can be applied. This is because the success of strategies depends on translation from strategies to operations. There are almost 35 percent of articles in the literature that proposed hierarchical-based approach. The percentage reported in Balfaqih et al. (2016) systematic review is more than 100 percent because some scholars used multiple approaches to measure supply chain performance.

Nevertheless, their study shows that operational performance can be measured using any approach and specifically for manufacturing industry, a systematic framework is still limited (Balfaqih et al., 2016). One of the interesting findings in their study pointed that environmental friendliness could be analysed across supply chain if measured using the same method. This is in line with previous recommendations by scholars on integration of environmental element (Chardine-Baumann & Botta-Genoulaz, 2014; Gunasekaran & Ngai, 2012). Therefore, this study is interested in perspective-based approach specifically for manufacturing industry and integrating environmental friendliness and coined the termed GSCOP.

GSCOP criteria for supply chain performance measurements are taken from popular criteria and highest cited criterion in the literature such as cost, flexibility, responsiveness and environmental friendliness (Balfaqih et al., 2016; Chardine-Baumann & Botta-Genoulaz, 2014; Gunasekaran & Ngai, 2012). Table 2.7 shows popular performance measurement criteria of supply chain based on systematic review of supply chain performance measurement from 1998 to 2015 (Balfaqih et al., 2016). Cost reduction remains popular criteria for measurement of supply chain performance while flexibility and responsiveness remain important (Azevedo, Carvalho, & Machado, 2011). It was found that environmental criteria is not well integrated into supply chain performance objective framework (Chardine-Baumann & Botta-Genoulaz, 2014) but is one of the main performance measurement criteria of supply chain (Balfaqih & Yunus, 2014).

Table 2.7 Performance measurement criteria of supply chain

| Criteria | Count | Source |
|---|---|---|
| Cost | 35 | (Bai & Sarkis, 2010; Banomyong & Supatn, 2011; Berrah & Vernadat, 2012; Bhattacharya et al., 2014; Bigliardi & Bottani, 2010; Bullinger, Kühner, & Van Hoof, 2002; Chan & Qi, 2003, 2006; Chen & Larbani, 2005; Cho, Lee, Ahn, & Hwang, 2014; Clivillé & Berrah, 2012; Dey & Cheffi, 2013; Eskafi, Roghanian, & Jafari-eskandari, 2015; Galankashi, Memari, Anjomshoae, Ma'aram, & Helmi, 2014; Galasso, Ducq, Lauras, Gourc, & Camara, 2014; Gopal & Thakkar, 2012; Lai, Ngai, & Cheng, 2002; Liang, 2015; Naini, Aliahmadi, & Jafari-eskandari, 2011; Persson & Olhager, 2002; Pramod & Banwet, 2011; Santiteerakul, Sekhari, Bouras, & Sopadang, 2015; Sellitto, Pereira, Borchardt, da Silva, & Viegas, 2015; Shafiee, Lotfi, & Saleh, 2014; Shah & Singh, 2001; Soni & Kodali, 2010; Tavana, Kaviani, Caprio, & Rahpeyma, 2016; Thakkar, Kanda, & Deshmukh, 2009; Theeranuphattana & Tang, 2007; Trivedi & Rajesh, 2013; van Hoek, 1998; Varma, Wadhwa, & Deshmukh, 2009; Wibowo & Sholeh, 2015; Wong, 2009; Xu, Li, & Wu, 2009) |
| Flexibility | 17 | (Angerhofer & Angelides, 2006; Aramyan, Oude Lansink, Van der Vorst, & Van Kooten, 2007; Bai, Sarkis, Wei, & Koh, 2012; Balfaqih & Yunus, 2014; Beamon, 1999; Cai, Liu, Xiao, & Liu, 2009; Chan & Qi, 2003; Cho et al., 2014; Clivillé & Berrah, 2012; Drzymalski, Odrey, & Wilson, 2010; Gong & Yan, 2015; Lai et al., 2002; Liang, 2015; Sellitto et al., 2015; Theeranuphattana & Tang, 2007; Wibowo & Sholeh, 2015; Xu et al., 2009) |
| Responsiveness | 9 | (Aramyan et al., 2007; Beamon, 1999; Chan & Qi, 2006; Cho et al., 2014; Clivillé & Berrah, 2012; Drzymalski et al., 2010; Lai et al., 2002; Theeranuphattana & Tang, 2007; Wibowo & Sholeh, 2015) |
| Environmental Friendliness | 6 | (Bhattacharya et al., 2014; Chardine-Baumann & Botta-Genoulaz, 2014; Gunasekaran & Ngai, 2012; Naini et al., 2011; Pramod & Banwet, 2011; Santiteerakul et al., 2015) |

Source: Balfaqih et al. (2016)

In this study, criteria in Table 2.7 are selected because these are relevant for manufacturing industry as proposed by previous scholars with inclusion of environmental friendliness (Beamon, 1999; Chardine-Baumann & Botta-Genoulaz, 2014; Gunasekaran & Ngai, 2012). In the study of LCSC, environmental friendliness is needed to ensure manufacturing firms achieve its operational performance.

### 2.7.1 Cost Reduction

Cost reduction throughout supply chain processes is one of the reasons multiple firms enter supply chain networks (Wibowo & Sholeh, 2015). In the literature, some scholars viewed cost as economic performance because it is associated with financial value. For example, Zhu, Sarkis and Lai (2008) defined economic performance as manufacturing plant's ability to reduce costs associated with purchased materials, energy consumption, waste treatment, waste discharge and fines for environmental accidents. On the other hand, they defined operational performance as manufacturing plant's capabilities to more efficiently produce and deliver products to customers. Since cost is related to financial value and operations, Zhu et al. (2013) have redefined cost as economic avoidance and operational performance measurement.

Chardine-Baumann and Botta-Genoulaz (2014) and Green et al. (2012) defined cost as economic performance but Balfaqih et al. (2016) in their systematic review of operational performance have confirmed that cost is the most popular operational performance criteria. Furthermore, for perspective-based approach to measuring supply chain performance, any performance criteria can be used as long as it is related to industry and investigation.

Firms ability to reduce cost related to product design, materials purchase, product supplies, production process, delivery to customers impact firms' operations. In addition, product return cost and all supply chain activities also affect the operational performance of firms (Chardine-Baumann & Botta-Genoulaz, 2014). Therefore, to achieve operational performance, manufacturing firms need to reduce cost associated with supply chain processes.

### 2.7.2 Flexibility

Flexibility can be defined as reconfiguration capacity of the supply chain (Calantone & Dröge, 1999). There are several dimensions or categories of flexibility that can be divided into four stages. The first stage which is operational flexibility consists of machine, material handling, operations, automation, labour, process, routing and program output flexibility. Basically, operational flexibility means flexible process or capability of range of operations. The second stage is tactical flexibility that consists of product, volume, delivery and production flexibility. In this stage, the flexibility is focused at plant level or manufacturing. The third stage of flexibility is flexibility such as new product or process design, market and expansion of the system. In this regard, this stage shows that the flexibility is at strategic level. The fourth stage is supply chain flexibility, which consists of robustness, reconfiguration, relationship, logistics, organizational and inter-organizational. In this stage, the concern for firms is to align or network with other supply chain partners to ensure that the processes and operations are flexible. For example, flexibility enable firms to find new suppliers and logistics provider to increase production capacity or to introduce different transportation modes or different design to existing products that firms' have (Pathak, Day, Nair, Sawaya, & Kristal, 2007) or Build-to-Order (BTO) supply chain (Gunasekaran & Ngai, 2012).

Flexibility allows firms to cater to wider customer segments because customers are able to customize products and services, which in the end will help firms to achieve customer satisfaction and operational performance. Firms are able to maximize the capacity of production when firms' suppliers are able to meet production's demand, supply of products are diversified, production process and delivery to customers are flexible (Chardine-Baumann & Botta-Genoulaz, 2014). Thus, manufacturing firms can achieve operational performance when such supply chain processes are flexible.

### 2.7.3 Responsiveness

Responsiveness can be defined as the ability of supply chain to respond to customers' requirements in the shortest time frame by increasing agility to respond to customer demands and increase flexibility to respond to changing customer demands (Roh, Hong, & Min, 2014). Gunasekaran, Lai and Cheng (2008) defined responsiveness as operational performance results in terms of response to market demands, delivery speed, dependability of customers and manufacturing lead time.

In those responsiveness definitions, it shows that responsiveness and flexibility are linked and responsiveness in the supply chain results from firm's ability to respond to customers' demand through product design, raw materials purchase, source of raw materials, delivery to customer, sales, return of products from customers and supply chain processes (Chardine-Baumann & Botta-Genoulaz, 2014). Therefore, manufacturing firms are able to achieve operational performance when the firms' supply chain processes and meeting market demands are responsive.

### 2.7.4 Environmental Friendliness

Environmental friendliness can be defined as firms achieving better performance by not harming the environment through less energy consumption, less energy consuming processes and clean energy (Gunasekaran & Ngai, 2012).

Firms environmental friendliness can be assessed through its energy consumption, clean energy fuel in operation, green value chain in operation and life cycle assessment to support environmental friendliness principle (Gunasekaran & Ngai, 2012).

## 2.8 Low Carbon Performance

There has been overwhelming scientific evidence that climate change caused by increasing carbon emissions poses serious risks to humankind in terms of economy, social and environment (Glienke & Guenther, 2016). If carbon emissions continue to increase and lead to warming of planet Earth by two percent, this will result in a global GDP loss (Dong et al., 2017) while Asian countries will lose as much as six percent of GDP (Asian Development Bank Institute, 2013). In terms of economy, increasing carbon emissions will cause natural resources to be scarce and depleted. For example, high level of seawater will reduce the availability of land for productive activities and the high temperature will damage and destroy natural resources. Thus, production cost will increase, and products will be limited to customers that can afford to consume the product. Poverty level will increase due to higher cost of living. To ensure that the economy grow, government entice firms with incentives to produce more goods and services for consumption and to meet the demand of the population. Meeting the demand for consumers will increase the natural resources extraction. In Asia, firms' extraction of resources have increased from 22 percent in 1985 to 31 percent in 2005 (Asian Development Bank Institute, 2013) that leads to increase carbon emissions in the atmosphere. This carbon emissions increment causes resource security, rising and increasingly volatile natural resource prices, and climate change (Schandl et al., 2016).

In order to achieve carbon emissions reduction, scholars have looked at factors leading to firms' ability to reduce carbon emissions because carbon emissions reduction has become more critical compared to other environmental performance measurement. This is because as much as 62 percent of firms in the supply chain networks believe that climate-related issue has greater impact on their business operations within the next six years (Carbon Disclosure Project, 2017). For example, firms in the supply chain networks require their supplier to disclose and reduce carbon emissions through ISO standards reporting and MyCarbon reporting. Due to that, 434 million tonnes of carbon emissions equivalent of USD12.4 billion cost saving have been achieved (Carbon Disclosure Project, 2017). Other performance measurement such as reduction of waste water, solid wastes, decrease of hazardous materials consumption and decrease of environmental accidents (Zhu et al., 2013) are widely used in the literature but almost 75 percent of supply chain firms see climate change risks as more important than any other related environmental performance measures (Carbon Disclosure Project, 2017). Therefore, specific measurement to reduce carbon emissions is needed (Mao et al., 2016). As firms are moving towards LCP, measuring and recording of carbon emissions throughout the energy use, product and materials are needed (Böttcher & Müller, 2015). Specifying on LCP will help firms to work with their supply chain partners to reduce carbon emissions and increase carbon reporting and supply chain emissions target.

LCP is an environmental outcome (performance). LCP refers to firm's strategic commitment on carbon emission reduction and climate change (Boiral et al., 2012) through overall carbon emission reduction, less use of carbon-intensive materials and less energy use (Böttcher & Müller, 2015). The definition of LCP comes from the concept of measuring carbon emissions called CF. Definition of CF as shown in Table 2.8 is taken from grey literature. It shows the estimation of carbon emissions in the supply chain and operations to reduce carbon emissions that leads to LCP. The uniqueness of LCP compared to environmental performance is that for LCP, there is a need to quantify carbon emissions based on measures and actions of firms to reduce carbon emissions (based on per unit of output) while environmental performance can be measured based on statements. Therefore, the measurement of LCP based on quantification of per unit output of carbon emissions should provide more rich and accurate information regarding carbon emissions reduction in manufacturing firms.

Table 2.8 Carbon footprint definition in grey literature

| | Definition | Source |
|---|---|---|
| **British Sky Broadcasting (Sky)** | The carbon footprint was calculated by "measuring the CO2 equivalent emissions from its premises, company-owned vehicles, business travel and waste to landfill. | (Patel, 2006) |
| **Carbon Trust** | … a methodology to estimate the total emission of greenhouse gases (GHG) in carbon equivalents from a product across its life cycle from the production of raw material used in its manufacture, to disposal of the finished product (excluding in-use emissions).<br>… a technique for identifying and measuring the individual greenhouse gas emissions from each activity within a supply chain process step and the framework for attributing these to each output product (we [The Carbon Trust] will refer to this as the product's 'carbon footprint'). | (Carbon Trust, 2007) |
| **Energetics** | … the full extent of direct and indirect CO2 emissions caused by your business activities. | (Energetics, 2007) |
| **ETAP** | …the 'Carbon Footprint' is a measure of the impact human activities have on the environment in terms of the amount of greenhouse gases produced, measured in tonnes of carbon dioxide. | (ETAP, 2007) |
| **Grub** | A carbon footprint is a measure of the amount of carbon dioxide emitted through the combustion of fossil fuels. In the case of a business organization, it is the amount of CO2 emitted either directly or indirectly as a result of its everyday operations. It also might reflect the fossil energy represented in a product or commodity reaching market. | (Grubb, Grubb, & Ellis, 2007) |

Source: Shaharudin & Fernando (2015)

The commitment of firm to reduce carbon emissions is critical to achieve environmental performance. However, currently environmental performance is measured through reduction of air emissions, reduction of waste water, reduction of solid wastes, decrease of hazardous materials consumption, decrease of environmental accidents and firm's environmental situation improvement (Zhu et al., 2013). Even though there is reduction of air emissions that represent GHGs emissions, the measurement for environmental performance is not specifically for firms to reduce carbon emissions. Thus, firms need to measure carbon emissions in order to achieve environmental performance. Böttcher and Müller (2015) investigated on determinants, LCSC practices and LCP measured LCP through energy use per unit of output, carbon emissions of product per unit of output and use of carbon-intensive materials per unit of output. This measurement is more related to carbon emissions reduction and in accordance with the definition provided by Boiral et al. (2012) adopted by this study. In addition, it shows that LCP is part of environmental performance but specifically for reducing carbon emissions. A study by Fernando and Hor (2017) measures LCP on carbon emissions per unit revenue, carbon emissions in operations, fees paid for carbon discharge, emissions in the production process and overall carbon emissions.

In the literature, several studies on LCP are evident. For example, Nishitani et al. (2013) studied LCSC practices by 197 Japanese manufacturing firms pursuing to achieve LCP. Their study found that total carbon emissions reduction and carbon emissions reduction per output are different from upstream industries and downstream industries. Their study indicates different LCSC practices are needed for different supply chain processes (upstream and downstream). Similarly, there is a study by Zhang et al. (2012) on determinants of carbon emissions reduction, practices of carbon emissions reduction and LCP of 85 Chinese manufacturing firms. Their study viewed supply chain pressures as determinant for manufacturing firms to adopt low carbon strategy to achieve LCP. Furthermore, their study measure environmental performance in general as defined by Zhu et al. (2013) not specific for carbon emissions reduction such as Böttcher and Müller (2015). On the other hand, a study by Böttcher and Müller (2015) on 159 German manufacturing firms investigate determinants, LCSC practices on LCP. Their study only investigated product development, production process and logistics for carbon emissions reduction while determinants are stakeholders as a whole. Another study by Luo et al. (2016) on 176 Indian manufacturing firms looked into institutional-based determinants with top management support as mediator for firms to adopt LCSC practices. Yet, their study has not defined relationship between determinants with LCP and LCSC practices with LCP. In this study, institutional-based served as determinants for manufacturing firms to adopt LCSC practices that consists of internal and external supply chain practices to achieve LCP.

### 2.8.1 Measurement of Low Carbon Performance

In order to achieve LCP, measuring carbon emissions is essential. There are several methods to measure carbon emissions. In the study of Böttcher and Müller (2015), LCP measurement was adopted and adapted from Maxwell, Sheate and van der Vorst (2006) environmental performance measures. Nevertheless, the LCP construct was adjusted to focus solely on carbon emissions. In their study, LCP was defined as a unit of revenue in the production.

There are several studies in the literature, which measurement can be adopted and adapted for LCP measurement (Beske-Janssen, Johnson, & Schaltegger, 2015; Blechinger & Shah, 2011; Burgess, Singh, & Koroglu, 2006; Grosvold, Hoejmose, & Roehrich, 2014). Scholars have conceptualized and compared and contrast various GHGs accounting standards as shown in Table 2.9 and translated these GHGs quantification standards to understandable perspective that respondents are able to understand. Basically, carbon protocols can be divided into four groups (Baldo, Marino, Montani, & Ryding, 2009):

17. Specific guidelines such as Publicly Available Specification (PAS 2050) for GHGs calculation and monitoring. PAS 2050 guidelines targeted for specific and ad-hoc cases regarding carbon reporting.
18. General guidelines such as ISO standards for carbon calculation. For example, ISO 14000 and ISO 50000. The ISO guidelines for reporting carbon emissions for firms are similar to Life Cycle Assessment (LCA) method in reporting.
19. Calculation tools for specific carbon emissions calculation. For example, transportation carbon emission and consumer behaviour carbon emission.
20. Life Cycle Assessment (LCA) method to identify amount of carbon emissions according to phases. LCA will categorize carbon emissions according to the source of emissions ranging from tier I and tier II for direct sources and tier III for indirect sources of carbon emissions.

Measurement of carbon emissions is a method or technique to record and measure carbon emissions. What carbon information to record and measure are taken from resources of GHGs accounting standards. These standards serve as guidelines for countries and firms to record and measure carbon emissions across supply chain processes. In Table 2.9, several resources of GHGs standards are presented. Out of those accounting standards, WRI/WBCSD are widely adopted because it is the recommendation for countries pledging to reduce GHGs under the Kyoto Protocol and Paris Climate Change to record and measure GHGs based on this standard. Scholars also use this standard because the measurement tool for CF adopted by this standard is by the use of LCA. For Malaysia, MyCarbon guidelines, targets Malaysian firms to reduce its GHGs emissions voluntarily by identifying which activities contributes to the highest emissions. Furthermore, this guideline is also using LCA to measure GHGs particularly carbon emissions. In addition, MyCarbon guidelines is not designed to quantify individual GHGs mitigation project nor strategies to reduce GHGs (United Nations Development Programe Malaysia, 2014) but MyCarbon guidelines is to prepare firms in recording and measuring GHGs especially carbon emissions across firm operations with supply chain processes as an option. MyCarbon guidelines also should be used with other similar guidelines such as WRI/WBCSD to help firms record, measure and achieve LCP.

Table 2.9 GHGs accounting standards resources

| Resource | Description | Source |
|---|---|---|
| World Resource Institute/World Business Council on Sustainable Development (WRI/WBCSD) | There are two standards: (1) A Product Life Cycle Accounting and Reporting Standard and (2) Corporate Accounting and Reporting Standard. | (WRI/WBCSD, 2004, 2005) |
| ISO 14064 | ISO 14064 (parts 1 and 2): it is an international standard for determination of boundaries, quantification of GHG emissions, and removal. It also provides standard for designing of GHG mitigation projects. | (ISO, 2006b, 2006a) |
| Publicly Available Specifications 2050 (PAS2050), British Standard Institution (BSI) | Specifies the requirements for assessing the life cycle GHG emissions of goods and services. | (PAS, 2008) |
| 2006 IPCC guidelines for National GHG inventories | All sources of GHG emissions are classified into four sectors—energy, industrial process and product use, agriculture, forestry and other land use, and waste. | (IPCC, 2014; PAS, 2008; Penman et al., 2006) |
| MyCarbon Guidelines | The main purpose of these Guidelines is to provide information to facilitate reporting by organisations using the above standard, i.e. A Corporate Accounting and Reporting Standard (Corporate Standard) on a voluntary basis for their operations in Malaysia. It is for the organisations to understand the emissions that they are responsible for, know how much they are emitting, and which activities are causing the highest emissions. | (United Nations Development Programe Malaysia, 2014) |

Source: Shaharudin & Fernando (2015)

#### 2.8.1.1 Kyoto Protocol

The Kyoto Protocol is an international agreement among countries with common interest to reduce GHGs emission. It started in Kyoto, Japan in 1997 and came into effect on February 2005. Kyoto Protocol uses WRI/WBCSD resource to record and measure GHGs emissions. Under the Protocol, each country has to do the following:

21. Record and measure their GHGs emissions for each year
22. Compare GHGs emissions and reduce or maintain it to the basic year that has been agreed upon signing the Kyoto agreement
23. Create action plan to reduce GHGs emissions and submit to Kyoto convention

Countries that pledges in the Kyoto Protocol will have to meet their emission targets through national measures. In addition, Kyoto Protocol also introduced three mechanisms to help countries meeting its target. These mechanisms are aimed at firm-level through market-based strategy (United Nations, 1998):

1. International emissions trading: under this mechanism, firms have incentive to reduce carbon emissions because government will set a limit for firms called carbon cap. If firms produce emissions over the limit, that firm need to buy emission credits from firms that produces less carbon emissions. Thus, by turning carbon credits into monetary value, firms have incentive to reduce carbon emissions.

24. Clean Development Mechanism (CDM): under this mechanism, firms in developed countries can invest in carbon reduction program in developing countries to earn carbon credits.
25. Joint Implementation (JI): under this mechanism, firms can undertake or finance emissions reduction programs in developing countries and earn carbon credits. In addition, host country will benefit from foreign investment and technology transfer.

In 2015, a new convention called Paris Climate Change Summit was introduced. This time around major changes have taken place where world leaders finally accept that they have to combat GHGs emissions and reduce it to reduce climate change. However, the difference between Kyoto Protocol and Paris Climate is that Kyoto Protocol focuses in GHGs reduction of countries while Paris Climate Change maintain what has been agreed upon in Kyoto Protocol but focuses more on carbon emissions reduction. The Kyoto Protocol is said to be a failure due to heavy emitters of GHGs such as USA did not pledge nor make actions to reduce their GHGs emissions while in Paris Climate Change even though there is no enforcement of previous conventions plans, still, countries especially all heavy emitters of GHGs have already pledge to reduce their GHGs emissions. However, it is yet to see whether Paris Climate Change summit will become successful as carbon tax is yet to be implemented even though this mechanism has been introduced in Kyoto Protocol. As a result, firms' incentives to change to renewable energy come from its low carbon practices and pressures from stakeholders.

#### 2.8.1.2 MyCarbon Guidelines

MyCarbon is a program introduced by the Malaysian government to reduce carbon emissions and achieve carbon reduction of 40% by the year 2020 (United Nations Development Programe Malaysia, 2014). The objectives of MyCarbon is to create globally recognized standard GHG reporting in Malaysia, reduce carbon emissions at firms' level, providing incentives, training and guidance and develop and analyse drivers for CF. There are 26 organizations that adhered to the call and participated in this pilot program, which ended in August 2014. The framework proposed by MyCarbon is developed by taking into consideration suggestions and comments from firms and government officials who participated in this program.

The difference between MyCarbon and Kyoto Protocol is that MyCarbon identify only direct and indirect emissions as mandatory in their reporting while firms' related activities are optional. For example, it is compulsory for firms to record fuel combustion, process emissions and fugitive emissions, which are direct emissions from firms. In addition, indirect emissions from consumption of electricity, heat, steam and cooling system for own use are also mandatory for firms to report. On the other hand, emissions from firms' activities such as purchased materials and fuels, transport-related activities, waste disposal, leased assets and sold goods and services are optional for firms to report.

In short, firms are required to measure and report their energy use and purchase while other supply chain activities are optional for reporting.

Both Kyoto Protocol and MyCarbon guidelines record and measure GHGs especially carbon emissions using LCA method. Scholars have conceptualized these protocols by categorizing type of emission information and measurement to reduce carbon emissions. For example, both Kyoto Protocol and MyCarbon guidelines introduced tier I and tier II of direct emissions and tier III for indirect emissions. Based on these protocols, scholars have identified energy source and energy use that are related to direct emissions and supply chain processes that are related to indirect emissions as practices to reduce carbon emissions at manufacturing firms.

## 2.9 Underpinning Theory

Pressure from stakeholders to reduce carbon emissions is well-documented in the literature. Yet, limited evidence is available to understand the determinants of LCSC in Malaysia. Determinants of LCSC practices can be identified through the understanding of organizational theory. This is because the organizational theory provides insight to explain organizational behaviours and explore the factors that affect different actors across the supply chain (Glover et al., 2014). For example, institutional theory describes how pressures from internal and external environment can influence firms' decisions. Therefore, from the theory, government regulations, customer pressure, environmental NGOs, technological advancement and top management are understandably influencing firms to adopt low carbon practices to reduce carbon emissions in the supply chain (Böttcher & Müller, 2015; Luo et al., 2017), which also would influence Malaysian manufacturing firms to adopt LCSC practices.

According to Sarkis et al. (2011) organizational theory can be defined as a management insight to explain or describe organizational behaviours, designs or structures. Due to increasing interest from scholars and firms in environmental management, new knowledge and extension of emergent theory at the organizational level is needed. Particularly, the field of supply chain and operations management have seen more interest taking place in the literature (Sarkis et al., 2011). Scholars believe that environmental management studies such as LCSC can contribute towards the extension and in-depth knowledge of organizational theories. LCSC study is a multi-disciplinary field between business (supply chain and operations management) and science (environmental studies such as carbon emissions). Nowadays, firms are expected to take care of the environment while pursuing economic and social objectives. As a result, firms are practicing green practices that can help them to achieve environmental performance. Since firms' products and supply chain processes are contributing to environmental degradation, firms need to reduce environmental degradation especially carbon emissions in the supply chain. Therefore, the importance of environmental studies in the supply chain such as LCSC studies are contributing to the growth and understanding of organizational theories (Sarkis et al., 2011).

However, organizational theories are just starting to be widely adopted in the supply chain and operations (Sarkis et al., 2011). The reason is evident in the literature as 42 percent of studies conducted on GSCM in Asian did not specifically mention use of theory (Geng et al., 2017). Nevertheless, there are several popular organizational theories used by scholars to support GSCM and LCSC studies such as Institutional theory, Contingency theory, Resource Based View and Stakeholder theory. While Institutional theory focus on internal and external pressures for firms to adopt certain practices, its inclusion of internal practices still not empirically justified. On the other hand, Contingency theory that investigates firm's adaption to the environment of the business has not seen an increase in linkage in multidisciplinary studies due to its similarities with Institutional theory and scholars' understanding that this theory is to explain firm's contingency plan. Another widely used organizational theory is Resource-based view theory that focuses on firm's internal capabilities that are indifferent that competitors. Nevertheless, this theory is not suitable to explain why firm change over time or what pressure firm to change. Similarly, Stakeholder theory is used by scholar to explain stakeholders that have influence on firm's practices but for this study, Institutional theory is regards as more robust as it is able to explain adoption of non-stakeholder such as green technology that is important for carbon emissions reduction.

Out of all organizational theories for GSCM and LCSC studies, one systematic review investigation by scholars found that Institutional theory is the most widely used by scholars in the Asian context as shown in Table 2.10 (Geng et al., 2017). The systematic review provided by Geng et al. (2017) pointed out that Institutional theory and Contingency theory are adopted by scholars to identify external drivers and explain practices with performance relationship respectively. Their findings also show that there is still lack of understanding and contribution for organizational theories in study related to GSCM and LCSC. However, that study only considered only Asian region. Nevertheless, it shows that more investigation with underpinning theory is needed. Therefore, this study's adoption of Institutional theory to explain the determinants of LCSC and relationship between LCSC practices will contribute to the existing knowledge of organizational theory in the field of environmental management.

Table 2.10 Previous studies in Asia with theoretical lens

| Theory | Count | Percentage |
|---|---|---|
| Institutional Theory | 7 | 14 |
| Contingency Theory | 6 | 12 |
| Resource Based View | 6 | 12 |
| Social Capital Theory | 2 | 4 |
| Resource Dependency Theory | 2 | 4 |
| Stakeholder Theory | 2 | 4 |
| Production Frontier Theory | 1 | 2 |
| Stage Theory | 1 | 2 |
| Transaction Cost Economics | 1 | 2 |
| Not Specified | 21 | 42 |

Source: Geng et al. (2017)

### 2.9.1 Institutional Theory

The institutional theory examines how internal pressures (Zhu et al., 2013) and external pressures influence a firm to adopt or apply an organizational practice (Hirsch, 1975; Lai, Wong, & Cheng, 2006). It is one of the most developed and robust theory in management approach literature (Clemens & Douglas, 2006) and widely used in green issues studies (Jennings & Zandbergen, 1995; King & Lenox, 2000; Lounsbury, 2008). In this study, Institutional theory is used to explain how determinants of LCSC practices pressure Malaysian manufacturing firms to adopt LCSC practices and how these practices effect the relationship with operational performance (GSCOP) and environmental performance (LCP).

There are three pillars or isomorphic drivers of institutional theory (DiMaggio & Powell, 1977):

26. Coercive isomorphic: firms must reluctantly accept the formal and external pressures upon them which they are dependent on such as government regulation.
27. Normative isomorphic: firms behave based on collective expectations from legitimate behaviour, which is perception that the actions taken are in accordance with social values, norms, beliefs and definitions (Suchman, 1995). This is to give assurance to competitors that it will maintain procedural legitimacy (Sodero, Rabinovich, & Sinha, 2013).
28. Mimetic isomorphic: firms respond to pressures by mimicking other firm's conduct of the same structure such as competitors that has similar size and operates in the same industry. This is also called as benchmarking and it is very popular in developed countries (Aerts, Cormier, & Magnan, 2006). A mimetic process is undertaken when firms faced with uncertainty such as ambiguous goals and poor understanding of innovations (DiMaggio & Powell, 1977; Sodero et al., 2013).

Understanding pillars of Institutional theory is important because the use of this theory is to understand what pressures firms to adopt certain practices. In addition, this theory also is able to explain why firms are adopting certain practices. For example, due to high carbon emissions emitted by manufacturing firms, government and customers are demanding manufacturing firms to reduce carbon emissions. Environmental regulations such as Kyoto Protocol mechanisms (carbon trading, CDM and JI), Waste of Electronics & Electrical Equipment (WEEE), Climate Change Act (in the UK), American Clean Energy Bill and Restriction of Hazardous Substance (RoHS) (Laosirihongthong et al., 2013) have pressured firms to adopt LCSC practices. On the other hand, customers in China is found to have coercive pressure on firms more than governmental regulations (Zhang et al., 2012; Zhu et al., 2007) while customers in developing countries have normative pressure (Sarkis et al., 2011).

Furthermore, Institutional theory is also flexible in explaining why firms adopt certain practices. For example, in a study of Zhu et al. (2013) in Chinese manufacturing industry found that governmental regulations, customer pressure and environmental NGOs as determinants that pressures firms to adopt environmental practices while Zhang et al. (2012) found that governmental regulations, supply chain pressure, competitions are determinants that pressure firms to adopt environmental practices in Chinese manufacturing industry. Both scholarly studies focus on manufacturing firms in China and investigated environmental practices to achieve environmental performance, but both have different results on determinants that pressure firms to adopt certain practices. The reason is while Zhu et al. (2013) studied environmental practices in manufacturing firms residing in downstream industries, Zhang et al. (2012) studied environmental practices in manufacturing firms residing in upstream industries that produce higher carbon emissions and wastes. In order to confirm this notion, a study by Zailani et al. (2013) in Malaysian manufacturing firms have similar findings with Zhu et al. (2013) on determinants of environmental practices while Nishitani et al. (2013) investigating upstream industries of Japanese manufacturing firms have similar findings with Zhang et al. (2012). Therefore, the usefulness of Institutional theory to explain various determinants of LCSC practices and practices-performances relationship is the reason for this study's adoption of Institutional theory. In addition, this theory is able to explain why practices are adopted through understanding of cultural and industrial backgrounds.

In the literature, several studies on GSCM and LCSC with performance have been widely based on Institutional theory. A study by Colwell and Joshi (2013) of 199 Canadian manufacturing firms on institutional pressures with top management support moderates the relationship between institutional pressures and corporate environmental responsiveness found that Institutional theory has two major limitations that it ignores top management support and this theory only focuses on survivability of firms. However, their study findings was challenged by Luo et al. (2016) investigating 176 Indian manufacturing firms regarding antecedents of LCSC practices. Their study used institutional pressures with top management support as mediator but in order to explain the effect of top management, Contingency theory is used. Their findings contradicted with Colwell and Joshi (2013) on top management support moderates practices but they have suggested that more investigation on this matter is advisable. This study on the contrary view top management support as institutional pressure and will contribute further to the discussion of top management in the literature. In another study, Institutional theory has been used to explain sustainable practices across dairy supply chains (Glover et al., 2014). They conducted 70 semi-structured interviews with various supply chain stakeholders and found that Institutional theory is able to explain why certain practices are being implemented instead of identifying what pressures firms to adopt. In their study, while investigating the coercive pressure of supermarket on dairy supply chain, they found coercive power of supermarkets have consequences on supply chain. A study by Zhu et al. (2013) of 396 Chinese manufacturing firms on institutional pressures and GSCM practices found that mimetic and normative pressures are influential determinants affecting the implementation of GSCM in manufacturing. A study by Laosirihongthong et al. (2013) of 190 Thai manufacturing firms examined GSCM practices with performances by adopting several organizational theories such as Resource Based View, Transaction Cost Economics, Agency, Network theory and Institutional theory to explain how firms adopt GSCM practices. However, their study only used Institutional theory to identify institutional pressures for firms to adopt GSCM practices. Another study by Grosvold et al. (2014) used Institutional theory to explore the relationship between practices, measurement and performance. Their study contributes to the discussion on Institutional theory that have been debated in the literature.

There is a school of thought that accepts that institutional forces (government) drive firms to isomorphism (adopt and change) (Baum & Oliver, 1992; Haveman, 1993; Scott, 1987). On the other hand, another school of thought believe that it is not firms that change to adopt and modify (isomorphism) to environment but it is because of firms' strategies and industry, forcing institutional (example, government) to exert coercive pressure unto firms (Hoffman, 2001; Milstein, Hart, & York, 2002). It is suggested that firms' strategy is optimized when firms comply with stakeholder demands (pressures) but the reality is that firms only make slight internal changes to protect its operational core (Grosvold et al., 2014). For example, the second school of thought argued that firms adhere to governmental regulations, customers and environmental NGOs pressures by adopting environmental standards certification, but the reality is that firms adopting that certification is to appease its stakeholders. In other words, the first school of thought believe firms are reactive to isomorphism while the second school of thought believe that firms are proactively forcing government to change or implement policies. Still, firms are unable to execute any strategies as they wish because firms are constrained by institutional pressures (Scott, 1991) even though firms' strategies are changing all the time due to the dynamic nature of business environment. This study follows the first school of thought where institutional pressures force firms to adopt certain practices similar to scholars with similar research interest (Zailani et al., 2013; Zhang et al., 2012; Zhu et al., 2013).

## 2.10 Theoretical Framework Development

The objective of theoretical framework is to help understand the overall investigation and serves as a guideline for this study. The theoretical framework of this study is shown in Figure 2.11, which is to achieve overall research objectives. Theory that will govern this theoretical framework is Institutional theory from determinants to practices. The interest of this study is to investigate determinants of LCSC practices, LCSC practices and its relationship with GSCOP and LCP with GSCOP serving as mediating variable. There are existing frameworks in the literature that this study can help extend and improve. By conceptualizing and extending previous studies framework, this study can contribute to the literature by developing a framework of LCSC practices in Malaysian manufacturing industry and extend existing knowledge on LCSC practices.

### 2.10.1 Steps in Developing Theoretical Framework

In order to develop theoretical framework, a systematic approach is advisable. Steps taken to develop theoretical framework are as follows:

29. Identify relevant studies in the literature on GSCM and LCSC to help develop theoretical framework (Table 2.11).
30. Conceptualization by criticizing the strengths and weaknesses as well as relevancy of their studies to the development of theoretical framework (Figure 2.5, Figure 2.6, Figure 2.7, Figure 2.8, Figure 2.9, Figure 2.10).
31. Develop theoretical framework (Figure 2.11).

### 2.10.2 Identify Key Articles for Theoretical Framework Development

There are several key articles in the literature that can help develop a framework for this study. In Table 2.11, key articles of GSCM and LCSC in the literature were collected to help in theoretical framework development for determinants, LCSC practices and performances in Malaysian manufacturing industry. For the purpose of relevancy, only studies related to GSCM and LCSC in manufacturing industries are selected.

Table 2.11 Key articles for theoretical framework development

| Industry | Country | Title | Source |
|---|---|---|---|
| Manufacturing | - | Manufacturing strategy and environmental consciousness | (Sarkis, 1995) |
| Manufacturing | China | Institutional-based antecedents and performance outcomes of internal and external green supply chain management practices | (Zhu et al., 2013) |
| Manufacturing | Germany | Drivers, Practices and Outcomes of Low-carbon Operations: Approaches of German Automotive Suppliers to Cutting Carbon Emissions | (Böttcher & Müller, 2015) |
| Manufacturing | Malaysia | Green supply chain management, environmental collaboration and sustainability performance | (Chin et al., 2015) |
| Manufacturing | Malaysia | The impact of external institutional drivers and internal strategy on environmental performance | (Zailani et al., 2013) |
| Manufacturing | China | CO 2 emission reduction within Chinese iron & steel industry: practices, determinants and performance | (Zhang et al., 2012) |

### 2.10.3 Conceptualization of Key Articles for Theoretical Framework Development

Scholars have conceptualized GSCM processes as consisting of green procurement, green product, green production, green distribution and green logistics. An early study that conceptualized GSCM was done by Sarkis (1995). The proposed framework by Sarkis (1995) is shown in Figure 2.5. The scholar conceptualized GSCM practices by omitting product development from supply chain process as this activity involves product design and process design. Furthermore, scholar differentiated green distribution as packaging and transportation but reverse logistics as collecting back product, packaging and recycle of waste.

On the other hand, Chin et al. (2015) as shown in Figure 2.6 conceptualized GSCM practices based on Sarkis (1995) but differentiated between green distribution and green logistics. However, even though separation between green distribution and green logistics are evident, reverse logistics is taken under the definition of logistics. Their studies differentiated green logistics so as to further study green logistics in detail. In a study by Laosirihongthong et al. (2013) it was found that reverse logistics do not have significant impact on performance. Therefore, a differentiation between green distribution and green logistics is required for the development of theoretical framework.

A study by Zailani et al. (2013) as shown in Figure 2.7 conceptualized GSCM practices by identifying institutional pressures from Institutional theory that pressure manufacturing firms to adopt eco-design to achieve environmental performance. However, their study only investigated external pressures of governmental regulation and customer pressure on part of GSCM practices, which is green product, green production and green distribution. Therefore, a more comprehensive study investigating institutional pressures on internal and external environmental practices in the supply chain is required.

Similarly, a study by Zhu et al. (2013) as shown in Figure 2.8 investigated institutional pressures on Chinese manufacturing firm’s adoption of internal and external GSCM practices to achieve performances. Their study is similar to Zailani et al. (2013) but covered both internal and external GSCM practices. Furthermore, their focus of study on relationship between GSCM practices and performances are also important for this study’s theoretical framework development. In their study, operational performance, environmental performance and economic performance were investigated. However, scholars did not study how GSCM practices that are related to operations in the production of product affects operational performance that subsequently improves environmental performance. Their study looked at how GSCM practices improved environmental and operational performance that leads to economic performance. In the literature, studies on GSCM practices on economic performance is abundant but study on environmental performance is increasing (Zhu et al., 2013). Yet, conceptualization of GSCM studies on operational performance has not seen much research (Corbett & Klassen, 2006). Therefore, a study on relationship of environmental practices in the supply chain affecting operational performance and environmental performance is required.

In a study by Zhang et al. (2012) on determinants, practices and performances of low carbon practices as shown in Figure 2.9 is one of the closest to this study. Even though these scholars identified determinants based on Institutional theory and Resource Based View theory, these scholars did not investigate how these determinants affected manufacturing firms in China adopting low carbon practices in the supply chain. Their study investigated how pressures from governmental regulations, supply chains, competitors, financial cost and capacities affected low carbon reduction practices in manufacturing firms. Therefore, a study on how determinants affects low carbon practices in the supply chain to achieve performances is required.

An early attempt to develop LCSC framework was done by Böttcher and Müller (2015) as shown in Figure 2.10. Their study however only investigated internal supply chain practices such as low carbon product, low carbon production and low carbon distribution. Furthermore, their study investigated stakeholder as a whole not as an individual group. Thus, there is no evidence whether governmental regulations or customers or environmental NGOs are the ones pressuring manufacturing firms to adopt LCSC practices. In addition, their study also did not differentiate between low carbon distribution and low carbon logistics and the underpinning theory was not specified. Moreover, Böttcher and Müller (2015) separated external institutional pressure from stakeholders from the internal pressure from competitiveness expectations. Competitiveness expectations only looked into firms' image, marketing opportunity, cost reduction, differentiation from competitors, customer rewards and access to funds (Böttcher & Müller, 2015). There is no evidence that top management support and green technology that are related to low carbon practices is being investigated. Therefore, a study on determinants consisting of internal and external pressures on low carbon practices in the supply chain consisting of internal and external practices is required.

Taking into account previous studies as shown in Figure 2.5, Figure 2.6, Figure 2.7, Figure 2.8, Figure 2.9 and Figure 2.10, this study is able to develop a theoretical framework that can answer to the needs of manufacturing industry and addressing several limitations of previous studies on LCSC. Figure 2.11 is the theoretical framework that has been developed based on the understanding and conceptualization of previous studies related to GSCM and LCSC studies. This theoretical framework includes determinants from internal and external institutional pressures such as governmental regulations, customer pressure, green technology, environmental NGOs and top management support.

In addition, these institutional pressures are being investigated with LCSC practices that include internal and external supply chain practices such as low carbon product, low carbon procurement, low carbon production, low carbon distribution and low carbon logistics. In this study, low carbon distribution and low carbon logistics are defined and differentiated where low carbon distribution refers to green packaging and warehousing and low carbon logistics refers to transportation mode and technologies for transportation. Determinants and LCSC practices relationship with performances are also investigated. As carbon emissions is highly emitted from operational activities of firms, reducing carbon emissions in the operations is important. Therefore, manufacturing firms practicing LCSC practices should be able to reduce carbon emissions in the supply chain and achieve operational performance. Operational performance then should be measured with criteria that can reduce carbon emissions such as flexibility, responsiveness, cost and environmental friendliness. In this study, operational performance is termed as GSCOP. Achieving operational performance also leads to environmental performance specifically in reducing carbon emissions. In this study, environmental performance is the ultimate outcome, which is termed as LCP and GSCOP mediating effect on LCP is also investigated.

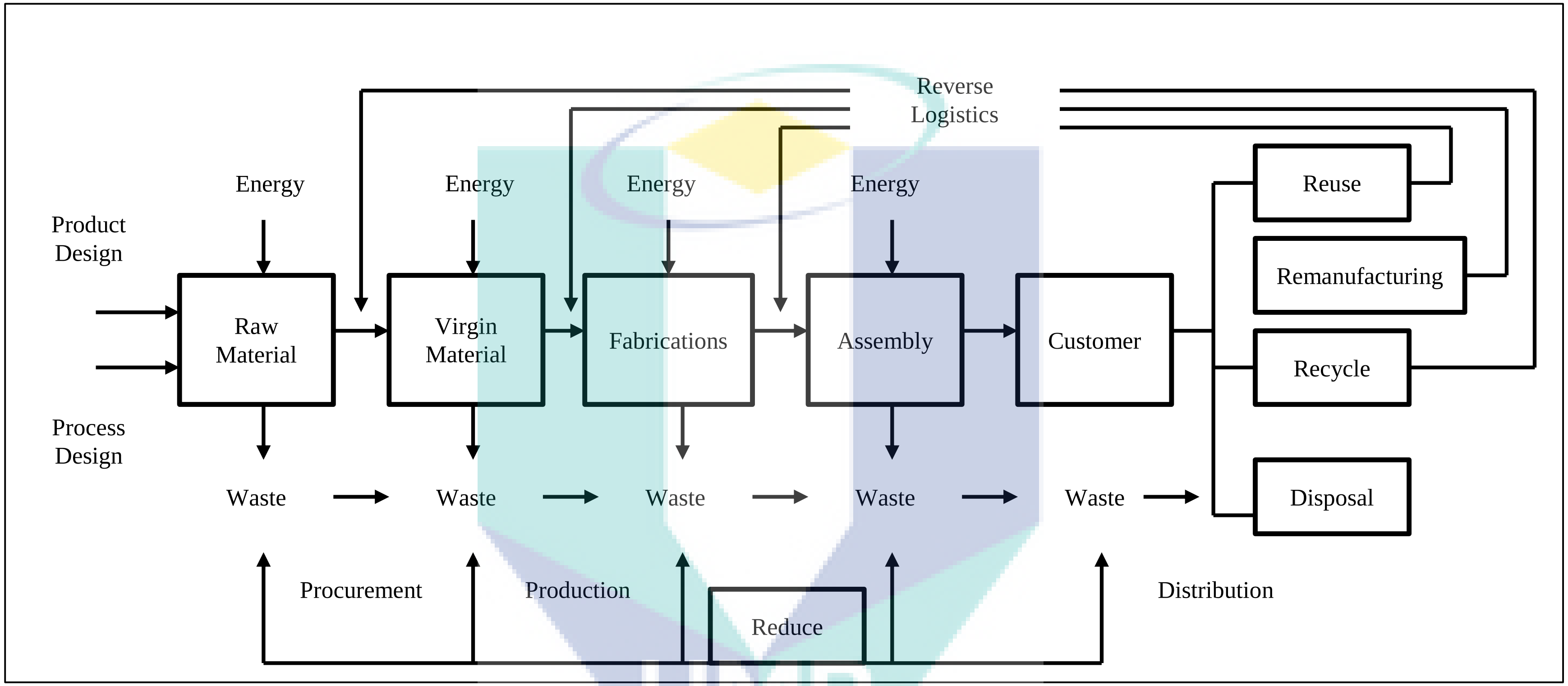


Figure 2.5 Conceptualization of GSCM practices by Sarkis

Source: Sarkis (1995)

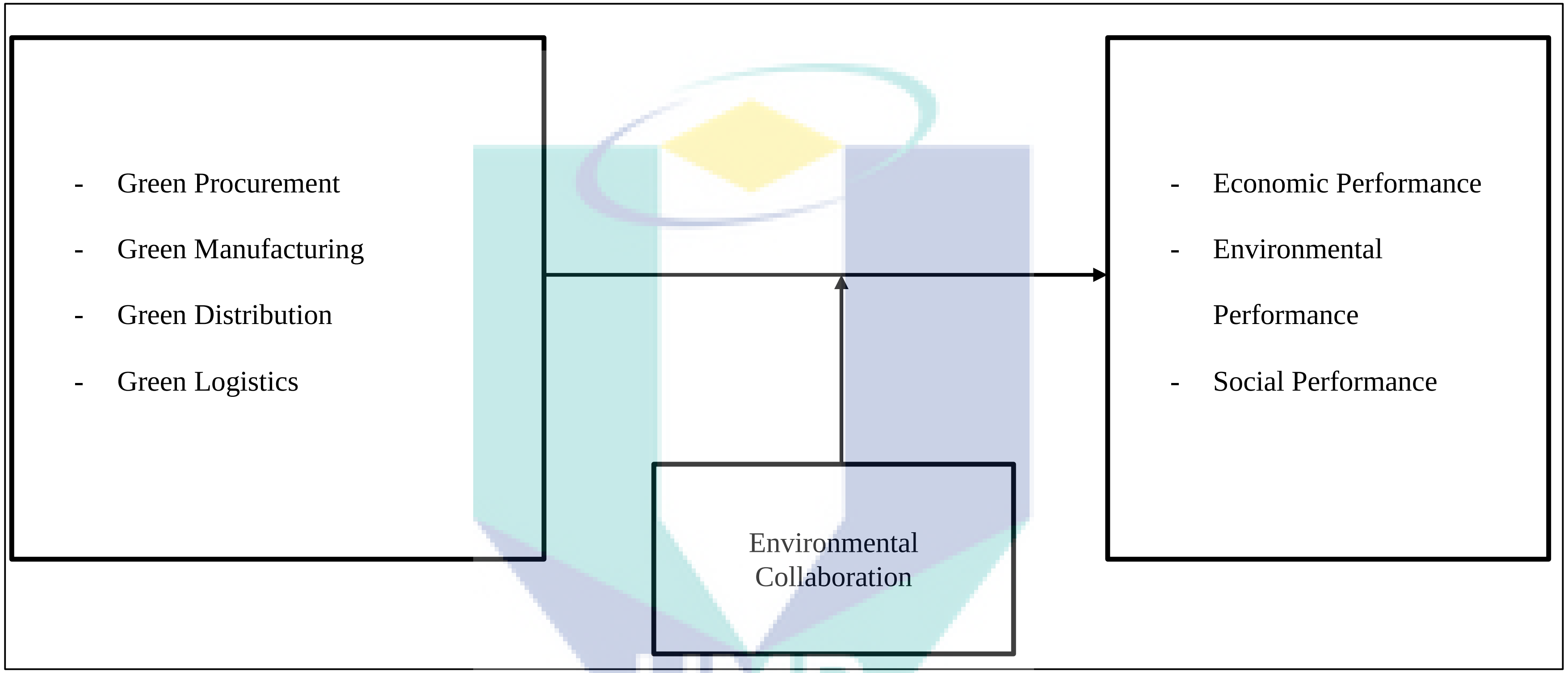


Figure 2.6 Conceptualization of GSCM practices by Chin, Tat and Sulaiman
Source: Chin et al. (2015)

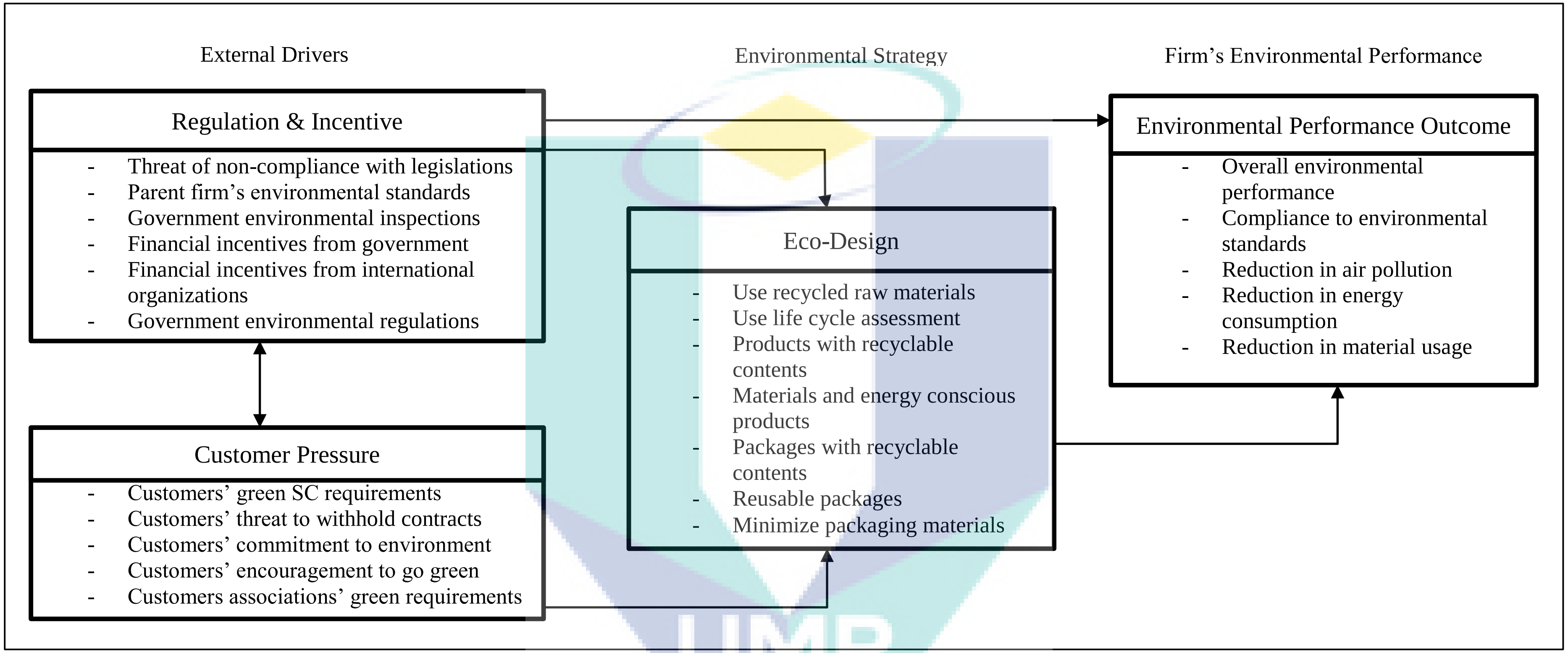


Figure 2.7 Conceptualization of GSCM practices by Zailani, ElTayeb, Hsu and Tan

Source: Zailani et al. (2013)

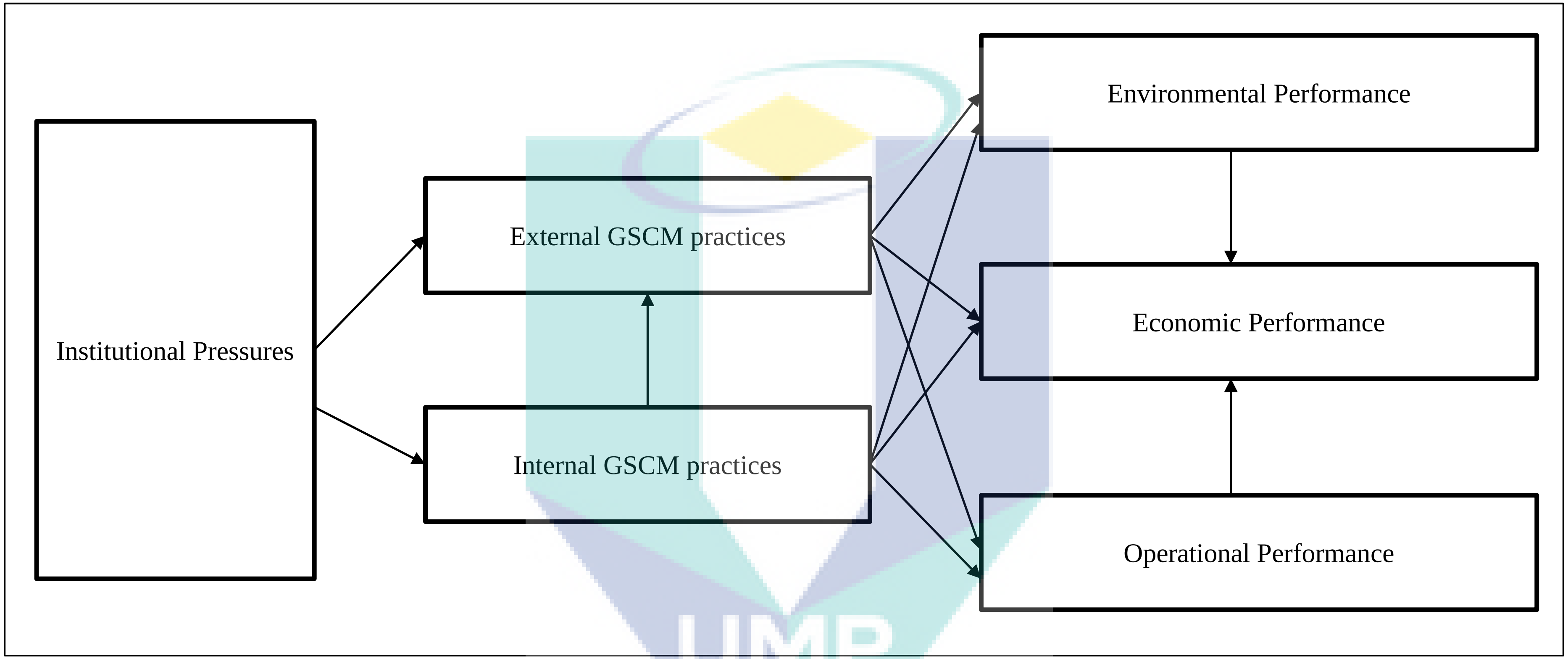


Figure 2.8 Conceptualization of GSCM practices by Zhu, Sarkis and Lai

Source: Zhu et al. (2013)

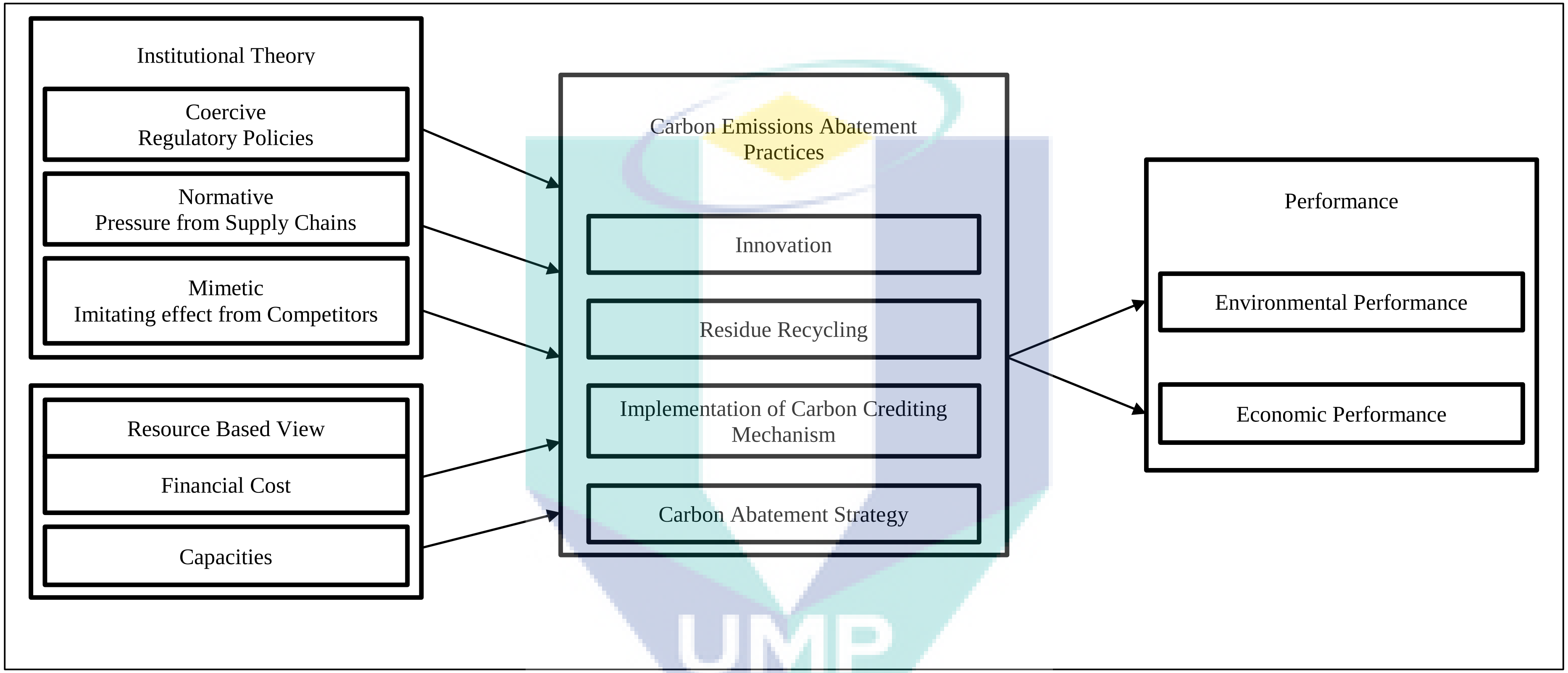


Figure 2.9 Conceptualization of LCSC practices by Zhang, Wang, Yin and Su

Source: Zhang et al. (2012)

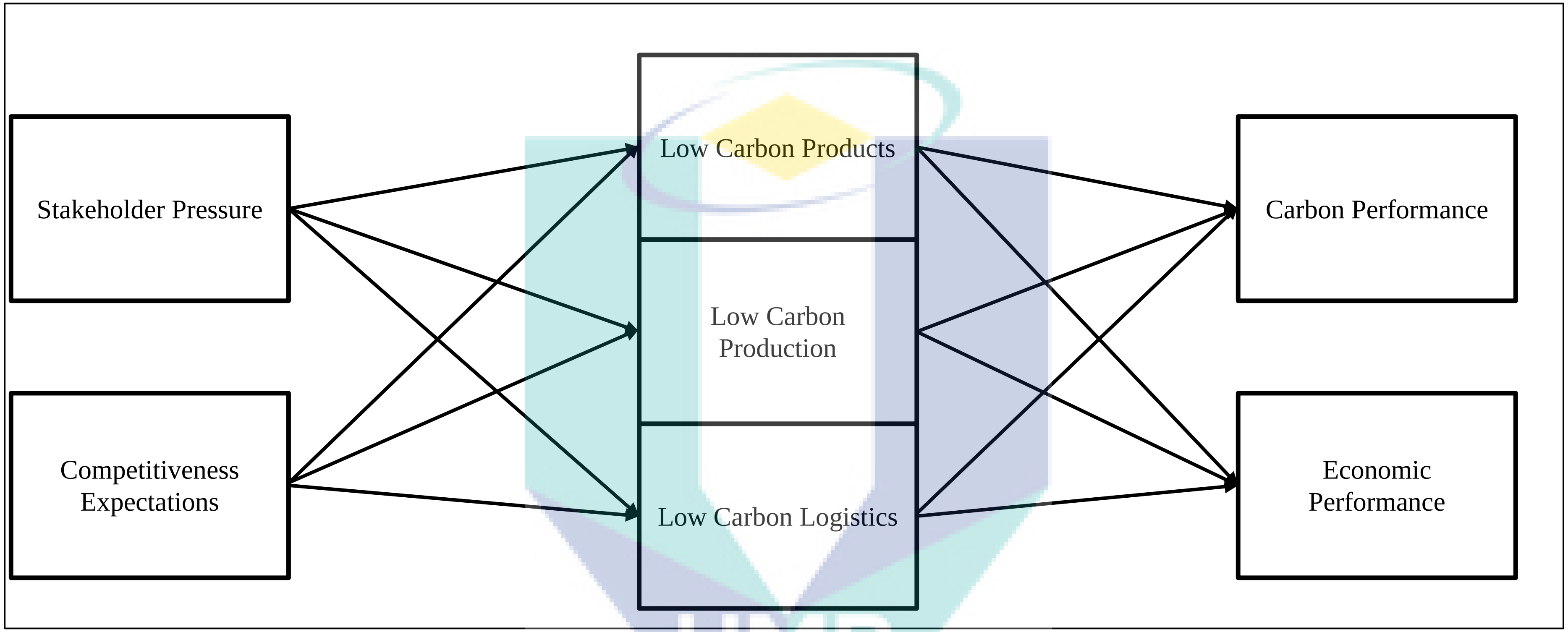


Figure 2.10 Conceptualization of LCSC practices by Bottcher and Muller

Source: Böttcher & Müller (2015)

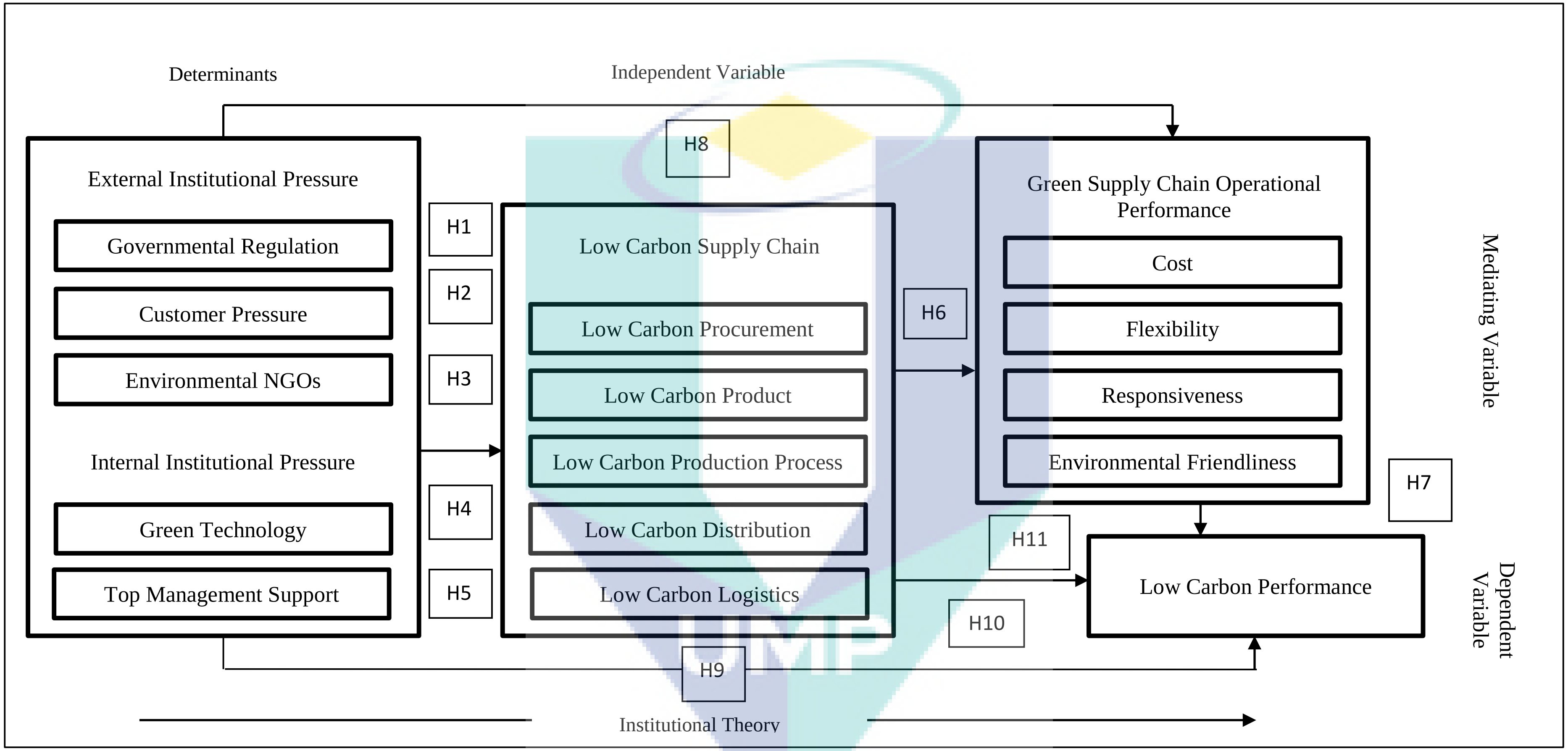


Figure 2.11 Theoretical framework

## 2.11 Hypotheses Development

### 2.11.1 Determinants of Low Carbon Supply Chain Practices with Low Carbon Supply Chain Practices

Determinants of LCSC practices are institutional pressures that force manufacturing firms to adopt LCSC practices to achieve carbon emissions reduction. It was found that external institutional pressures such as governmental regulations and customers are pressuring manufacturing firms to reduce carbon emissions by adopting LCSC practices (Böttcher & Müller, 2015). Studies of effect of governmental regulations on GSCM and LCSC practices are plenty in the literature. In a study by Zhang et al. (2012) on carbon emissions reduction in Chinese manufacturing firms found that governmental regulation has a positive effect on carbon emissions reduction practices and acted as an agent to promote low carbon practices when regulations are stricter. In addition, a study by Zailani et al. (2013) in Malaysian manufacturing firms found that governmental regulations can help manufacturing firms achieve environmental performance with proper incentives. Moreover, their study also indicates that the impact of regulations on environmental performance is higher when firms are adopting environmental practices. Governmental regulations is significantly important as it is closely related to customer pressure. In a study by Zhu et al. (2013) on Chinese manufacturing firms found that manufacturing firms perceived regulations as targeted at direct emissions such as energy source and purchase that are not directly influenced by customers, which explained low environmental concerns from regulations. Due to that, their study indicates that the relationship between governmental regulations and environmental concerns are significantly negative. Similarly, Zailani et al. (2013) pointed that customer pressure should be considered together with governmental regulations due to positive correlation between them. Customers pressure firms to adopt LCSC practices and firms adhere to governmental regulations to satisfy customer’s demands. Furthermore, it is found that regulations and incentives helped firms to initiate LCSC practices and achieve environmental performance. As regard the Institutional theory, governmental regulations in Malaysian manufacturing industry has coercive pressure on firms. Therefore, governmental regulations play an important role in adoption of LCSC practices in manufacturing firms. This led to the following hypothesis:

**H1: The higher the governmental regulation, the higher the LCSC practices adoption**

Customer pressure is also another important determinant that pressures manufacturing firms to adopt LCSC practices. Scholars have found that customers pressure has similar coercive pressure like governmental regulations because in the country and industry that lack enforcement of environmental regulations, firms are still pressured to adopt LCSC practices to satisfy their customers (Zhang et al., 2012; Zhu et al., 2013). Countries like Malaysia and China that are known for its developed manufacturing industry have seen manufacturing firms more concerned with reducing carbon emissions and environmental degradation through customer collaboration practices than governmental regulations (Zailani et al., 2015; Zhang et al., 2012). In developed countries such as USA, UK and Canada, customers pressure is known to have normative pressure because it is expected of firms to produce low carbon product. Due to environmental consciousness in those countries are higher, manufacturing firms are collaborating and learning with customers on reducing carbon emissions and environmental degradation practices (Sarkis et al., 2011). Therefore, manufacturing firms in developing countries such as China and Malaysia are learning from the developed countries' customers whether institutional or end user (Zhu et al., 2013). This led to the following hypothesis:

**H2: The higher the customer pressure, the higher the LCSC practices adoption**

Environmental NGOs are also influential and in some countries, environmental NGOs play a significant role in carbon emissions reduction practices (Kolk & Pinkse, 2007). In China, due to high carbon emissions, environmental NGOs are pressuring manufacturing firms to adopt LCSC practices (Zhu et al., 2013) even to the extreme of demanding firms to close production and provide reports to the media on firms' environmental practices. Another significant and positive influence of environmental NGOs are in the form of firms adopting international certifications such as ISO 14000 for environmental management and ISO 50001 for energy management. ISO issuance is NGO's responsibility to provide guidelines for firms to reduce environmental degradations and carbon emissions. In Malaysia, environmental NGOs play a supporting role and enforcer for the Malaysian government by educating, training and monitoring firms on low carbon practices (Ministry of Natural Resources and Environment Malaysia, 2011). In another study, environmental NGOs are found to have significant effect on firms LCSC practices similar to governmental regulations (Ageron et al., 2012). Therefore, environmental NGOs can affect manufacturing firms' operations and influence firms to adopt LCSC practices. With regard to the Institutional theory, environmental NGOs in Malaysia have normative pressure on manufacturing firms. Thus, firms need to adhere to environmental regulations so that environmental NGOs will legitimize their effort to reduce carbon emissions. This led to the following hypothesis:

**H3: The higher the environmental NGOs, the higher the LCSC practices adoption**

Investment on green technology can help manufacturing firms to reduce carbon emissions and improve efficiency and negative effects on the environment (Fernando et al., 2016a). Similarly, a study by Jiang and Chen (2016) in China manufacturing firms found that green technology investment by firms is positively related to customer low carbon demands. As customers are pressuring firms to adopt LCSC practices to reduce carbon emissions, manufacturing firms increase their investment in green technology even at the expense of their profits. Investment in green technology is more appropriate because green technology can substitute standard technology to reduce carbon emissions but standard technology is not able to replace green technology in reducing carbon emissions (Chen et al., 2015). Therefore, to reduce carbon emissions, manufacturing firms should consider green technology investment. In Malaysia, green technology incentives are provided by government to help firms reduce carbon emissions (Ng et al., 2012). With regard to Institutional theory, green technology has mimetic pressure on Malaysian manufacturing firms. This is because when firms are able to reduce carbon emissions through green technology, other firms and competitors will try to replicate the success on their firms as well. This led to the following hypothesis:

**H4: The higher the green technology adoption, the higher the LCSC practices adoption**

Top management support is important for manufacturing firms to adopt LCSC practices (Green et al., 2012). There are numerous studies on the effect of top management support on LCSC practices adoption. In a study by Luo et al. (2016) investigating Indian manufacturing industry, found that top management support mediates the relationship between institutional pressures with LCSC practices. On the other hand, a study by Gunasekaran and Gallear (2012) confirmed that top management support is significantly important for LCSC practices adoption because resources and commitment from management starts with top management. In Malaysia, Zailani et al. (2015) found that green innovation as a result of manufacturing firms practicing GSCM comes from initiatives and commitment of top management. Therefore, top management support is important for manufacturing firms to adopt LCSC practices. With regard to Institutional theory, top management support has coercive pressure on Malaysian manufacturing firms. This is due to the fact that top management can influence firms to adopt governmental regulations. This leads to the following hypothesis:

**H5: The higher the top management support, the higher the LCSC practices adoption**

### 2.11.2 Low Carbon Supply Chain Practices with Green Supply Chain Operational Performance

LCSC practices involve low carbon procurement, low carbon product, low carbon production process, low carbon distribution and low carbon logistics. A study by Böttcher and Müller (2015) in German manufacturing firms found a positive relationship between LCSC practices with performances. Additionally, Zailani et al. (2012) investigated green procurement in Malaysian manufacturing firms found that green procurement leads to significant improvement in GSCOP. A study by Zhang et al. (2012) on low carbon practices in Chinese manufacturing firms found that low carbon practices can lead to improvement of performances. Zhu et al. (2013) investigated both internal and external GSCM practices on performances in Chinese manufacturing firms found that there is positive relationship between GSCM practices and performances such as GSCOP, environmental and economics. Therefore, manufacturing firms adopting internal and external LCSC practices will lead to improvement in GSCOP. This led to the following hypothesis:

**H6: The LCSC practices has positive and significant relationship with GSCOP**

Low carbon procurement refers to the relationship between suppliers and manufacturing firms on raw materials, packaging and carbon emissions reduction goals. Low carbon procurement stresses on relationship with suppliers to eliminate waste, carbon emissions and to ensure meeting customers' demands. As a result, manufacturing firms will be more flexible, responsive and reduce cost as well as environmental friendliness (Gunasekaran & Ngai, 2012). For example, through closer relationship with suppliers through product design and sharing carbon emissions reduction objective, manufacturing firms can tailor product to the specification of customers such as low carbon product, Build-to-Order concept (BTO) and firms can deliver product to customer in shorter time (Gunasekaran & Ngai, 2012) as well as at a reduced cost (Büyüközkan & Çifçi, 2012). Therefore, by practicing low carbon procurement, manufacturing firms' relationship with suppliers enable firms to achieve supply chain performance such as cost reduction, flexibility, responsiveness and environmental friendliness. This leads to the following hypotheses:

**H6ai: low carbon procurement has positive and significant relationship with cost reduction**

**H6aii: low carbon procurement has positive and significant relationship with flexibility**

**H6aiii: low carbon procurement has negative and significant relationship with responsiveness**

**H6aiv: low carbon procurement has positive and significant relationship with environmental friendliness**

Low carbon product refers to design and process of product during product development that take carbon emissions into consideration (Böttcher & Müller, 2015). Due to increasing pressure by stakeholders for manufacturing firms to reduce carbon emissions (Sangle, 2011), firms are focusing on low carbon product (Böttcher & Müller, 2015). As customer demand for low carbon products, firms become more focused on producing what is required by customers. By doing so, firms are able to reduce cost of designing product. Furthermore, as customer demands for environmental friendly products, firms are designing and producing products using recycle raw materials and less carbon intensive materials (Shaw, Shankar, Yadav, & Thakur, 2012). In addition, due to low carbon product, firms are now able to increase its flexibility. Previously, many scholars understood flexibility as a means for firms to cope with uncertainty (Shaw et al., 2012). However, as pressure from stakeholders for firms to produce low carbon products increases, firms are no longer unsure of the market demand. This has increased firms' flexibility in catering to customers' demand for several environmental features of the products. Thus, firms are able to meet the requirement of different customers from different markets with its low carbon products. In this respect, customers are also able to choose products and features that they wanted (Sarkis et al., 2011). As product line expands, firms are able to cater to global market and satisfy its customer base (Gunasekaran & Ngai, 2012). On the other hand, firms are able to introduce new products easily with flexible process and product design at operations and supply chain level. Customer satisfaction will guarantee firms with reduced cost in operations and products (Büyüközkan & Çifçi, 2012). With this, manufacturing firms practicing low carbon product will be able achieve GSCOP. This leads to the following hypotheses:

**H6bi: low carbon product has positive and significant relationship with cost reduction**

**H6bii: low carbon product has positive and significant relationship with flexibility**

**H6biii: low carbon product has positive and significant relationship with responsiveness**

**H6biv: low carbon product has positive and significant relationship with environmental friendliness**

Low carbon production process refers to carbon emissions reduction related to energy, process of product development and machinery and equipment. In order to make low carbon product, it is important for manufacturing firms to focus on low carbon production process (Ninlawan et al., 2010). This is because low carbon product is made in production that require high volume of energy, technology and equipment and emits large amount of carbon emissions. In a study by Lee (2011) and Lee (2012) in Korean manufacturing firm found that low carbon production process enable firms to achieve GSCOP. For example, through flexibility in the production, firms can reduce carbon emissions as it only produces according to customer requirements. Firms also will be able to reduce carbon emissions and reduced operational costs (Büyüközkan & Çifçi, 2012) when firms have good customer relationship. Therefore, manufacturing firms practicing low carbon production process will enjoy improvement in GSCOP (Gunasekaran & Ngai, 2012). This led to the following hypotheses:

**H6ci: low carbon production process has positive and significant relationship with cost reduction**

**H6cii: low carbon production process has positive and significant relationship with flexibility**

**H6ciii: low carbon production process has positive and significant relationship with responsiveness**

**H6civ: low carbon production process has positive and significant relationship with environmental friendliness**

Low carbon distribution refers to low carbon packaging, low carbon materials for packaging, recyclable pallet and energy efficient system at warehouse (Holt & Ghobadian, 2009). Previous studies focusing on low carbon distribution (Böttcher & Müller, 2015) and green distribution (Green et al., 2012; Laosirihongthong et al., 2013; Zailani et al., 2015, 2012) found that low carbon distribution has a significant relationship with GSCOP. Even though some scholars failed to differentiate between low carbon distribution and low carbon logistics, their discussion of low carbon distribution is centred around packaging. For example, through flexibility, firms and its supply chain partners can practice Just-in-Time (JiT) concept by reducing inventory kept at the warehouse, which can help to reduce use of energy and carbon emissions. Firms are also able to respond to market demand in shorter time and reduce carbon emissions and energy use when practicing low carbon distribution. Therefore, manufacturing firms can achieve GSCOP with low carbon distribution that includes practicing low carbon packaging, low carbon energy and warehousing. This led to the following hypotheses:

**H6di: low carbon distribution has positive and significant relationship with cost reduction**

**H6dii: low carbon distribution has positive and significant relationship with flexibility**

**H6diii: low carbon distribution has positive and significant relationship with responsiveness**

**H6div: low carbon distribution has positive and significant relationship with environmental friendliness**

Low carbon logistics refers to carbon emissions reduction for transporting products to supply chain partners and customers. Stakeholders are pressuring firms to reduce carbon emissions across the supply chain process including logistics (Böttcher & Müller, 2015). This is because low carbon logistics can mitigate the impact of climate change and carbon emissions by choosing low carbon transportation mode, low carbon technologies for transportation and reducing carbon emissions during the transportation of products (Scholtens & Kleinsmann, 2011). In a study by Cosimato and Troisi (2015), low carbon logistics enabled environmental friendliness, cost reduction, flexibility and responsiveness. Manufacturing firms are more flexible with different types of deliveries available and more responsive through e-commerce and enterprise resource planning to manage logistics (Gunasekaran & Ngai, 2012). In addition, firms can reduce energy and carbon emissions as well as cost through low carbon logistics. Therefore, manufacturing firms practicing low carbon logistics will be able to achieve GSCOP. This led to the following hypotheses:

**H6ei: low carbon logistics has positive and significant relationship with cost reduction**

**H6eii: low carbon logistics has positive and significant relationship with flexibility**

**H6eiii: low carbon logistics has positive and significant relationship with responsiveness**

**H6eiv: the low carbon logistics has positive and significant relationship with environmental friendliness**

### 2.11.3 Green Supply Chain Operational Performance with Low Carbon Performance

GSCOP is a supply chain performance that results in operational performance. Manufacturing firms are focusing on cost reduction, flexibility, responsiveness (Beamon, 1999) and environmental friendliness in the supply chain (Gunasekaran & Ngai, 2012). Through GSCOP, manufacturing firms can achieve LCP (Chardine-Baumann & Botta-Genoulaz, 2014). This is due to productivity increases in operations from operational strategies such as JIT, Total Quality Management (TQM), lean production, agile manufacturing, collaborative manufacturing, global supply chain and Customer Relationship Management (CRM) (Gunasekaran & Ngai, 2012). These operational strategies reduce waste and emissions, eliminate redundancy processes and cost that leads to better LCP. Therefore, firms can achieve LCP when firms have flexibility, responsiveness, cost reduction and environmental friendliness in its operations. This led to the following hypothesis:

**H7: GSCOP has positive and significant relationship with LCP**

Design costs, purchase costs of raw materials, sourcing costs of raw materials, production costs, delivery costs, return costs and the supply chain costs impact supply chain performance (Chardine-Baumann & Botta-Genoulaz, 2014). The impact of costs will affect manufacturing firms LCP (Hatakeda, Kokubu, Kajiwara, & Nishitani, 2012). This is because the reason for firms to reduce carbon emissions and wastes is to reduce its costs especially operating cost (Büyüközkan & Çifçi, 2012). There are multiple studies on firms pursuing LCSC practices that achieve favourable LCP and cost reduction (Chien & Shih, 2007; Green et al., 2012). In addition, a study by Wong et al. (2012) pointed that firms pursuing LCP should emphasize on improvement of its operations to take advantage of cost reduction benefits. Therefore, cost reduction will enable firms to achieve GSCOP and LCP. This leads to the following hypothesis:

**H7a: Cost reduction has positive and significant relationship with LCP**

Flexibility can measure production's ability to adjust to volume and schedule fluctuations (Beamon, 1999). Flexibility is important and widely used in analysing supply chain performance (Balfaqih et al., 2016). As flexibility is part of GSCOP, the emergence of LCSC as a tool to balance LCP while manufacturing firms pursue GSCOP and economic performances (Zhu, Geng, Sarkis, & Lai, 2011; Zhu et al., 2007) shows that there is relationship between GSCOP and LCP. Findings from investigation by Yu et al. (2014) have confirmed that there is a positive and significant relationship between GSCOP and LCP. This is because flexibility enable firms to reduce number of backorders, reduce number of late orders, ability to respond to poor supplier performance, poor delivery performance and the ability to accommodate new products, new markets and new competitors (Beamon, 1999). These advantages of flexibility are evident for maximizing capacity and capability of production so that there is less waste and emissions due to poor performance. Therefore, manufacturing firms that have the flexibility will gain GSCOP and that will lead to LCP improvement. This leads to the following hypothesis:

**H7b: Flexibility has positive and significant relationship with LCP**

For a responsive supply chain, several factors need to be taken into consideration such as transport mode decisions, locations of its facilities, manufacturing and cost of raw materials (Alonso-villar, 2005; Krugman & Venables, 1995). It was found that a responsive supply chain leads manufacturing firms to LCP (Youn et al., 2012). This has been confirmed by Martí et al. (2015) study on supply chain responsiveness stating that GSCOP and LCP are interrelated. Therefore, manufacturing firms that take into consideration transport mode, location, manufacturing and cost of raw materials to ensure their ability to respond to customers in the shortest time will achieve GSCOP that will lead to LCP. This leads to the following hypothesis:

**H7c: Responsiveness has positive and significant relationship with LCP**

Environmental friendliness is an objective to reduce energy consumption and fostering cleaner energy in the supply chain (Gunasekaran & Ngai, 2012). According to Balfaqih et al. (2016), environmental friendliness is one of the most popular supply chain performance criteria and should be adopted to measure firms' operational performance. A study by Wong et al. (2012) emphasized that environmental friendliness in operations will help manufacturing firms to achieve LCP. Therefore, manufacturing firms that employ environmental friendliness to reduce energy will be able to achieve GSCOP and LCP. This leads to the following hypothesis:

**H7d: Environmental friendliness has positive and significant relationship with LCP**

### 2.11.4 Determinants of Low Carbon Supply Chain Practices with Green Supply Chain Operational Performance

Determinants of LCSC practices can be divided into external pressure and internal pressure. For external pressure, governmental regulations, customer pressure and environmental NGOs can affect manufacturing firms' operational performance. This is evident in a study by Zhu and Geng (2013) on governmental regulation for Chinese manufacturing firms to achieve performance and Zhang and Yang (2016) that found customers to have significant positive result on operational performance. In addition, environmental NGOs can have a positive effect on operational performance when it regulates manufacturing firms' practices (Zhu et al., 2013). Similarly, internal pressure such as top management support and green technology adoption will affect manufacturing firms' operational performance. These are evident in a study of Dubey and Ali (2015) that found firms with green technology have superior operational performance and a study by Fernando and Hor (2017) that found top management support has positive effect on environmental friendliness, which is operational performance. When firms' supply chain is flexible, firms are able to offer more products and cater to wider markets. Furthermore, through expansion of product offering, firms can react to market changes. This is done through a responsive supply chain. Due to the demand of environmental products and call for firms to adopt greener materials and reduce carbon emissions, firms that has environmental friendliness through green technology will be able to reduce cost and avoid paying fines for environmental degradation and carbon discharge (Fernando & Hor, 2017). Therefore, this leads to the following hypotheses:

**H8: The higher the determinants of LCSC practices, the higher the GSCOP**

**H8a: The higher the governmental regulation, the higher the GSCOP**

**H8ai: The higher the governmental regulation, the higher the cost reduction**

**H8aii: The higher the governmental regulation, the higher the flexibility**

**H8aiii: The higher the governmental regulation, the higher the responsiveness**

**H8aiv: The higher the governmental regulation, the higher the environmental friendliness**

**H8b: The higher the customer pressure, the higher the GSCOP**

**H8bi: The higher the customer pressure, the higher the cost reduction**

**H8bii: The higher the customer pressure, the higher the flexibility**

**H8biii: The higher the customer pressure, the higher the responsiveness**

**H8biv: The higher the customer pressure, the higher the environmental friendliness**

**H8c: The higher the environmental NGOs, the higher the GSCOP**

**H8ci: The higher the environmental NGOs, the higher the cost reduction**

**H8cii: The higher the environmental NGOs, the higher the flexibility**

**H8ciii: The higher the environmental NGOs, the higher the responsiveness**

**H8civ: The higher the environmental NGOs, the higher the environmental friendliness**

**H8d: The higher the green technology adoption, the higher the GSCOP**

**H8di: The higher the green technology adoption, the higher the cost reduction**

**H8dii: The higher the green technology adoption, the higher the flexibility**

**H8diii: The higher the green technology adoption, the higher the responsiveness**

**H8div: The higher the green technology adoption, the higher the environmental friendliness**

**H8e: The higher the top management support, the higher the GSCOP**

**H8ei: The higher the top management support, the higher the cost reduction**

**H8eii: The higher the top management support, the higher the flexibility**

**H8eiii: The higher the top management support, the higher the responsiveness**

**H8eiv: The higher the top management support, the higher the environmental friendliness**

### 2.11.5 Determinants of Low Carbon Supply Chain Practices with Low Carbon Performance

Determinants of LCSC practices adopted are from Institutional theory. Several studies on GSCM and LCSC practices adopted institutional based pressures to investigate manufacturing firms LCSC practices to achieve LCP. In a study by Zailani et al. (2013) in Malaysian manufacturing firms found that institutional based pressure are significantly influencing firms' LCP. A study by Zhu et al. (2013) in Chinese manufacturing firms found that institutional based pressures have direct relationship with LCP. Therefore, stakeholder pressures such as governmental regulations, customer pressure, environmental NGOs (Böttcher & Müller, 2015), green technology (Tavoni, de Cian, Luderer, Steckel, & Waisman, 2012) and top management support (Green et al., 2012) are important determinants that pressures firms to achieve LCP. This leads to the following hypotheses:

**H9: The higher the determinants of LCSC practices, the higher the LCP**

It has been long established that firms' initial environmental performance is influenced by governmental regulation (Gray & Deily, 1996; Laplante & Rilstone, 1996). Literature shows consistent findings that firms' business activities should comply with environmental regulations and improve their environmental performance (Ding et al., 2016). Accordingly, the government sets policies, including both regulations and incentives, both of which are necessary for enforcing and motivating firms to improve their environmental performance (Zailani et al., 2013). It was found that government regulations and enforcement should be increased in order to achieve LCP. The result is also similar to Zailani et al. (2013) findings that governmental regulation influence firms'

LCP directly and indirectly. On the other hand, the study by He et al. (2015) on carbon tax and cap-and-trade regulations found that government environmental regulations lead to LCP even without both carbon regulations (carbon tax and cap-and-trade). This leads to the following hypothesis:

**H9a: The higher the governmental regulation, the higher the LCP**

Customers exert pressure on firms (York & Venkataraman, 2010). As consumers now become more environmental conscious and demand environmentally friendly products, firms are pressured to supply more environmental friendly products that will not lead to environmental degradations and the production of high carbon emissions. The pressure by consumers is well documented. For example, customers pressure has been found to have positive and significant relationship with LCP (ElTayeb et al., 2010; Zailani et al., 2013; Zhu & Geng, 2013). In China and Malaysia, firms are taking responsibility towards the environment and creating innovative products that are environmental friendly and of low carbon due to customers pressure (Liu, Li, Zuo, Zhang, & Wang, 2008; Lo & Leung, 2000; Zailani et al., 2015) while in other countries there are also consumers who are willing to pay more for environmental friendly products as in England and Canada (Ball & Craig, 2010; Carter, Kale, & Grimm, 2000). This leads to the following hypothesis:

**H9b: The higher the customer pressure, the higher the LCP**

Environmental NGOs, media and customers will hold manufacturing firms accountable for the products and the supply chain practices (Beske-Janssen et al., 2015). In a study by Nizam et al. (2013) on low carbon policies in Malaysia highlighted that in order for Malaysia to reduce carbon emissions, collaboration with environmental NGOs is important. For example, in a study by Dos Santos et al. (2014) on South African firms implementing environmental practices in the supply chain, underlined that firms worked with NGOs. The reason is because firms are being pressured by environmental NGOs to provide evidence of environmental practices being implemented (Auger, Devinney, Louviere, & Burke, 2010; Waysheh & Klassen, 2010). That is why, it was found that environmental practices are recognized by stakeholders such as governments, customers and environmental NGOs (Foerstl et al., 2015). Similarly, in a study by Wu and Pagell (2011) on sustainable supply chain and operations found that environmental NGOs compelled firms to consider environmental practices. In addition, firms working with environmental NGOs that possess more information on carbon emissions will help firms to achieve LCP (Liu, 2014). This leads to the following hypothesis:

**H9c: The higher the environmental NGOs participation, the higher the LCP**

Green technology is deployed to reduce carbon emissions (Asian Development Bank Institute, 2012). A study by Anbumozhi (2015) highlighted the importance of technology, finance and capacity building for developing countries to achieve LCP. As policymakers stress the importance of green technology, scholars also found that green technology is one of the main practices of LCSC to help firms reduce carbon emissions (Chen et al., 2015; Shaharudin & Fernando, 2015). A study by Jiang and Chen (2016) on Chinese manufacturing industry found that green technology investment increases when customers demand for low carbon product increases. Therefore, as governmental regulations and customers pressure are known institutional pressures for manufacturing firms to achieve LCP, green technology will also increase and help firms to reduce carbon emissions. This leads to the following hypothesis:

**H9d: The higher the green technology, the higher the LCP**

Top management support plays an important role for firms to achieve LCP (Green et al., 2012). Due to the importance of carbon emissions reduction, top management will need information to make strategic planning and decisions to achieve LCP. For example, Fernando et al. (2016a) in their study on green technology firms in Malaysia found that top management support contributes greatly to green innovation practices. Similarly, Wong and Karia (2010) found top management support to be significant to firms. Furthermore, it was found that the role of top management's commitment is important for supply chain firms who seek to achieve LCP (Foerstl et al., 2015; Gattiker & Carter, 2010; Liang et al., 2007). In addition, the support of top management's positive relationship with environmental practices has been illustrated by scholars and found to be important (Abdulrahman, Gunasekaran, & Subramanian, 2014; Jabbour & de Sousa Jabbour, 2016). These findings are aligned with previous studies that top management must be fully committed for LCP to be successful (Rice, 2003; Zsidisin & Siferd, 2001). Therefore, top management support is important for manufacturing firms to achieve LCP (Tachizawa et al., 2015) as decisions on carbon emissions reduction through management of manpower, product development, supply chain and operations are made by top management. This leads to the following hypothesis:

**H9e: The higher the top management support, the higher the LCP**

### 2.11.6 Low Carbon Supply Chain Practices with Low Carbon Performance

Firms practicing LCSC practices to reduce carbon emissions throughout its supply chain (Nishitani et al., 2013). It was found that in Chinese manufacturing firms practicing low carbon practices in their supply chain have achieved LCP (Zhang et al., 2012). In addition, the literature provide evidence that firms practiced LCSC to improve LCP and firm's performance (Nikbakhsh, 2009; Testa & Iraldo, 2010). There are many manufacturing firms practicing LCSC in various sectors such as iron and steel, cement, rubber, aluminium, paper, oil sands, chemical fibre, hydraulic presses, methanol production, logistics and trade sectors to reduce carbon emissions because these sectors in the manufacturing industry are emitting high carbon emissions (Huisingh et al., 2015). LCSC practices improving firms' LCP are not limited to manufacturing industry only but also to other industries and countries (Vachon & Mao, 2008). Therefore, manufacturing firms practicing LCSC will lead to LCP. This leads to the following hypothesis:

**H10: LCSC practices has positive and significant relationship with LCP**

Low carbon procurement involves carbon emissions reduction when purchasing and processing raw materials to virgin materials (Sarkis, 2003). Low carbon purchasing has been extensively covered in the literature (Eltayeb & Zailani, 2009; ElTayeb et al., 2010; Eltayeb, Zailani, & Jayaraman, 2009; Green et al., 2012; Hsu et al., 2013; Zhu et al., 2012; Zhu et al., 2008) pointed out the significance of low carbon procurement for firms to achieve LCP. The reason is because carbon emissions largely come from energy generation and supplies of carbon-intensive materials. Energy generation and carbon-intensive materials are supplied by firms' suppliers. Therefore, Lee et al. (2012) suggested that firms should focus on low carbon procurement to improve LCP. This suggestion is also supported by Giovanni (2012) stressing that firms that intends to achieve LCP should adopt specific low carbon practices such as low carbon procurement so that production of product will not generate higher carbon emissions. Therefore, manufacturing firms adopting low carbon procurement can help firms to achieve LCP. This leads to the following hypothesis:

**H10a: Low carbon procurement has positive and significant relationship with LCP**

Low carbon product involves product design and specification and production process design (Sarkis, 2003). Products that has low carbon specification and environmental friendly design will help firms to reduce carbon emissions while production planning of producing a product with low carbon as an objective will further reduce carbon emissions. Sprengel and Busch (2011) pointed out that firms are able to reduce carbon emissions if they are able to map and design the product during the development of low carbon products. In addition, a study by Böttcher and Müller (2015) found that firms are positively motivated to produce low carbon products in order to achieve LCP. On the other hand, the study by Simon and Albert (2015) on three EU countries found that by focusing on important product development and strategy would allow firms to achieve LCP. Thus, this leads to the following hypothesis:

**H10b: Low carbon product has positive and significant relationship with LCP**

Low carbon production process is one of the main contributors of increasing carbon emissions (Shafii & Sinha, 2011). There is consensus in the literature that low carbon production process is important for manufacturing firms to reduce carbon emissions and achieving LCP. For example, in a study by Böttcher and Müller (2015) of automotive manufacturing in Germany has found that the strongest impact of LCSC practices on LCP is low carbon production. In India, the result is also similar to the previous studies where it was found that production process contributes significantly to LCP objective (Sangle, 2011). Similarly, Huisingh et al. (2015) stressed the importance of adopting low carbon production to achieve LCP for manufacturing firms in China. This leads to the following hypothesis:

**H10c: Low carbon production process has positive and significant relationship with LCP**

Low carbon distribution ensures firms' packaging and inventory are environmentally friendly. Packaging will affect the transportation mode and quantity that transportation can take (Ninlawan et al., 2010) while inventory keeping depends on energy activities and space of warehousing products before shipping to customers. For example, a study by Danloup et al. (2015), firms were able to reduce carbon emissions by at least 26 percent by focusing on low carbon distribution in EU firms while in Malaysia, low carbon emissions requires operations manager to consider low carbon distribution (Fernando et al., 2016a). To achieve LCP, Wang, Lai and Shi (2011) proposed carbon emissions reduction through warehousing and location of warehouses while green packaging through cooperation with customers is also critical (Vachon & Klassen, 2008; Yu et al., 2014). This leads to the following hypothesis:

**H10d: Low carbon distribution has positive and significant relationship with LCP**

Low carbon logistics encompasses carbon emissions reduction in transportation modes, consolidation of shipments and efficient use of energy as well as low carbon technologies for transportation (Böttcher & Müller, 2015). Transportation, which is part of logistics service provided by firms to ship products to customers produces high carbon emissions (Tacken et al., 2014). For example, von der Gracht and Darkow (2016) found that low carbon logistics is important for firms to achieve LCP. In addition, Garg et al. (2015) also supported the idea in their study on low carbon logistics and a study by Tacken et al. (2014) confirmed that low carbon logistics practice is indeed important to firms and have a strong relationship with LCP. Due to this, it is recommended that firms consolidate shipment and manage transport (Kellner & Igl, 2015) as well as manage and substitute with low carbon transportation modes (Böttcher & Müller, 2015). This leads to the following hypothesis:

**H10e: Low carbon logistics has positive and significant relationship with LCP**

### 2.11.7 Mediating effect of Green Supply Chain Operational Performance on Low Carbon Supply Chain Practices and Low Carbon Performance

In the literature, it was found that GSCOP improvements can result in LCP due to LCSC practices such as waste reduction, resources conservation and carbon reductions (Zhu et al., 2013). The most supporting evidence of GSCOP as a mediating effect between LCSC practices with LCP can be seen in a study by Lee et al. (2012) where in their study they found that there is a significant link between LCSC practices and performance. They found significant indirect relationship between LCSC practices implementation and performance through mediating variable of GSCOP. The result shows improved performance. Similarly, a study by Zhu et al. (2013) regarding GSCM practices on economic performance, operational performance and environmental performance found that GSCM practices do not directly affect LCP but improve it indirectly with GSCOP. Thus, LCSC practices of this study can improve GSCOP, which would subsequently help firms to achieve LCP.

Specifically, flexibility in operations is still open for discussion as Carlsson (1989) pointed out that in operations, flexibility depends on timeframe while Thomé, Scavarda, Pires, Ceryno and Klingebiel (2014) argued that the flexibility need to be aligned with the requirements placed upon the supply chain. Furthermore, Stevenson and Spring (2007) have used flexibility, which is part of GSCOP as a secondary input in their study. All of these leads to the confirmation that GSCOP is suitable as a mediating variable between supply chain practices and performance outcome. Taking into consideration previous studies where GSCOP has mediating effect on LCSC practices and LCP (Lee et al., 2012; Zhu et al., 2013) this leads to the following hypotheses:

**H11: GSCOP mediates the relationship between LCSC Practices and LCP**

**H11ai: Cost reduction mediates the relationship between low carbon procurement and LCP**

**H11aii: Flexibility mediates the relationship between low carbon procurement and LCP**

**H11aiii: Responsiveness mediates the relationship between low carbon procurement and LCP**

**H11aiv: Environmental friendliness mediates the relationship between low carbon procurement and LCP**

**H11bi: Cost reduction mediates the relationship between low carbon product and LCP**

**H11bii: Flexibility mediates the relationship between low carbon product and LCP**

**H11biii: Responsiveness mediates the relationship between low carbon product and LCP**

**H11biv: Environmental friendliness mediates the relationship between low carbon product and LCP**

**H11ci: Cost reduction mediates the relationship between low carbon production process and LCP**

**H11cii: Flexibility mediates the relationship between low carbon production process and LCP**

**H11ciii: Responsiveness mediates the relationship between low carbon production process and LCP**

**H11civ: Environmental friendliness mediates the relationship between low carbon production process and LCP**

**H11di: Cost reduction mediates the relationship between low carbon distribution and LCP**

**H11dii: Flexibility mediates the relationship between low carbon distribution and LCP**

**H11diii: Responsiveness mediates the relationship between low carbon distribution and LCP**

**H11div: Environmental friendliness mediates the relationship between low carbon distribution and LCP**

**H11ei: Cost reduction mediates the relationship between low carbon logistics and LCP**

**H11eii: Flexibility mediates the relationship between low carbon logistics and LCP**

**H11eiii: Responsiveness mediates the relationship between low carbon logistics and LCP**

**H11eiv: Environmental friendliness mediates the relationship between low carbon logistics and LCP**

## 2.12 Chapter Summary

In this chapter, the status of low carbon reduction in manufacturing industry worldwide and in Malaysia is discussed. Followed by the introduction of low carbon supply chain consisting of overview of the current low carbon supply chain practices in the world and in Malaysia are presented. In addition, the definition is discussed and the determinants for low carbon supply chain practices that leads to adoption of low carbon supply chain practices are shown in respective order. After the determinants, this chapter presents the low carbon practices that makes up low carbon supply chain practices. Then, the practices lead to firm achieving performances such as green supply chain operational performance and environmental performance. The justification as to why operational performance leads to environmental performance is also presented before revealing the definition and measurement of environmental performance that is low carbon performance. Subsequently, the justifications of how researcher conceptualize the relationship between determinants and low carbon supply chain practices towards achieving operational and environmental performances are shown and supported by Institutional theory. Also, the process on how researcher develop theoretical framework and develop hypotheses are presented in this chapter.

# CHAPTER 3

# METHODOLOGY

## 3.1 Introduction

This study follows a scientific method, which involved a proper business research approach. In this chapter, data gathering process will be presented to ensure reliable findings, which will follow in the next chapter. This study's use of explanatory study aims at explaining research problem and its scope, developing theoretical framework and developing hypothesis for further understanding. Thus, this chapter explains the methodology of how this study will treat and analyse the data based on the scientific research method and theoretical framework that has been developed. This chapter begins with the explanation of research paradigms followed by research design, which contains information such as population, unit of analysis, sample size and sampling method and designing survey instrument. Next, details of measurement for variables and constructs will be presented. Following this, data collection and preliminary test sections will be discussed before revealing statistical data analysis section and chapter summary.

## 3.2 Research Paradigms

The concept of paradigm was introduced by Thomas Kuhn in the early 1960s, which refers to people's value judgements, norms, standards, frames of reference, perspectives, ideologies, myths, theories and approved procedures (Gummesson, 2000). This procedure refers to the method of thinking or research philosophy. Knowledge philosophies have acknowledged several paradigms with regard to research philosophy. In the study of social science, there are two school of thoughts. The first discipline believe that reality is constructed by each person, which is constructivist view while the second discipline believe that reality is external and waiting to be discovered, which is positivist view (Gray, 2004). This study follows the Positivist school of thought. Positivist assumes that generalization can be achieved through accumulation of facts by following a scientific method (Gray, 2004). In addition, positivist searches for causal relationship that assumes natural and social worlds are object that can be measured based on logic and mathematics (Burgess et al., 2006). On the other hand, phenomenalism, post-modernism and interpretivism are opposite of positivist where those paradigms believes there is no causal relationship between subjects and objects but the answer is based on the interpretation of subjects (Gray, 2004). These paradigms are called constructivist paradigm. Table 3.1 summarizes the differences between positivist and constructivist point of view. Positivism is known to be a quantitative research method while constructivist is known to be a qualitative research method. This study proposed a theoretical framework to investigate relationship between causal and objects. Therefore, this study follows the positivist paradigm. This chapter will only discuss and present positivist paradigm as this research method is adopted by this study.

Table 3.1 Features of the quantitative and qualitative paradigm

| | **Quantitative (Positivist) Paradigm** | **Qualitative (Constructivist) Paradigm** |
|---|---|---|
| Features | Applies scientific principles | Applies understanding principles |
| | Uses prediction | Uses exploration |
| | Values objectivity | Values inter-subjectivity |
| | Aims to produce quantitative data | Aims to produce qualitative data |
| | Uses large statistical samples | Uses small theoretical samples |
| | Concerned with hypothesis testing | Concerned with generating theories |
| | Data is highly specific and precise | Data is rich and descriptive |
| | The location is artificial | The location is natural |
| | Reliability is high | Reliability is low |
| | Validity is low | Validity is high |
| | Can claim generalization from sample to population | Can claim transferability from context to similar context |

Source: Hussey & Hussey (1997)

Table 3.1 shows that this study is aligned with positivist paradigm. In this regard, this study will apply scientific principles to investigate the research. The research questions in this study will be valued through prediction and objectivity. In this study, the prediction is based on causal relationship between variables while objectivity drives this study to investigate research questions based on realistic measurement. Through measuring all studied variables, this study aims to produce empirical data that will require statistical analysis. The output of this study is more reliable because of large samples involved compared to qualitative study. In addition, the output of this study can also claim generalizability as sample is taken from population.

### 3.2.1 Justification of Paradigm

This research applied the positivist ontology (nature of reality) because many renowned scholars in the fields of supply chain and operations management and environmental management conducted their studies by applying quantitative methodology and empirical epistemology (justified belief) (Ageron et al., 2012; Böttcher & Müller, 2015; Dubey & Ali, 2015; Lee et al., 2012; Tachizawa et al., 2015; Zailani et al., 2013; Zhu & Geng, 2013; Zhu et al., 2013). Since there is already a significant amount of studies covering the determinants, practices and theories to support the work undertaken in this study, quantitative method is chosen for this study.

Moreover, the second justification for applying positivist paradigm is in accordance with Remenyi, Williams, Money and Swartz (1998) suggestion that a methodological framework could be derived from a review of relevant literature which provide a researcher with a clear expectation of how a particular phenomenon is likely to behave. In the literature, there are studies on LCSC practices, performance outcomes such as GSCOP and LCP as well determinants of LCSC practices but lacking in framework that defines LCSC practices. Thus, this study has clarified the phenomenon based on the review of literature in the field of supply chain and operations management regarding carbon emissions. For example, this study understands that internal pressure such as top management and green technology as well as external pressure such as governmental regulations, customer and environmental NGOs will drive manufacturing firm to adopt LCSC practices. Manufacturing firms reducing carbon emissions in procurement, product development, production process, distribution and logistics will enable firms to achieve operational excellence and save the environment from pollution. For example, LCSC practices will help firms to reduce cost, achieve flexibility and responsiveness as well as less energy and carbon in the operations. Furthermore, manufacturing firm is able to achieve environmental performance by reducing carbon emissions.

The third justification for adopting positivist approach is that scientific approach as discussed earlier allows this study to test hypotheses and rely on objective measures to support the findings of this study (Wicks & Freeman, 1998). The purpose of investigating causal relationship between variables is to determine which determinants, LCSC practices are acceptable for manufacturing firm and which hypothesis relationship is significant. The significant relationship will provide an understanding of which determinants and

LCSC practices is more important for manufacturing firms to achieve operational performance and environmental performance.

The fourth justification is that the advantage of scientific method means the findings or data from this study can be replicated in future studies for verification purposes. In this case, it is important for this study to replicate and expand the knowledge of LCSC as this study is considered an early attempt in the Malaysian context.

The fifth reason to employ positivist paradigm is due to gaps in the literature pointing towards more empirical studies to be conducted and the target audience such as scholars, practitioners and policymakers would find this study useful. Quantitative study requires large sample size and statistical analysis. Therefore, this study's findings can be generalized to the population and statistical results would prove useful for further studies and policies enactment.

Based on the understanding of differences between quantitative and qualitative methods as shown in Table 3.2 and justifications why this study adopts the positivist paradigm, the presentation of this study has to follow guidelines of quantitative methodology so that it is in accordance with scientific method of positivist paradigm. The assumptions and differences between qualitative and quantitative methodologies are taken from Creswell (1994) as shown in Table 3.2.

Table 3.2 Guidelines of the quantitative and qualitative methodologies

| Assumption | Question | Quantitative | Qualitative |
|---|---|---|---|
| Ontological | What is the nature of reality? | Reality is objective and singular, apart from researcher | Reality is subjective and multiple as seen by participants in a study |
| Epistemological | What is the relationship of the researcher to that researched? | Researcher is independent from that being researched | Researcher interacts with that being researched |
| Axiological | What is the role of values? | Unbiased | Biased |
| Rhetorical | What is the language of research? | Formal. Based on set definitions. Impersonal voice and use of accepted quantitative words | Informal. Evolving decisions. Personal voice and accepted qualitative words |
| Methodological | What is the process of research? | Deductive process. Cause and effect. Static design-categories isolated before study. Context-free. Generalizations leading to prediction, explanation and understanding. Accurate and reliable through validity and reliability | Inductive process. Mutual simultaneous shaping of factors. Emerging design-categories identified during research process. Contest-bound. Patterns, theories developed for understanding. Accurate and reliable through verification |

Adopted from: Creswell (1994)

The first assumption that need to be followed in order to stay true to positivist paradigm is the ontological assumption. This study views reality as the objective and apart from the researcher. As there are many empirical studies on low carbon practices and LCSC practices and operations management fields by other scholars, it is safe to assume that determinants of LCSC practices, LCSC practices, operational outcome and environmental outcome can be measured objectively.

The second assumption, which is epistemology is concerned with the knowledge being valid knowledge (Collis & Hussey, 2013). Phenomena that can be observed and measured means it can be validated whether it is valid (sound logic). This study will be measured using selected psychometric constructs adopted and adapted from previous studies in the same field that has been proven to be valid.

The third assumption is axiological assumption that is concerned with values. After careful consideration and conducting content analysis of the literature, even though objects identified in this study were confirmed from the literature review, the researcher's interest in the outcomes and relationship are unbiased because all of these objects as proposed in the theoretical framework are present before researcher knew and undertook this study.

The fourth assumption is rhetorical assumption, which is the language used for reporting of this study. This study assumes that all main constructs are well defined and are based on accepted definitions from the literature. Furthermore, the methodological approach for this study is one of quantitative method that has been following the theoretical framework proposed in Chapter Two. Testing the hypotheses will follow the theoretical framework that has been established.

## 3.3 Research Process

This study applies scientific principles in designing this research. One of the scientific principles is methodology, which is by using the deductive method (quantitative). In Figure 3.1, the figure shows the research process to develop LCSC framework. Based on LCSC studies in the literature, this study then applies scientific principles to carry out the investigation. This study started by identifying the research topic that would be to the researcher's interest and suitable for management research contributions. The next step is to do preliminary data gathering by going through journal articles in the literature and develop content analysis to understand and gather information regarding the research topic based on the collected literature. After that, theoretical framework based on the literature review that has been analysed was presented with hypotheses development. Then, the research methodology for this study will be discussed specifically on how to conduct this study and how data is to be collected. Next, the data collection, data analysis will follow before this study could refine the existing model or discuss the knowledge gained and compare it with findings by other scholars available in the literature. Lastly, the conclusion and implications of the study will further contribute to the literature.

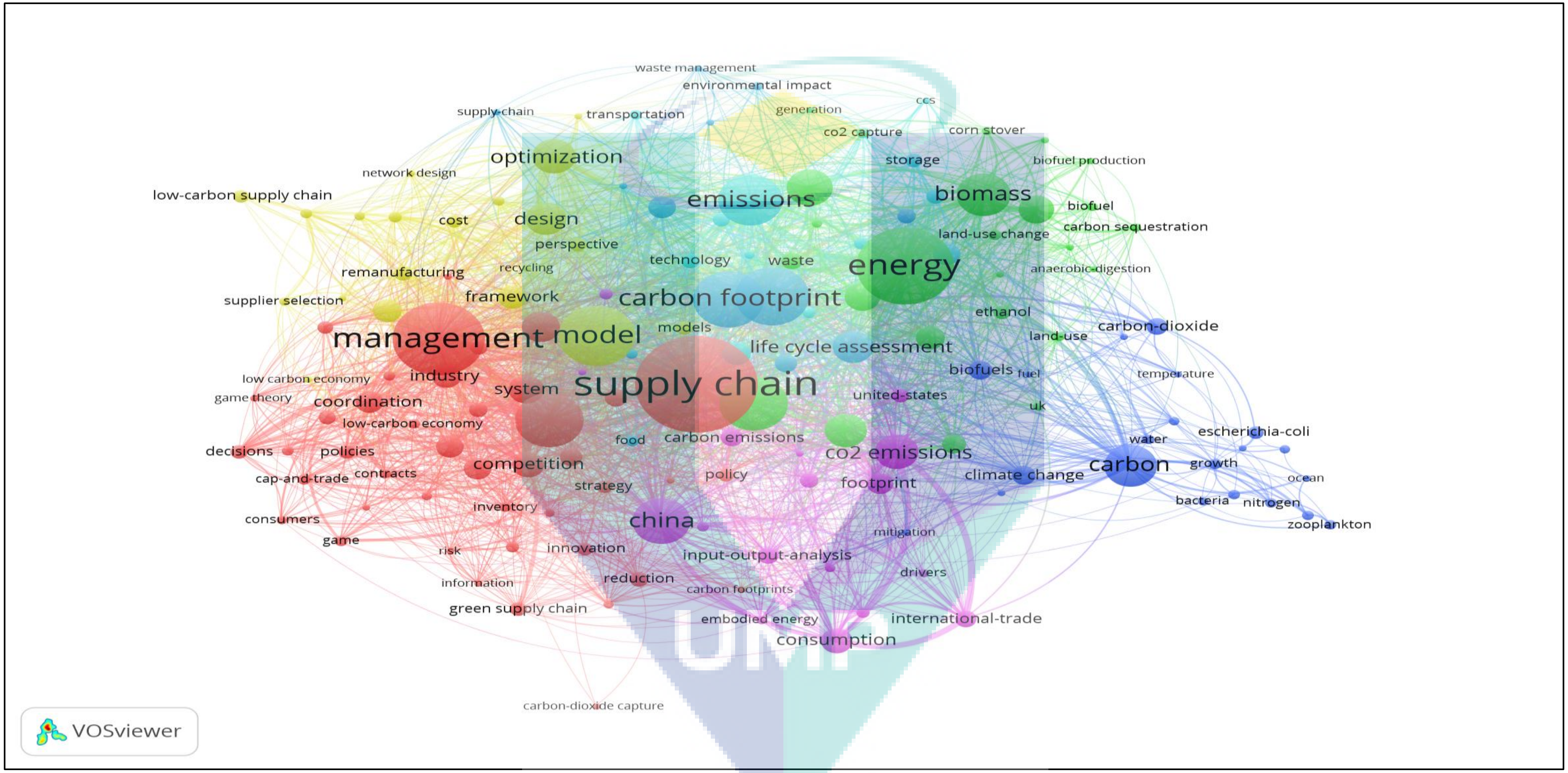


Figure 3.1 Research process framework

Source: Shaharudin et al. (2019)

### 3.4 Research Design

This section discusses how research questions are answered. This study follows the research process that is derived from positivist paradigm. In order for this study to be in line with positivist paradigm (Saunders, Lewis, & Thornhill, 2009), research design has to consists of:

32. Justification of selected research problem
33. Literature review prior to the research problem
34. Hypotheses development that describes the research problem
35. Research design underlining what data are needed to test hypotheses
36. Analysing hypotheses by describing methods to identify true or false hypotheses

This study has stated its research questions and objectives of research in Chapter 1 while literature review and hypotheses development with regard to research problem were discussed in Chapter 2. In this chapter, research design and the method to analyse hypotheses will be discussed. Based on the research design, this study selected research problem based on current literature review no less than five years on LCP in the supply chain and manufacturing industry. After selecting articles that are useful to the investigation of LCP, this study tries to identify the literature gaps, future research and most importantly current research trend in the literature. After understanding of the research needed to be carry out, this study performs literature review relating to the research problem.

This study has undertaken comprehensive systematic literature review on determinants of LCSC, LCSC practices, GSCOP, LCP and institutional theory. This is to ensure that the literature is able to contribute to the research problem. In addition, only journal articles from Web of Science and Scopus databases were selected as main articles to support the knowledge of determinants of LCSC, LCSC practices, GSCOP, LCP and institutional theory. On the other hand, there are also articles from other reputable databases and reference books being used to help solve the research problem.

After performing systematic literature review and establishing understanding of the variables involve in this study, hypotheses were then developed to describe the research problem. The hypotheses were also in line with institutional theory as to ensure that the relationships are supported by the theory. After developing hypotheses, this study has underlined the data collection method to test the hypotheses. More in-depth research design pertaining to data collection can be found in the next sub-section. After data has been collected, the data will be analysed based on the developed hypotheses. This will allow this study to confirm or reject the hypotheses and contribute to the literature of LCP.

### 3.4.1 Population

Sekaran and Bougie (2010) defined population as the entire group of people, events or topics of interest that the researcher wishes to investigate while population also can be said as full set of cases in which a sample is taken (Saunders et al., 2009). Cases in the definition can be described as persons or objects. In this study, the cases refer to firms in the manufacturing industry in Malaysia. The full set of cases (firms in the population) is taken from the directory of the Federation of Malaysian Manufacturers (FMM), which represents the entire member of population (sample frame). Sample frame can be defined as the listing of all units in the working population from which the sample will be selected (Jupp, 2001). In this regard, the sample frame for this study are firms practicing LCSC in the manufacturing industry.

This directory is useful because the interest of this study is LCSC practices in manufacturing firms. In the literature, other scholars investigating supply chain and LCSC used FMM directory as the source of their population (Chin et al., 2015; Eltayeb & Zailani, 2009; ElTayeb et al., 2010; Federation of Malaysian Manufacturing, 2017; Fernando & Saththasivam, 2017; Hsu et al., 2013; Saidon, 2012; Zailani et al., 2013). In the FMM Directory 2017 directory there are 2463 manufacturing firms registered in Malaysia. This number helps to determine total number of sample size needed to generalize and to represent the overall member of the chosen population. Out of 2463 manufacturing firms, 2252 firms have green certification or low carbon reduction certification as shown in FMM Directory 2017.

In addition, there is another directory that can be used such as directory from Malaysia External Trade Development Corporation (MATRADE). However, this study will use only FMM directory because MATRADE directory has more than 20 categories of industry. The problem with a directory that lists according to categories rather than individual firms is that it might be duplicated in other categories and Leslie (1995) argued that category directory should be avoided in order to have good sample frame. In addition, this study requires information such as firm's name, contact number and business type that are important. Using the FMM directory is easier because it gives directory numbering so that researcher do not need to manually count, and it is easier to plan for data collection purposes. Additionally, the information of CEO and quality standards that the directory presented help to reach respondents easier especially the quality standards because it enables this study to identify firms from the total population that possess ISO standards so that they can be the target respondents of this study. As shown in Table 3.3, information provided by FMM directory and MATRADE directory are as follows:

Table 3.3 Comparison between FMM and MATRADE directories

| Information | FMM Directory | MATRADE Directory |
|---|---|---|
| Company Name | ✓ | ✓ |
| Registration Number | ✓ | ✓ |
| Directory Numbering | ✓ | - |
| Year of Incorporation | ✓ | ✓ |
| Website | ✓ | ✓ |
| Office Address | ✓ | ✓ |
| Factory Address | ✓ | ✓ |
| Telephone Number | ✓ | ✓ |
| Fax Number | ✓ | ✓ |
| Email Address | ✓ | ✓ |
| Chief Executive Name | ✓ | - |
| Business Enquiries Name | ✓ | ✓ |
| Number of Employees | ✓ | - |
| Product Manufactured | ✓ | ✓ |
| Additional Product Information | ✓ | - |
| Standards Information | ✓ | - |

This study will use the FMM directory based on justifications and considerations of a good sample frame. According to Saunders et al. (2009), a good sample frame consists of:

37. listing individual firms in manufacturing industry
38. updated information of firms every year
39. used by other scholars in the same field or topic of interest

### 3.4.2 Unit of Analysis

This study will investigate LCSC practices in manufacturing firms. Therefore, the unit of analysis is manufacturing firm. Manufacturing firm is chosen as unit of analysis because carbon emissions from the manufacturing industry is one of the highest contributors to air pollution. Thus, this study's unit of analysis are manufacturing firms available in the FMM directory. The person of interest from manufacturing firm that can answer the questionnaire are described in Table 3.4. The reason for this study to choose top management as person of interest is because these people have knowledge on LCSC practices at their respective firms.

Table 3.4 Unit of analysis

| Type | Source |
|---|---|
| Chief Executive Office<br>Environment Health Safety Officer<br>Energy Officer<br>Chief Operating Officer<br>Managing Director<br>General Manager<br>Operation Manager<br>Supply Chain Manager<br>Logistics Manager<br>R&D Director/Manager | (Fernando & Wah, 2017; Rao & Holt, 2005; Zailani et al., 2013) |

### 3.4.3 Sample Size and Sampling Method

According to Saunders et al. (2009), to determine sample size and sampling method, it is necessary to follow four stages:

40. Identify sampling frame based on research questions or objectives
41. Decide on suitable sample size
42. Select appropriate sampling technique
43. Check that the sample is representative of the population

For the first stage, in determining sample frame, this study has chosen manufacturing firms practicing LCSC based on FMM directory that has 2463 manufacturing firms as total number of populations. The second stage that needed attention is to decide the suitable sample size for this study to ensure that the sample size's answers to the research questions or objectives can represent the targeted population. The reason any study needs a sample size is because researcher is not undertaking a census study. Thus, it is a compromise between the accuracy of findings and the amount of researcher's investment. The accuracy of findings is closely related to data confidence level. Confidence level here refers to the level of certainty that the data collected will be able to represent the total population (Saunders et al., 2009). Since probability and confidence level requires statistical analysis and calculation, statisticians have recommended a larger sample size. Also, it was found that the larger the sample size the lesser the chances of getting sampling error (Isaac & Michael, 1995). This is because if the sample size is small, the chances to draw different cases from total cases is highly unlikely. To make matters simpler for researcher, statisticians have employed a rule of thumb for sample size distribution.

#### 3.4.3.1 Determining Sample Size

According to Cohen (1992) for statistical power analysis, sample size (n), significance criterion (a), effect size (ES) and statistical power are related to each other and that each is a function of the other three. This is the formula to determine the sample size required. Due to the fact that sample size, significance criterion, effect size and power are inter-related, statisticians have recommended a large sample size. This is because having large sample size will enable this study to meet the requirement of power, significance criterion and effect size. This criterion is important for any investigation as statistical study relevancy depends on this formula. Knowing that the requirement to perform statistical analysis is to meet these requirements, this study is able to determine the minimum sample size.

In order to find the best solution for sample size and meet the requirement for statistical analysis as stated by Cohen (1992), this study uses statistical software G-Power analysis (Faul et a., 2007) to find the number of samples required to obtain certain power. G-Power analysis is recommended by Hair, Hult, Ringle and Sarstedt (2014). For example, with predictors of five, sample size of 138 is sufficient to yield power of 0.95. On the other hand, using G-Power software to determine power for given sample size of 357 and 331 cases yielded 0.9999927 for five predictors. The example given is for 0.95 value but Cohen (1992) pointed that power of 0.80 is proposed for general use and should not be lower than that because it will incur too great a risk of Type II error of statistical test. Type II error is an error of retaining false null hypothesis while incorrectly rejecting a null hypothesis is referring to Type I error. Thus, using .80 power, this study will only need a minimum of 92 sample size. In this study, G-Power software will be used in determining the sample size as the software is able to calculate how many samples are required for given power (beta value), effect size (predictive accuracy) and standard error (confidence level). Therefore, using this software to calculate sample size will fulfil all requirement to perform quantitative investigation. In that regard, sample size of 98 to 138 are minimum samples to meet the statistical requirements. Upon completion of data collection, there are 143 samples able to be collected for this study.

#### 3.4.3.2 Sampling Method

Good sample sizes to represent the entire population can be done through proper sampling method. The choice of suitable sampling method depends on research questions or objectives whether the research need face-to-face communication with respondents, geographical area of targeted population and nature of sampling frame (Saunders et al., 2009). This study's research questions or objectives need to be addressed using statistical inferences and does not require face-to-face contact with respondents. Next, this study uses sampling frame that has strata (group) not cluster. The difference between strata and cluster is that the former is individual cases that has been grouped while cluster is individual cases that has been put into several categories. In that sense, choosing the FMM directory in this study shows that the chosen sampling frame is strata-based. Thus, the suitable sampling method for this study is to use stratified random sampling.

*Stratified Random Sampling*

Stratified random sampling is a modification of random sampling in which the population is divided into relevant strata (group) based on one or a number of similar attributes (homogeneous) (Saunders et al., 2009) and non-overlapping subgroups (Bhattacherjee, 2012). Group in this study refers to Table 3.4 that can consist of chief executive officer, managing director, environmental & health manager, senior manager, energy manager and R&D director/manager. The first step in performing stratified random sampling is to identify and divided the population into relevant groups that are mutually exclusive. For example, Chief Executive Officer should be different from Chief Operating Officer or Managing Director in terms of its attributes. The second step is to randomly select firms based on top management groups. In this study, disproportionate sampling is used as there is no numbers available for each group except for Chief Operating Officer and Managing Director and the total population is huge. According to Sekaran and Bougie (2016), when the sample is too small or huge, researcher can adopt disproportionate stratified random sampling. In addition, this study has used FFM

Directory 2017 altogether with firm's website information to complete the missing information regarding firms. After performing the first step and second step, this study will be able to achieve better representation from each segment of the population and has rich information from different group.

### 3.5 Designing Survey Instrument

In this study, the measurement or questions were adopted from previous studies in the field of supply chain. The adoption of measurement is to ensure validity and reliability. This study adopted measurements that have been tested or studies that provided cronbach alpha or composite reliability. In the absence of statistical justifications, measurements are adopted from published reputable journal articles to ensure validity and reliability.

After adopting questions from the literature, this study adapts those questions in the context of Malaysian manufacturing industry. As a result, this study will be able to reduce the risk of deceptive and inaccurate data collection because of poor design of survey instrument when developed from the beginning. Furthermore, Dillman (2000) found that respondents are not inclined to answer questionnaire that has long questions, mystified questions and poorly design questions. Therefore, survey instrument needs to be carefully designed and variables need to be precisely defined before sending it to respondents to answer. The last step taken before sending survey to respondents is to ensure that those questions are understandable. Thus, before sending the survey to respondents, this study sought feedback from experts with regard to the contents, language and format of the questionnaire. According to Sekaran (2013) expert opinion or face validity is also part of preliminary test analysis. Therefore, this study has taken precautionary steps such as adopting measurements from valid and reliable sources, adapting to Malaysian manufacturing context and performing preliminary test.

### 3.6 Data Collection

Before data can be collected, self-administered questionnaire requires this study to precisely define the questions. This is because unlike interviewer-based questionnaires, the self-administered questionnaires' interaction with respondents is lesser and it has fixed time or time series. Furthermore, it needs to be administered to a sample that can represent the entire population. Thus, if the survey questionnaire is poorly designed, it will affect the findings and not able to represent the population. As a result, this study would need to recollect data or choose another time series and compare the findings, which is costly in terms of cost, time and willingness of respondents to answer the questionnaire for the second time is unlikely (Saunders et al., 2009). Furthermore, to ensure that the right respondent answering the questionnaire, this study need to verify targeted respondent's name, position and contact number by validating the information given in the FMM Directory 2017 and firm's website. For missing contact, this study needs to contact the person in charge given by the directory to get the email or contact number of the targeted respondent.

In order to avoid this issue, reviewing literature and discussion with relevant parties such as supervisor is necessary. In addition, this study should precisely define the independent variable and dependent variable as closely to the literature as possible. As the relationship between variables will be tested using statistical analysis, measurement will need to be clearly presented. Both statistical analysis and measurement of variables will be detailed at the end of this chapter.

### 3.6.1 Data Collection Method

As mentioned previously, the data will be collected through self-administered questionnaire in the form of internet-based. This is because internet-based questionnaire gives better response rate and are widely used in the literature (Bernard, 2006; Clemens & Douglas, 2006; Eltayeb & Zailani, 2009; ElTayeb et al., 2010; Eltayeb et al., 2009; Fernando et al., 2016a; Gattiker & Carter, 2010; Simon & Albert, 2015; Vachon & Klassen, 2008; von der Gracht & Darkow, 2016; Yu et al., 2014; Zailani et al., 2013; Zailani et al., 2015). In Malaysia, internet-based questionnaire is also recommended because Malaysia has good internet infrastructure and firms provide active emails and website addresses. In this study, data will be collected together through structured questionnaires based on variables that are being studied.

In order to construct the measurement items, variables identified in this study need to be clear and in accordance with the findings in the literature. Thus, after careful reviewing the literature, the relationship that exist between variables are presented. This is important because the relationship between variables will be tested through statistical analysis and this variables information or relationship will be collected through questionnaire that will be answered by respondents.

#### 3.6.1.1 Designing Individual Questions

This study adopts and adapts questionnaires in the literature because it is more reliable and more efficient that developing questionnaires from scratch. Adopting questions from established studies can be defined as taking measurement items from the literature without making any changes while adaption of measurement items results in taking measurement items from the literature and change it to suit the context of the study.

In the literature, there are many relevant questionnaires that can be used by this study. The choice of questionnaires adopted from literature will be presented at the measurement section of this chapter. Those questions taken from literature review then will be designed according to type that is suitable for this study. For example, there are open-ended questions, closed-ended (Dillman, 2000) questions and force-choice questions (DeVaus, 2002). This study design the survey with close-ended questions because it is quicker to answer and easier for respondents (Saunders et al., 2009). Specifically, the used of close-ended questions are discussed in detail in measurement variables section where each section inside the questionnaire are mapped and detailed to which type of scale was chosen.

#### 3.6.1.2 Question Coding

After selecting type of close-ended questions for the survey questionnaires, this study needs to code the questions because computer analysis only works with coding. Close-ended questions is easier to code because respondents choose answer based on pre-determined items. For example, in rating questions, Likert scale have 1 for very low and 5 for very high. If respondents rate any number from 1 to 5, it is considering as code that computer can analyse. In addition, using internet-based questionnaires to collect data will make it even easier because the system will pre-coding the questions. For example, given any type of close-ended questions, Google Form will automatically pre-code the answer while open-ended questions will not be pre-code. This study will use Likert scale for measuring variables and there are no negative questions. The open-ended questions will be manually coded and check before running statistical analysis.

#### 3.6.1.3 First Question Selection

Filter question can be used to ensure that the data findings can represent the population. A study on LCSC include filter question such as whether respondent has quality standards such as energy management standard (ISO 50001) or environmental management (ISO 14000). If the respondent the represent the firm does not obtained quality standards, respondent is asked to provide a reason. Having a good first question will entice respondent to continue answering the survey as the first question is direct, easy to understand and given respondent a sense that overall questions are uncomplicated.

#### 3.6.1.4 Raising Response Rate

In any research issue pertaining to reasonable response rate is always been a challenge for any study. For internet-based questionnaires, it is important to check regularly the questionnaires in the system because it might not be working during system maintenance or system down. The layout of the questionnaires also might be different from the point of view of researcher and respondents because every respondent will view the questionnaires from different computers that have different monitor sizes, capabilities and operating systems. Thus, it is better for this study to design the internet-based questionnaire with simple yet interactive and interesting layouts. This is the first step to increase the response rate from respondents.

The second consideration that researcher can do is to adhere to general operating guidelines or netiquette (Hewson, Yule, Laurent, & Vogel, 2003). The guidelines include ensuring emails are relevant to respondents so that it will not end up in junk email or considered as spam. In addition, sending the email to over 20 groups are unacceptable because respondents might belong to more than one group and respondents might receive multiple emails from researcher if the email is sent to over 20 groups. This is the reason why choosing the best directory that reduce the duplicates is essential to any research. More on this matter will be discussed in detail in survey distribution section.

The third practice that this study undertake is to embed the hyperlink or link of internet survey with cover letter so that respondents do not have to download the survey file. Furthermore, respondents might think that the email contains viruses or spam.

The fourth preparation for this study to achieve good response rate is to send the internet-based questionnaires on less peak days such as Friday or during public holidays (Saunders et al., 2009). This study also will only send emails or reminders on Tuesday and Wednesday because Monday and Friday will not be a good time to ask respondents to fill the questionnaires. The time of questionnaires will be sent is around 0900 or 1000 hour after respondents have arrives and checked their work email.

The fifth practice to increase response rate can only be done after sending emails or internet-based questionnaires to respondents. Follow up one week after the email is out is recommended (Saunders et al., 2009). The reminder should also include a copy of questionnaire or hyperlink of the questionnaire. The next step after second reminder is to send a last reminder a week after the second reminder but with a new cover letter stressing the importance of answering this questionnaire (Saunders et al., 2009). Other than that, token of appreciation or internet-based coupon can increase the response rate (Dillman, 2000) can be considered.

#### 3.6.1.5 Survey Length

The questionnaire has 79 questions divided into six sections. It is estimated that the time taken for respondent to answer the questionnaire is around 15 minutes. The questionnaire consists of eleven questions on firm profile in section A and 20 questions on determinants of LCSC practices in section B. In section C, there are 22 questions regarding LCSC practices. In addition, there are 18 questions on GSCOP in section D and three questions on LCP in section E. Lastly in section F, there are five questions pertaining to profile of respondent.

#### 3.6.1.6 Cover Letter

Cover letter is important to increase response rate (Dillman, 2000). This self-administered questionnaire is accompanied by cover letter in two forms. First the cover letter is embedded in email to respondents and second cover letter will be viewable when respondents open the link to internet-based survey. This cover letter follow the guideline by Dillman (2000) to include banner or title of the questionnaire's topic and graphical logo to add interest to respondents. In addition, the logo and name of Universiti Malaysia Pahang (UMP) and Faculty of Industrial Management (FIM) will be included as both represent reputable brand name to the industry.

#### 3.6.1.7 Survey Distribution

As mentioned earlier, this study will use internet-based questionnaire to collect data. Google Drive offers a platform for this study to create Google Form to develop and design questionnaire. Thus, after identifying the measurement variables that this study would use, close-ended questions are used to capture information from respondents. The questions then will be transferred into Google Form and hyperlink of the questionnaire will be automatically created for distribution. Then, the list of information such as name, email address and firm's name obtained from FMM directory will be used to distribute to the respondents. In order to ensure that the right person with knowledge in regard to LCSC answer the survey, this study will double check the name and email address from FMM directory with firm's website. If there is an updated information or more qualified person to answer the survey, the email will be sent to that particular person.

Since there are 2463 manufacturing firms identified in FMM directory, this study needs to send survey link through email to all firm. As the netiquette of distributing internet-based questionnaire, it is unacceptable to blast emails to all respondents at once. Even Gmail allowed 450 emails to be sent at once, it might be considered as spam mail. Thus, the correct way to do is to personally email each respondent with personal salutation, name and firm's name. Since there are 2463 firms available in FMM directory this method is tedious. That is why, in order to do so, researcher has to send bulk email through method called "merge emails". Using this method, the steps that this study has to take is as followed:

44. Obtain list of contact information from FMM directory and transfer to Microsoft Excel
45. Make sure each contact has firm's name, address, email address and contact person name
46. Write a cover letter embed inside email and code it accordingly
47. Import the list of contacts from Microsoft Excel to Microsoft Outlook
48. Go to settings and turn on offline mode

After sending the emails, respondents will be required to answer the questionnaire by clicking on the hyperlink provided and once completed, respondents are required to click "submit" button.

## 3.7 Preliminary Test

Initially before the questionnaire is finalized and before transfer to Google Form, there is a need to conduct a preliminary test. The purpose of preliminary test is to refine the questionnaires, check the appropriateness and to improve long and confusing questions (Fernando & Wah, 2017) so that respondents will have no problem answering the questionnaire. Therefore, preliminary test was conducted by sending the questionnaire to academicians and practitioners to check whether the questionnaire is understandable to the context of Malaysian respondents. Feedback for improvements from experts as shown in Table 3.5 were amended before finalising the questionnaire.

Table 3.5 Preliminary test experts

| Designation | Cluster / Major |
|---|---|
| Academician | Supply Chain |
| Academician | Sustainable Development |
| Academician | Audit |
| Academician | English |
| Practitioner | Supply Chain International Certificate |
| Practitioner | Supply Chain International Certificate |
| Practitioner | Supply Chain International Certificate |
| Practitioner | Supply Chain |
| Practitioner | Environmental Health Safety |
| Practitioner | CEO |

Based on the preliminary test, practitioners have suggested to redefine LCSC with the perspective of firm. According to practitioners, if firm is to answer the questionnaire with definition of LCSC from the literature, most firm will not able to answer. This is because for firm, if the question is "do you practice low carbon supply chain?", most firm that are not directly reduce carbon emissions will not be able to answer as that question is the first or filter question. Thus, this study has offered a detail version of LCSC definition in the questionnaire. The other comment from preliminary test is that whether the LCP measurement is in quantity of carbon emissions or perception of respondent. Therefore, this study has removed description of "per output" so that respondent will answer based on their perceptive knowledge.

## 3.8 Pilot Test

Preliminary test was conducted by getting feedbacks from experts and improving survey questions. On the other hand, pilot test was conducted to evaluate the performance of survey through actual study of targeted population. In the literature, there are several scholars recommending number of samples for pilot test. There are three recommendations for pilot test sample requirement:

- 10 to 30 samples for pilot test (Hill, 1998)
- 10 percent of overall sample size for pilot test (Isaac & Michael, 1995)
- 20 samples for pilot test (Boyd, Westfall, & Stasch, 1977)

This study conducted pilot test with 20 samples requirement as this is the minimum requirement to perform statistical analysis. 20 sets of questionnaires were sent to manufacturing firms to ensure that the survey questions were well understood and reliable. To do so, this study performed reliability test based on 20 questionnaires received from manufacturing firms. The measurement used to evaluate reliability of the questions is Cronbach Alpha (CA). It is used to measure intercorrelations of variables in used and provide low requirement of reliability values. The acceptable value for CA is 0.6 to ensure that research variables are reliable (Flynn, Sakakibara, Schroeder, Bates, & Flynn, 1990; Nunnally, 1994). Table 3.6 shows Cronbach alpha values for this study met the requirement and therefore the instrument used to record feedback from respondent was reliable and well understood by respondents.

Table 3.6 Pilot test

| Variable | Cronbach's Alpha |
|---|---|
| Government Regulation | 0.87 |
| Customer Pressure | 0.95 |
| Environmental NGOs | 0.92 |
| Green Technology | 0.83 |
| Top Management Support | 0.77 |
| Low Carbon Procurement | 0.96 |
| Low Carbon Product | 0.93 |
| Low Carbon Production Process | 0.93 |
| Low Carbon Distribution | 0.89 |
| Low Carbon Logistics | 0.91 |
| Cost Reduction | 0.87 |
| Responsiveness | 0.88 |
| Flexibility | 0.92 |
| Environmental Friendliness | 0.92 |
| Low Carbon Performance | 0.89 |
| Overall Cronbach Alpha | 0.89 |

As all variable achieve values higher than 0.60, this study will be able to proceed with data collection. Real data collection for final output will not include these 20 surveys used for pilot test.

## 3.9 Statistical Data Analysis

This study proposed the use of IBM SPSS statistical software version 24 for descriptive analysis. For validity constructs, goodness of data and hypothesis testing, Partial Least Square Structural Equation Modelling (PLS-SEM) will be used to compute the data. PLS-SEM is preferred compare to Covariance-Based Structural Equation Modelling (CB-SEM) because this study used existing established theory of institutional in a less developed area of multidisciplinary research. Therefore, the primary objective of the study is to predict and explain the LCSC model. As shown in Table 3.7, PLS-SEM treats each indicator having contributed equally to forming a composite while CB-SEM uses common score for set of indicators (Henseler et al., 2014). Using PLS-SEM for this study will provide rich information on indicators contribution that is useful for LCSC model development. On the other hand, CB-SEM will be able to empirically predict the theoretical model usefulness to real world scenario. However, some scholars argued that the common factors from CB-SEM are not the concern of researchers when developing theoretical model. In addition, if this study uses CB-SEM method for hypothesis testing, with complex model of LCSC it almost always giving inadequate fit (Hair, Hult, Ringle, & Sarstedt, 2017) while PLS-SEM allows this study to develop the model with acceptable fit and contribute to the theory. Moreover, PLS-SEM produces path coefficients that improve $R^2$ and thus provide this study with prediction of LCP of manufacturing firms when practicing LCSC. For CB-SEM, it is unsuitable for prediction of path as it provides high or low score depending on the chosen factor scores (Dijkstra & Henseler, 2015). Additionally, data distribution also plays an important role in determining whether to adopt CB-SEM or PLS-SEM software. For PLS-SEM, it able to handle normal distribution and non-normal distribution data. Most of the time, PLS-SEM is preferred due to its capability of handling non-parametric data distribution and most of the time data collection from survey in social science is not normal distribution. Also, PLS-SEM has more statistical power that will provide the relationship established in research objective as more significant than using CB-SEM software. Scholars also found that in a simulation study between PLS-SEM and CB-SEM findings show that PLS-SEM has better result and when the measurement models have more than four indicators with score of 0.70, there is no difference between the result of using both methods (Reinartz, Haenlein, & Henseler, 2009). From these justifications, the use of PLS-SEM is recommended for this study to perform statistical analysis.

In order to run the analysis, data acquired from survey questionnaire will need to be pre-code. Results of running the analysis will provide this study with descriptive statistics, goodness of data, reliability and correlation between independent variables and dependent variable. For modelling technique, PLS-SEM SmartPLS 3.0 version 3.2.8 software will be used because this study model is complex with mediating variable. Thus, for all of these requirements, PLS-SEM technique is more suitable (Lohmöller & Wold, 1982) and it will be problematic for CB-SEM to fulfil these requirements (Hair et al., 2014; Lohmöller & Wold, 1982). For structural equation modelling, a two-step analysis is generally recommended (Shah & Goldstein, 2006), which is validating the measurement model and testing the proposed hypotheses. The analyses will be performed using SmartPLS 3.0 version 3.2.8 because of its usability (Temme, Kreis, & Hildebrandt, 2010) as shown in Table 3.7.

Table 3.7 Characteristics of PLS-SEM

| | PLS-SEM | CB-SEM |
|---|---|---|
| Research type | theory less-developed | theory well-developed |
| Indicator treatment | Weighted composites of indicators | Common factor between sets of indicators |
| Usefulness | Information on indicators forming construct | Directly measure theoretical concept |
| Hypothesis | Improve fit indices | Require strong fit |
| Prediction Usability | Improve $R^2$ | Unsuitable for prediction |
| Data distribution | Parametric and Non-parametric | Parametric |
| Statistical power | Render more significant relationship | Less significant |

### 3.9.1 Descriptive Analysis

Descriptive analysis is performed to obtain information of the respondents. These respondents are representative or samples from the entire population that this study is investigating. Thus, through descriptive analysis, information regarding profile of firms and profile of respondents who fill the questionnaire will be used to understand the background of the study. In order to understand the respondents, descriptive analysis will provide information in terms of mean, percentage and frequency of the distribution of respondent.

### 3.9.2 Measurement Model Analysis

Measurement Model Analysis is simply the validity and reliability of the survey instruments used in the questionnaire. If the survey instruments are able to capture information as understood, then the instrument is valid. In addition, reliability is also important because even though the instrument is valid, the data should also be reliable and consistent with the findings of previous studies in the literature.

#### 3.9.2.1 Validity

As questionnaire is being used to obtain information from respondents to answer the research questions or objectives, the questionnaire needs to be able to measure what this study intends to measure. In that sense, the questionnaire is actually representing the reality of what is the research investigation. The type of validity is shown in Figure 3.2. At this stage, this study needs to assess the degree of accuracy of the construct. This is called content validity. This can be done through face validity, where it is logical to researcher to assume that the questions asked would be able to achieve the desired answer. Face validity is done when designing the questionnaire and preliminary test.

On the other hand, construct validity, which is the measurement of the construct is called criterion validity. Criterion validity as its name suggest is the checklist for measurement with certain criteria. In short, this study makes predictions based on certain criteria that the result will be in accordance with theory of the construct. Furthermore, once the investigation is being operationalize or questionnaire is being answered by respondents, the validity of the answer is called congruent validity. Under congruent validity, convergent validity and discriminant validity are used to test the model (Sekaran & Bougie, 2010). However, when discussing about the validity of the questionnaire, it is referring to convergent validity, discriminant validity and construct validity.

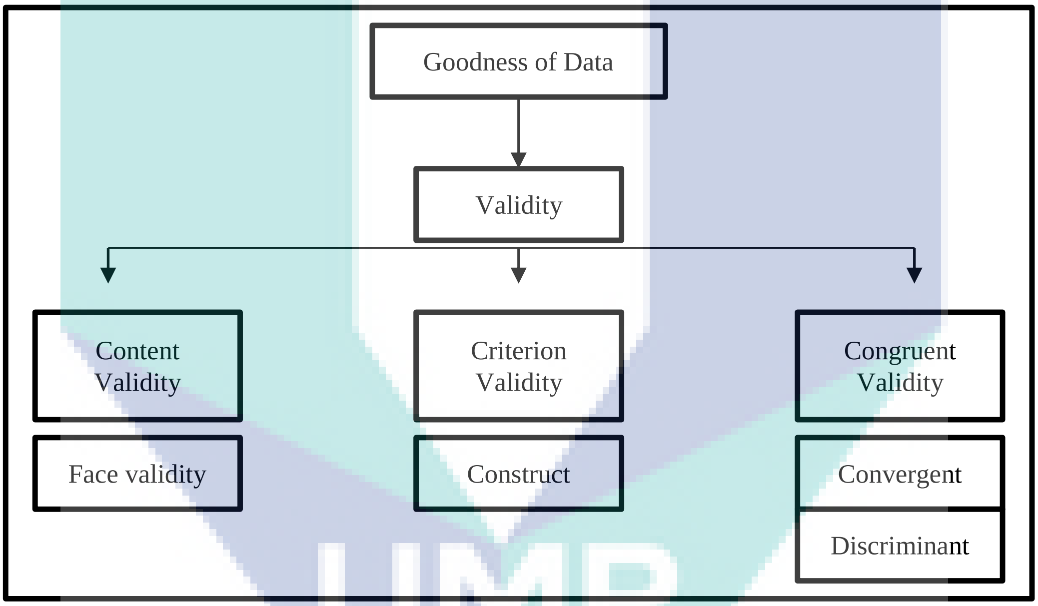


Figure 3.2 Types of validity
Source: Sekaran & Bougie (2010)

*Construct Validity*

Construct validity refers to the extent the measurement questions actually measure the presence of those constructs that are indented to be measured (Saunders et al., 2009). In this sense, questions or items from the literature and theory should be able to measure the construct and should be able to be conceptualized the construct (Hair et al., 2014). In statistics, construct validity refers to items of measurement that measures latent variable. Latent variable is not directly observed but directly measured. In this study, construct validity is the first step taken before designing questionnaire. The construct validity for this study is based from the theory of Institutional theory and justified from previous studies in the literature.

*Convergent Validity*

Convergent validity can be defined as a degree of two measures of constructs are related (Sekaran & Bougie, 2010). In this sense, the convergent validity is to measure whether the constructs that should be related is proven related. Once data is obtained, statistical analysis can be performed. Hair et al. (2014) suggested validity to be measured through several statistical tests to ensure that items (questions) are not problematic:

- Outer loading
- Composite Reliability (CR)
- Average Variance Extracted (AVE)

All items will be assessed on outer loading score of 0.5, 0.6, 0.7 and 0.708. If the outer loading score is 0.4, it is possible to accept if other loadings have high scores and if retaining the indicators will contribute to content validity (Hair et al., 2017). However, in this study, the cut off value is 0.5 for outer loading as this is commonly found in the literature. For CR, the acceptable values are between 0.6 to 0.7 is recommended for exploratory study and 0.7 to 0.9 is satisfactory (Hair et al., 2017). Therefore, in this study, a cut off value of 0.7 is acceptable. In addition, AVE score should be higher than 0.5 (Hair et al., 2017).

*Discriminant Validity*

Discriminant validity can be defined as measures to assess that the constructs that do not have any relationship is proven to be not having any relationship. It is the opposite of convergent validity. In statistical analysis, Hair et al. (2014) and Henseler, Ringle and Sarstedt (2015) proposed that to measure discriminant validity statistical tests should be performed:

- Heterotrait-monotrait ratio of correlations (HTMT)

For HTMT, the stringent criterion is HTMT.85 (Kline, 2015) while the more conservative criterion is HTMT.90 (Gold, Malthora, & Segars, 2001). Thus, if the value is higher than 0.85 or 0.90, there is a problem of discriminant validity. In this study, values lower than 0.90 are required to show there is no discriminant validity.

#### 3.9.2.2 Reliability

Reliability is also another important goodness of data requirements. It is to measure the instruments that this study use to collect data from respondents are constantly measures whatever concept it is investigating (Sekaran & Bougie, 2010) and to check whether the constructs measured are consistent. In statistical analysis, construct reliability can be measured using tests such as:

- Composite Reliability (CR)
- Average Variance Extracted (AVE)

According to Fornell and Larcker (1981), satisfactory values for CR should be 0.7 and above. However, for exploratory study, CR value of 0.6 is acceptable (Ramayah, Hwa, Chuah, Ting, & Memon, 2016). On the other hand, for AVE, it should be greater than 0.5 (Hair et al., 2017). In this study, CR value of 0.7 and above is required while AVE value of 0.5 is the acceptable value.

### 3.9.3 Hypothesis Testing

In order to test the hypothesis, the research model will be built using SmartPLS 3.2.8 software. After drawing the overall research model based on theoretical framework, the path coefficients will be formed using bootstrapping procedure. This procedure is important because this test provides outer weights, outer loadings and path coefficients through estimation of standard errors for the estimates. Bootstrapping enable subsamples to be created and replaced from the set of data.

In order to examine hypothesis, path coefficients are needed. Path coefficients shows the relationship between hypothesized constructs. The standard value for path coefficients is +1 and -1, where the closer the value to +1 the stronger positive relationship while coefficients closer to -1 indicating strong negative relationship (Ramayah et al., 2016). As path coefficients will always show significance towards positive or negative, standard error value should be obtained and the significance level should be at least 0.05 (Hair et al., 2017). This is because the standard error for 0.01 (1% significance level) is

2.54 and for 0.05 (5% significance level) is 1.96 in a two-tailed test. However, for one-tailed test, which will be used in this study, the significance level of one percent is 2.33 and for five percent is 1.645. Therefore, this study will use five percent significance level that indicates the t-value should be 1.645 and above to be accepted. In order to assess the structural model, certain values and tests need to be performed:

- t-value
- p-value
- $R^2$
- Effect Sizes ($f^2$)
- Predictive Relevance ($Q^2$)

Abovementioned values can be assessed when performing Bootstrapping procedure. It is recommended to perform Bootstrapping because SmartPLS 3.0 software version 3.2.8 is a non-parametric analysis in which it does not make assumption of data distribution. Hence, when data is non-normal, the t-value will be inflated or deflated that will lead to Type 1 error (Ramayah et al., 2016). Through Bootstrapping procedure, the result will assume normal distribution so that t-value for significance testing of the hypothesis can be assumed (Wong, 2013). This study will accept t-value for the hypothesis if the value is higher than 1.645 for five percent significance level of one-tailed test. To identify whether there is an effect exists, p-value will be reported. The p-value for one-tailed test should be lesser than 0.05 (Hair et al., 2017). On the other hand, to assess the predictive accuracy of the model, $R^2$ value is needed. However, this value depends on the discipline of study whether it is acceptable. Regardless, there are scholars that have determined standard rule of thumb for $R^2$:

- 0.26 (substantial), 0.13 (moderate), 0.02 (weak) (Cohen, 1988)
- O.67 (substantial), 0.33 (moderate), 0.19 (weak) (Chin, 1998)
- 0.75 (substantial), 0.50 (moderate), 0.25 (weak) (Hair et al., 2017)
- Equal or greater than 0.10 (Falk & Miller, 1992)

In regards to effect size of the construct, $f^2$ is used (Cohen, 1988). This $f^2$ is used to explain the effect or impact of $R^2$ whether it can strongly explain the construct. The suggested values for $f^2$ are 0.35 (large), 0.15 (medium) and 0.02 (small) respectively. Lastly, to predict the relevancy of the path model, $Q^2$ is required. This $Q^2$ is to predict how close the predicted value compares to the original value. If the predicted is closer to original value, the path model has high predictive accuracy (Ramayah et al., 2016). In order to obtain $Q^2$, a technique called Blindfolding in SmartPLS 3.0 version 3.2.8 need to be performed. According to Hair et al. (2017), the value should be higher than zero.

### 3.9.4 Assessing Common Method Bias

Common method bias is another statistical test that need to be performed due to inputs or answers for independent and dependent variables in the questionnaire is obtained from single source. Common method bias is a problem that affect the validity of the research. This is because the termed "method bias" is referring to the measurement such as specific items, scale type, response format and general context (Fiske, 1982).

There are many factors that can lead to common method bias. For example, respondent answer according to social norm rather than feelings, respondent answer according to the like or dislike of particular person, respondent mood, respondent negativity towards the world other than own-self, the question is written as what respondent anticipated, question is written in systematic way that allows respondent to answer in a systematic way, respondent is able to predict the study based on the written question order and the number or questions and length of questions too short that respondent can recall while answering all questions (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). Furthermore, this study only uses single source of measurement for instrument that is through Likert scale to obtain data from respondents. This will lead to common method bias if remedies are not practice before and after data collection. Before questionnaire is answered by respondent, this study has taken several precaution steps such as:

- The order of the questions based on variables are not systematic
- The use of different type of scale
- The question has acceptable length and number
- Eliminating social desirability in questions

In order to test common method bias, full collinearity test through Variance Inflation Factor (VIF) will be used. The acceptable value for VIF should be lower than 5 to ensure the model is free from common method bias (Hair et al., 2017).

### 3.9.5 Mediating Effect

This study has a mediating variable that is GSCOP. Thus, to assess mediating effect, this study needs to perform mediating analysis to support the claim that this mediating variable is indeed mediates between independent variables and dependent variable. In order to do so, Preacher and Hayes (2004) have devised a strategy to assess mediating effect:

49. The mediator (M) should be related to the causal variable (X)
50. The mediator (M) should be related to the effected variable (Y)
51. The relationship between X and Y should be smaller when stratified with the M that the relationship between X and Y before stratification

Using SmartPLS 3.0 software version 3.2.8, Bootstrapping test will be used to study the effects for mediation (Preacher & Hayes, 2004). In Bootstrapping, this test will generate a new replacement samples and distribute the sample to test the relationship of X and M and M on Y. This process is repeated until the desired sample size is reached (Preacher & Hayes, 2004).

### 3.9.6 Non-Response Bias

Non-response bias is a missing value from the data collection such as missing answer from the survey (Hill, Roberts, Ewings, & Gunnell, 2012). The missing value is categorized as unit level, which means respondent of the survey failed to answer or reluctant to answer some questions from the survey. As a result, the unanswered question become non-response bias. Nevertheless, non-response bias is not an issue if the study has large sample size (De Winter et al., 2005). However, the problem in treating non-response bias is when the sample size is small. In a study of firm as unit of analysis, the response rate is relatively small even though the population is big. Therefore, analysing and providing enough evidence that non-response bias is not affecting the study is needed (Sheikh & Mattingly, 1981).

Non-response bias can be addressed through splitting the dataset into two or several categories. For example, early response to the survey and late response to the survey based on the timestamp. Then, both groups answers will be compared to see if there is a significant difference (Barclay, 2002). When both early and late groups' answers have low differences, it can be concluded that there is no response bias. Furthermore, in a study such as this, the non-response is predicted to be high as found in similar studies in the literature (Fernando et al., 2018; Zailani et al., 2015). Accordingly, the non-response respondents can be treated as late-group responses. Therefore, late response respondents in this study's data collection will become a proxy for non-response respondents. In order to confirm that there is no issue with non-response bias, Mann-Whitney U test or independent t-test will be performed (De Winter & Dodou, 2010). The Mann-Whitney U test will be performed if the data collected is non-normal in distribution while independent t-test will be undertaken when data is normally distributed. The Mann-Whitney U test uses two-tailed to accept or reject a hypothesis. If the value is less than 0.05, it means that the hypothesis is accepted and there is a significant difference between early and late response. If the value is more than 0.05, the hypothesis is rejected, and it shows that there is no significant difference between early and late response. If there is no significant difference, it means that there is no issue with non-response bias. Similarly, independent t-test also requires the dataset to be split into early and late response (Nachar, 2016). The late response again will be used as a proxy for non-response respondents. If there is no significant difference, then it can be concluded that there is no issue with non-response bias (Etter & Perneger, 1997).

## 3.10 Validation of Research Findings

Upon completion of statistical data analysis that will be presented in Chapter 4 of results and analysis, this study will also validate the statistical findings by providing discussion with expert in the industry. This is useful to confirm that empirical findings of this study are accurate and practically useful. This study will use Google Form to capture information on open ended answers from experts in the industry to validate the findings of this study. The first step taken by this study to undertake this process is by choosing five important findings from the statistical analysis and send to five experts in the industry. The second step is to identify experts in the industry. The experts consist of supply chain manager, logistics manager, chief executive officer, managing director and energy officer from reputable firms in Malaysia that practice LCSC. The third step is to provide Google Form with five questions regarding empirical findings and asked five industrial experts to provide their views on those findings. The fourth step is to analyse the answers provided by industrial experts by comparing with empirical evidence. The last step is to use both statistical findings and industrial experts' validation to enrich Chapter 5 discussion.

### 3.11 Measurement of Variables and Constructs

Since LCSC is a new concept, existing measures cannot be used for this study without some adaption (Böttcher & Müller, 2015). For the development of measurements for this study, guidelines by Churchil (1979) and Hensley (1999) were followed. First, this study conceptually specified the constructs. Second, performing extensive literature review to identify existing scales that were suitable for the construct. Third, the instrument was assessed and preliminary test by academicians and practitioners. This study selection of items to be adopted are based on several criteria as followed:

52. Item adopted is taken from the same disciplines of supply chain and operations management.
53. Next, the item adopted is chosen based on the quantity that one paper offered rather than take item from different scholars or papers. If the item is not sufficient, another paper or scholar's measurement will be used together with the existing measurement.
54. Then, item that is similar or not related will be removed. If there is no removal of items, all original item adopted will be taken as measurement.

#### 3.11.1 Measurement of Determinant Variables

Determinants or drivers are variables that explain the relationship between another variable that are nominally in a cause and effect relationship. In this study, there are five determinants of LCSC practices and the measurements that were adopted and then adapted to the context of this study. Measurement items are shown in Table 3.9, Table 3.10, Table 3.11, Table 3.12 and Table 3.13.

Table 3.8 Governmental regulation as determinant of LCSC practices

| Variable | Adapted Item | Original Item | Source |
|---|---|---|---|
| GOV1 | Our firm has adopted LCSC practices due to environmental regulations (such as waste emission, cleaner production etc.). | National environmental regulations (such as waste emission, cleaner production etc.) | (Zhu et al., 2013) |
| GOV2 | Our firm has adopted LCSC practices due to resource saving or conservation regulations. | National resource saving and conservation regulations | |
| GOV3 | Our firm has adopted LCSC practices due to export countries' environmental regulations. | Regional environmental regulations (such as waste emissions, cleaner production etc.) | |
| GOV4 | Our firm received attainment after implementing environmental regulations. | Regional resource saving and conservation regulations | |

Table 3.9 Customer pressure as determinant of LCSC practices

| Variable | Adapted Item | Original Item | Source |
|---|---|---|---|
| CUST1 | Our firm's products have increase firm's green image in the eye of customers (consumers). | Establishing company's green image | (Zhu et al., 2013) |
| CUST2 | Our firm's products meet global market requirements. | Sales to foreign customers | |
| CUST3 | Our firm's products meet green expectation from domestic customers. | Environmental requirements from domestic customers | |
| CUST4 | Our firm's product has been recognized by domestic customers. | Environmental awareness of Chinese consumers | |

Table 3.10 Green technology as determinant of LCSC practices

| Variable | Adapted Item | Original Item | Source |
|---|---|---|---|
| GT1 | Our firm has deployed latest low carbon technology. | Our firm has deployed latest green technology | (Fernando et al., 2016a) |
| GT2 | Our firm continuously exploits the potential technology. | Our firm continuously exploits the potential of technology | |
| GT3 | Our firm has set up in-house R&D unit. | Our firm has set up in-house R&D unit | |
| GT4 | Our firm has made greater use of low carbon technology. | Our firm has made greater use of green technology | |

Table 3.11 Environmental NGOs as determinant of LCSC practices

| Variable | Adapted Item | Original Item | Source |
|---|---|---|---|
| ENGO1 | Environmental NGOs has pressured our firm to practice LCSC. | Drivers: our company adopt environmental practices due to pressures from NGO | (Tachizawa et al., 2015) |

| Variable | Adapted Item | Original Item | Source |
| --- | --- | --- | --- |
| ENGO2 | Our firm has participated in industrial community linkage activities organized by environmental NGOs. | Industrial professional group activities | (Zhu et al., 2013) |
| ENGO3 | Our firm is closely monitored by environmental NGOs. | The news media follows our industry closely | |
| ENGO4 | Our firm's low carbon practices are recognized by environmental NGOs. | Public environmental awareness (community, NGO etc.) | |

Table 3.12 Top management support as determinant of LCSC practices

| Variable | Adapted Item | Original Item | Source |
| --- | --- | --- | --- |
| TPM1 | Our firm's top management fully supports LCSC practices. | Our firm's environmental efforts received full support from our top management | (Colwell & Joshi, 2013) |
| TPM2 | Our firm's top management consistently assessed LCSC practices. | Top management was committed to reducing harmful emissions resulting from our operations | |
| TPM3 | Our firm's top management has demonstrated leadership on LCSC practices. | Our top management team consistently assessed the impact our business had on the environment | |
| TPM4 | Our firm's top management are committed to adopt LCSC best practices. | Our top management team demonstrated behaviour that indicated that they valued the natural environment as much as profits | |

### 3.11.2 Measurement of Independent Variables

Independent variable is the variable that has impact to the dependent variable. The variable was tested to see whether LCSC practices has influence or impact to LCP in manufacturing industry in Malaysia. Under LCSC practices there are five practices; low carbon procurement (Table 3.14), low carbon product (Table 3.15), low carbon production process (Table 3.16), low carbon distribution (Table 3.17) and low carbon logistics (Table 3.18).

Table 3.13 Low carbon procurement of LCSC practices as independent variable

| Variable | Adapted Item | Original Item | Source |
|---|---|---|---|
| LCPROC1 | Our firm provide design specification to suppliers that include low carbon requirements for purchased items. | Providing design specification to suppliers that include environmental requirements for purchased items | (Zhu et al., 2013) |
| LCPROC2 | Our firm provide collaborate with suppliers to meet low carbon objectives. | Cooperation with suppliers for environmental objectives | |
| LCPROC3 | Our firm has requested environmental audit report from suppliers. | Environmental audit for suppliers' inner management | |
| LCPROC4 | Our firm has required suppliers to comply with environmental related standards (ISO14001, ISO50001). | Suppliers' ISO 14000 certification | |
| LCPROC5 | Our firm has included low carbon practices as one supplier selection criteria. | Suppliers are selected using environmental criteria | |

Table 3.14 Low carbon product of LCSC practices as independent variable

| Variable | Adapted Item | Original Item | Source |
|---|---|---|---|
| LCPROD1 | Our firm use life cycle assessment to develop low carbon related products. | Use of life cycle assessment | (Böttcher & Müller, 2015) |
| LCPROD2 | Our firm use renewable or recycled raw materials for product development. | Use of renewable and/or recycled raw materials | |
| LCPROD3 | Our firm has less carbon-intensive raw materials during product development. | Reduction of use of carbon-intensive materials | |
| LCPROD4 | Our firm less use carbon emissions during product development. | Reduction of carbon emissions in utilization phase | |

Table 3.15 Low carbon production process of LCSC practices as independent variable

| Variable | Adapted Item | Original Item | Source |
|---|---|---|---|
| LCPROS1 | Our firm has measurement of carbon emissions along production processes. | Measurement of carbon emissions along production processes | (Böttcher & Müller, 2015) |
| LCPROS2 | Our firm has use of energy/carbon efficient equipment for production processes. | Use of energy/carbon efficient equipment | |
| LCPROS3 | Our firm has use of low carbon/carbon-free energy sources. | Use of low-carbon/carbon-free energy sources | |
| LCPROS4 | Our firm has recycling of carbon-intensive scrap. | Recycling of carbon-intensive scrap | |

Table 3.16 Low carbon distribution of LCSC practices as independent variable

| Variable | Adapted Item | Original Item | Source |
|---|---|---|---|
| LCDIS1 | Our firm has collaborated with suppliers to use low carbon distribution network. | Cooperating with supplier to reduce packaging | (Zhu et al., 2013) |
| LCDIS2 | Our firm has requirement for suppliers to use environmental packaging (degradable and non-hazardous). | Require suppliers to use environmental packaging (degradable and non-hazardous) | |
| LCDIS3 | Our firm ask suppliers to use recyclable pallet system when they deliver supplies to us. | We ask suppliers to use recyclable pallet system when they deliver supplies to us | (Holt & Ghobadian, 2009) |
| LCDIS4 | Our firm has analysed energy efficiency systems in our warehouses operation. | We have energy efficiency systems in operation in our warehouses We consider environmental matters generally in our transport decisions | |
| LCDIS5 | Our firm expect suppliers to take back their packaging or pallet systems to supply goods to us. | We expect our suppliers to take back their packaging or pallet systems they use to supply goods to us | |

Table 3.17 Low carbon logistics of LCSC practices as independent variable

| Variable | Adapted Item | Original Item | Source |
|---|---|---|---|
| LCLOG1 | Our firm has frequently conducted carbon emissions assessment for transportation activities. | Measurement of carbon emissions of transportation processes | (Böttcher & Müller, 2015) |
| LCLOG2 | Our firm has consolidation of shipments to ensure we achieve low carbon emissions. | Consolidation of shipments to reduce carbon emissions | |
| LCLOG3 | Our firm has use carbon-efficient technologies to design transportation networks/routes. | Use of carbon-efficient technologies for transportation | |
| LCLOG4 | Our firm has use of low carbon transportation modes. | Use of low-carbon transportation modes | |

### 3.11.3 Measurement of Mediating Variables

The mediating variable is the variable that causes mediation between independent variable and dependent variable. This variable is also known as intervention variable because it intervenes the relationship between independent variable and dependent variable. In this study, GSCOP is a mediating variable that consists of flexibility Table

3.19), responsiveness (Table 3.20), cost reduction (Table 3.21) and environmental friendliness (Table 3.22).

Table 3.18 Cost of GSCOP as mediating variable

| Variable | Adopted Item | Original Item | Source |
|---|---|---|---|
| COST1 | Our firm has reduced cost of product design. | Our firm has reduced cost of product resign | (Chardine-Baumann & Botta-Genoulaz, 2014) |
| COST2 | Our firm has reduced unnecessary cost from purchased materials. | Our firm has reduced unnecessary cost from purchased materials | |
| COST3 | Our firm has reduced production cost. | Our firm has reduced production cost | |
| COST4 | Our firm has reduced transportation cost. | Our firm has reduced transportation cost | |
| COST5 | Overall, our firm has reduced supply chain cost. | Overall, our firm has reduced supply chain cost | |

Table 3.19 Flexibility of GSCOP as mediating variable

| Variable | Adopted Item | Original Item | Source |
|---|---|---|---|
| FLEX1 | Our firm's suppliers are flexible. | Our firm's suppliers are flexible | (Chardine-Baumann & Botta-Genoulaz, 2014) |
| FLEX2 | Our firm's supply of products is flexible. | Our firm's supply of products is flexible | |
| FLEX3 | Our firm's production process is flexible. | Our firm's production process is flexible | |
| FLEX4 | Our firm's delivery to customer is flexible. | Our firm's delivery to customer is flexible | |

Table 3.20 Responsiveness of GSCOP as mediating variable

| Variable | Adopted Item | Original Item | Source |
|---|---|---|---|
| RESP1 | Our firm has responsive product design to meet customer requirement. | Our firm has responsive product design to meet customer requirement | (Chardine-Baumann & Botta-Genoulaz, 2014) |
| RESP2 | Our firm has responsive quality raw materials purchase to meet customers' demand. | Our firm has responsive quality raw materials purchase to meet customers' demand | |
| RESP3 | Our firm has responsive delivery to customers. | Our firm has responsive delivery to customers | |
| RESP4 | Our firm has responsive product return for customers. | Our firm has responsive product return for customers | |
| RESP5 | Our firm has responsive supply chain to meet customers' demand. | Our firm has responsive supply chain to meet customers' demand | |

Table 3.21 Environmental friendliness of GSCOP as mediating variable

| Variable | Adapted Item | Original Item | Source |
|---|---|---|---|
| ENVF1 | Our firm has used less energy consumption. | Less energy consuming process | (Gunasekaran & Ngai, 2012) |
| ENVF2 | Our firm use clean energy fuel to support in operation. | Clean energy fuel | |
| ENVF3 | Our firm has design green value chain to support our operation. | Design for greening value chain | |
| ENVF4 | Our firm use life cycle assessment to support principle of environmental friendliness. | Life cycle value chain | |

### 3.11.4 Measurement of Dependent Variables

Dependent variable is the main variable or focus of this study. Dependent variable is affected by other factors such independent variable. In this study, LCP is dependent variables and the purpose of this study is to see whether LCSC practices affect LCP, GSCOP affect LCP and determinants of LCSC practices affect LCP. Table 3.23 shows the LCP measurement.

Table 3.22 LCP as dependent variable

| Variable | Adapted Item | Original Item | Source |
|---|---|---|---|
| LCP1 | Our firm has reduced of carbon emissions. | Energy use (per unit of output) | (Böttcher & Müller, 2015) |
| LCP2 | Our firm has reduced of energy use. | Carbon emissions (per unit of output) | |
| LCP3 | Our firm has reduced use of carbon-intensive materials. | Use of carbon-intensive materials (per unit of output) | |

### 3.11.5 Measurement of Demographic Variables

Demographic variables are used to collect data on firm profile and respondent profile. Thus, it can be divided into two categories as shown in Table 3.24. For type of industry, even though FMM directory providing individual firms, in the CD-ROM provided by FMM Directory, there is an option to look for firms under each sector in manufacturing industry. There are also questions regarding firm's involvement with LCSC that have been included in the survey. The inclusion of these questions is to further contribute to the understanding of LCSC practices in Malaysian manufacturing industry.

Table 3.23 Demographic respondents

| | Item | Source |
|---|---|---|
| **Firm Profile** | Green International Standards | (Eltayeb & Zailani, 2009) |
| | Type of industry | (Fernando & Hor, 2017) |
| | Age of the firm | (Eltayeb & Zailani, 2009) |
| | Type of products | |
| | Ownership status | (Fernando & Hor, 2017) |
| | Number of employees | (Eltayeb & Zailani, 2009) |
| **Respondent Profile** | Job position | (Fernando & Wah, 2017) |
| | Years in the firm | (Eltayeb & Zailani, 2009) |
| | Qualification of respondent | |
| | Gender of respondent | |
| | Age of respondent | |

## 3.12 Chapter Summary

This chapter presents the methodology for performing this study. Through understanding of positivist paradigm and justification why this study adopts this paradigm, a clear research process is able to be determined. Following from the research process, identification of population, unit of analysis, sample size, sampling method and designing questionnaire are presented. This is in accordance of the scientific method of positivist paradigm and research process. Then, this chapter underline how data will be collected from the sample identified previously. In that section, matters on questionnaire design and data collection such as type of variables asked in the questionnaire, how this study design individual questions, coding of questions, the use of first question and cover letter for data collection are discussed. In addition, the length of the questionnaire, and how the questionnaire is distributed also are presented in that section. In order to show that the questionnaire is reliable and valid, preliminary test will be performed before respondents answer the questionnaire. Once the data is collected from respondents, statistical analysis need to be performed. Therefore, type of statistical analysis that will be conducted were outlined. Lastly, the chapter ends with important measurement for variables used in this study.

# CHAPTER 4

# DATA ANALYSIS & RESULTS

## 4.1 Introduction

This chapter presents findings of the study after data was collected. Collected data are analysed with statistical software to extract information on demographic profile of firm and respondent, model measurement of convergent validity and discriminant validity and hypothesis testing as well as mediating effect. This chapter begins with demographic analysis. Then, followed by convergent validity and discriminant validity reporting that were presented in chapter 3 such as outer loadings, Composite Reliability (CR), Average Variance Extracted (AVE), Coefficient of Determination ($R^2$), Effect Size ($f^2$), Predictive Relevancy ($Q^2$) and Heterotrait-Monotrait (HTMT). Subsequently, hypothesis measurement through Bootstrapping procedure to analyse hypothesis described in chapter 2 and mediation effect will be reported in this chapter.

## 4.2 Demographic Profile

This section is to present demographic profile based on data that was collected. Data were analysed using IBM SPSS software version 24 to extract information regarding response rate, firm profile, Low Carbon Supply Chain (LCSC) profile and respondent profile. Profile of firm describes basic information about sample's profile such as type of industry, ownership status, location of firm, age of firm and number of employees working at firm. In addition, information regarding LCSC practices such as justification for LCSC adoption, incentives for LCSC and type of incentives for LCSC were also discussed. Respondent profile on the other hand captures information regarding position of respondent at the firm, qualification, gender and age group. This information is vital for understanding whether these respondents are able to represent the population in identifying LCSC practices to achieve Low Carbon Performance (LCP).

### 4.2.1 Response Rate

Survey questions were sent to participating firms in LCSC in the manufacturing industry listed in directory of Federal Malaysian Manufacturers (FMM) 2017. As many as 700 questionnaires were sent in the first week of September 2018 until end of fourth week September 2018 as shown in Table 4.1. There were 700 questionnaires sent to manufacturing firms after filtering list of firms in the directory to only include with ISO certification as a preliminary proof of practicing low carbon practices. After the end of fourth week, 143 questionnaires were collected resulting in 20.4 percent of response rate. There are no missing values as this study used Google Form with required question option to ensure that respondents are unable to continue answering the next question without the previous questions being answered. Thus, all 143 returned questionnaires were complete and useable.

Table 4.1 Response rate

| | **Total** |
|---|---|
| Total Questionnaire sent | 700 |
| Total Questionnaire received | 143 |
| Total Questionnaire useable | 143 |
| Non-response rate | 557 |

Response rate is considered sufficient for this study with regard to mail-based survey (Sekaran & Bougie, 2016) as previous studies that employ survey-based study in Malaysia also found to have similar response rate as shown in Table 4.2. Furthermore, two gentle reminders were sent to respondents to increase the response rate in an effort to include as many samples as possible. The reminders were drafted with different message as to help manufacturing firms to understand the importance of this study and their contributions to this study. Regardless, completed surveys received were sufficient to represent manufacturing population based on sample frame of FMM directory 2017 and to perform statistical analysis.

Based on the response rate result, minimum response rate is expected as this study employed two filter questions to ensure relevancy and reliability of data. The first filter question is information on ISO certification. As international standards certification becoming a norm and justification for firm to show commitment to environmental management and quality management, this study focused on firms that acquire ISO certification. Table 4.4 shows that all respondent has ISO certification that directly or indirectly related to carbon emissions reduction. The second filter question imposed in the questionnaire is whether firm practice carbon emissions reduction. This question is important as ISO certification as a proof of practicing carbon emissions reduction is not entirely vigorous. Selecting respondents that practice LCSC is important to ensure that results of this study are reliable. That is the reason why the response rate is consider low but reliable.

Table 4.2 Scholarly work response rate in Malaysia using survey method

| No | Paper | Title | Sample Size |
|---|---|---|---|
| 1 | (Zailani et al., 2012) | Sustainable supply chain management (SSCM) in Malaysia: A survey | 106 |
| 2 | (Zailani et al., 2013) | The impact of external institutional drivers and internal strategy on environmental performance | 132 |
| 3 | (Abdullah & Yaakub, 2014) | Reverse logistics: Pressure for adoption and the impact on firm's performance | 101 |
| 4 | (Zailani et al., 2015) | Green Innovation Adoption in Automotive Supply Chain: The Malaysian case | 153 |
| 5 | (Fernando et al., 2016) | Does a firm’s innovation category matter in practising eco-innovation? Evidence from the lens of Malaysia companies practicing green technology | 150 |
| 6 | (Fernando, Bee, Jabbour, & Thomé, 2018) | Understanding the effects of energy management practices on renewable energy supply chains: Implications for energy policy in emerging economies | 151 |
| 7 | (Fernando & Chukai, 2018) | Value Co-Creation, Goods and Service Tax (GST) Impacts on Sustainable Logistic Performance | 145 |
| 8 | (Fernando, Jabbour, & Wah, 2019) | Pursuing green growth in technology firms through the connections between environmental innovation and sustainable business performance: Does service capability matter? | 95 |

The non-response rate of questionnaires was statistically analysed using Mann-Whitney test. This test is used to prove two things; i) to prove that the early and late response has no difference in opinion or answer and ii) to show that the late response is a proxy to non-responses. Mann-Whitney test is chosen to prove there is no significance differences between two groups (early response and late response or non-response) because data in this study is not normally distributed. Table 4.3 shows the ranks and test statistics information from Mann-Whitney test through IBM SPSS software.

Table 4.3 Non-response bias

| Group | N | Mean Rank |
|---|---|---|
| Early | 39 | 72.14 |
| Late | 104 | 71.95 |
| Total | 143 | |
| | **Low Carbon Performance** | |
| Mann-Whitney U | 2022.500 | |
| Wilcoxon W | 7482.500 | |
| Z | -.028 | |
| Asymp. Sig. (2-tailed) | .978 | |

This study divided samples into two groups namely "Early" for respondents that reply to the survey within one week after the survey commenced (1st week of September 2018) and "Late" group for respondents that reply after a week until the cut off time (end of 4th week of September 2018). From the timestamp given by Google Form, it shows that there are 39 early respondents and remaining 104 for late respondents. After identifying descriptive information about the early and late group respondents, investigation on differences in answer between groups need to be undertaken. Based on the Asymptotic two-tailed significance value, it shows that the value is greater than 0.05 which means the hypothesis or assumption is rejected. The assumption or hypothesis for non-response bias is that there is a significant difference between early and late (or non-response) respondents answers. Therefore, it can be concluded that there is no issue with non-response bias since late response has been taken as proxy or representative for unresponsive respondents.

### 4.2.2 Respondent Profile

Respondent for this study is manufacturing firms operating in Malaysia and listed in FMM directory 2017. All 143 surveys collected were analysed using IBM SPSS software version 24. Table 4.4 shows demographic profile of the respondent who represented their firm in measuring LCSC practices to achieve LCP. Questions such as position of respondent, years at firm, qualification, gender and age group were asked to understand the background of respondent and to justify the results analysis. For example, demographic profile of respondent is used to justify LCSC practices in Malaysian manufacturing industry.

Table 4.4 Respondent demographic profile

| Demographic | Categories | Overall | |
|---|---|---|---|
| | | Frequency | Percent (%) |
| Position | Chief Executive Office | 4 | 2.8 |
| | Environment Health Safety Officer | 12 | 8.4 |
| | Energy Officer | 13 | 9.1 |
| | Chief Operating Officer | 12 | 8.4 |
| | Managing Director | 13 | 9.1 |
| | General Manager | 21 | 14.7 |
| | Operation Manager | 32 | 22.4 |
| | Supply Chain Manager | 19 | 13.3 |
| | Logistics Manager | 13 | 9.1 |
| | R&D Director/Manager | 4 | 2.8 |
| Years at firm | Less than 5 years | 21 | 14.7 |
| | 6 to 10 years | 49 | 34.3 |
| | 11 to 15 years | 40 | 28.0 |
| | More than 15 years | 33 | 23.1 |
| Qualification | Doctorate Degree | 5 | 3.5 |
| | Master's Degree | 74 | 51.7 |
| | Professional Certificate | 56 | 39.2 |
| | Undergraduate Degree | 8 | 5.6 |
| Gender | Male | 94 | 65.7 |
| | Female | 49 | 34.3 |
| Age | Less than 30 years old | 4 | 2.8 |
| | 31 to 40 years old | 36 | 25.2 |
| | 41 to 50 years old | 60 | 42.0 |
| | More than 50 years old | 43 | 30.1 |

Based on Table 4.4 respondent demographic profile, most respondent who answered the survey on behalf of their respective firms are in the middle to top management positions such as operations manager (22.4%), general manager (14.7%), supply chain manager (13.3%), logistics manager (9.1%), energy officer (9.1%), managing director (9.1%) and environmental health safety officer (8.4%) respectively. On the other hand, this study was able to get fair response from top management positions including chief operating officer (8.4%), R&D director (2.8%) and chief executive officer (2.8%). All respondent position shows ability to holistically understand overall process and activities of supply chain at their respective firm. This ensure the obtained result can help this study to understand LCSC practices to achieve LCP at manufacturing firms in Malaysia.

Furthermore, respondents have greater understanding of LCSC practices to achieve LCP as most respondents were at their respective firms in manufacturing industry for 6 to 10 years (34.3%), around 11 to 15 years (28.0%), fair number for more than 15 years (23.1%) and reasonable number for less than 5 years at firm (14.7%). Most of respondents have master's degree (51.7%) and professional certificate (39.2%) while small number of undergraduate degree (5.6%) and doctorate degree (3.5%) make up the number for qualification of respondents. There were 94 male respondents (65.7%) and 49 female respondents (34.3%) and most of the respondents belong to age group of 41 to 50 years old (42.0%), more than 50 years old (30.1%) and 31 to 40 years old (25.2%). Only a small number of respondent age less than 30 years old (2.8%).

Based on the demographic profile of respondents, all 143 respondents demographic profile show respondents were good representative for manufacturing firm and able to give feedback on the survey regarding LCSC practices to achieve LCP. In addition, these respondents were good representative for respective manufacturing firms because these firms hold ISO standards certificates (Table 4.5) that resemblance firms to being knowledgeable and practicing LCSC. In order to understand more on LCSC practices in reducing carbon emissions in manufacturing industry, a profile of firm is required.

### 4.2.3 Firm Demographic Profile

All 143 collected surveys that were analysed using IBM SPSS software version 24 recorded firm demographic profile as shown in Table 4.5. Firm demographic profile is used to understand whether the manufacturing firm answering the survey is qualified to represent the targeted population in investigation of LCSC practices in manufacturing industry. In addition, firm's demographic profile is useful for building discussion on LCSC practices.

Based on Table 4.5, most firms have adopted environmental management practice through ISO 14001 (61.9%). ISO certification by manufacturing firms give evidence that firms are practicing environmental management that has been the key for LCSC practices. Moreover, manufacturing firms usually will hold several ISO certifications to meet the requirement of multiple stakeholders and for exporting product requirement. Other than environmental management certification, firms that responded to the survey also implementing ISO 26000 for corporate social responsibility (17.0%), ISO 14024 for environmental labels and declarations (6.8%) and ISO 9001 for quality management system (6.3%) respectively. Furthermore, there were manufacturing firms that have ISO 14067 (carbon management) with 4.5 percent and ISO 50001 (energy management) with 3.4 percent.

There are many sectors in manufacturing industry. Based on the result shown in Table 4.5, most of firms were operating in electric and electronics sector (36.4%). This is understandable as there are many firms in Malaysia operating in this sector. In addition, there were ample number of manufacturing firms responding to the survey from automotive sector (13.3%), energy and heat transfer sector (8.4%), agricultural and food (7.7%), building material (5.6%) and metal sector (5.6%) respectively. There were also firms in capacity and building for manufacturing (4.9%), packaging, paper and plastics (4.2%), utility (3.5%), industrial machine rubber (2.8%) and pharmaceutical sector (2.1%).

Most of responded firms were around in the manufacturing industry for 10 to 15 years (33.6%) and large number of firms also have been in the industry for 16 to 20 years (30.8%). On the other hand, there were balance number of firms that have been in the industry for more than 20 years (18.9%) and currently established firms less than 10 years (16.8%). Out of 143 responded firms, 97 firms were producing industrial product (67.8%) and 46 firms were producing consumer product (32.2%). As large number of firms were either producing industrial and consumer products, most of these manufacturers were Malaysian fully owned firms (42.0%) and local and foreign joint venture firms (32.2%). Other manufacturers proportionately were American-based firm (11.2%), Japanese-based firm (8.4%) and European-based firm (6.3%) respectively.

Since respondents were largely industrial product manufacturers, most firms have more than 500 employees (49.0%) followed by 100 to 250 employees (22.4%), 251 to 500 employees (18.9%) and fair amount of less than 100 employees (9.8%). Most firms are located in central region states such as Kuala Lumpur, Selangor, Putrajaya, Cyberjaya and Negeri Sembilan (49.7%). This is understandable as this region is occupied by electric and electronic firms. The second region that has high number of manufacturing firms is the northern region that includes Perlis, Kedah, Penang and Perak (43.4%) followed by southern region (4.2%) and east coast region (2.8%) respectively. Table 4.5

firm demographic profile provides clear understanding of type of sector and type of product that contribute to LCSC practices to achieve LCP. Additional information is required to further understand Malaysian manufacturing industry LCSC practices.

Table 4.5 Firm demographic profile

| Demographic | Categories | Overall | |
|---|---|---|---|
| | | Frequency | Percent (%) |
| ISO Certification | ISO 14001 (environmental management) | 109 | 61.9 |
| | ISO 14024 (environmental labels & declarations) | 12 | 6.8 |
| | ISO 14067 (carbon management) | 8 | 4.5 |
| | ISO 50001 (energy management) | 6 | 3.4 |
| | ISO 26000 (corporate social responsibility) | 30 | 17.0 |
| | ISO 9001 (quality management) | 11 | 6.3 |
| Type of Industry | Agricultural/Food | 11 | 7.7 |
| | Automotive | 19 | 13.3 |
| | Building Material | 8 | 5.6 |
| | Capacity building and assistance for manufacturing sector | 7 | 4.9 |
| | Consumer/Office Machines | 5 | 3.5 |
| | Electrical/Electronics | 52 | 36.4 |
| | Energy/Heat Transfer | 12 | 8.4 |
| | Furniture | 3 | 2.1 |
| | Industrial Machine Rubber | 4 | 2.8 |
| | Metal | 8 | 5.6 |
| | Packaging/Paper/Plastics | 6 | 4.2 |
| | Pharmaceutical | 3 | 2.1 |
| | Utility | 5 | 3.5 |
| Age of Firm | Less than 10 years | 24 | 16.8 |
| | 10 to 15 years | 48 | 33.6 |
| | 16 to 20 years | 44 | 30.8 |
| | More than 20 years | 27 | 18.9 |
| Type of Product | Consumer Product | 46 | 32.2 |
| | Industrial Product | 97 | 67.8 |
| Ownership Status | American-based Firm | 16 | 11.2 |
| | European-based Firm | 9 | 6.3 |
| | Japanese-based Firm | 12 | 8.4 |
| | Local and Foreign Joint Venture | 46 | 32.2 |
| | Malaysian Fully Owned | 60 | 42.0 |
| Number of Employees | Less than 100 | 14 | 9.8 |
| | 100 to 250 | 32 | 22.4 |
| | 251 to 500 | 27 | 18.9 |
| | More than 500 | 70 | 49.0 |
| Location of firm | North (Perlis, Kedah, Penang, Perak) | 62 | 43.4 |
| | Central (Kuala Lumpur, Selangor, Putrajaya, Cyberjaya, Negeri Sembilan) | 71 | 49.7 |
| | Southern (Johor, Melaka) | 6 | 4.2 |
| | East Coast (Kelantan, Terengganu, Pahang) | 4 | 2.8 |

### 4.2.4 Firm Low Carbon Practice Demographic Profile

In order to investigate LCSC practices, several questions on low carbon practices have been included in the survey. These questions were asked to help this study understand manufacturing firms low carbon practices in Malaysia. Through these understanding, a greater contribution to the literature and policymakers are applicable. Table 4.6 depicts demographic profile of responded firms' low carbon practice.

Table 4.6 Firm's low carbon practice demographic profile

| Demographic | Categories | Overall | |
|---|---|---|---|
| | | **Frequency** | **Percent (%)** |
| Firm concern with low carbon reduction | Yes (please specify below) | 143 | 100.0 |
| | No (please provide reason below) | 0 | 0 |
| Justification concerning low carbon reduction | Customer Demand | 31 | 21.7 |
| | Program & Practice | 20 | 14.0 |
| | Environmental & Low Carbon Support | 27 | 18.9 |
| | Regulation & Policy | 65 | 45.5 |
| Years adopting low carbon practice | Less than 1 year | 53 | 37.1 |
| | 1 to 3 years | 68 | 47.6 |
| | More than 3 years | 22 | 15.4 |
| Firm received support/incentives from Malaysian government for reducing carbon emissions | Yes (please specify the incentive below) | 86 | 60.1 |
| | No (please indicate the reason below) | 57 | 39.9 |
| Type of incentives | Green Tax | 33 | 23.1 |
| | Green Technology | 14 | 9.8 |
| | Government Tax Reduction | 39 | 27.3 |
| | Not Aware | 57 | 39.9 |
| Participate in Malaysian governmental carbon emissions reduction program | Yes (please specify below) | 27 | 18.9 |
| | No (please provide reason below) | 116 | 81.1 |
| Justification for participation | Stakeholder Environmental Program | 9 | 6.3 |
| | Energy Efficiency & Renewable Energy Program | 6 | 4.2 |
| | Clean Development Mechanism | 12 | 8.4 |
| | Not Related to Business | 15 | 10.5 |
| | Lack of Program Information | 21 | 14.7 |
| | Lack of Program Awareness | 80 | 55.9 |
| Dedicated department to reduce carbon emissions | Yes | 48 | 33.6 |
| | No | 95 | 66.4 |
| Department to monitor carbon emissions | Yes | 101 | 70.6 |
| | No | 42 | 29.4 |

Table 4.6 first question was included in the survey to serve as a filter question to ensure respondent is qualified to answer the question. Furthermore, the first question also helps to check whether respondent directly or indirectly wanted to reduce carbon emissions or is concerned with carbon emissions at the firm. Clearly, the result shows that all 143 firms answering the survey were concerned with carbon emissions reduction. Most of responded firms support low carbon emissions through adhering to regulation and policy (45.5%), customer demand (21.7%), supporting cause of environmental and low carbon (18.9%) and through environmental program and practice at firm (14.0%) respectively. Based on the survey, many firms have been adopting low carbon practice for around 1 to 3 years (47.6%) and less than a year (37.1%). This shows that manufacturing low carbon practice is at initiation and development stages. However, there were also 22 participated firms in this survey that have been practicing low carbon practice for more than 3 years (15.4%).

In terms of incentives, most firms received tax reduction from the government (27.3%) and green tax for adopting environmentally friendly practices (23.1%). In addition, firms are also adopting low carbon practice through green technology adoption (9.8%). However, almost 40 percent of manufacturing firms are not aware of available incentives for low carbon reduction given by the Malaysian government. These numbers contribute largely to manufacturing firm's participation in governmental carbon emissions reduction program. As a result, more than 80 percent of firms that responded specified that they did not participate in any governmental carbon emissions program. The reasons for manufacturing firms being unaware of low carbon incentives and not participating in low carbon program by the Malaysian government are due to the lack of program awareness (55.9%), lack of program information (14.7%) and not related to their business (10.5%). On the other hand, 27 firms that participated in the Malaysian government carbon emissions program stated that the reason for firms participating was because it is part of their stakeholder environmental program (6.3%) and clean development mechanism (4.2%). Further query from dedicated department for carbon emissions reduction showed that more than 66 percent of manufacturing firms do not have dedicated department to reduce carbon emissions. However, manufacturing firms have a department at the firm to monitor carbon emissions (70.6%) with only 42 out of 143 firms that did not have department to monitor carbon emissions. Overall, demographic profile of low carbon practices showed evidence that manufacturing firms that responded to this survey were able to represent the population of Malaysian manufacturing industry and have been practicing low carbon practices. Therefore, the proposed theoretical model for LCSC practices to achieve LCP can be tested through model measurement analysis and structural measurement analysis.

### 4.3 Data Validation

Selection of statistical software depends on the type of data gathered. Most statistical software requires normal distribution data to provide valuable data visualization. However, there are also statistical software that enable non-normal distribution data. Accordingly, structural equation modelling software such as SmartPLS allows non-normal distribution data to provide meaningful information (Hair et al., 2017). Thus, it is the first requirement to determine whether collected data is normally distributed or non-normal. To do so, skewness and kurtosis test need to be performed. There are two tests to determine whether data collected is skewed and the level of kurtosis. Univariate and multivariate skewness and kurtosis can be performed to identify type of data (Mardia, 1974). Importantly, the skewness will show whether it is highly skewed, moderately skewed or achieving symmetry. The rule of thumb is as follows:

- If skewness less than -1 or more than +1, it is highly skewed
- If skewness is between -1 and -0.5 or 0.5 and +1, it is moderately skewed
- If skewness is between -0.5 and 0.5, the data is symmetric
- On the other hand, kurtosis shows the shape or central peak on the graph. The rule of thumb for kurtosis is as follows:
- A normal distribution has kurtosis of 3
- A distribution less than 3 or more than 3 are non-normal and called platykurtic and leptokurtic respectively

This study had used skewness and kurtosis calculator online from (Webpower, 2019) to perform the test. Table 4.7 shows univariate for each item of the construct and multivariate for overall construct of the model score of skewness and kurtosis. Based on the result, it shows that the data collected is skewed and the data has leptokurtic kurtosis based on Mardia's multivariate kurtosis test. Therefore, choosing SmartPLS software that can handle non-normal distribution data is recommended. This is to ensure that data gathered will give meaningful information.

Table 4.7 Skewness and kurtosis

```
Sample size:  143
Number of variables:  63

Univariate skewness and kurtosis
```

| | Skewness | SE_skew | Kurtosis | SE_kurt |
|---|---|---|---|---|
| GOV1 | -0.127465129 | 0.2027312 | -2.012093587 | 0.4027923 |
| GOV2 | -0.448849900 | 0.2027312 | -1.824247234 | 0.4027923 |
| GOV3 | -0.771611109 | 0.2027312 | -1.424741723 | 0.4027923 |
| GOV4 | -0.670106183 | 0.2027312 | -1.573159101 | 0.4027923 |
| CUST1 | -0.466322741 | 0.2027312 | -0.974676075 | 0.4027923 |
| CUST2 | -0.842890074 | 0.2027312 | -0.040127421 | 0.4027923 |
| CUST3 | -0.560147286 | 0.2027312 | -0.595002172 | 0.4027923 |
| CUST4 | -0.834519682 | 0.2027312 | -0.127448796 | 0.4027923 |
| GT1 | -0.410410079 | 0.2027312 | -0.401747717 | 0.4027923 |
| GT2 | -0.351059597 | 0.2027312 | 0.788015089 | 0.4027923 |
| GT3 | 0.015478303 | 0.2027312 | -1.321095501 | 0.4027923 |
| GT4 | -0.159523802 | 0.2027312 | 0.001108746 | 0.4027923 |
| ENGO1 | -0.236703448 | 0.2027312 | -0.968385117 | 0.4027923 |
| ENGO2 | -0.333578785 | 0.2027312 | -0.618610275 | 0.4027923 |
| ENGO3 | -0.066254114 | 0.2027312 | -1.377174531 | 0.4027923 |
| ENGO4 | -0.177008989 | 0.2027312 | -0.673121375 | 0.4027923 |
| TPM1 | 0.074606026 | 0.2027312 | -0.589329353 | 0.4027923 |
| TPM2 | 0.187177503 | 0.2027312 | -0.708863449 | 0.4027923 |
| TPM3 | -0.305652646 | 0.2027312 | 0.493175420 | 0.4027923 |
| TPM4 | -0.405435532 | 0.2027312 | 0.192270004 | 0.4027923 |
| LCPROC1 | -0.153230019 | 0.2027312 | -0.685442617 | 0.4027923 |
| LCPROC2 | -0.136230828 | 0.2027312 | -0.575601824 | 0.4027923 |
| LCPROC3 | -0.062304156 | 0.2027312 | -0.844432783 | 0.4027923 |
| LCPROC4 | -0.110428160 | 0.2027312 | -0.717048240 | 0.4027923 |
| LCPROC5 | -0.114474387 | 0.2027312 | -0.822492809 | 0.4027923 |
| LCPROD1 | 0.878483697 | 0.2027312 | -1.245890153 | 0.4027923 |
| LCPROD2 | 1.031472044 | 0.2027312 | -0.949544073 | 0.4027923 |
| LCPROD3 | 0.703409962 | 0.2027312 | -1.526766917 | 0.4027923 |
| LCPROD4 | 1.071967042 | 0.2027312 | -0.863156981 | 0.4027923 |
| LCPROS1 | -0.461818114 | 0.2027312 | -0.637297193 | 0.4027923 |
| LCPROS2 | -0.337354425 | 0.2027312 | -1.052631948 | 0.4027923 |
| LCPROS3 | -0.133281880 | 0.2027312 | -1.228394961 | 0.4027923 |
| LCPROS4 | -0.044654984 | 0.2027312 | -0.309308147 | 0.4027923 |
| LCDIS1 | -0.608196872 | 0.2027312 | 1.055555509 | 0.4027923 |
| LCDIS2 | -0.616294669 | 0.2027312 | 0.446446103 | 0.4027923 |
| LCDIS3 | -0.550559570 | 0.2027312 | -0.084547314 | 0.4027923 |
| LCDIS4 | -0.508232883 | 0.2027312 | -0.238182263 | 0.4027923 |
| LCDIS5 | -0.248305242 | 0.2027312 | -0.665747944 | 0.4027923 |
| LCLOG1 | -0.579928136 | 0.2027312 | -0.147340049 | 0.4027923 |
| LCLOG2 | -0.463563433 | 0.2027312 | -0.269864014 | 0.4027923 |
| LCLOG3 | -0.348162760 | 0.2027312 | -0.437225944 | 0.4027923 |
| LCLOG4 | -0.629120546 | 0.2027312 | -0.310683468 | 0.4027923 |

Table 4.7 (continue)

| | Skewness | SE_skew | Kurtosis | SE_kurt |
|---|---|---|---|---|
| COST1 | -0.379470556 | 0.2027312 | -0.731068168 | 0.4027923 |
| COST2 | -0.507123875 | 0.2027312 | -0.935851952 | 0.4027923 |
| COST3 | -0.177872714 | 0.2027312 | -0.812651622 | 0.4027923 |
| COST4 | -0.379470556 | 0.2027312 | -0.731068168 | 0.4027923 |
| COST5 | -0.371383450 | 0.2027312 | -0.818275389 | 0.4027923 |
| FLEX1 | -0.054643177 | 0.2027312 | -0.355385423 | 0.4027923 |
| FLEX2 | -0.026683972 | 0.2027312 | -0.209755833 | 0.4027923 |
| FLEX3 | 0.009018893 | 0.2027312 | 0.154317626 | 0.4027923 |
| FLEX4 | -0.122697630 | 0.2027312 | -0.543429657 | 0.4027923 |
| RESP1 | -0.223119006 | 0.2027312 | -0.839321758 | 0.4027923 |
| RESP2 | -0.125509814 | 0.2027312 | -0.585232231 | 0.4027923 |
| RESP3 | -0.239526997 | 0.2027312 | -0.749451643 | 0.4027923 |
| RESP4 | -0.225042192 | 0.2027312 | -0.766353198 | 0.4027923 |
| RESP5 | -0.177872714 | 0.2027312 | -0.812651622 | 0.4027923 |
| ENVF1 | -0.092497901 | 0.2027312 | -0.375767963 | 0.4027923 |
| ENVF2 | -0.060643620 | 0.2027312 | -0.298519197 | 0.4027923 |
| ENVF3 | -0.160576458 | 0.2027312 | -0.595028211 | 0.4027923 |
| ENVF4 | -0.089876558 | 0.2027312 | -0.524389145 | 0.4027923 |
| LCP1 | -0.166958884 | 0.2027312 | -0.712232171 | 0.4027923 |
| LCP2 | -0.180635552 | 0.2027312 | -0.699094445 | 0.4027923 |
| LCP3 | -0.029651925 | 0.2027312 | -0.976305780 | 0.4027923 |

Mardia's multivariate skewness and kurtosis

| | b | z | p-value |
|---|---|---|---|
| Skewness | 2527.240 | 60232.54331 | 0 |
| Kurtosis | 4407.212 | 20.62745 | 0 |

## 4.4 Model Measurement

After performing descriptive analysis of manufacturing firms participating in the survey, model measurement analysis needs to be undertaken. This is because the survey questions were based on theoretical model developed for investigating LCSC practices to achieve LCP. In order to ensure that the model is valid and reliable, convergent validity, discriminant validity and reliability need to be established. Figure 4.1 shows theoretical model for this study in SmartPLS software version 3.2.8.

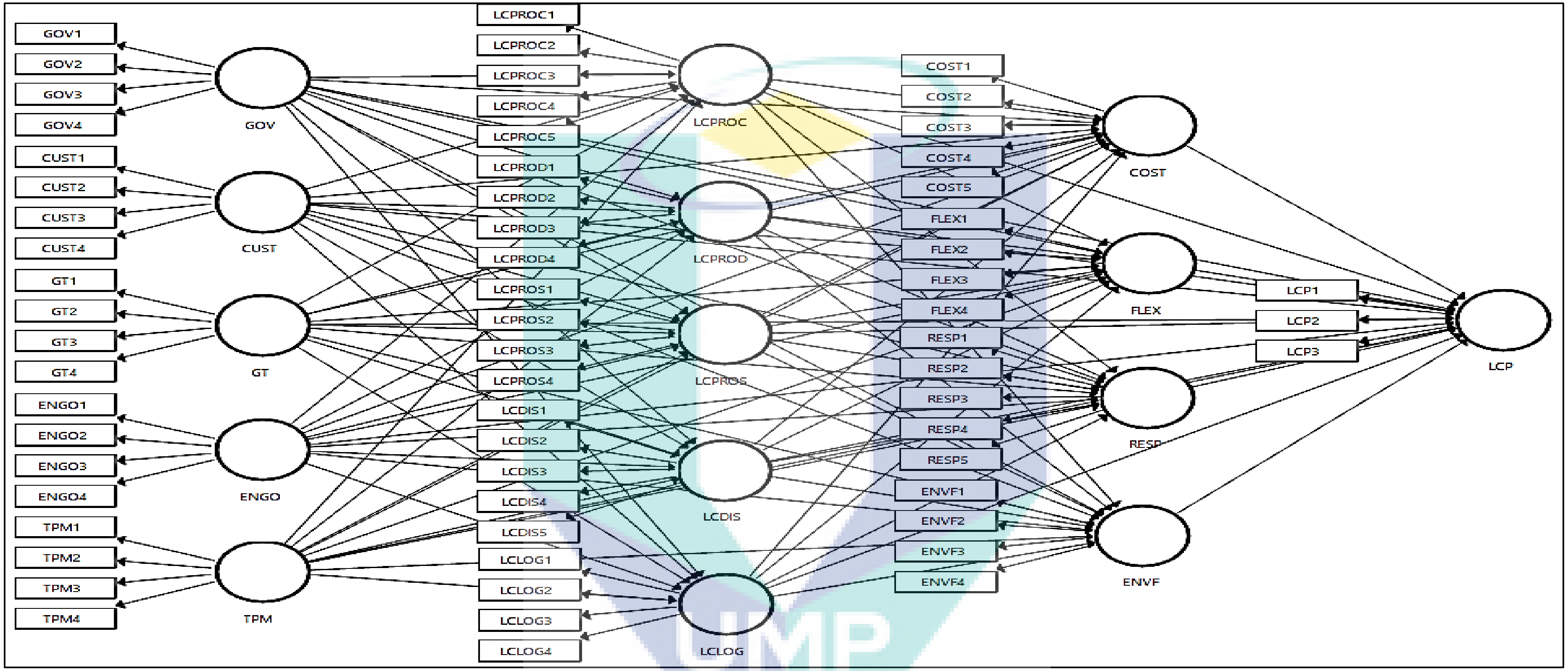


Figure 4.1 Theoretical model with SmartPLS

### 4.4.1 Convergent Validity and Reliability

Convergent validity is measured on loadings, CR and AVE (Hair et al., 2017). The value for loadings and AVE should be 0.5 and above while for CR the value should be more than 0.7. Based on Table 4.8 and Figure 4.2, the value for loadings were above 0.5. Thus, all item loadings met the acceptable value. Loadings higher than 0.5 means that the item or survey question was reliable as an indicator for construct. For example, all loading items for low carbon procurement were above 0.9. Thus, it shows that each survey question or item provide understanding for low carbon procurement. Since all loading values were above 0.5, all items were retained.

The next value that is needed to establish convergent validity and reliability is AVE. The minimum value to show importance of the construct is to achieve AVE value 0.5 and above. Based on the results shown in Table 4.8, all AVE value was above 0.5. Therefore, all construct was valid and reliable in the theoretical model. Only green technology construct has the lowest AVE score of 0.586. This is due to item TPM2 that has the lowest loading but acceptable value among all loadings. According to Hair et al. (2017), item loading score has an impact on the construct value. Nevertheless, top management support construct is retained as it met the requirement.

Another criterion for convergent validity and reliability is CR. The acceptable value for explanatory study is CR above 0.7 (Hair et al., 2017). Based on Table 4.8, CR values were all above 0.7. It shows that the theoretical model is reliable to explain LCSC practices to achieve LCP. This is contributed to the development of theoretical model that has been tested and revised through preliminary test and pilot test. During pilot test, this model achieved significant result based on CA. While CA took the minimum reliability value, CR value is more stringent and took the highest value. Therefore, based on loadings, AVE and CR scores, this study has established good convergent validity and reliability.

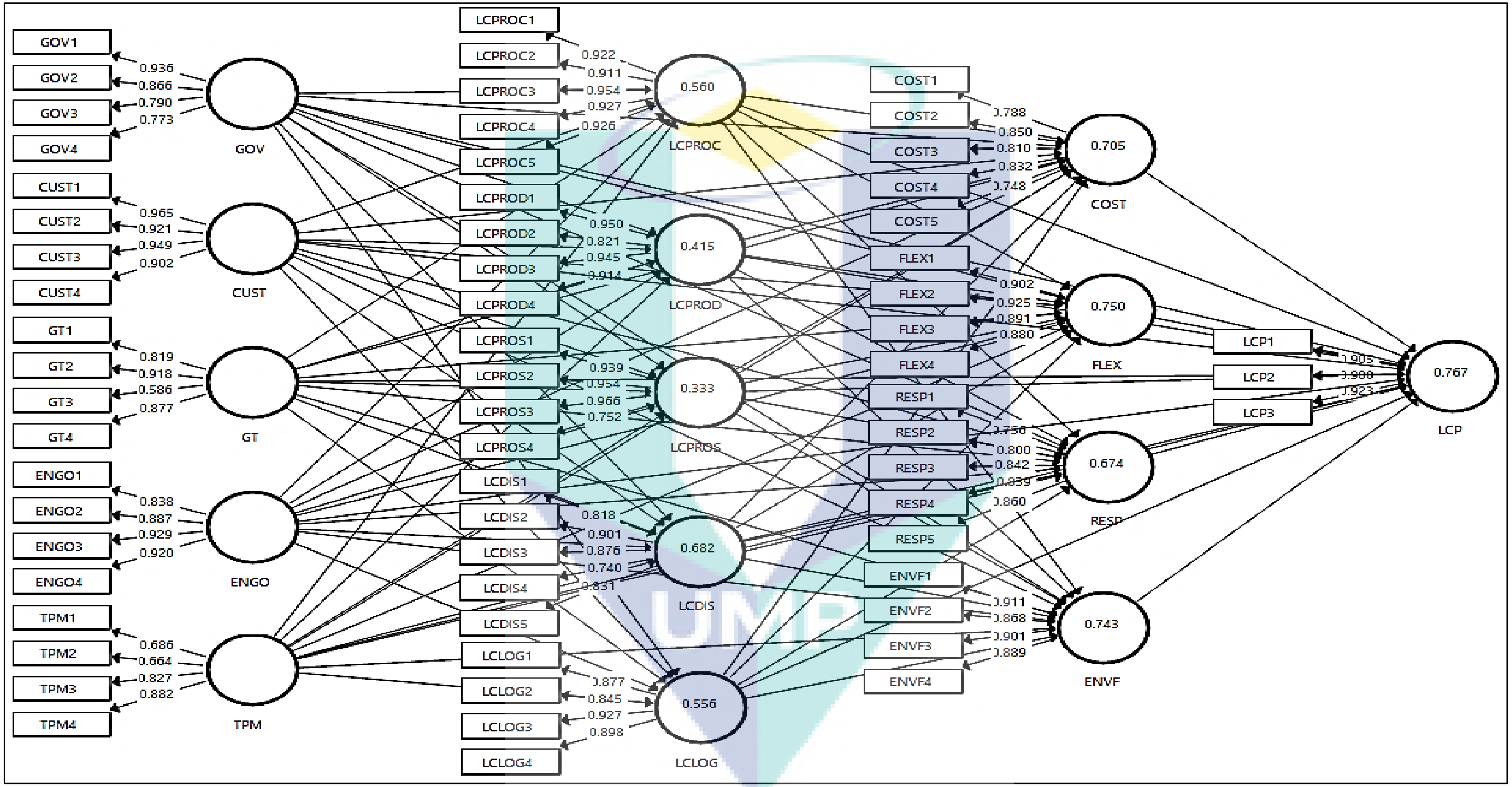


Figure 4.2 Structured model with SmartPLS

Table 4.8 Convergent validity

| Construct | Item | Loadings | CR | AVE | $R^2$ | $f^2$ | $Q^2$ |
|---|---|---|---|---|---|---|---|
| Governmental Regulation | GOV1 | 0.936 | 0.907 | 0.711 | | 0.003 | |
| | GOV2 | 0.866 | | | | | |
| | GOV3 | 0.790 | | | | | |
| | GOV4 | 0.773 | | | | | |
| Customer Pressure | CUST1 | 0.965 | 0.965 | 0.873 | | 0.042 | |
| | CUST2 | 0.921 | | | | | |
| | CUST3 | 0.949 | | | | | |
| | CUST4 | 0.902 | | | | | |
| Environmental NGO | ENGO1 | 0.838 | 0.941 | 0.800 | | 0.008 | |
| | ENGO2 | 0.887 | | | | | |
| | ENGO3 | 0.929 | | | | | |
| | ENGO4 | 0.920 | | | | | |
| Green Technology | GT1 | 0.819 | 0.852 | 0.593 | | 0.001 | |
| | GT2 | 0.918 | | | | | |
| | GT3 | 0.586 | | | | | |
| | GT4 | 0.877 | | | | | |
| Top Management Support | TPM1 | 0.686 | 0.854 | 0.595 | | 0.008 | |
| | TPM2 | 0.664 | | | | | |
| | TPM3 | 0.827 | | | | | |
| | TPM4 | 0.882 | | | | | |
| Low Carbon Procurement | LCPROC1 | 0.922 | 0.969 | 0.861 | 0.560 | 0.023 | 0.445 |
| | LCPROC2 | 0.911 | | | | | |
| | LCPROC3 | 0.954 | | | | | |
| | LCPROC4 | 0.927 | | | | | |
| | LCPROC5 | 0.926 | | | | | |
| Low Carbon Product | LCPROD1 | 0.950 | 0.950 | 0.827 | 0.415 | 0.027 | 0.311 |
| | LCPROD2 | 0.821 | | | | | |
| | LCPROD3 | 0.945 | | | | | |
| | LCPROD4 | 0.914 | | | | | |
| Low Carbon Production Process | LCPROS1 | 0.939 | 0.948 | 0.823 | 0.333 | 0.013 | 0.246 |
| | LCPROS2 | 0.954 | | | | | |
| | LCPROS3 | 0.966 | | | | | |
| | LCPROS4 | 0.752 | | | | | |
| Low Carbon Distribution | LCDIS1 | 0.818 | 0.920 | 0.697 | 0.682 | 0.096 | 0.439 |
| | LCDIS2 | 0.901 | | | | | |
| | LCDIS3 | 0.876 | | | | | |
| | LCDIS4 | 0.740 | | | | | |
| | LCDIS5 | 0.831 | | | | | |
| Low Carbon Logistics | LCLOG1 | 0.877 | 0.937 | 0.787 | 0.556 | 0.060 | 0.400 |
| | LCLOG2 | 0.845 | | | | | |
| | LCLOG3 | 0.927 | | | | | |
| | LCLOG4 | 0.898 | | | | | |

Table 4.8 Continued

| Construct | Item | Loadings | CR | AVE | R2 | f2 | Q2 |
|---|---|---|---|---|---|---|---|
| Cost Reduction | COST1 | 0.788 | 0.903 | 0.650 | 0.705 | 0.027 | 0.418 |
| | COST2 | 0.850 | | | | | |
| | COST3 | 0.810 | | | | | |
| | COST4 | 0.832 | | | | | |
| | COST5 | 0.748 | | | | | |
| Flexibility | FLEX1 | 0.902 | 0.944 | 0.809 | 0.750 | 0.057 | 0.554 |
| | FLEX2 | 0.925 | | | | | |
| | FLEX3 | 0.891 | | | | | |
| | FLEX4 | 0.880 | | | | | |
| Responsiveness | RESP1 | 0.756 | 0.911 | 0.673 | 0.674 | 0.068 | 0.410 |
| | RESP2 | 0.800 | | | | | |
| | RESP3 | 0.842 | | | | | |
| | RESP4 | 0.839 | | | | | |
| | RESP5 | 0.860 | | | | | |
| Environmental Friendliness | ENVF1 | 0.911 | 0.94 | 0.796 | 0.743 | 0.085 | 0.539 |
| | ENVF2 | 0.868 | | | | | |
| | ENVF3 | 0.901 | | | | | |
| | ENVF4 | 0.889 | | | | | |
| Low Carbon Performance | LCP1 | 0.905 | 0.935 | 0.827 | 0.767 | | 0.556 |
| | LCP2 | 0.900 | | | | | |
| | LCP3 | 0.923 | | | | | |

### 4.4.2 Discriminant Validity

Discriminant validity is measured through HTMT ratio (Henseler et al., 2015). The more stringent cut off value is 0.85 (Kline, 2015) while the more conservative value is 0.90 (Gold et al., 2001). Table 4.9 shows that the value for discriminant validity through HTMT test were lower than 0.85 value. This shows that all construct questions were different and were not interchangeable in its meaning. For example, with a score lower than 0.85 or 0.90, it shows that each construct is unique and has no overlap in definition or understanding. Based on the result, top management support construct questions were almost similar to low carbon performance, but the similarities did not affect the validity as the value is at 0.85. Therefore, discriminant validity is established for the model. Based on convergent validity and discriminant validity results, the theoretical model investigating LCSC practices to achieve LCP is valid and reliable.

Table 4.9 Heterotrait-Monotrait (HTMT) ratio

| Construct | COST | CUST | ENGO | ENVF | FLEX | GOV | GT | LCDIS | LCLOG | LCP | LCPROC | LCPROD | LCPROS | RESP | TPM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| COST | | | | | | | | | | | | | | | |
| CUST | 0.838 | | | | | | | | | | | | | | |
| ENGO | 0.496 | 0.495 | | | | | | | | | | | | | |
| ENVF | 0.659 | 0.538 | 0.357 | | | | | | | | | | | | |
| FLEX | 0.518 | 0.396 | 0.231 | 0.812 | | | | | | | | | | | |
| GOV | 0.285 | 0.250 | 0.508 | 0.241 | 0.192 | | | | | | | | | | |
| GT | 0.506 | 0.438 | 0.504 | 0.572 | 0.671 | 0.447 | | | | | | | | | |
| LCDIS | 0.764 | 0.635 | 0.615 | 0.615 | 0.635 | 0.356 | 0.746 | | | | | | | | |
| LCLOG | 0.658 | 0.632 | 0.563 | 0.589 | 0.529 | 0.221 | 0.542 | 0.684 | | | | | | | |
| LCP | 0.707 | 0.475 | 0.433 | 0.846 | 0.781 | 0.356 | 0.647 | 0.741 | 0.476 | | | | | | |
| LCPROC | 0.593 | 0.594 | 0.502 | 0.612 | 0.636 | 0.234 | 0.573 | 0.784 | 0.716 | 0.564 | | | | | |
| LCPROD | 0.279 | 0.232 | 0.290 | 0.798 | 0.744 | 0.242 | 0.531 | 0.401 | 0.391 | 0.644 | 0.458 | | | | |
| LCPROS | 0.477 | 0.549 | 0.452 | 0.371 | 0.340 | 0.269 | 0.404 | 0.441 | 0.597 | 0.309 | 0.427 | 0.214 | | | |
| RESP | 0.838 | 0.687 | 0.535 | 0.837 | 0.730 | 0.351 | 0.613 | 0.810 | 0.719 | 0.844 | 0.668 | 0.568 | 0.472 | | |
| TPM | 0.736 | 0.64 | 0.623 | 0.842 | 0.845 | 0.471 | 0.788 | 0.832 | 0.777 | 0.850 | 0.785 | 0.686 | 0.481 | 0.843 | |

## 4.5 Structural Measurement

Structural measurement is an analysis of hypothesis developed from theoretical model. In addition, specific indirect effect was also analysed as there is mediating effect hypothesized by this study. In order to test structural model of this study, Bootstrapping procedure using SmartPLS software version 3.2.8 was used. The procedure will produce t-value and p-value for direct effect and indirect effect. The direct effect is to measure direct hypothesis and the cut off value for direct effect one-tail t-value is 1.645 while for indirect effect the cut off value for mediating effect is 1.965.

The result for direct effect of the hypothesis will be presented first. There were 78 hypotheses ranging from determinants of LCSC, LCSC practices, GSCOP and LCP. Each direct effect path was presented with its standard beta (denote as ß - path coefficient), t-value and p-value. In addition, as depicted in Table 4.8, $R^2$, $f^2$ and $Q^2$ will also be reported with each hypothesis. The reason for $R^2$, $f^2$ and $Q^2$ being used for structural reporting altogether with hypothesis is because $R^2$, $f^2$ and $Q^2$ help to show statistical significance if the path achieves acceptable value. This is because $R^2$ of 0.75, 0.50 and 0.25 are considered as substantial, moderate and weak (Hair et al., 2017). $f^2$ value of 0.02 is consider as weak effect, 0.13 is consider as moderate effect and 0.26 is consider as substantial effect (Cohen, 1988) while $Q^2$ value larger than 0 means the predictive variable is relevant to LCP (Figure 4.3). For example, for predictor variable of environmental friendliness, the effect it has on LCP was 74 percent ($R^2$ = 0.743). The strength of environmental friendliness as a predictor for LCP was acceptable ($f^2$ = 0.085), and there was predictive relevancy of environmental friendliness as predictor to LCP ($Q^2$ = 0.538). Thus, comparing with environmental friendliness t-value and p-value will provide a statistically significant path for hypothesis. Table 4.9 shows path coefficient of hypothesis.

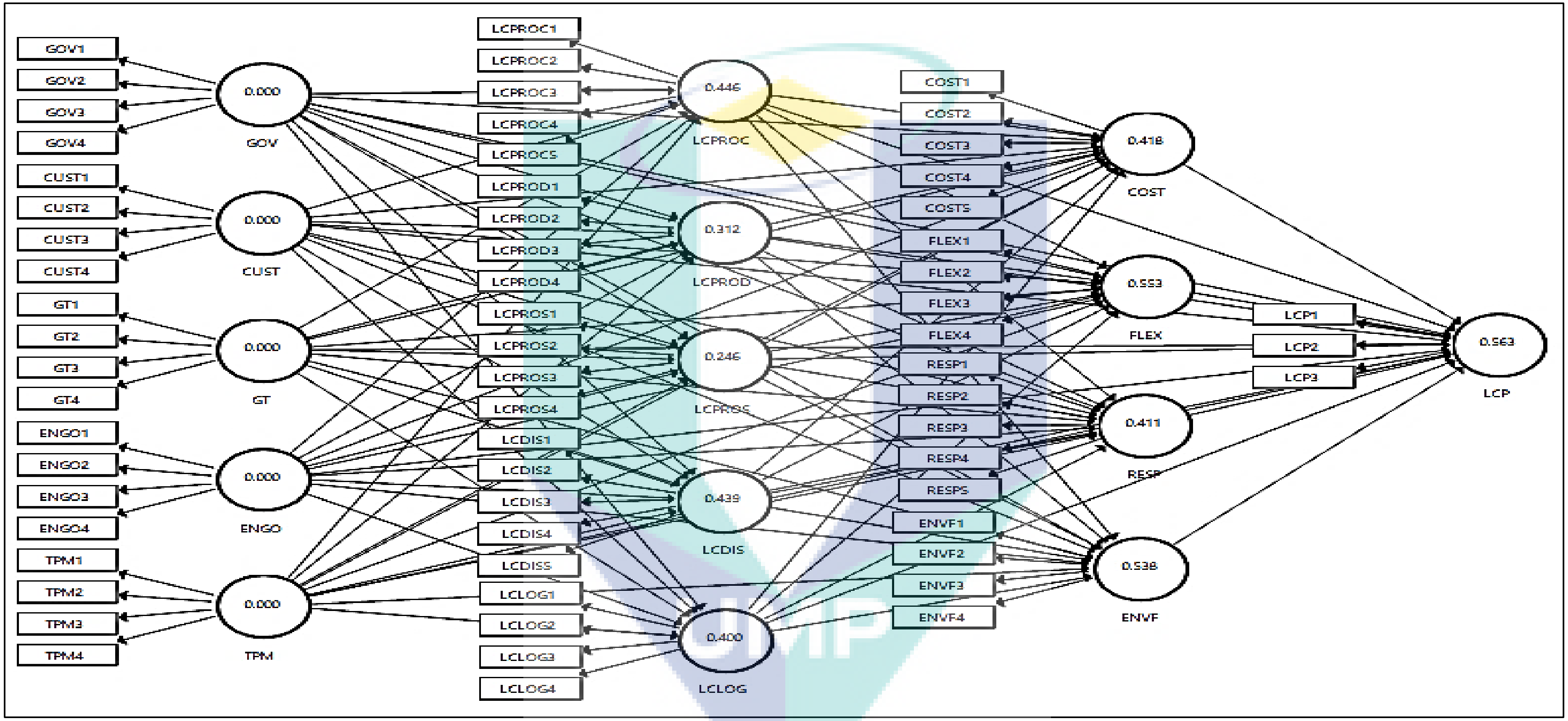


Figure 4.3 Predictive relevance with SmartPLS (blindfolding)

Table 4.10 Hypothesis testing (path coefficients)

| Hypothesis | Path | Std Beta | Std Error | t-value | p-value | Confidence Interval Bias Corrected |  | Decision |
|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  | 5.00% | 95.00% |  |
| H1a | Government Regulation -> Low Carbon Procurement | 0.127 | 0.067 | 1.904 | 0.029 | 0.017 | 0.239 | Accept |
| H1b | Government Regulation -> Low Carbon Product | -0.038 | 0.080 | 0.481 | 0.316 | -0.158 | 0.095 | Reject |
| H1c | Government Regulation -> Low Carbon Production Process | 0.090 | 0.044 | 2.023 | 0.022 | 0.011 | 0.155 | Accept |
| H1d | Government Regulation -> Low Carbon Distribution | 0.125 | 0.062 | 2.019 | 0.022 | 0.209 | 0.005 | Accept |
| H1e | Government Regulation -> Low Carbon Logistics | 0.180 | 0.073 | 2.472 | 0.007 | 0.293 | 0.054 | Accept |
| H2a | Customer Pressure -> Low Carbon Procurement | 0.211 | 0.049 | 4.316 | p<0.001 | 0.124 | 0.284 | Accept |
| H2b | Customer Pressure -> Low Carbon Product | 0.173 | 0.067 | 2.604 | 0.005 | 0.063 | 0.284 | Accept |
| H2c | Customer Pressure -> Low Carbon Production Process | 0.337 | 0.056 | 5.985 | p<0.001 | 0.238 | 0.431 | Accept |
| H2d | Customer Pressure -> Low Carbon Distribution | 0.218 | 0.047 | 4.674 | p<0.001 | 0.143 | 0.295 | Accept |
| H2e | Customer Pressure -> Low Carbon Logistics | 0.280 | 0.065 | 4.325 | p<0.001 | 0.156 | 0.377 | Accept |
| H3a | Environmental NGO -> Low Carbon Procurement | -0.032 | 0.066 | 0.481 | 0.315 | -0.138 | 0.079 | Reject |
| H3b | Environmental NGO -> Low Carbon Product | 0.147 | 0.087 | 1.692 | 0.046 | 0.006 | 0.287 | Accept |
| H3c | Environmental NGO -> Low Carbon Production Process | 0.262 | 0.054 | 4.819 | p<0.001 | 0.178 | 0.353 | Accept |
| H3d | Environmental NGO -> Low Carbon Distribution | 0.326 | 0.057 | 5.766 | p<0.001 | 0.239 | 0.426 | Accept |
| H3e | Environmental NGO -> Low Carbon Logistics | 0.388 | 0.065 | 5.943 | p<0.001 | 0.278 | 0.485 | Accept |
| H4a | Green Technology -> Low Carbon Procurement | 0.748 | 0.059 | 12.662 | p<0.001 | 0.649 | 0.837 | Accept |
| H4b | Green Technology -> Low Carbon Product | 0.176 | 0.082 | 2.162 | 0.016 | 0.051 | 0.317 | Accept |
| H4c | Green Technology -> Low Carbon Production Process | 0.318 | 0.064 | 4.947 | p<0.001 | 0.208 | 0.418 | Accept |
| H4d | Green Technology -> Low Carbon Distribution | 0.347 | 0.057 | 6.115 | p<0.001 | 0.257 | 0.442 | Accept |

Table 4.10 Continued

| Hypothesis | Path | Std Beta | Std Error | t-value | p-value | Confidence Interval Bias Corrected | | Decision |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 5.00% | 95.00% | |
| H4e | Green Technology -> Low Carbon Logistics | 0.042 | 0.061 | 0.684 | 0.247 | -0.053 | 0.138 | Reject |
| H5a | Top Management -> Low Carbon Procurement | 0.121 | 0.059 | 2.056 | 0.020 | 0.210 | 0.022 | Accept |
| H5b | Top Management -> Low Carbon Product | 0.467 | 0.062 | 7.523 | p<0.001 | 0.369 | 0.570 | Accept |
| H5c | Top Management -> Low Carbon Production Process | 0.143 | 0.057 | 2.488 | 0.007 | 0.060 | 0.249 | Accept |
| H5d | Top Management -> Low Carbon Distribution | 0.314 | 0.058 | 5.371 | p<0.001 | 0.215 | 0.399 | Accept |
| H5e | Top Management -> Low Carbon Logistics | 0.360 | 0.056 | 6.489 | p<0.001 | 0.279 | 0.459 | Accept |
| H6ai | Low Carbon Procurement -> Cost Reduction | 0.189 | 0.101 | 1.880 | 0.030 | 0.039 | 0.37 | Accept |
| H6aii | Low Carbon Procurement -> Flexibility | 0.194 | 0.101 | 1.909 | 0.028 | 0.036 | 0.358 | Accept |
| H6aiii | Low Carbon Procurement -> Responsiveness | 0.156 | 0.083 | 1.889 | 0.030 | 0.023 | 0.287 | Accept |
| H6aiv | Low Carbon Procurement -> Environmental Friendliness | 0.028 | 0.093 | 0.299 | 0.382 | -0.139 | 0.176 | Reject |
| H6bi | Low Carbon Product -> Cost Reduction | 0.009 | 0.063 | 0.137 | 0.445 | -0.109 | 0.101 | Reject |
| H6bii | Low Carbon Product -> Flexibility | 0.520 | 0.045 | 11.605 | p<0.001 | 0.443 | 0.592 | Accept |
| H6biii | Low Carbon Product -> Responsiveness | 0.141 | 0.049 | 2.877 | 0.002 | 0.054 | 0.214 | Accept |
| H6biv | Low Carbon Product -> Environmental Friendliness | 0.260 | 0.081 | 3.228 | 0.001 | 0.116 | 0.376 | Accept |
| H6ci | Low Carbon Production Process -> Cost Reduction | 0.203 | 0.082 | 2.466 | 0.007 | 0.048 | 0.326 | Accept |
| H6cii | Low Carbon Production Process -> Flexibility | 0.003 | 0.062 | 0.045 | 0.482 | -0.087 | 0.112 | Reject |
| H6ciii | Low Carbon Production Process -> Responsiveness | 0.147 | 0.055 | 2.653 | 0.004 | 0.060 | 0.233 | Accept |
| H6civ | Low Carbon Production Process -> Environmental Friendliness | 0.121 | 0.066 | 1.835 | 0.034 | 0.012 | 0.226 | Accept |

Table 4.10 Continued

| Hypothesis | Path | Std Beta | Std Error | t-value | p-value | Confidence Interval Bias Corrected | | Decision |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 5.00% | 95.00% | |
| H6di | Low Carbon Distribution -> Cost Reduction | 0.309 | 0.090 | 3.415 | p<0.001 | 0.157 | 0.455 | Accept |
| H6dii | Low Carbon Distribution -> Flexibility | 0.184 | 0.091 | 2.018 | 0.022 | 0.015 | 0.327 | Accept |
| H6diii | Low Carbon Distribution -> Responsiveness | 0.381 | 0.057 | 6.637 | p<0.001 | 0.285 | 0.474 | Accept |
| H6div | Low Carbon Distribution -> Environmental Friendliness | 0.564 | 0.072 | 7.816 | p<0.001 | 0.447 | 0.673 | Accept |
| H6ei | Low Carbon Logistics -> Cost Reduction | 0.189 | 0.099 | 1.905 | 0.029 | 0.025 | 0.345 | Accept |
| H6eii | Low Carbon Logistics -> Flexibility | 0.060 | 0.087 | 0.688 | 0.246 | -0.079 | 0.206 | Reject |
| H6eiii | Low Carbon Logistics -> Responsiveness | 0.235 | 0.053 | 4.398 | p<0.001 | 0.122 | 0.304 | Accept |
| H6eiv | Low Carbon Logistics -> Environmental Friendliness | -0.035 | 0.077 | 0.450 | 0.327 | -0.161 | 0.092 | Reject |
| H7a | Cost Reduction -> Low Carbon Performance | 0.133 | 0.058 | 2.282 | 0.011 | 0.037 | 0.229 | Accept |
| H7b | Flexibility -> Low Carbon Performance | 0.247 | 0.070 | 3.505 | p<0.001 | 0.124 | 0.365 | Accept |
| H7c | Responsiveness -> Low Carbon Performance | 0.277 | 0.091 | 3.039 | 0.001 | 0.130 | 0.426 | Accept |
| H7d | Environmental Friendliness -> Low Carbon Performance | 0.300 | 0.087 | 3.442 | p<0.001 | 0.157 | 0.438 | Accept |
| H8ai | Government Regulation -> Cost Reduction | 0.225 | 0.083 | 2.694 | 0.004 | 0.372 | 0.094 | Accept |
| H8aii | Government Regulation -> Flexibility | 0.460 | 0.079 | 5.848 | p<0.001 | 0.329 | 0.583 | Accept |
| H8aiii | Government Regulation -> Responsiveness | -0.091 | 0.084 | 1.077 | 0.141 | -0.238 | 0.039 | Reject |
| H8aiv | Government Regulation -> Environmental Friendliness | 0.302 | 0.099 | 3.046 | 0.001 | 0.46 | 0.127 | Accept |
| H8bi | Customer Pressure -> Cost Reduction | 0.179 | 0.096 | 1.859 | 0.032 | 0.009 | 0.325 | Accept |
| H8bii | Customer Pressure -> Flexibility | 0.388 | 0.085 | 4.560 | p<0.001 | 0.248 | 0.521 | Accept |
| H8biii | Customer Pressure -> Responsiveness | 0.135 | 0.084 | 1.610 | 0.054 | 0.008 | 0.273 | Reject |
| H8biv | Customer Pressure -> Environmental Friendliness | 0.213 | 0.107 | 1.994 | 0.023 | 0.024 | 0.367 | Accept |

Table 4.10 Continued

| Hypothesis | Path | Std Beta | Std Error | t-value | p-value | Confidence Interval Bias Corrected | | Decision |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 5.00% | 95.00% | |
| H8ci | Environmental NGO -> Cost Reduction | 0.556 | 0.068 | 8.159 | p<0.001 | 0.418 | 0.663 | Accept |
| H8cii | Environmental NGO -> Flexibility | -0.003 | 0.081 | 0.036 | 0.486 | -0.123 | 0.139 | Reject |
| H8ciii | Environmental NGO -> Responsiveness | 0.041 | 0.080 | 0.511 | 0.305 | -0.084 | 0.185 | Reject |
| H8civ | Environmental NGO -> Environmental Friendliness | 0.379 | 0.084 | 4.521 | p<0.001 | 0.235 | 0.512 | Accept |
| H8di | Green Technology -> Cost Reduction | 0.084 | 0.070 | 1.203 | 0.115 | -0.015 | 0.209 | Reject |
| H8dii | Green Technology -> Flexibility | -0.012 | 0.055 | 0.225 | 0.411 | -0.110 | 0.062 | Reject |
| H8diii | Green Technology -> Responsiveness | 0.255 | 0.059 | 4.300 | p<0.001 | 0.162 | 0.360 | Accept |
| H8div | Green Technology -> Environmental Friendliness | 0.193 | 0.074 | 2.599 | 0.005 | 0.070 | 0.313 | Accept |
| H8ei | Top Management -> Cost Reduction | 0.105 | 0.084 | 1.255 | 0.105 | -0.055 | 0.229 | Reject |
| H8eii | Top Management -> Flexibility | 0.102 | 0.078 | 1.295 | 0.098 | -0.019 | 0.236 | Reject |
| H8eiii | Top Management -> Responsiveness | 0.611 | 0.077 | 7.896 | p<0.001 | 0.483 | 0.729 | Accept |
| H8eiv | Top Management -> Environmental Friendliness | 0.213 | 0.092 | 2.309 | 0.011 | 0.069 | 0.373 | Accept |

Table 4.10 Continued

| Hypothesis | Path | Std Beta | Std Error | t-value | p-value | Confidence Interval Bias Corrected | | Decision |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 5.00% | 95.00% | |
| H9a | Government Regulation -> Low Carbon Performance | 0.350 | 0.078 | 4.459 | p<0.001 | 0.211 | 0.463 | Accept |
| H9b | Customer Pressure -> Low Carbon Performance | 0.346 | 0.069 | 5.035 | p<0.001 | 0.248 | 0.466 | Accept |
| H9c | Environmental NGO -> Low Carbon Performance | 0.154 | 0.077 | 1.985 | 0.024 | 0.041 | 0.284 | Accept |
| H9d | Green Technology -> Low Carbon Performance | 0.109 | 0.063 | 1.728 | 0.042 | 0.216 | 0.016 | Accept |
| H9e | Top Management -> Low Carbon Performance | 0.188 | 0.065 | 2.905 | 0.002 | 0.097 | 0.305 | Accept |
| H10a | Low Carbon Procurement -> Low Carbon Performance | 0.150 | 0.103 | 1.455 | 0.073 | -0.015 | 0.306 | Reject |
| H10b | Low Carbon Product -> Low Carbon Performance | 0.189 | 0.058 | 3.261 | 0.001 | 0.098 | 0.297 | Accept |
| H10c | Low Carbon Production Process -> Low Carbon Performance | 0.119 | 0.077 | 1.553 | 0.061 | -0.017 | 0.241 | Reject |
| H10d | Low Carbon Distribution -> Low Carbon Performance | 0.225 | 0.097 | 2.313 | 0.011 | 0.060 | 0.372 | Accept |
| H10e | Low Carbon Logistics -> Low Carbon Performance | 0.248 | 0.105 | 2.374 | 0.009 | 0.063 | 0.409 | Accept |

### 4.5.1 Determinants of Low Carbon Supply Chain to Low Carbon Supply Chain Practices

Result of hypotheses are shown in Table 4.10 with evidence of t-value, p-value, $R^2$, $f^2$ and $Q^2$. This is following the guideline of Hair et al. (2017) on reporting for structural measurement. The first hypothesis is on government regulation to LCSC practices. H1a shows the relationship between government regulation and low carbon procurement. The result shows that H1a was positive and significant (ß - path coefficient = 0.127; t-value = 1.904). H1b predicts the relationship between government regulation and low carbon product. The finding shows that H1b was rejected (ß - path coefficient = -0.038; t-value = 0.481). H1c presents the relationship between government regulation and low carbon production process. The outcome shows that H1c was positive and significant (ß - path coefficient = 0.090; t-value = 2.023). H1d shows the relationship between government regulation and low carbon distribution. The result shows that H1d was positive and significant (ß - path coefficient = 0.125; t-value = 2.019). H1e predicts the relationship between government regulation and low carbon logistics. The finding shows that H1e was positive and significant (ß - path coefficient = 0.180; t-value = 2.472).

The second hypothesis is on customer pressure to LCSC practices. H2a presents the relationship between customer pressure and low carbon procurement. The outcome shows that H2a was positive and statistically significant (ß - path coefficient = 0.211; t-value = 4.316; p-value = <0.001). H2b shows the relationship between customer pressure and low carbon product. The result shows that H2b was positive and statistically significant (ß - path coefficient = 0.173; t-value = 2.604; p-value = 0.005). H2c predicts the relationship between customer pressure and low carbon production process. The finding shows that H2c was positive and statistically significant (ß - path coefficient = 0.337; t-value = 5.985; p-value = <0.001). H2d presents the relationship between customer pressure and low carbon distribution. The outcome of H2d shows positive and statistically significant effect (ß - path coefficient = 0.218; t-value = 4.674; p-value = <0.001). H2e shows the relationship between customer pressure and low carbon logistics. The result shows H2e was positive and statistically significant (ß - path coefficient = 0.280; t-value = 4.325; p-value = <0.001).

The third hypothesis is on environmental NGOs and LCSC practices. H3a predicts the relationship between environmental NGOs and low carbon procurement. The finding shows that H3a was rejected (ß - path coefficient = -0.032; t-value = 0.481). H3b presents the relationship between environmental NGOs and low carbon product. The outcome shows that H3b was positive and significant (ß - path coefficient = 0.147; t-value = 1.692). H3c shows the relationship between environmental NGOs and low carbon production process. The result shows that H3c was positive and statistically significant (ß - path coefficient = 0.262; t-value = 4.819; p-value = <0.001). H3d predicts the relationship between environmental NGOs and low carbon distribution. The finding shows that H3d was positive and statistically significant (ß - path coefficient = 0.326; t-value = 5.766; p-value = <0.001). H3e presents the relationship between environmental NGOs and low carbon logistics. The outcome shows that H3e was positive and statistically significant (ß - path coefficient = 0.388; t-value = 5.943; p-value = <0.001).

The fourth hypothesis is on green technology and LCSC practices. H4a shows the relationship between green technology and low carbon procurement. The result shows that H4a was positive and statistically significant (ß - path coefficient = 0.748; t-value = 12.662; p-value = <0.001). H4b predicts the relationship between green technology and low carbon product. The finding shows H4b was positive and significant (ß - path coefficient = 0.176; t-value = 2.162). H4c presents the relationship between green technology and low carbon production process. The outcome shows H4c was positive and statistically significant (ß - path coefficient = 0.318; t-value = 4.947; p-value = <0.001). H4d shows the relationship between green technology and low carbon distribution. The result shows H4d was positive and statistically significant (ß - path coefficient = 0.347; t-value = 6.115; p-value = <0.001). H4e predicts the relationship between green technology and low carbon logistics. The finding shows H4e was rejected (ß - path coefficient = 0.042; t-value = 0.684).

The fifth hypothesis is on top management support on LCSC practices. H5a presents the relationship between top management and low carbon procurement. The outcome shows H5a was positive and significant (ß - path coefficient = 0.121; t-value = 2.056). H5b shows the relationship between top management and low carbon product. The result shows H5b was positive and statistically significant (ß - path coefficient = 0.467; t-value = 7.523; p-value = <0.001). H5c predicts the relationship between top management and low carbon production process. The finding shows that H5c was positive and significant (ß - path coefficient = 0.143; t-value = 2.488). H5d presents the relationship between top management and low carbon distribution. The outcome shows that H5d was positive and statistically significant (ß - path coefficient = 0.314; t-value = 5.371; p-value = <0.001). H5e shows the relationship between top management and low carbon logistics. The result shows that H5e was positive and statistically significant (ß - path coefficient = 0.360; t-value = 6.489; p-value = <0.001).

### 4.5.2 Low Carbon Supply Chain Practices to Green Supply Chain Operational Performance

The hypotheses involved is between LCSC practices to operational performance of GSCOP. In the theoretical model, LCSC practices are independent variable and GSCOP is mediating variable. This section starts with independent variable low carbon procurement relationship on GSCOP. Based on Table 4.10, hypothesis H6ai predicts the relationship between low carbon procurement and cost reduction. The finding shows that H6ai was positive and significant (ß - path coefficient = 0.189; t-value = 1.880; $f^2$ = 0.02; $R^2$ = 0.705; $Q^2$ = 0.446). H6aii presents the relationship between low carbon procurement and flexibility. The outcome shows that H6aii was positive and significant (ß - path coefficient = 0.194; t-value = 1.909; $R^2$ = 0.750; $f^2$ = 0.23; $Q^2$ = 0.446). H6aiii shows the relationship between low carbon procurement and responsiveness. The result shows H6aiii was positive and significant (ß - path coefficient = 0.156; t-value = 1.889; $R^2$ = 0.674; $Q^2$ = 0.446). H6aiv predicts the relationship between low carbon procurement and environmental friendliness. The finding shows that H6aiv was rejected (ß - path coefficient = 0.028; t-value = 0.299). The contribution of low carbon procurement to accurately predicting GSCOP ($Q^2$ = 0.446) is evident.

The next independent variable is low carbon product and its relationship on GSCOP. Based on Table 4.10, hypothesis H6bi presents the relationship between low carbon product and cost reduction. The outcome shows H6bi was rejected (ß - path coefficient = 0.009; t-value = 0.137). H6bii shows the relationship between low carbon product and flexibility. The result shows that H6bii was positive and statistically significant (ß - path coefficient = 0.520; t-value = 11.605; p-value = <0.001; $R^2$ = 0.750; $f^2$ = 0.224; $Q^2$ = 0.312). H6biii predicts the relationship between low carbon product and responsiveness. The finding shows that H6biii was positive and statistically significant (ß - path coefficient = 0.141; t-value = 2.877; p-value = 0.002; $R^2$ = 0.674; $f^2$ = 0.085; $Q^2$ = 0.312). H6biv presents the relationship between low carbon product and environmental friendliness. The outcome shows that H6biv was positive and statistically significant (ß -

path coefficient = 0.260; t-value = 3.228; p-value = <0.001; $R^2$ = 0.743; $f^2$ = 0.492; $Q^2$ = 0.312). There is predictive relevance of low carbon product to GSCOP ($Q^2$ = 0.312).

The next independent variable is low carbon production process and its relationship with GSCOP. As shown in Table 4.10, hypothesis H6ci shows the relationship between low carbon production and cost reduction. The result shows that H6ci was positive and significant (ß - path coefficient = 0.203; t-value = 2.466; $R^2$ = 0.705; $Q^2$ = 0.246). H6cii predicts the relationship between low carbon production process and flexibility. The finding shows that H6cii was rejected (ß - path coefficient = 0.003; t-value = 0.045). H6ciii presents the relationship between low carbon production process and responsiveness. The outcome shows H6ciii was positive and statistically significant (ß - path coefficient = 0.147; t-value = 2.653; p-value = 0.004; $R^2$ = 0.674; $Q^2$ = 0.246). H6civ shows the relationship between low carbon production process and environmental friendliness. The result shows H6civ was positive and significant (ß - path coefficient = 0.121; t-value = 1.835; $R^2$ = 0.743; $Q^2$ = 0.246). Low carbon product shown that it has no effect ($f^2$ = <0.02) but relevant to prediction of GSCOP ($Q^2$ = 0.246).

Another independent variable of LCSC practices is low carbon distribution and its relationship with GSCOP. Table 4.10 shows the relationship between H6di of low carbon distribution and cost reduction. The result shows H6di was positive and statistically significant (ß - path coefficient = 0.309; t-value = 3.415; p-value = <0.001; $R^2$ = 0.705; $f^2$ = 0.081; $Q^2$ = 0.439). H6dii predicts the relationship between low carbon distribution and flexibility. Finding shows that H6dii was positive and significant (ß - path coefficient = 0.184; t-value = 2.018; $R^2$ = 0.750; $Q^2$ = 0.439). H6diii presents the relationship between low carbon distribution and responsiveness. The outcome shows H6diii was positive and statistically significant (ß - path coefficient = 0.381; t-value = 6.637; p-value = <0.001; $R^2$ = 0.674; $f^2$ = 0.096; $Q^2$ = 0.439). H6div shows the relationship between low carbon distribution and environmental friendliness. The result shows that H6div was positive and statistically significant (ß - path coefficient = 0.564; t-value = 7.816; p-value = <0.001; $R^2$ = 0.743; $Q^2$ = 0.439). Low carbon distribution relationship predictive relevance is significantly high ($Q^2$ = 0.439).

Additionally, independent variable low carbon logistics also its relationship with GSCOP has been tested. H6ei predicts the relationship between low carbon logistics and cost reduction. The finding shows that H6ei was positive and significant (ß - path coefficient = 0.189; t-value = 1.905; $R^2$ = 0.705; $Q^2$ = 0.400). H6eii presents the relationship between low carbon logistics and flexibility. The outcome shows that H6eii was rejected (ß - path coefficient = 0.060; t-value = 0.688). H6eiii shows the relationship between low carbon logistics and responsiveness. The result shows that H6eiii was positive and statistically significant (ß - path coefficient = 0.235; t-value = 4.398; p-value = <0.001; $R^2$ = 0.674; $f^2$ = 0.040; $Q^2$ = 0.400). H6eiv predicts the relationship between low carbon logistics and environmental friendliness. The finding shows that H6eiv was rejected (ß - path coefficient = -0.035; t-value = 0.450). Low carbon logistics has positive and significant impact to GSCOP. Low carbon logistics has acceptable predictive relevancy ($Q^2$ = 0.400).

### 4.5.3 Green Supply Chain Operational Performance to Low Carbon Performance

This study hypothesized the relationship between operational performance GSCOP and environmental performance of LCP. H7a presents the relationship between cost reduction of GSCOP and low carbon performance. The outcome shows H7a is positive and significant (ß - path coefficient = 0.133; t-value = 2.282; $R^2$ = 0.767; $f^2$ = 0.027; $Q^2$ = 0.418). H7b shows the relationship between flexibility and low carbon performance. The result shows H7b is positive and statistically significant (ß - path coefficient = 0.247; t-value = 3.505; p-value = <0.001; $R^2$ = 0.767; $f^2$ = 0.057; $Q^2$ = 0.553). H7c predicts the relationship between responsiveness and low carbon performance. The finding shows that H7c is positive and statistically significant (ß - path coefficient = 0.277; t-value = 3.039; p-value = 0.001; $R^2$ = 0.767; $f^2$ = 0.068; $Q^2$ = 0.411). H7d predicts the relationship between environmental friendliness and low carbon performance. The outcome shows that H7d is positive and statistically significant (ß - path coefficient = 0.300; t-value = 3.442; p-value = <0.001; $R^2$ = 0.767; $f^2$ = 0.085; $Q^2$ = 0.538). Overall, Table 4.10, shows that GSCOP has positive and significant relationship with LCP.

### 4.5.4 Determinants of Low Carbon Supply Chain to Green Supply Chain Operational Performance

This study postulated that determinants of LCSC practices has positive and significant effect on manufacturing firm's operational performance. H8ai shows the relationship between government regulation and cost reduction. The result shows H8ai is positive and statistically significant (ß - path coefficient = 0.225; t-value = 2.694; p-value = 0.004;). H8aii predicts the relationship between government regulation and flexibility. The finding shows that H8aii is positive and statistically significant (ß - path coefficient = 0.460; t-value = 5.848; p-value = <0.001; $f^2$ = 0.036). H8aiii presents the relationship between government regulation and responsiveness. The outcome shows that H8aiii is rejected (ß - path coefficient = -0.091; t-value = 1.077). H8aiv shows the relationship between government regulation and environmental friendliness. The result shows H8aiv is positive and statistically significant (ß - path coefficient = 0.302; t-value = 3.046; p-value = 0.001).

This study also investigates the relationship between customer pressure and GSCOP. Based on H8bi, the finding shows that the hypothesis is positive and significant (ß - path coefficient = 0.179; t-value = 1.859; $f^2$ = 0.575). H8bii presents the relationship between customer pressure and flexibility. The outcome shows that H8bii is positive and statistically significant (ß - path coefficient = 0.388; t-value = 4.560; p-value = <0.001). H8biii shows the relationship between customer pressure and responsiveness. The result shows that H8biii is rejected (ß - path coefficient = 0.135; t-value = 1.610; $f^2$ = 0.093). H8biv predicts the relationship between customer pressure and environmental friendliness. The finding shows that H8biv has positive and significant effect (ß - path coefficient = 0.213; t-value = 1.994; $f^2$ = 0.081).

On the other hand, environmental NGOs relationship with cost reduction was investigated under hypothesis H8ci. The finding shows that H8Ci is positive and statistically significant (ß - path coefficient = 0.556; t-value = 8.159; p-value = <0.001). However, H8cii relationship between environmental NGOs and flexibility is rejected (ß - path coefficient = -0.003; t-value = 0.036). In addition, hypothesis H8ciii between environmental NGOs and responsiveness is also rejected (ß - path coefficient = 0.041; t-value = 0.511). Nevertheless, for hypothesis 8civ between environmental NGOs and environmental friendliness is positive and statistically significant (ß - path coefficient = 0.379; t-value = 4.521; p-value = <0.001).

Green technology was hypothesized as driver for GSCOP. H8di shows the relationship between green technology and cost reduction. The result shows that H8di is rejected (ß - path coefficient = 0.084; t-value = 1.203). Another hypothesis H8dii predicts the relationship between green technology and flexibility. However, the finding shows that H8dii is rejected as well (ß - path coefficient = -0.012; t-value = 0.225). H8diii presents the relationship between green technology and responsiveness. The outcome shows that H8diii is positive and statistically significant (ß - path coefficient = 0.255; t-value = 4.300; p-value = <0.001). H8div shows the relationship between green technology and environmental friendliness. The result shows that H8div is positive and statistically significant (ß - path coefficient = 0.193; t-value = 2.599; p-value = 0.005).

Top management support was postulated to have positive and significant relationship with GSCOP. Nevertheless, based on Table 4.10, relationship between top management and cost reduction for H8ei is rejected (ß - path coefficient = 0.105; t-value = 1.255). Furthermore, the relationship between top management and flexibility for H8eii is also rejected (ß - path coefficient = 0.102; t-value = 1.295). H8eiii predicts the relationship between top management and responsiveness. The finding shows that H8eiii has positive and statistically significant effect on GSCOP (ß - path coefficient = 0.611; t-value = 7.896; p-value = <0.001). H8eiv presents the relationship between top management and environmental friendliness. The outcome shows that H8eiv is positive and significant (ß - path coefficient = 0.213; t-value = 2.309; $f^2$ = 0.144).

### 4.5.5 Determinants of Low Carbon Supply Chain on Low Carbon Performance

This study objective is to help achieve LCP especially for manufacturing firms. Therefore, a systematic review of the literature on drivers for manufacturing firms to achieve LCP was done. Furthermore, this study also investigates the relationship between determinants of LCSC and LCP. H9a shows the relationship between government regulation and low carbon performance. The result shows that H9a has positive and statistically significant to LCP (ß - path coefficient = 0.350; t-value = 4.459; p-value = <0.001). H9b predicts the relationship between customer pressure and low carbon performance. The finding shows that H9b is positive and statistically significant (ß - path coefficient = 0.346; t-value = 5.035; p-value = <0.001; $f^2$ = 0.042). H9c presents the relationship between environmental NGOs and low carbon performance. The outcome shows that H9c is positive and significant (ß - path coefficient = 0.154; t-value = 1.985). H9d shows the relationship between green technology and low carbon performance. The result shows that H9c is positive and significant (ß - path coefficient = 0.109; t-value = 1.728). H9e predicts the relationship between top management and low carbon performance. The finding shows that H9e is positive and statistically significant (ß - path coefficient = 0.188; t-value = 2.905; p-value = 0.002). Thus, it proves that determinants underlined in this study contributes to LCP.

### 4.5.6 Low Carbon Supply Chain Practices to Low Carbon Performance

This study hypothesized that manufacturing firms that practice LCSC will be able to achieve LCP. H10a presents the relationship between low carbon procurement and low carbon performance. The outcome shows that H10a is rejected (ß - path coefficient = 0.150; t-value = 1.455). H10b shows the relationship between low carbon product and low carbon performance. The result shows that H10b is positive and statistically significant (ß - path coefficient = 0.189; t-value = 3.261; p-value = 0.001; $R^2$ = 0.767; $Q^2$ = 0.445). H10c shows the relationship between low carbon production process and low carbon performance. The result shows that H10c is rejected (ß - path coefficient = 0.119; t-value = 1.553). H10d predicts the relationship between low carbon distribution and low carbon performance. The finding shows that H10d is positive and significant (ß - path coefficient = 0.225; t-value = 2.313; $R^2$ = 0.767; $Q^2$ = 0.445). H10e presents the relationship between low carbon logistics and low carbon performance. The outcome shows that H10e is positive and significant (ß - path coefficient = 0.248; t-value = 2.374; $R^2$ = 0.767; $Q^2$ = 0.445). The overall finding shows that LCSC practices influences LCP except low carbon procurement and low carbon production process.

### 4.5.7 Mediating Effect of Green Supply Chain Operational Performance on Low Carbon Supply Chain Practices and Low Carbon Performance

There are 20 hypotheses for mediating effect of GSCOP on the relationship of LCSC practices and LCP. Table 4.11 shows the result of indirect effect path coefficient from SmartPLS Bootstrapping procedure. In order to accept or reject the hypothesis, a two-tailed 95 confidence level value of 1.965 was used. This is because mediating effect has two possibilities either supporting or no effect on the relationship. For GSCOP, this study will investigate whether cost reduction, flexibility, responsiveness and environmental friendliness mediates the relationship between LCSC practices of low carbon procurement, low carbon product, low carbon production process, low carbon distribution and low carbon logistics on low carbon performance

Table 4.11 Specific indirect effect (path coefficient)

| Hypothesis | Path | Std Beta | Std Error | t-value | p-value | Confidence Interval Bias Corrected 5.00 % | 95.00 % | Decision |
|---|---|---|---|---|---|---|---|---|
| H11ai | Low Carbon Procurement -> Cost Reduction -> Low Carbon Performance | 0.026 | 0.019 | 1.384 | 0.083 | 0.002 | 0.063 | Reject |
| H11aii | Low Carbon Procurement -> Flexibility -> Low Carbon Performance | 0.115 | 0.039 | 2.953 | 0.002 | 0.062 | 0.190 | Accept |
| H11aiii | Low Carbon Procurement -> Responsiveness -> Low Carbon Performance | 0.054 | 0.025 | 2.166 | 0.015 | 0.023 | 0.113 | Accept |
| H11aiv | Low Carbon Procurement -> Environmental Friendliness -> Low Carbon Performance | 0.101 | 0.040 | 2.489 | 0.007 | 0.044 | 0.182 | Accept |
| H11bi | Low Carbon Product -> Cost Reduction -> Low Carbon Performance | 0.011 | 0.012 | 0.922 | 0.179 | -0.005 | 0.035 | Reject |
| H11bii | Low Carbon Product -> Flexibility -> Low Carbon Performance | -0.009 | 0.022 | 0.407 | 0.342 | -0.048 | 0.020 | Reject |
| H11biii | Low Carbon Product -> Responsiveness -> Low Carbon Performance | 0.013 | 0.020 | 0.613 | 0.270 | -0.019 | 0.048 | Reject |
| H11biv | Low Carbon Product -> Environmental Friendliness -> Low Carbon Performance | 0.004 | 0.026 | 0.161 | 0.436 | -0.037 | 0.048 | Reject |
| H11ci | Low Carbon Production -> Cost Reduction -> Low Carbon Performance | 0.123 | 0.048 | 2.529 | 0.006 | 0.053 | 0.214 | Accept |
| H11cii | Low Carbon Production -> Flexibility -> Low Carbon Performance | 0.022 | 0.026 | 0.831 | 0.203 | -0.011 | 0.072 | Reject |
| H11ciii | Low Carbon Production -> Responsiveness -> Low Carbon Performance | 0.096 | 0.034 | 2.831 | 0.002 | 0.050 | 0.162 | Accept |
| H11civ | Low Carbon Production -> Environmental Friendliness -> Low Carbon Performance | 0.085 | 0.043 | 1.997 | 0.023 | 0.027 | 0.167 | Accept |

Table 4.11 Specific indirect effect (path coefficient)

| Hypothesis | Path | Std Beta | Std Error | t-value | p-value | Confidence Interval Bias Corrected 5.00 % | 95.00 % | Decision |
|---|---|---|---|---|---|---|---|---|
| H11di | Low Carbon Distribution -> Cost Reduction -> Low Carbon Performance | -0.010 | 0.018 | 0.571 | 0.284 | -0.047 | 0.014 | Reject |
| H11dii | Low Carbon Distribution -> Flexibility -> Low Carbon Performance | 0.071 | 0.029 | 2.454 | 0.007 | 0.143 | 0.037 | Accept |
| H11diii | Low Carbon Distribution -> Responsiveness -> Low Carbon Performance | 0.017 | 0.026 | 0.638 | 0.262 | -0.016 | 0.068 | Reject |
| H11div | Low Carbon Distribution -> Environmental Friendliness -> Low Carbon Performance | -0.034 | 0.034 | 1.020 | 0.154 | -0.100 | 0.013 | Reject |
| H11ei | Low Carbon Logistics -> Cost Reduction -> Low Carbon Performance | 0.171 | 0.068 | 2.521 | 0.006 | 0.067 | 0.284 | Accept |
| H11eii | Low Carbon Logistics -> Flexibility -> Low Carbon Performance | 0.132 | 0.042 | 3.167 | 0.001 | 0.074 | 0.203 | Accept |
| H11eiii | Low Carbon Logistics -> Responsiveness -> Low Carbon Performance | 0.073 | 0.029 | 2.464 | 0.007 | 0.034 | 0.127 | Accept |
| H11eiv | Low Carbon Logistics -> Environmental Friendliness -> Low Carbon Performance | 0.108 | 0.037 | 2.904 | 0.002 | 0.053 | 0.179 | Accept |

Hypothesis H11ai shows the mediating effect of cost reduction on low carbon procurement relationship with low carbon performance. The result shows that H11ai has no mediation effect on the relationship and thus rejected (ß - path coefficient = 0.026; t-value = 1.384). H11aii predicts the mediating effect of flexibility on low carbon procurement and low carbon performance. The finding shows that H11aii is positive and statistically significant (ß - path coefficient = 0.115; t-value = 2.953; p-value = 0.002; $Q^2$ = 0.553). H11aiii presents the mediating effect of responsiveness on low carbon procurement and low carbon performance. The outcome shows that H11aiii is positive and significant (ß - path coefficient = 0.054; t-value = 2.166; $Q^2$ = 0.411). H11aiv depicts the mediating effect of environmental friendliness on low carbon procurement and low carbon performance. The hypothesis H11aiv shows it is positive and significant (ß - path coefficient = 0.101; t-value = 2.489; $Q^2$ = 0.538).

H11bi shows the mediating effect of cost reduction on the relationship of low carbon product and low carbon performance. The result shows that H11bi is rejected (ß - path coefficient = 0.011; t-value = 0.922). Similarly, the mediating effect of flexibility on the relationship between low carbon product and low carbon performance is also rejected (ß - path coefficient = -0.009; t-value = 0.407). H11biii presents the mediating effect of responsiveness on low carbon product and low carbon performance. H11biii also found to be rejected (ß - path coefficient = 0.013; t-value = 0.613). H11biv depicts the mediating effect of environmental friendliness on the relationship of low carbon product and low carbon performance. The hypothesize shows that it is also rejected (ß - path coefficient = 0.004; t-value = 0.161). Based on the finding, it shows that GSCOP has no mediating effect on low carbon product relationship with low carbon performance.

On the other hand, cost reduction under hypothesis H11ci shows that there is a positive and significant effect on the relationship between low carbon production process and low carbon performance (ß - path coefficient = 0.123; t-value = 2.529; $Q^2$ = 0.418). H11cii predicts that flexibility mediates the relationship between low carbon production and low carbon performance. The finding shows that H11cii is rejected and has no mediating effect (ß - path coefficient = 0.022; t-value = 0.831). H11ciii presents that responsiveness mediates between low carbon production process and low carbon performance. The outcome shows that H11ciii is positive and statistically significant towards the relationship between low carbon production process and low carbon performance (ß - path coefficient = 0.096; t-value = 2.831; p-value = 0.002; $Q^2$ = 0.411).

H11civ shows the mediating effect of environmental friendliness on the relationship between low carbon production process and low carbon performance. The result shows that there is a mediating effect (ß - path coefficient = 0.085; t-value = 1.997; $Q^2$ = 0.538). Therefore, the result shows that there is a mediating effect of GSCOP on the relationship between low carbon production process and low carbon performance.

H11di posits the mediating effect of cost reduction on the relationship between low carbon distribution and low carbon performance. The hypothesis shows that H11di is rejected (ß - path coefficient = -0.010; t-value = 0.571). H11dii shows the mediating effect of flexibility on the relationship between low carbon distribution and low carbon performance. The result shows that H11dii is positive and significant (ß - path coefficient = 0.071; t-value = 2.454; $Q^2$ = 0.553). H11diii predicts the mediating effect of responsiveness on the relationship between low carbon distribution and low carbon performance. The finding shows that H11diii is rejected (ß - path coefficient = 0.017; t-value = 0.489). H11div presents the mediating effect of environmental friendliness on the relationship between low carbon distribution and low carbon performance. The outcome shows that hypothesis H11div is also rejected (ß - path coefficient = -0.034; t-value = 1.4020). Overall, GSCOP shows that there is a mediating effect between LCSC practices and LCP but most of the hypotheses were rejected.

H11ei depicts the mediating effect of cost reduction on the relationship between low carbon logistics and low carbon performance. The hypothesis shows H11ei is positive and significant (ß - path coefficient = 0.171; t-value = 2.521; $Q^2$ = 0.418). H11eii shows the mediating effect of flexibility on the relationship of low carbon logistics and low carbon performance. The result shows that H11eii has positive and statistically significant effect on the relationship between LCSC practices and LCP (ß - path coefficient = 0.132; t-value = 3.167; p-value = 0.001; $Q^2$ = 0.553). H11eiii predicts the mediating effect of responsiveness on the relationship of low carbon logistics and low carbon performance. The finding shows that H11eiii positively and significantly affect the relationship (ß - path coefficient = 0.073; t-value = 2.64; $Q^2$ = 0.411). H11eiv presents the mediating effect of environmental friendliness on the relationship between low carbon logistics and low carbon performance. The outcome shows that environmental friendliness has positive and statistically significant effect on the relationship (ß - path coefficient = 0.108; t-value = 2.904; p-value = 0.002; $Q^2$ = 0.538).

## 4.6 Common Method Bias

Data collected and analyzed need to be free from biasness. Biasness can be either due to this study's single respondent answering both LCSC practices and LCP or due to respondent falsely answering the survey question. For example, respondent answering consistently throughout the survey even though it not related or untrue. Therefore, collinearity test is recommended to identify whether this study's data that has been analyzed is free from biasness. One method proposed and widely reported in the literature is to report variance inflation factors (VIF). The acceptable score for VIF is that the value should be lower than 5 (Hair et al., 2017). Table 4.12 shows the result of VIF taken from SmartPLS software version 3.2.8. VIF result shows that all variables were free from common method bias as all score lower than 5.

Table 4.12 Summary of variance inflation factors (VIF)

| | GOV | CUST | ENGO | GT | TPM | LCPROC | LCPROD | LCPROS | LCDIS | LCLOG | COST | FLEX | RESP | ENVF | LCP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| COST | | | | | | | | | | | | | | | 4.035 |
| CUST | | | | | | 1.573 | 1.573 | 1.573 | 1.573 | 1.573 | 2.059 | 2.059 | 2.059 | 2.059 | 3.288 |
| ENGO | | | | | | 1.717 | 1.717 | 1.717 | 1.717 | 1.717 | 1.967 | 1.967 | 1.967 | 1.967 | 2.193 |
| ENVF | | | | | | | | | | | | | | | 4.921 |
| FLEX | | | | | | | | | | | | | | | 4.306 |
| GOV | | | | | | 1.404 | 1.404 | 1.404 | 1.404 | 1.404 | 1.514 | 1.514 | 1.514 | 1.514 | 1.607 |
| GT | | | | | | 2.233 | 2.233 | 2.233 | 2.233 | 2.233 | 2.728 | 2.728 | 2.728 | 2.728 | 2.792 |
| LCDIS | | | | | | | | | | | 3.665 | 3.665 | 3.665 | 3.665 | 4.228 |
| LCLOG | | | | | | | | | | | 2.691 | 2.691 | 2.691 | 2.691 | 2.858 |
| LCP | | | | | | | | | | | | | | | |
| LCPROC | | | | | | | | | | | 2.752 | 2.752 | 2.752 | 2.752 | 2.902 |
| LCPROD | | | | | | | | | | | 1.798 | 1.798 | 1.798 | 1.798 | 3.122 |
| LCPROS | | | | | | | | | | | 1.671 | 1.671 | 1.671 | 1.671 | 1.700 |
| RESP | | | | | | | | | | | | | | | 4.135 |
| TPM | | | | | | 2.395 | 2.395 | 2.395 | 2.395 | 2.395 | 3.969 | 3.969 | 3.969 | 3.969 | 4.605 |

## 4.7 Industrial Experts Validation

This study has sent out Google Form to five industrial experts in Malaysian manufacturing firms that hold chief executive officer, managing director, supply chain manager, logistics and energy officer positions at respective firms. There were five questions based on several statistical findings. Questions were based on hypotheses findings and industrial experts are required to give their opinions and validate the findings based on their experience working in the industry. All five questions were open ended questions to obtain rich information on the topic. The findings are shown in Table 4.13:

Table 4.13 Industrial expert findings

| No | Question | Chief executive officer of C firm | Managing director of S firm | Supply chain manager at K firm | Logistics manager at A firm | Energy officer at J firm |
|---|---|---|---|---|---|---|
| 1 | How important is product with less carbon emissions to your operations and environmental goals? | Very important as our company produce product that is based on energy efficiency | We produce electronics components to other hardware companies and it is part of our job to ensure that the product meets the requirements of environmental goals of our customers | Product with less carbon or green product actually helped to increase company's profit. Because of that our company produces less carbon product so that we can meet the demand of our customer | Very important for our firm as our firm need to monitor carbon emissions from our transportation and storing parts and materials | Very important because we use a lot of energy to produce our products. Our customer has asked us to adhere to international standards and come out with more energy efficient products |
| 2 | It was found that environmental NGOs has influence on many manufacturing firms to improve operations and environmental goals. What do you think of this statement? | Yes, we work with environmental NGOs and government agencies to promote energy efficiency and one of the goals is to reduce environmental problem such as carbon emissions | Partially correct as we also work with environmental NGOs, but they have no influence in our decisions on operations and environmental goals. We are a company focusing on improving performances be it operations or environment | Yes, we worked closely with NGOs not only in Malaysia but also from our parent company by providing them with information about our company. We also engage with NGOs as they work with government agencies and we need to meet government regulations. Because of that we never had problem with government and NGOs. So, yes, because we work closely with NGOs, our operations and environmental goals are achievable | We work with environmental NGOs and it helped our company to learn how to better reduce carbon and NGOs help to make our customer trust our company | Not sure but as my capacity as energy engineer, my company work closely with NGOs in helping them to understand how our product improves our lives and these NGOs mostly spokesperson for companies will help to teach customers to reduce energy or use energy more efficiently |

Table 4.13 Continued

| No | Question | Chief executive officer of C firm | Managing director of S firm | Supply chain manager at K firm | Logistics manager at A firm | Energy officer at J firm |
|---|---|---|---|---|---|---|
| 3 | Which one is more important for firm to reduce carbon emissions in the supply chain - internal capabilities such as top management support and green technology or external capabilities such as Malaysian regulations, customer requirements and environmental NGOs pressure? and Why do you think so? | Customer requirement is important and green technology. But if top management did not support the initiative then it is impossible to reduce carbon emissions | Top management supports environmental goals that include carbon emissions reduction. Green technology is also important and used in our production. Regulations, customers and NGOs also are important for our company as we also export products to our international partners and we have to follow regulations and customer requirements there. Recently our partner has asked us to improve our policy to include greener processes of products due to NGOs pressure | I think if company's top management not supporting carbon emissions then it is impossible to achieve carbon emission reduction. Same with green technology because to reduce carbon emission we need specific technology to do so. Of course, our government and customer also play a role in reducing carbon emissions but in our company, it is our policy to take care of the environment while ensuring we meet the requirements of our customer | The top management certainly support reducing carbon emissions initiatives and we work with our partners such as Toyota and Perodua to reduce emissions. So, top management is important. Customer also important because our long-term customers such as Toyota and Perodua require us to monitor our carbon emissions | I would say green technology would be the most important, but management must support company's carbon emission reduction goal as well. Customer requires us to improve energy efficiency but without better equipment and green technology, we can only improve the process |

Table 4.13 Continued

| No | Question | Chief executive officer of C firm | Managing director of S firm | Supply chain manager at K firm | Logistics manager at A firm | Energy officer at J firm |
|---|---|---|---|---|---|---|
| 4 | In your opinion, do you think your firm practicing carbon emissions reduction throughout the supply chain will be able to achieve operational and environmental goals? Please provide a reason based on your firm experience. | Yes. Our company practice and has green certification that support carbon emissions reduction. From practicing carbon emissions reduction and certification, our operations and environmental goals are met every time | Yes. The whole supply chain partners must work together in reducing carbon emissions. Our company work closely with suppliers and transportation service partners to achieve that goal | Yes. Our company practice carbon emissions reduction especially we have green process in production. Because of that we are able to achieve all of our operational objectives, our customer happy with our performance and we are happy to be one of the top companies caring for the environment | I believe if our firm reduce carbon emissions and meet the requirements of our customers and government, we can achieve our operational and environmental goals. We have been in the industry more than 15 years and we have changed from focusing on efficient transportation to monitoring carbon emissions | Yes, company can improve performances when addressing carbon emissions because it is the new requirement by government, customer and to survive in the business. When I talked with my friends working in competing companies, I can say that many companies have practicing carbon emissions reduction. So, reducing carbon emissions is a new standard for company to stay in business and appeal to customers |
| 5 | From the definition of low carbon supply chain provided, do you think the practices are being adopted by your firm? | Yes, our company directly reduce carbon emissions and we directly try to control the emissions as our product focus on energy efficiency | Yes, those practices have been adopted in our company | Yes, we practice LCSC from buying materials to sending products to our customers | Yes, we have those practices at our firm | Yes, monitoring energy that produce carbon emission, heat that produce carbon emission and carbon particles from production process are critical to our company |

## 4.8 Chapter Summary

This chapter presents the demographic profiles of both respondents answering the survey and firms' profile through analyzing using IBM SPSS version 24. Additionally, this study separated LCSC demographic profile so that more information on LCSC practices in Malaysian manufacturing industry can be discussed. The response rate of this study was 20 percent and the justification for the low response rate as well as non-response have been explained before presenting the type of data. Based on data collection, the data was non-normal distribution based on Mardia's multivariate skewness and kurtosis test. Therefore, SmartPLS software version 3.2.8 was used for model measurement and structural measurement as well as mediating effects. Model measurement was analyzed through series of tests such as convergent validity, reliability and discriminant validity. In addition, for structural measurement, 78 direct effect hypotheses and 20 indirect effect hypotheses were analyzed through bootstrapping test. Data shows that there was mediating effect of GSCOP on the relationship between LCSC practices and LCP. The data proven that the model was free from common method bias. This can be justified by looking at the reporting of VIF. As VIF score for all variables were lower than 5, thus, it can be assumed that the data is free from biasness. Therefore, the next chapter is able to discuss the findings of the hypotheses to answer research objectives of this study pertaining to LCSC practices in achieving LCP.

# CHAPTER 5

# DISCUSSION

## 5.1 Introduction

This chapter begins with recapitulation of research objectives of this study. Findings in the previous chapter will be discussed here in accordance with research objectives. Furthermore, justification of the findings based on scholarly works and demographic profiles will be presented. This chapter will also discuss implication of this study, limitations and conclusion of the study.

## 5.2 Recapitulation of the Research Objectives

This study aims to investigate LCSC practices to achieve LCP in the Malaysian manufacturing industry. Therefore, as shown in Chapter 1, the research objectives for this study are:

55. To develop a theoretical framework of LCSC based on Malaysian manufacturing industry practices by examining determinants of LCSC practices, determinants of GSCOP and determinants of LCP and its relationship
56. To investigate the relationship between determinants and LCSC practices
57. To investigate the relationship between LCSC practices and GSCOP
58. To investigate the relationship between GSCOP and LCP
59. To investigate the mediating effect of GSCOP to leverage the link of LCSC practices and firm outcomes in Malaysian manufacturing industry

Research objectives 1 was developed through systematic review of the literature on LCP in supply chain and operations. Then, these objectives were answered and presented in Chapter 2 literature review. Research objective 2 that investigated the relationship between determinants and LCSC practices was found to be positive and significant as shown in Chapter 4. Research objective 3 that investigated the relationship between LCSC practices and LCP also found that there is a positive and significant effect. Research objective 4 presented in previous chapter found that there is a link between GSCOP and LCP. The mediating effect investigated in research objective 5 shows that GSCOP mediates the relationship between LCSC practices and LCP. Specifically, research findings for each research objective will be explained in the next section.

## 5.3 Discussion on Findings

There are 11 hypotheses as shown in LCSC theoretical framework consisting of 78 direct effects and 20 indirect effects. Direct effect hypotheses answers research objectives 5 to research objectives 10 while indirect or specific effect answers research objective 11. The acceptance rate for direct effect is 78 percent with 17 direct hypotheses rejected and the acceptance rate for indirect effect is 55 percent with 9 hypotheses rejected. These information shows that the conceptualization of LCSC practices to achieve LCP and inclusion of GSCOP as mediating is proven.

### 5.3.1 Research Objective: Investigation of Relationship between Determinants and Low Carbon Supply Chain Practices

The first research objective is on the investigation of relationship between determinants and LCSC practices that can be found in hypotheses H1 to H5 in Chapter 4 Table 4.9. For hypothesis H1 which is between government regulations and LCSC practices, it was found that government regulations has positive and significant impact on low carbon procurement, low carbon production process, low carbon distribution and low carbon logistics but not low carbon products. Previous scholars also found a similar finding where external and internal pressures including government regulations affect LCSC practices and green practices of firms (Luo et al., 2017; Zhu et al., 2013). In addition, the relationship between determinants and LCSC practices also supported by Institutional theory (Glover et al., 2014) where coercive pressure forced firms to adopt LCSC practices to sustain in the business. These hypotheses suggested that government regulations is critical for manufacturing firms in its adoption of LCSC practices. Furthermore, environmental regulations by the Malaysian government and countries worldwide have pressured manufacturing firms to reduce carbon emissions and to practice green in their supply chain and operations.

The findings of government regulations' impact on low carbon procurement in hypothesis H1a shows that buyer-supplier relationship is important for LCSC practices. Monitoring of suppliers' low carbon practices and green certification as well as collaboration with suppliers are part of manufacturing firm's effort to reduce carbon emissions in procurement process. As countries worldwide pledged to reduce carbon emissions to lessen climate change effect, manufacturing firms need to adhere to stringent government environmental regulations and adopt these requirements in its supply chain and operations. The result shows that firms agree that low carbon procurement is critical for reducing carbon emissions in the supply chain.

Nevertheless, hypothesis H1b between government regulations and low carbon product was rejected. This is in line with the finding of Böttcher and Müller (2015) that low carbon product is still wanting of awareness from customers. As manufacturing firms in Malaysia are producing product based on the requirements of customers, government regulations on the designing and specification of product is still limited. Government regulations tend to focus on the process of producing products rather than specification of low carbon products. Thus, it shows that government regulations for low carbon product is more on the process of the products and producing the products rather than designing products with low carbon requirement.

As a result, hypothesis H1c shows positive and significant relationship between government regulations and low carbon production process. Previous scholars also found positive relationship between regulations and low carbon production processes (Savino & Shafiq, 2018; Xu et al., 2016). As production process has been identified as process that produces major carbon emissions, government regulations on low carbon production process is critical to achieve LCP. Furthermore, energy efficiency for production and low carbon technology are regarded as practice and investment to reduce carbon emissions in the production.

Another contributor of carbon emission due to extensive network of process and energy used for product storing is low carbon distribution. Based on the findings of hypothesis H1d, it shows that government regulations has a positive and significant impact on low carbon distribution and network. Previous studies found that distribution network and energy used need to be regulated in order to achieve LCP (Du et al., 2016; International Energy Agency, 2016). Closer relationship between supply chain partners in using environmental packaging and adopting energy efficiency at the warehouses are imperative for LCSC practices. Malaysian government low carbon regulations and incentives for energy efficiency and renewable energy are some of the regulations that firms need to adhere and adopt. Therefore, manufacturing firms found that government regulations has impacted firms to adopt low carbon distribution.

Low carbon logistics is critical for LCSC practices as it is one of the major contributors to carbon emissions worldwide. Hypothesis H1e proved that government regulations including environmental regulation play an important role in manufacturing firms adopting LCSC practices. Majority of previous studies underline the positive impact of government regulations to low carbon logistics (Abdullah & Yaakub, 2014; Fernando et al., 2015; Gardas, Raut, & Narkhede, 2018; Govindan & Soleimani, 2017; Pinheiro, de Francisco, Piekarski, & de Souza, 2019). Due to transportation’s carbon emissions, government regulations has been imposed to firms to monitor and choose mode of transportation that produce lower carbon emissions. Furthermore, manufacturing firms also design its transportation route to be more efficient and at the shortest distance. These practices show that government regulations has positive and significant impact on manufacturing firms low carbon logistics practice.

The second hypothesis which is H2 is between customer pressure and LCSC practices. Findings show that customer pressure indeed pressure manufacturing firms to adopt LCSC practices. While according to Institutional theory where customer pressure notably is normative pressure, it was found in this study that customer pressure has coercive pressure compared to government regulations. In hypothesis H2a, it was found that customers pressure firms to adopt low carbon procurement. Practically, there are many examples of firms producing what customer wants based on the specification and requirement of customers. This finding is in line with previous studies that found customers has the power to influence firms in adopting LCSC practices (Fernando et al., 2016; Jasmi & Fernando, 2018; Zhu et al., 2013). Indeed, customer preference of low carbon product stems the importance of manufacturing firms opting for low carbon materials and auditing suppliers' environmental practices. This is because supplies of low carbon materials and working with environmental certification, firms will ensure manufacturing firms abide to customer low carbon requirements.

Customers growing demand for low carbon products to reduce carbon emissions has increased the pressure on firms to adopt low carbon product design and specifications. Nowadays, firms need to address design and specification of product with less carbon-intensive materials and prolong the lifecycle of the product as well as designing the recycling of the product after use. Customers viewed these practices as the responsibility of manufacturing firms and this has put pressure on firms to achieve carbon emissions reduction throughout product development and production process. As shown in hypothesis H2b, customers indeed pressured manufacturing firms to adopt low carbon product development.

As for customers pressure and low carbon production process presented in H2c, customers are demanding manufacturing firms to reduce overall carbon emissions. In the literature, there are plenty of evidence with regard to customers' pressure significant impact on low carbon production process (Abdullah & Yaakub, 2014; Fernando et al., 2016; Wu, Huo, Zhang, & Zhang, 2018; Zhang & Yang, 2016). Since customer sees production of product as main source of carbon emissions, manufacturing firms have focused on adopting cleaner technology for production of product, lean process and energy efficiency. Through technology advancements, low carbon process and energy efficiency, manufacturing firms are able to prove to customers that the products they produce are less carbon-intensive.

H2d postulates that customers pressure firms to adopt low carbon distribution. This hypothesis is also supported by previous studies (Ghavamifar, Makui, & Taleizadeh, 2018; Laczko, Hullova, Needham, Rossiter, & Battisti, 2018). The reason for customers concerns with reduction of carbon emissions in distribution and network of manufacturing firms has long been established where customer demand firms to reduce carbon emissions through changing the packaging to environmentally friendly packaging and in the case of business-to-business, customers demand manufacturing firms to take back the packaging or reuse the pallets. As a result, manufacturing firms nowadays are beginning to practice low carbon distribution to appease customer requirements.

Low carbon logistics also is significant for manufacturing firms. Essentially, this is due to customers pressuring firms to reduce carbon emissions through efficient transportation of products and the practice of consolidation of products has become a norm between customers and firms. Hypothesis H2e proposed that customers pressure firms to reduce carbon emissions in logistics process. The relationship has been found to be positive and supported by previous studies as well (Accorsi, Gallo, & Manzini, 2017; Govindan & Soleimani, 2017; Shou, Li, Park, & Kang, 2017; Wu et al., 2018). Therefore, manufacturing firms found that customers pressure firms to reduce carbon emissions through logistics practice.

Environmental NGOs monitor and act as check-and-balance for manufacturing firms to not exceed permissible carbon emissions and to produce low carbon products for customers. The influence of environmental NGOs varies where USA and China have strong environmental NGOs that pressure manufacturing firms to reduce carbon emissions while in some other countries, they have little or low influence. In Malaysia, environmental NGOs work closely with government agencies to monitor manufacturing firms. In addition, Malaysian environmental NGOs role is the creation of low carbon society awareness. Yet, the finding of the relationship between environmental NGOs and LCSC practices is positive and significant except for low carbon procurement. H3a predicts the relationship between environmental NGOs and low carbon procurement and the hypothesis was rejected. The reason for this result can be explained by the role of environmental NGOs in Malaysia that focuses on awareness of LCSC practices and low carbon society practices. In this sense, environmental NGOs in Malaysia monitor the end process of the supply chain such as products, production processes, distribution and logistics. As such, manufacturing firms view environmental NGOs as having no impact on its adoption of low carbon procurement. Similar finding is also found in the study of Fawcett and Killip (2018).

The result of this study shows that environmental NGOs have positive and significant impact on low carbon product. This is true as environmental NGOs in Malaysia spread low carbon awareness and collaborate with government agencies as well as manufacturing firms to increase customer preference towards low carbon product. A study by Böttcher and Müller (2015) supported the claim that environmental NGOs has an impact on low carbon product of firms. Therefore, hypothesis H3b shows that while environmental NGOs applies pressure on firms to adopt LCSC practices, it also strengthens the acceptance of firm's low carbon product in the market. In the future with more customers demanding for low carbon product this will increase the effect of environmental NGOs towards firm's LCSC practices.

Environmental NGOs also plays an important role in manufacturing firm's low carbon production process as shown in hypothesis H3c. Due to large emissions coming from production processes, environmental NGOs focus its effort in production processes. Similar findings can be found and supported in the literature showing how environmental NGOs require manufacturing firms to practice LCSC (Dos Santos et al., 2014; Fawcett & Killip, 2018; Liu et al., 2018; Qorri, Mujkić, & Kraslawski, 2018; Reefke & Sundaram, 2017). Environmental NGOs that monitor and seek cooperation from manufacturing firms pressure firms to measure carbon emissions and use carbon-free materials. Failure to do so would result in manufacturing firms be reported and would lose customers. For instance, Chinese manufacturing firms that failed to reduce carbon emissions have been reported by environmental NGOs that work closely with Chinese government to shut down production that does not met environmental regulations (Wang, 2010).

As environmental NGOs has a role to monitor and work closely with government agencies, manufacturing firms simultaneously need to ensure that its carbon emissions from warehousing, energy used, and transportation are kept within the level allowed by environmental regulations. Thus, hypothesis H3d and H3e show that environmental NGOs are significantly impacting on manufacturing firms low carbon distribution and low carbon logistics practices. As environmental NGOs has persuasive power, they a to persuade customers, manufacturing firms seized the opportunity to participate in industrial community linkage activities organized by environmental NGOs. This helps ensure firms ability to sustain in the business and obtain support for LCSC practices from all supply chain partners.

Other than government regulations, customers pressure and environmental NGOs that are external pressures to manufacturing firms, internal pressure such as green technology adoption also impact firms in LCSC practices. Adopting green technology is another practice of carbon emissions reduction as green technology enables firms to achieve more energy efficient, cleaner and less carbon emissions. Even though green technology is viewed as expensive investment, with continuing technological advancements made, green technology is becoming cheaper and easily accessible to manufacturing firms. Nowadays, there are many firms meeting their stakeholders' objectives through green technology. One of the impacts of green technology is on low carbon procurement. Hypothesis H4a shows that manufacturing firms viewed green technology as an enabler of low carbon procurement. Suppliers that have green technology will give better impression that they are able to produce low carbon materials. When first tier suppliers in the network of supply chain are able to reduce carbon emissions with green technology, it will enable other supply chain partners including product development and production process to meet LCP. As a result, the whole supply chain network benefits from green technology. In the literature, there are several studies that shows green technology improves firms LCSC practices (Fernando et al., 2015; Li, Deng, Xia, Zhang, & Skitmore, 2018; Tippayawong, Tiwaratreewit, & Sopadang, 2015) especially in procurement (Chan & Lau, 2001).

As for low carbon product, the ability of firms to design and provide low carbon specifications also depends on the availability of green technology. This justification is in line with a study of Liu, Blome, Sanderson and Paulraj (2018) that underline how green technology increases the performance of product development and overall performance of firms. The improvement from green technology stemmed from R&D and exploitation of latest technology that not only are able to reduce carbon emissions but also to develop low carbon product. Therefore, green technology indeed has a positive and significant impact on low carbon product.

Other than impact on product design and development, green technology also enables manufacturing firms to produce low carbon products. Hypothesis H4c shows green technology is positively and statistically significant in its relationship with low carbon production process. Scholars in the literature also found that green technology is critical for low carbon production process (Li et al., 2018; Tippayawong et al., 2015; Vachon & Klassen, 2008). This is because the source of carbon emissions in production process comes from technology of machinery and equipment and energy used operating the machinery and equipment. Through green technology manufacturing firms can reduce carbon emissions from machinery and equipment used and achieve better energy efficiency. As carbon emissions increasingly becomes an important issue for manufacturing firms, pressure by stakeholders to adopt green technology intensifies.

Furthermore, green technology that is able to reduce energy or provide more energy efficiency is also useful for low carbon distribution. Previous study on warehousing and supply chain network found that green technology is pivotal in managing warehouses energy and distribution to meet LCP (Chen et al., 2017; Shaw et al., 2016). In addition, the implementation of pallet system to supply goods across the supply chain is able to reduce carbon emissions. These benefits through green technology provide significant relationship between green technology and low carbon distribution for manufacturing firms.

Even though so, the finding shows that green technology has no relationship with low carbon logistics. Even though low carbon logistics provide firms with more carbon efficient transportation and the determination of more efficient routes, manufacturing firms were not deploying green technology for such purposes. This finding is similar to the finding of Prajogo and Olhager (2016). The reason for insignificant effect of green technology on low carbon logistics is due to the fact that manufacturing firms viewed logistics as transportation of products to customer. Most of the time there are two options for firms which is either to provide logistics service to customers or customers will have its own logistics provider to work closely with manufacturing firms. Thus, firms believe that green technology has less impact or no influence on its logistics practice. Furthermore, there are three types of most used transportation mode namely air freight, maritime freight and land transportation. Green technology has less impact on type of transportation as firms believe that by consolidating products, reducing carbon emissions and having efficient routes for transportation were evident enough to achieve low carbon logistics. Hence, green technology has been widely adopted for reducing carbon emissions in procurement, product design, production of product and warehousing where its impact are more evident than in logistics process.

Another internal pressure for manufacturing firms to adopt LCSC practices come from top management. Based on the results, it shows that all hypotheses under H5 were accepted. This proves that top management support is important for adoption of LCSC practices. The result also was in accordance with previous studies found in the literature with regard to top management influence on LCSC practices (Böttcher & Müller, 2015; Luo et al., 2017). Through top management support of LCSC practices of low carbon procurement, manufacturing firms are able to reduce carbon emissions by choosing suppliers that are in line with firms' low carbon policy. Furthermore, top management that supports low carbon product will enable more products that has less carbon content to be available in the market place. In addition, this will provide manufacturing firms with cleaner technology for producing the product and a leaner process that emits less carbon emissions. On top of that, manufacturing firms that receives support from top management will share carbon information and reduce carbon emissions together in the supply chain network so that LCP can be achieved. Consequently, the storage in warehouses and network distribution of products will emit less carbon emissions. This would also prompt firms to use low carbon transportation, consolidate products and determine lowest carbon emission routes for transportation. Therefore, for internal pressure of LCSC practices, top management support is vital and was evident in the finding of this study.

### 5.3.2 Research Objective: Investigation of Relationship between Low Carbon Supply Chain Practices and Green Supply Chain Operational Performance

Carbon emissions reduction throughout the supply chain can help manufacturing firms achieve GSCOP of cost reduction, flexibility, responsiveness and environmental friendliness in operations. One of the most critical practice to reduce carbon emissions is low carbon procurement. As firms use less carbon-intensive materials, firms are able to achieve carbon emissions reduction. Furthermore, with both firms and suppliers practicing carbon emissions reduction, this will lead to operational performance. Thus, hypothesis H6 posits that low carbon procurement has positive and significant effect on GSCOP. Based on the finding, it shows that low carbon procurement positively affects cost reduction, flexibility and responsiveness but not environmental friendliness. Through carbon emissions reduction practice in procurement, manufacturing firms are able to reduce cost of redesigning product to meet environmental objective. This is in line with previous study in the literature that provide benefits of LCSC practices toward cost reduction in operations (Colwell & Joshi, 2013; Fernando et al., 2018) Furthermore, firms also able to reduce cost of repurchasing less carbon-intensive materials as stakeholders such as customers nowadays are demanding for less carbon and environmental friendly product. In addition, operations of firms will be affected when switching to more stringent requirement for less energy used and greener process. That is why low carbon procurement has a positive and significant effect on cost reduction.

Low carbon procurement was also found to be significant for flexibility and responsiveness of firms' operations. Firms are able to minimize the disruption in production causes by changing of carbon-intensive materials to less carbon-intensive materials with closer relationship with its suppliers that are practicing low carbon. Also, changing from conventional production process to greener production process requires closer relationship with low carbon suppliers. Manufacturing firms that have closer relationship with suppliers will be able to cater to a wider range of customers. Thus, low carbon procurement practice that enables closer relationship between buyers-sellers helps manufacturing firms to achieve GSCOP. This is similar to the findings in the literature in regards to LCSC practices to achieve flexibility (Dissanayake & Cross, 2018; Savvidis et al., 2019) and responsiveness (Liu et al., 2018; Rajesh, 2017)

However, the relationship between low carbon procurement and environmental friendliness was rejected. This is understandable as environmental friendliness focus on energy consumption and life cycle of product. Since suppliers are only involved in manufacturing firms' product design, energy consumption reduction and life cycle of product were out of suppliers' control. The finding is similar to the finding of Goossens et al. (2017). Yet, it can be argued that firms need to work with energy suppliers to help achieve better GSCOP. Regardless, current practice of suppliers supplying low carbon materials and their support shows that suppliers are able to help manufacturing firms reduce cost in production by becoming more flexible in production and responsive to customers' demand. This finding is in line with previous study where LCSC practices lead to GSCOP (Xiaosong & Lai, 2012; Zhang, Tse, Doherty, Li, & Akhtar, 2018).

Another LCSC practice to achieve GSCOP is through low carbon product. This practice directly affects GSCOP as manufacturing firms that produce low carbon products can be viewed as firms that have green operations. The relationship between LCSC practices and GSCOP has been proven by findings in the supply chain and operations literature (Du, Hu, & Wang, 2017; Zhu et al., 2013). However, the finding between low carbon products and cost reduction in operations returns an insignificant result. The reason for the negative relationship is because current cost for low carbon product is considered expensive as its operations involve the use of sophisticated and expensive green technology. Additionally, manufacturers need to ensure that the production process emits less carbon and is greener than conventional product production. These requirements make it difficult for manufacturing firms to produce at a cheaper cost. Thus, low carbon product can also be negative to cost reduction when manufacturing firms are thinking about short-term cost reduction rather than the long-term goal of carbon emissions reduction (Tseng, Chiu, Tan, & Siriban-Manalang, 2013).

While low carbon product is not significant to cost reduction in operations of firms, low carbon product has a positive and significant impact on flexibility, responsiveness and environmental friendliness of firms' operations. This is due to the increasing awareness of low carbon product and the prospering of market for low carbon products. This can be seen in the previous studies where low carbon products demand and supply are increasing (Martí et al., 2015) and manufacturers are pushed to meet the customers' demand through low carbon operations (Du, Tang, et al., 2016; Skeete, 2019). As firms gear up for GSCOP, its design of low carbon product also becomes environmentally friendly as it includes low carbon emissions process, less carbon-intensive materials and less energy used. Studies by Chardine-Baumann and Botta-Genoulaz (2014) and Gunasekaran and Ngai (2012) investigated how manufacturing firms' product and service leads to environmental friendliness throughout the supply chain. As a result, manufacturing firms that design low carbon products are able to achieve GSCOP.

This study investigates manufacturing firms that produce products or offer services in Malaysia. As found in the study, 68 percent of participating firms were producing industrial products which means supplying of energy, materials, resources and product that will be completed by other firms. Thus, it is understandable that low carbon production process has positive effect on cost reduction. As these firms are producing for another firms, its offering must achieve lowest possible cost to retain its customer. Since low carbon awareness is increasing and every manufacturer need to do their part in reducing carbon emissions, manufacturers' customers are also pressuring firms to reduce carbon emissions while retaining a low-cost production process. However, as a result of focusing on production process cost reduction, manufacturing firms will not be able to achieve flexibility in production. The result shows insignificant relationship between low carbon production process with flexibility. This is because manufacturing firms that produce products with less carbon emissions in the production has to switch its processes to a more carbon efficient and the use of less carbon-intensive materials and energy. Nevertheless, firms are able to achieve responsiveness as a wider range of customers are demanding for low carbon production processes nowadays. Therefore, the relationship between low carbon production process and responsiveness was positive and statistically significant. Responsiveness of manufacturing firms also lead firms to achieve environmental friendliness. This is true as firms that have low carbon production process will adopt less energy consumption, use clean energy for production and has green value chain since wider customer demands low carbon practice in operations. The finding of this study is in line with previous study on the impact of cost reduction, responsiveness and environmental friendliness (Dissanayake & Cross, 2018; Fernando et al., 2018; Shou et al., 2017; Wu et al., 2018) while the negative finding of flexibility is also supported by the previous studies in manufacturing industry (Prater, Biehl, & Smith, 2001; Slack, 2005).

After low carbon products have been produced, they will be stored or moved along the supply chain. Storing the product at warehouses and movement of products have impact on the environment particularly in terms of carbon emissions. Thus, firms are beginning to reduce the impact on environment by practicing low carbon distribution. Examples of the practice of low carbon distribution includes less energy used for warehouses, the use of non-hazardous packaging and pallet system among supply chain partners. The practice of low carbon distribution is found to be positive and significant towards GSCOP. Thus, it shows that by practicing low carbon distribution, manufacturing firms are able to achieve cost reduction, flexibility, responsiveness and environmental friendliness. Firms are able to achieve cost reduction in terms of reusing packaging and pallet systems that are widely practiced in manufacturing nowadays. Furthermore, firms are also able to achieve flexibility as a result of collaboration between firms and supply chain network in movement of materials and products. In addition, firms are able to achieve responsiveness as its distribution process can cater to both conventional and low carbon distribution processes required by customers. Also, with greater collaboration with supply chain partners to reduce carbon emissions, opting for non-hazardous packaging and using energy efficiently for warehouses will lead firms to an environmental friendliness objective. Therefore, the practice of low carbon distribution positively affects GSCOP of manufacturing firms. This is also found in previous study in manufacturing context (Zhang et al., 2012; Zhang & Yang, 2016).

After storing and moving products along the supply chain, the products will be transferred to end-customers. Transferring product to customers require firms to design and plan for transportation routes, mode of transport and consolidation of products. These logistics practice leads to high carbon emissions. In order to ensure firms achieve GSCOP, firms make efforts to reduce its carbon emissions in logistics process. This is because firms are pressured by stakeholders to ensure that carbon emissions in the operations is reduced and logistics process has impact on the overall operations of firms. Based on the finding, it was found that low carbon logistics has a positive relationship with cost reduction and responsiveness while having a negative relationship with flexibility and environmental friendliness. The result shows that manufacturing firms that practice low carbon logistics will be able to cut the cost of operations when practicing low carbon logistics as firms consolidate products to ensure fewer trips to transport the products. In addition, firms are also able to reduce cost of operations as firms design its routes of transportation and use of technology to predict the best possible routes to ensure shortest distance for transportation. Thus, this will lead to firms being able to reduce carbon emissions and cost. Furthermore, firms also will avoid being fined for carbon pollution from its frequent transportation if firms practice low carbon logistics. The benefits of low carbon logistics also include responsiveness in operations for manufacturing firms. As firms are able to meet customers' requirements for low carbon transportation mode and low carbon transportation activities, firms indirectly are also able to cater to customers that requires the conventional or non-low carbon logistics. Therefore, practicing low carbon logistics make sense for manufacturing firms as it gives benefits for meeting wider stakeholder's objectives. This finding is also similar to the finding in the literature with regard to cost reduction and responsiveness of low carbon logistics to operational performance (Gligor & Holcomb, 2012; Rajesh, 2017; Wu et al., 2018). However, the finding also found that low carbon logistics is insignificant towards flexibility and environmental friendliness. The reason for insignificant in flexibility is because firms have to opt for less carbon emissions transportation modes, less carbon emissions routes and investing in technology to monitor carbon emissions in transport and route system. Based on the finding, it shows that firms consider low carbon logistics as a practice to support reduction of cost in operations and meeting wider range of customer preferences rather than to support operations flexibility and environmental friendliness. On the other hand, environmental friendliness was found to have a negative relationship with low carbon logistics due to its primary objective of measuring energy and life cycle of a product that are indirectly related to low carbon logistics. The relationship proved to be insignificant as manufacturing firms consider low carbon logistics has limited impact on energy being used and prolonging the life cycle of the product. The insignificant finding of flexibility and environmental friendliness are also found to be supported by previous studies (Fantazy, Kumar, & Kumar, 2009; Hingley, Lindgreen, Grant, & Kane, 2011; Yu, Cadeaux, & Song, 2017).

### 5.3.3 Research Objective: Investigation of Relationship between Green Supply Chain Operational Performance and Low Carbon Performance

It has been hypothesized that manufacturing firms that able to achieve GSCOP including cost reduction, flexibility, responsiveness and environmental friendliness will be able to achieve environmental performance of LCP. This is because manufacturing firms that are able to reduce cost of operations, has a flexible production process, able to cater to wider customers and has environmentally friendly production will be able to achieve carbon emissions reduction. Based on the finding, it shows that indeed GSCOP has positive effect on LCP thus hypothesis H7 was accepted. In hypothesis H7a, as manufacturing firms are able to reduce cost of operations, it will lead to leaner and greener production process and efficient use of materials for production. As a result, manufacturing firms are able to achieve LCP. In addition, firms that can interchangeably manage its production to be flexible in producing products will be able to reduce carbon emissions. This is because when firms are flexible, they can produce products whenever customers require the production to run. In that sense, manufacturing firms can practice build-to-order and still be able to meet customer demands. This practice allows firms to produce without having any disruption in the production. As a result, firms are able to reduce carbon emissions. The ability to produce products when required also enable firms to be responsive. Firms are able to target different customer segments and are able to practice responsive supply chain such as responsive product design, responsive raw materials requisition and responsive product delivery. Thus, firms can directly identify customers preference and reduce excessive process in the operations. This will lead firms to achieve better carbon emissions reduction. The finding is in line with previous study of Zhu et al. (2013) that shows the positive relationship between GSCOP and LCP.

### 5.3.4 Research Objective: Investigation of Relationship between Determinants and Green Supply Chain Operational Performance

This study in proposing comprehensive theoretical model for LCSC practices to achieve LCP has investigated the relationship between determinants of LCSC practices and GSCOP. This is because the relationship between external pressures such as government regulations, customer pressure, environmental NGOs and internal pressure including green technology adoption and top management support are important to develop GSCOP for manufacturing firms.

Government regulations has been found in the literature and supported by theory as significant and coercive towards firms' practices. In this study, the finding shows that government regulations has a positive and significant effect on cost reduction, flexibility and environmental friendliness while having negative effect on responsiveness. The empirical finding shows that government regulations and policies have pressured manufacturing firms to reduce cost of operations. The regulations are put into practice so as to ensure firms' operating expenses do not exceed or affect profits of the firm. Respondent that participated in this study viewed government regulations as controlling manufacturing firms from exiting the industry due to lower income or profits. To remain competitive and sustain, manufacturing firms need to ensure they are able to reduce cost of product design, cut unnecessary cost, reduce production cost and transportation cost while meeting environmental objectives such as low carbon emissions. Furthermore, pressure from low carbon regulations have forced manufacturing firms to be flexible in meeting the requirement of conventional customer and low carbon customers. In that sense, government regulations are important for manufacturing firms to achieve environmental friendliness. As low carbon regulations have been put into practice, manufacturing firms have to comply and focus on less energy consumption, choice of efficient energy and renewable energy and to design life cycle of products that would include environmental management. Due to government regulations' positive effect on cost reduction, flexibility and environmental friendliness, scholars have proposed GSCOP to meet LCP (Balfaqih et al., 2016; Balfaqih & Yunus, 2014). However, government regulations that was predicted to be positive and significant towards responsiveness was found to be negative based on the survey finding. Nevertheless the negative relationship was also found in the literature in operations research (Evangelinos & Oku, 2006; Wang, 2002). Regulations are found to be responsive, which is similar to the finding in the literature as it depends on the type of regulations. In this case, manufacturing firms in Malaysia lack regulations on responsiveness. As a result, limited evidence was found with regard to government regulations' impact on responsive product design, quality raw materials, delivery to customers and product return.

On the other hand, customer also pressure manufacturing firms to achieve GSCOP. Based on the finding, it shows that customer pressure firms to reduce cost of operations, to be flexible in operations and to adopt environmental friendliness. It was also found that customer relationship with responsiveness is negative. The result implicates that customer viewed cost reduction as critical for manufacturing firms to achieve operational performance. This is because cost reduction is one of the oldest and most widely practiced in operations to sustain its business. Moreover, manufacturing firms need to be flexible as customer demand nowadays are becoming more complicated and sophisticated. For example, computer producers have to produce different type of computers for different type of consumers in order to meet customers demand. As a result, customer pressure is viewed as important for operational success in terms of flexibility. In addition, due to climate change and other environmental issues, customers are pressuring firms to have environmental operations such as environmental friendliness of energy and after life product design. These findings are in line with studies found in the literature (Ann et al., 2006; Kühl, Goutier, Ensslen, & Jochem, 2019; Qi, Huo, Wang, & Yeung, 2017). Nevertheless, customer pressure that was found to have insignificant impact on responsiveness can be found in a study by Pehrsson (2014) that vindicate the fact that when manufacturing firms' operations are similar to competitors, the responsiveness diminishes. In that regard, manufacturing firms that focus too much on cost reduction, flexibility and environmental friendliness will reduce its customer responsiveness.

Other than that, environmental NGOs also have an influence on GSCOP of manufacturing firms. However, based on the finding the influence of environmental NGOs on GSCOP is only positive for cost reduction and environmental friendliness. This is true as environmental NGOs in Malaysia prominent role is to increase awareness of LCP and to support government in regulations implementation and monitoring. As a result, environmental NGOs are found to be vocal in pressuring firms to reduce cost so that consumption of low carbon product can be increased. Furthermore, as environmental NGOs are pushing for more environmentally friendly practices, manufacturing firms are pressured to have environmental friendliness operations. This is in line with studies of Lit and Zhu (2019). The finding also presented the insignificant effect between environmental NGOs with flexibility and responsiveness. The insignificant effect is due to Malaysian environmental NGOs' emphasis and focus on firms' operations rather than the result of firms' operations. In this case, firms' responsive and flexible production were not primary concerns of environmental NGOs. This finding is similar to a finding of Darbari, Kannan, Agarwal and Jha (2017) where they found that firms that pursue operational performance will have an impact on its goal of environmental performance and vice versa. Since manufacturing firms that participated in this study focus on environmental performance, some manufacturing firms viewed flexibility and responsiveness of operations as not what the environmental NGOs perceive as a critical aspect for firms to improve.

Internal pressure also impacts manufacturing firms' GSCOP. In hypothesis H8d, it was found that green technology has a positive and significant effect on responsiveness and environmental NGOs while having insignificant effect on cost reduction and flexibility. The insignificant relationship between green technology investment and cost reduction is because green technology is expensive to adopt. In Malaysia, as most of manufacturing firms are producing industrial product for other firms, the technology adoption depends on the type of customers and products required by customers. Since green technology is not widely available for manufacturing firms, the flexibility of firms is also affected. Firms need to focus on flexible process rather than flexibility of green technology. A similar negative effect was also found by Omusebe, Wanjohi, Ismael and Iravo (2018). On the contrary, green technology has been found to have a positive effect on responsiveness of firms' operations and environmental friendliness. This is because firms that have green technology will be able to produce low carbon products. As a result, firms can cater to both non-low carbon market and low carbon market. Moreover, firms that invest in green technology will be able to meet low carbon energy and environmental friendliness in operations. These findings are consistent with finding of Shafique et al. (2018).

Top management support is also critical for manufacturing firms to achieve its objective either for GSCOP or LCP. However, the finding of this study found that top management support has insignificant relationship with cost reduction and flexibility. This can be attributed to top management's view that cost reduction is an old criterion for operations. Rather, the success of operations now depends on the firm's ability to meet customer demand and mitigating environmental issues. As a result, firms shift their focus from offering the lowest cost for product to the best cost for low carbon product. In addition, top management viewed flexibility in production as dependable on customer demand. As the respondents of the survey mostly are industrial product producers, the operations to meet the demand of customers is already determined. Therefore, flexibility in operations is not a primary concern of top management to meet operational performance. On the contrary, top management concerns seems to be an emphasis and focus on responsiveness in operations. The more responsive manufacturing firms are, the wider spectrum of customers the firms can target.  Support of top management is also underlined in the literature review by previous studies (Ann et al., 2006; Chae, 2009; Gupta, Esmaeilzadeh, Uz, & Tennant, 2019).

### 5.3.5 Research Objective: Investigation on Relationship between Determinants and Low Carbon Performance

This study hypothesized that determinants of LCSC practices have positive and significant effect on LCP. This is because when firms are pressured by government regulations, customers, environmental NGOs, availability of green technology and top management, it will lead to manufacturing firm's overall reduction in carbon emissions.

Based on the finding, it shows that all H9 hypotheses were supported. Manufacturing firms need to adhere to government regulations and policies related to environment as it was found to be statistically significant to firms' LCP. As governments all around the world has been tasked to reduce carbon emissions to mitigate climate change, manufacturing firms that produce high carbon emissions need to meet the requirements of local government regulations, national level regulations and exporting countries environmental regulations. Furthermore, customers these days is applying pressure on manufacturing firms to take a more proactive role in reducing carbon emissions and ensuring that the products offered do not impact the environment in a negative way. As a result, manufacturing firms have to reduce carbon emissions to appease customers and to meet customers' requirements. Even though manufacturing firms that participated in this study produce for other firms, the other firms as customers have an obligation to reduce carbon emissions of end-customers. Thus, customer pressure is critical to LCP. In addition, environmental NGOs also play a major role in monitoring and reporting manufacturing firms that do not meet the low carbon objective. The pressure by environmental NGOs is also critical for manufacturing firms to take into consideration. Moreover, it is the top management that make decisions on LCSC practices and the reduction of carbon emissions. Based on the profile of the firms that practice low carbon, it shows that top management's support is important for manufacturing firms to meet the objective of LCP. This result is consistent with the findings in the literature (Böttcher & Müller, 2015; Luo et al., 2017).

### 5.3.6 Research Objective: Investigation on Relationship between Low Carbon Supply Chain Practices and Low Carbon Performance

The importance of this research objective is because it answers the question as to whether manufacturing firms practicing LCSC can achieve LCP. LCSC practices of procurement, product design, production process, distribution and logistics have been theorized as having a positive and significant effect on firm's overall carbon emissions reduction. Based on the finding, it shows that manufacturing firms that practice low carbon product design, low carbon distribution and low carbon logistics were able to achieve LCP. However, the relationship between low carbon procurement and low carbon production process were found to have insignificant relationship with LCP. The practice of low carbon product design is found to be positive and statistically significant due to manufacturing firms in this study are producers of industrial products or suppliers to other firms. Therefore, its design and specification must meet the requirement of customers. Firms in Malaysia produce and export their products to other countries. Thus, it must meet stringent environmental regulations and low in carbon emissions. On the other hand, manufacturing firms also need to reduce carbon emissions for distribution and logistics in order to achieve LCP. The distribution among manufacturing firms in Malaysia shows the reason why most manufacturing firms were clustered and saturated in northern (43.4%) and central of Malaysia (49.7%). Manufacturing firms that are located close by will be able to practice low carbon distribution and low carbon logistics that can help firms achieve LCP. The finding is supported by various studies notably by Luo et al. (2017), Böttcher and Müller (2015) and (Zhang et al., 2012).

However, another critical LCSC practice such as low carbon procurement and low carbon production process were found to have insignificant effect on LCP relationship. Low carbon procurement is important as the supplies of low carbon materials will enable manufacturing firms to produce low carbon product and achieving LCP. Furthermore, firms are pressured to reduce carbon emissions in the production so that overall carbon emissions can be reduced. Yet, the result shows manufacturing firms viewed low carbon procurement as not contributing towards LCP. This is because firms it depends on the stakeholder's objectives. For example, the finding of Böttcher and Müller (2015) investigating stakeholder pressure and competitiveness of firm found that LCSC practices depend on the objective of stakeholder and perception of firm practicing LCSC. Firms viewed low carbon procurement as not contributing to LCP because firms participating in this study is of the view that their contribution is to meet operational performance so that customers will be satisfied. Furthermore, firms perceived low carbon product, low carbon distribution and low carbon logistics that are involved in this process more as more important for LCP. Similarly, for low carbon production process, manufacturing firms that produce for another manufacturers or firms need to fulfil operational objectives before fulfilling LCP objective. This can be seen in the next section where the mediating effect of GSCOP has provide linkage between LCSC practices and LCP.

### 5.3.7 Research Objective: Investigation of Mediating Effect of Green Supply Chain Operational Performance on Relationship between Low Carbon Supply Chain Practices and Low Carbon Performance

It has been hypothesized that manufacturing firms that are practicing LCSC will be able to achieve LCP. Yet, with manufacturing firms able to meet GSCOP while practicing LCSC will enable firms to achieve better LCP result. All in all, the finding shows that there is a mediating effect of GSCOP on the relationship of LCSC practices and LCP.

The first hypothesis depicts the mediating effect of GSCOP between low carbon procurement and LCP. Based on the finding, it shows that flexibility, responsiveness and environmental friendliness has a positive and significant impact for the relationship between low carbon procurement and LCP. Previously, the direct effect between low carbon procurement and LCP has been established and it was found that there is a negative effect for the relationship. However, through mediation of GSCOP, it was found that manufacturing firms that have flexibility, responsiveness and environmental friendliness will be able to achieve LCP. Thus, the mediating effect of GSCOP is important for manufacturing firms that practice LCSC to meet the objective of LCP. In addition, by being flexible, responsive and environmental friendliness in operations will ensure manufacturing firms focus more attention on improving relationship with suppliers. As a result, procurement process will be improved, and overall LCP can be achieved. However, cost reduction of GSCOP failed to mediate the relationship between low carbon procurement and LCP mainly due to the fact that cost reduction is not a primary concern for LCP but for GSCOP as shown in hypothesis H6a.

On the other hand, GSCOP was found to be of no effect on the relationship between low carbon product and LCP. This shows that manufacturing firms that design products to have low carbon specifications either are able to achieve GSCOP or LCP but not both performances. This justification can be found in the hypothesis H10b and hypothesis H6b. In direct effect hypothesis of H10b it shows that firms that practice low carbon product was able to achieve LCP and in hypothesis H6b it shows that firms that practice low carbon product achieved GSCOP. Therefore, the mediating effect of GSCOP that will enable firms to achieve better LCP was not found to be positive and significant. Another justification is that manufacturing firms in Malaysia mostly are producing products for other firms and to achieve performance depending on the objective of those firms. Regardless, manufacturing firms instil LCSC practices to help firms sustain in the business and cater to both non-green and green customers.

Previously in hypothesis H10c, it was found that LCSC practice of low carbon production process has negative impact on LCP. However, with the introduction of GSCOP as mediating effect, it was found that low carbon production process will enable the achievement of LCP when firms achieve cost reduction, responsiveness and environmental friendliness. Firms can achieve LCP when firms have cost reduction in operations because producing low carbon product is expensive and requires heavy investment in green technology. Thus, if the cost to produce low carbon product is cheaper, manufacturing firms have the incentives to pursue. Furthermore, ability to be responsive to changes in design, customer requirements, delivery and overall supply chain can help manufacturing firms to achieve LCP. Therefore, firms can achieve better LCP if firms consider responsiveness and environmental friendliness. All in all, with

GSCOP, manufacturing firms are able to achieve low carbon production process that meet the requirements of LCP.

Similarly, the introduction of GSCOP to entice the relationship between low carbon distribution and LCP has found to be positive and significant but only for flexible criterion. As direct effect between LCSC practices and GSCOP in hypothesis H6d and direct effect between LCSC practices and LCP in hypothesis H10 were accepted, it shows that the mediating effect for GSCOP on the relationship between LCSC practices and LCP is only minor. Nevertheless, it also depicts GSCOP as non- distraction for manufacturing firms, if firms need to choose between achieving GSCOP or LCP.

Likewise, the finding of mediating effect of GSCOP on the relationship between low carbon logistics and LCP was found to be positive and significant. This is because customers are important for firms and transportation of product to customers are operationally important for firms to manage. Thus, manufacturing firms viewed GSCOP as compatible with LCP. Therefore, the mediating effect of GSCOP provides manufacturing firms with better performances as firms can achieve customer satisfaction through both operational performance and environmental performance. All in all, the result of GSCOP as mediating between LCSC practices and LCP has the support from a study by Zhu et al. (2013) where scholars have found that GSCOP to have partial effect on LCSC practices relationship and LCP.

## 5.4 List of Contributions

Based on the findings in Chapter 4 and discussion of findings in Chapter 5, theoretical and practical implications can be identified. This section will discuss theoretical implication followed by practical implications.

### 5.4.1 Theoretical and Knowledge

This study provides theoretical framework that is supported by the Institutional theory. Institutional theory explains that government regulation has coercive pressure while customer has normative pressure (Fu, Kok, Dankbaar, Ligthart, & van Riel, 2018; Zhu et al., 2013). Then, there is an argument that Institutional theory not only can be used as justification for the adoption of practices, but also to show how and why firm change over time (Dacin et al., 2002). Early investigation by Zhu et al. (2005) shows that perhaps

Chinese consumers are changing and demanding more environmental friendly products from manufacturing firms. In this study, the empirical finding provide justification that customer pressure is coercive while government regulation is normative pressure. This is evident in the hypothesis H1a, H2a, H8a and H8b. Furthermore, it contributes to the knowledge of Institutional theory regarding empirical justification and understanding of isomorphic drivers. This has provided an avenue for future discussion on classification of isomorphic drivers. This is because customers nowadays are becoming more complex to manage and more demanding than the previous times.

Another implication of this study in terms of theoretical contribution is on the introduction of GSCOP as a mediating effect. In the early investigation by Zhu et al. (2013) that tries to link between operational performance and environmental performance found that it has partial support. Based on this study's empirical result, it shows that GSCOP can mediate between LCSC practices and LCP. This study also shows that for low carbon procurement and low carbon production process, introduction of GSCOP is able to help manufacturing firms achieve LCP. Thus, not only firms are able to achieve its performance, but firms can achieve both operational and environmental performances.

In the investigation of LCSC framework to achieve LCP, there were several attempts made on the framework of LCSC, but there were very limited studies with comprehensive framework that could provide empirical findings. This study on the other hand is more systematically developed. This study has discussed several determinants for LCSC practices, GSCOP and LCP that were found to be most widely cited in the literature. In addition, this study has developed GSCOP which is still lacking in the manufacturing industry due to various and differing operational performance objectives adopted by firms. Thus, by introducing GSCOP and by including most widely used operational performance criteria in manufacturing, this study has provided criteria that is important for manufacturing firms to achieve. Moreover, this study has presented and discussed the empirical findings for manufacturing firms that practice LCSC to achieve both GSCOP and LCP. Since manufacturing firms need to meet operational performance objectives and environmental performance, it is important that firms achieve both performances.

Finally, the investigation on LCP is important as nowadays the threat of climate change has becoming more serious than ever before. Every stakeholder is playing their part in mitigating climate change. One of the most highly advisable practice is to reduce carbon emissions from stakeholders' daily activities. Since manufacturing industry emits high carbon emissions, it is important for manufacturing firms to reduce carbon emissions throughout its processes. The whole supply chain network need to be redesigned to include carbon emissions abatement but the existing supply chain framework is lacking in low carbon practices (Benjaafar et al., 2013). This study provides LCSC practices to help manufacturing firms practically achieve LCP.

### 5.4.2 Practical and Industry

Based on the LCSC framework that has been introduced by this study, manufacturing firms are able to reduce carbon emissions while fulfilling customer requirements and firm's performance. The framework provides manufacturing firms understanding on important pressures from both external and internal. For example, government regulations, customer pressure and environmental NGOs proved that the pressure from the external should be within firms' control. On the other hand, the support from internal investment of green technology and top management's support are critical for firms to achieve customer requirements and firm's performance. This study has underlined most widely cited determinants that firms should consider in developing its LCSC practices.

Furthermore, the findings of this study provide indicators for manufacturing firms to improve low carbon procurement practice and low carbon production process. In addition, manufacturing firms can also include GSCOP to improve both procurement and production process to achieve LCP. Additionally, manufacturing firms should improve low carbon product design and specifications as manufacturing firms need to achieve GSCOP and LCP performances together in current industrial era.

Policymakers on the other hand should entice more benefits for firms to achieve GSCOP especially for responsiveness and flexibility as this study has shown that manufacturing firms have considered both responsiveness and flexibility as primary criteria for measuring operational performance. Thus, even though policymakers would like manufacturing firms to focus on improving environmental friendliness and LCP, firms still need to fulfil stakeholder's objectives of responsiveness and flexibility. Therefore, it is imperative for policymakers and manufacturing firms to consider GSCOP to achieve LCP.

Lastly, the role of environmental NGOs and green technology in the Malaysian manufacturing industry should get more attention from practitioners. As environmental NGOs become more proactive in Malaysia to promote LCP awareness, manufacturing firms need to improve current LCSC practices in order to meet the objective of LCP. Green technology on the other hand is still expensive but has been made available. This study had shown that investing in green technology is not a risky investment as customers are demanding more low carbon products and regulations on carbon emissions are becoming more stringent even for a developing country like Malaysia. Therefore, in order to mitigate the risk, manufacturing firms should gradually invest in green technology to better produce low carbon product and cater to wider range of customers.

## 5.5 Conclusion

Generally, this study examines the relationship between LCSC practices and LCP with the mediating effect of GSCOP. The context of the study is in Malaysian manufacturing industry as this industry emits high carbon emissions. As LCSC practices framework is still lacking and current supply chain model is unable to reduce carbon emissions, this study has developed a comprehensive LCSC model that shows external and internal drivers that pressure firms to practice LCSC. The consideration of drivers for LCSC practices does not solely come from previous research but also supported by established organizational theory called Institutional theory. From the understanding of the literature and theory, the LCSC framework has been developed to achieve LCP.

As the study investigated LCP in the Malaysian manufacturing industry, identifying LCSC practices are important. This helped to close gaps in the literature and contributes theoretically and practically. There are six practices including low carbon procurement, low carbon product design, low carbon production process, low carbon distribution and low carbon logistics that are hypothesized to help manufacturing firms to reduce carbon emissions. Furthermore, manufacturing firms also need to meet operational objectives. Yet, there are many criteria to measure success of operations. The literature is rich in conceptual findings but limited in empirical justifications. Thus, this study has proposed GSCOP that is based on most widely used operational criteria in manufacturing found in the literature. The practice of LCSC and GSCOP were also hypothesized to achieve LCP.

The findings of this study indicated that determinants of LCSC practices were positive and significant for LCSC practices, GSCOP and LCP. The relationship between LCSC practices and GSCOP and LCP were also found to be positive and significant. However, there were several hypotheses that were rejected but the most surprising result is that low carbon procurement and low carbon production process were found to be of no effect on LCP. Nevertheless, this study also found an interesting finding that by including mediating effect of GSCOP, manufacturing firms were able to achieve LCP for low carbon procurement and low carbon production process.

Based on the findings, it contributes to the knowledge of Institutional theory where customer pressure now has overtaken government regulations as coercive isomorphic. Furthermore, manufacturing firms should consider GSCOP to achieve LCP and this will give manufacturing firms an advantage as both performances would be able to be met at the same time. Practically, manufacturing firms should also be wary of the influence of customers and environmental NGOs. Firms should also improve green technology as it was found to help firms achieve better GSCOP and LCP results.

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**APPENDIX A**

**QUESTIONNAIRE**

Respected Dato / Datin / Sir / Madam / Mr / Ms,

My name is Muhammad Shabir Shaharudin, currently pursuing PhD at Faculty of Industrial Management, Universiti Malaysia Pahang (UMP). I am conducting a research under the supervision of Dr. Yudi Fernando as a partial requirement for my PhD. Your firm is selected as one of the significant respondents for this study and your input is highly appreciated to represent your firm. For your kind information, the purpose of this questionnaire is to study the impact of Low Carbon Supply Chain practices on manufacturing industry in Malaysia and to identify drivers of Low Carbon Supply Chain.

As Malaysia and almost all countries will and have signed carbon reduction treaty, improved low carbon policies is expected for manufacturing industry. This study will be able to help government to develop useful policies for your firm and manufacturing industry in Malaysia. Furthermore, this study will be able to help your firm to understand low carbon practices. It is believed that your firm is practicing Low Carbon Supply Chain in your operations and supply chain, thus the synthesized information would provide insight on how Low Carbon Supply Chain affect your operational performance and environmental performance. Consequently, the information provided would instil better understanding on the impacts of Low Carbon Supply Chain in the manufacturing industry in Malaysia.

Your honest opinion is requested. We can assure you that whatever information gathered will be treated with the utmost confidentiality and used strictly for academic purpose only. In addition, the findings of this study can be obtained should upon your request. This questionnaire consists of six (6) sections to be answered according to the given instruction. It will take you about 15 minutes to complete this survey form.

I am greatly appreciated the help of your firm and yourself in furthering this research endeavour. If you have any enquiries, please do not hesitate to contact me. Thank you very much for your kind cooperation.

I would like to invite you to fill out the form: **Determinants of Low Carbon Supply Chain in Malaysian Manufacturing Industry: Practices and Its Relationship on Green Supply Chain Operational Performance and Low Carbon Performance**.

**SECTION A: FIRM PROFILE**

The primary objective of this section is to get to know the background of the researched firm.

Please tick in the most appropriate response box or fill in with the most appropriate or closest answer to your firm.

Does your firm practice environmental management?

- [ ] Yes
- [ ] No

A1. Does your firm hold any green international organization standards?

- [ ] ISO 14001 (environmental management)
- [ ] ISO 14024 (environmental labels and declarations)
- [ ] ISO 14067 (carbon management)
- [ ] ISO 50001 (energy management)
- [ ] ISO 26000 (corporate social responsibility)
- [ ] ISO 9001 (quality management system)
- [ ] No (if your answer is no, please specify the reason below)

If your answer is No in question A1, please provide a reason

______________________________________________________________________

A2. Type of industry:

- [ ] Agricultural/Food
- [ ] Automotive
- [ ] Building Material
- [ ] Chemical
- [ ] Consumer/Office Machines
- [ ] Electrical/Electronics
- [ ] Energy/Heat transfer
- [ ] Furniture
- [ ] Industrial Machine Rubber
- [ ] Medical
- [ ] Metal
- [ ] Packaging/Paper/Plastics
- [ ] Pharmaceutical
- [ ] Rubber
- [ ] Textile/Clothing
- [ ] Utility
- [ ] Other: ______________________________________________________

A3. Age of firm:

- [ ] Less than 10 years
- [ ] 10 to 15 years
- [ ] 16 to 20 years
- [ ] More than 20 years

A4. Type of product:

- [ ] Consumer product
- [ ] Industrial product

A5. Ownership status:

- [ ] Malaysian fully owned
- [ ] Local and foreign joint venture
- [ ] American-based firm
- [ ] European-based firm
- [ ] Japanese-based firm
- [ ] Other ____________________

A6. Number of employees

- [ ] Less than 100
- [ ] 100 - 250
- [ ] 251 - 500
- [ ] More than 500

A7. Is your firm concern with low carbon emissions reduction?

- [ ] Yes (please specify below)
- [ ] No (please provide reason below)

Based on your answer in question A7, please provide justification

____________________

A8. Years firm adopting low carbon practice

- [ ] Less than 1 year
- [ ] 1 to 3 years
- [ ] More than 3 years

A9. Has your firm received any support/incentives from Malaysian government for reducing carbon emissions?

- [ ] Yes (please specify the incentive below)
- [ ] No (please indicate the reason below)

Based on your answer in question A9, please provide justification

____________________

A10. Does your firm participate in any Malaysian governmental carbon emissions reduction program?

- [ ] Yes (please specify below)
- [ ] No (please provide reason below)

Based on your answer in question A10, please provide justification

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A11. Does your firm have dedicated department to reduce carbon emissions?

- [ ] Yes
- [ ] No

A12. Does your firm have a department to monitor carbon emissions?

- [ ] Yes
- [ ] No

## SECTION B: DETERMINANTS OF LOW CARBON SUPPLY CHAIN PRACTICES

**Low Carbon Supply Chain (LCSC)** can be defined as control and reduction of carbon emissions or air pollution directly or indirectly in the supply chain.

Controlling the amount of carbon emissions release from firm's supply chain process and decision to reduce carbon emissions in the supply chain process are practices of LCSC.

In addition, controlling and reducing carbon emissions can be done directly or indirectly. Direct LCSC practice is regards as firm's management of the supply chain process focusing on controlling or reducing carbon emissions. On the other hand, indirect LCSC practice is firm's management of the supply chain process by focusing on "green" or environmentally friendly that indirectly resulting to carbon emissions reduction.

Please indicate your degree of agreement or disagreement in each statement by tick/circle for each question based on 5-point Likert scale:

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |

| | **Government Regulations** | | | | | |
|---|---|---|---|---|---|---|
| GRC1 | Our firm has adopted LCSC practices due to environmental regulations (such as waste emission, cleaner production etc.). | 1 | 2 | 3 | 4 | 5 |
| GRC2 | Our firm has adopted LCSC practices due to resource saving or conservation regulations. | 1 | 2 | 3 | 4 | 5 |
| GRC3 | Our firm has adopted LCSC practices due to export countries' environmental regulations. | 1 | 2 | 3 | 4 | 5 |
| GRC4 | Our firm received attainment after implementing environmental regulations. | 1 | 2 | 3 | 4 | 5 |

| | **Customer Pressure** | | | | | |
|---|---|---|---|---|---|---|
| CPC1 | Our firm's products have increase firm's green image in the eye of customers (consumers). | 1 | 2 | 3 | 4 | 5 |
| CPC2 | Our firm's products meet global market requirements. | 1 | 2 | 3 | 4 | 5 |
| CPC3 | Our firm's products meet green expectation from domestic customers. | 1 | 2 | 3 | 4 | 5 |
| CPC4 | Our firm's product has been recognized by domestic customers. | 1 | 2 | 3 | 4 | 5 |

| | **Green Technology** | | | | | |
|---|---|---|---|---|---|---|
| GTC1 | Our firm has deployed latest low carbon technology. | 1 | 2 | 3 | 4 | 5 |
| GTC2 | Our firm continuously exploits the potential technology. | 1 | 2 | 3 | 4 | 5 |
| GTC3 | Our firm has set up in-house R&D unit. | 1 | 2 | 3 | 4 | 5 |
| GTC4 | Our firm has made greater use of low carbon technology. | 1 | 2 | 3 | 4 | 5 |

| | Environmental NGOs | | | | | |
|---|---|---|---|---|---|---|
| ENC1 | Environmental NGOs has pressured our firm to practice LCSC. | 1 | 2 | 3 | 4 | 5 |
| ENC2 | Our firm has participated in industrial community linkage activities organized by environmental NGOs. | 1 | 2 | 3 | 4 | 5 |
| ENC3 | Our firm is closely monitored by environmental NGOs. | 1 | 2 | 3 | 4 | 5 |
| ENC4 | Our firm's low carbon practices are recognized by environmental NGOs. | 1 | 2 | 3 | 4 | 5 |

| | Top Management | | | | | |
|---|---|---|---|---|---|---|
| TMC1 | Our firm's top management fully supports LCSC practices. | 1 | 2 | 3 | 4 | 5 |
| TMC2 | Our firm's top management consistently assessed LCSC practices. | 1 | 2 | 3 | 4 | 5 |
| TMC3 | Our firm's top management has demonstrated leadership on LCSC practices. | 1 | 2 | 3 | 4 | 5 |
| TMC4 | Our firm's top management are committed to adopt LCSC best practices. | 1 | 2 | 3 | 4 | 5 |

## SECTION C: LOW CARBON SUPPLY CHAIN PRACTICES

**Low Carbon Supply Chain (LCSC)** practices can be defined as taking carbon emissions into consideration in regard to supply chain activities and processes.

Please indicate your degree of agreement or disagreement in each statement by tick/circle for each question based on 5-point Likert scale:

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |

| | **Low Carbon Procurement** | | | | | |
|---|---|---|---|---|---|---|
| PRC1 | Our firm provide design specification to suppliers that include low carbon requirements for purchased items. | 1 | 2 | 3 | 4 | 5 |
| PRC2 | Our firm provide collaborate with suppliers to meet low carbon objectives. | 1 | 2 | 3 | 4 | 5 |
| PRC3 | Our firm has requested environmental audit report from suppliers. | 1 | 2 | 3 | 4 | 5 |
| PRC4 | Our firm has required suppliers to comply with environmental related standards (ISO14001, ISO50001). | 1 | 2 | 3 | 4 | 5 |
| PRC5 | Our firm has included low carbon practices as one supplier selection criteria. | 1 | 2 | 3 | 4 | 5 |

| | **Low Carbon Product** | | | | | |
|---|---|---|---|---|---|---|
| PRD1 | Our firm use life cycle assessment to develop low carbon related products. | 1 | 2 | 3 | 4 | 5 |
| PRD2 | Our firm use renewable or recycled raw materials for product development. | 1 | 2 | 3 | 4 | 5 |
| PRD3 | Our firm has less carbon-intensive raw materials during product development. | 1 | 2 | 3 | 4 | 5 |
| PRD4 | Our firm less use carbon emissions during product development. | 1 | 2 | 3 | 4 | 5 |

| | Low Carbon Production Process | | | | | |
|---|---|---|---|---|---|---|
| PPC1 | Our firm has measurement of carbon emissions along production processes. | 1 | 2 | 3 | 4 | 5 |
| PPC2 | Our firm has use of energy/carbon efficient equipment for production processes. | 1 | 2 | 3 | 4 | 5 |
| PPC3 | Our firm has use of low carbon/carbon-free energy sources. | 1 | 2 | 3 | 4 | 5 |
| PPC4 | Our firm has recycling of carbon-intensive scrap. | 1 | 2 | 3 | 4 | 5 |

| | Low Carbon Distribution | | | | | |
|---|---|---|---|---|---|---|
| DIS1 | Our firm has collaborated with suppliers to use low carbon distribution network. | 1 | 2 | 3 | 4 | 5 |
| DIS2 | Our firm has requirement for suppliers to use environmental packaging (degradable and non-hazardous). | 1 | 2 | 3 | 4 | 5 |
| DIS3 | Our firm ask suppliers to use recyclable pallet system when they deliver supplies to us. | 1 | 2 | 3 | 4 | 5 |
| DIS4 | Our firm has analysed energy efficiency systems in our warehouses operation. | 1 | 2 | 3 | 4 | 5 |
| DIS5 | Our firm expect suppliers to take back their packaging or pallet systems to supply goods to us. | 1 | 2 | 3 | 4 | 5 |

| | Low Carbon Logistics | | | | | |
|---|---|---|---|---|---|---|
| LOG1 | Our firm has frequently conducted carbon emissions assessment for transportation activities. | 1 | 2 | 3 | 4 | 5 |
| LOG2 | Our firm has consolidation of shipments to ensure we achieve low carbon emissions. | 1 | 2 | 3 | 4 | 5 |
| LOG3 | Our firm has use carbon-efficient technologies to design transportation networks/routes. | 1 | 2 | 3 | 4 | 5 |
| LOG4 | Our firm has use of low carbon transportation modes. | 1 | 2 | 3 | 4 | 5 |

## SECTION D: GREEN SUPPLY CHAIN OPERATIONAL PERFORMANCE

**Green Supply Chain Operational Performance (GSCOP)** can be defined as objectives or assessment tool to evaluate firm's supply chain performance.

Please indicate your degree of agreement or disagreement in each statement by tick/circle for each question based on 5-point Likert scale:

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |

| | Cost reduction | | | | | |
|---|---|---|---|---|---|---|
| COS1 | Our firm has reduced cost of product resign. | 1 | 2 | 3 | 4 | 5 |
| COS2 | Our firm has reduced unnecessary cost from purchased materials. | 1 | 2 | 3 | 4 | 5 |
| COS3 | Our firm has reduced production cost. | 1 | 2 | 3 | 4 | 5 |
| COS4 | Our firm has reduced transportation cost. | 1 | 2 | 3 | 4 | 5 |
| COS5 | Overall, our firm has reduced supply chain cost. | 1 | 2 | 3 | 4 | 5 |

| | Flexibility | | | | | |
|---|---|---|---|---|---|---|
| FLX1 | Our firm's suppliers are flexible. | 1 | 2 | 3 | 4 | 5 |
| FLX2 | Our firm's supply of products is flexible. | 1 | 2 | 3 | 4 | 5 |
| FLX3 | Our firm's production process is flexible. | 1 | 2 | 3 | 4 | 5 |
| FLX4 | Our firm's delivery to customer is flexible. | 1 | 2 | 3 | 4 | 5 |

| | Responsiveness | | | | | |
|---|---|---|---|---|---|---|
| RES1 | Our firm has responsive product design to meet customer requirement. | 1 | 2 | 3 | 4 | 5 |
| RES2 | Our firm has responsive quality raw materials purchase to meet customers' demand. | 1 | 2 | 3 | 4 | 5 |
| RES3 | Our firm has responsive delivery to customers. | 1 | 2 | 3 | 4 | 5 |
| RES4 | Our firm has responsive product return for customers. | 1 | 2 | 3 | 4 | 5 |
| RES5 | Our firm has responsive supply chain to meet customers' demand. | 1 | 2 | 3 | 4 | 5 |

| | Environmental Friendliness | | | | | |
|---|---|---|---|---|---|---|
| EFR1 | Our firm has used less energy consumption. | 1 | 2 | 3 | 4 | 5 |
| EFR2 | Our firm use clean energy fuel to support in operation. | 1 | 2 | 3 | 4 | 5 |
| EFR3 | Our firm has design green value chain to support our operation. | 1 | 2 | 3 | 4 | 5 |
| EFR4 | Our firm use life cycle assessment to support principle of environmental friendliness. | 1 | 2 | 3 | 4 | 5 |

**SECTION E: LOW CARBON PERFORMANCE**

**Low Carbon Performance (LCP)** can be defined as strategic commitment by firm to reduce carbon emissions.

Please indicate your degree of agreement or disagreement in each statement by tick/circle for each question based on 5-point Likert scale:

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |

| | | | | | | |
|---|---|---|---|---|---|---|
| LCP1 | Our firm has reduced of carbon emissions. | 1 | 2 | 3 | 4 | 5 |
| LCP2 | Our firm has reduced of energy use. | 1 | 2 | 3 | 4 | 5 |
| LCP3 | Our firm has reduced use of carbon-intensive materials. | 1 | 2 | 3 | 4 | 5 |

**SECTION F: RESPONDENT PROFILE**

The primary objective of this section is to get to know the general profile of the respondent.

Please tick in the most appropriate response box or fill in with the most appropriate or closest answer.

F1. Position in firm:

- [ ] Chief Executive Office
- [ ] Managing Director
- [ ] Senior Manager
- [ ] R&D director/manager
- [ ] Environmental Health and Safety (EHS) manager
- [ ] Energy manager
- [ ] Other: ______________________________

F2. Years in firm:

- [ ] Less than 5 years
- [ ] 6 - 10 years
- [ ] 11 - 15 years
- [ ] More than 15 years

F3. Qualification of respondent:

- [ ] Secondary/SPM/O-Level
- [ ] Pre-University/STPM/A-Level
- [ ] Diploma
- [ ] Undergraduate Degree
- [ ] Postgraduate Degree
- [ ] Professional Certificate

F4. Gender of respondent:

☐ Male

☐ Female

F5. Age of respondent:

☐ Less than 30 years old

☐ 31 - 40 years old

☐ 41 - 50 years old

☐ More than 50 years old

Please leave your email below if you need a copy of executive summary of this study:

__________________________________________________________________________

Thank You for your time and participation

# APPENDIX B

# STATISTICAL OUTPUT

**Statistics**

Does your firm practice environmental management?

| | | |
|---|---|---|
| N | Valid | 143 |
| | Missing | 0 |

**Does your firm practice environmental management?**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Yes | 143 | 100.0 | 100.0 | 100.0 |

**$ISO_CERTIFICATION Frequencies**

| | | Responses | | Percent of Cases |
|---|---|---|---|---|
| | | N | Percent | |
| ISO CERTIFICATION[a] | ISO14001 | 109 | 61.9% | 90.1% |
| | ISO14024 | 12 | 6.8% | 9.9% |
| | ISO14067 | 8 | 4.5% | 6.6% |
| | ISO50001 | 6 | 3.4% | 5.0% |
| | ISO26000 | 30 | 17.0% | 24.8% |
| | ISO9001 | 11 | 6.3% | 9.1% |
| Total | | 176 | 100.0% | 145.5% |

a. Dichotomy group tabulated at value 1.

A2. Type of manufacturing sector

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Agricultural/Food | 11 | 7.7 | 7.7 | 7.7 |
| | Automotive | 19 | 13.3 | 13.3 | 21.0 |
| | Building Material | 8 | 5.6 | 5.6 | 26.6 |
| | Capacity building and assistance for manufacturing sector | 7 | 4.9 | 4.9 | 31.5 |
| | Consumer/Office Machines | 5 | 3.5 | 3.5 | 35.0 |
| | Electrical/Electronics | 52 | 36.4 | 36.4 | 71.3 |
| | Energy/Heat Transfer | 12 | 8.4 | 8.4 | 79.7 |
| | Furniture | 3 | 2.1 | 2.1 | 81.8 |
| | Industrial Machine Rubber | 4 | 2.8 | 2.8 | 84.6 |
| | Metal | 8 | 5.6 | 5.6 | 90.2 |
| | Packaging/Paper/Plastics | 6 | 4.2 | 4.2 | 94.4 |
| | Pharmaceutical | 3 | 2.1 | 2.1 | 96.5 |
| | Utility | 5 | 3.5 | 3.5 | 100.0 |
| | Total | 143 | 100.0 | 100.0 | |

A3. Age of firm

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 10 to 15 years | 48 | 33.6 | 33.6 | 33.6 |
| | 16 to 20 years | 44 | 30.8 | 30.8 | 64.3 |
| | Less than 10 years | 24 | 16.8 | 16.8 | 81.1 |
| | More than 20 years | 27 | 18.9 | 18.9 | 100.0 |
| | Total | 143 | 100.0 | 100.0 | |

A4. Type of product

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Consumer Product | 46 | 32.2 | 32.2 | 32.2 |
| | Industrial Product | 97 | 67.8 | 67.8 | 100.0 |
| | Total | 143 | 100.0 | 100.0 | |

**A5. Ownership status**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | American-based Firm | 16 | 11.2 | 11.2 | 11.2 |
| | European-based Firm | 9 | 6.3 | 6.3 | 17.5 |
| | Japanese-based Firm | 12 | 8.4 | 8.4 | 25.9 |
| | Local and Foreign Joint Venture | 46 | 32.2 | 32.2 | 58.0 |
| | Malaysian Fully Owned | 60 | 42.0 | 42.0 | 100.0 |
| | Total | 143 | 100.0 | 100.0 | |

**A6. Number of employees**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 100 to 250 | 32 | 22.4 | 22.4 | 22.4 |
| | 251 to 500 | 27 | 18.9 | 18.9 | 41.3 |
| | Less than 100 | 14 | 9.8 | 9.8 | 51.0 |
| | More than 500 | 70 | 49.0 | 49.0 | 100.0 |
| | Total | 143 | 100.0 | 100.0 | |

**Location of Firm**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | North (eg: PERLIS, KEDAH, PENANG, PERAK) | 62 | 43.4 | 43.4 | 43.4 |
| | Central (eg: KUALA LUMPUR, SELANGOR, PUTRAJAYA, CYBERJAYA, NEGERI SEMBILAN) | 71 | 49.7 | 49.7 | 93.0 |
| | Southern (eg: JOHOR, MELAKA) | 6 | 4.2 | 4.2 | 97.2 |
| | East Cost (eg: KELANTAN, TERENGGANU, PAHANG) | 4 | 2.8 | 2.8 | 100.0 |
| | Total | 143 | 100.0 | 100.0 | |

**A7. Is your firm concern with low carbon emissions reduction?**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Yes (please specify below) | 143 | 100.0 | 100.0 | 100.0 |

**Based on your answer in question A7, please provide justification**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Customer Demand | 31 | 21.7 | 21.7 | 21.7 |
| | Program & Practice | 20 | 14.0 | 14.0 | 35.7 |
| | Environmental & Low Carbon Support | 27 | 18.9 | 18.9 | 54.5 |
| | Regulation & Policy | 65 | 45.5 | 45.5 | 100.0 |
| | Total | 143 | 100.0 | 100.0 | |

**A8. Years firm adopting low carbon practice**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 1 to 3 years | 68 | 47.6 | 47.6 | 47.6 |
| | Less than 1 year | 53 | 37.1 | 37.1 | 84.6 |
| | More than 3 years | 22 | 15.4 | 15.4 | 100.0 |
| | Total | 143 | 100.0 | 100.0 | |

**A9. Has your firm received any support/incentives from Malaysian government for reducing carbon emissions?**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | No (please indicate the reason below) | 57 | 39.9 | 39.9 | 39.9 |
| | Yes (please specify the incentive below) | 86 | 60.1 | 60.1 | 100.0 |
| | Total | 143 | 100.0 | 100.0 | |

**Justify What is the reason?**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Green Tax | 33 | 23.1 | 23.1 | 23.1 |
| | Green Technology | 14 | 9.8 | 9.8 | 32.9 |
| | Government Tax Reduction | 39 | 27.3 | 27.3 | 60.1 |
| | Not Aware | 57 | 39.9 | 39.9 | 100.0 |
| | Total | 143 | 100.0 | 100.0 | |

**A10. Does your firm participate in any Malaysian governmental carbon emissions reduction program?**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | No (please provide reason below) | 116 | 81.1 | 81.1 | 81.1 |
| | Yes (please specify below) | 27 | 18.9 | 18.9 | 100.0 |
| | Total | 143 | 100.0 | 100.0 | |

**Based on your answer in question A10, please provide justification**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Stakeholder Environmental Program | 9 | 6.3 | 6.3 | 6.3 |
| | Energy Efficiency & Renewable Energy Program | 6 | 4.2 | 4.2 | 10.5 |
| | Clean Development Mechanism | 12 | 8.4 | 8.4 | 18.9 |
| | Not Related to Business | 15 | 10.5 | 10.5 | 29.4 |
| | Lack of Program Information | 21 | 14.7 | 14.7 | 44.1 |
| | Lack of Program Awareness | 80 | 55.9 | 55.9 | 100.0 |
| | Total | 143 | 100.0 | 100.0 | |

**A11. Does your firm have a dedicated department to reduce carbon emissions?**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | No | 95 | 66.4 | 66.4 | 66.4 |
| | Yes | 48 | 33.6 | 33.6 | 100.0 |
| | Total | 143 | 100.0 | 100.0 | |

**A12. Does your firm have a department to monitor carbon emissions?**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | No | 42 | 29.4 | 29.4 | 29.4 |
| | Yes | 101 | 70.6 | 70.6 | 100.0 |
| | Total | 143 | 100.0 | 100.0 | |

**F1. Position in firm**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Chief Executive Office | 4 | 2.8 | 2.8 | 2.8 |
| | Environment Health Safety Officer | 12 | 8.4 | 8.4 | 11.2 |
| | Energy Officer | 13 | 9.1 | 9.1 | 20.3 |
| | Chief Operating Officer | 12 | 8.4 | 8.4 | 28.7 |
| | Managing Director | 13 | 9.1 | 9.1 | 37.8 |
| | General Manager | 21 | 14.7 | 14.7 | 52.4 |
| | Operation Manager | 32 | 22.4 | 22.4 | 74.8 |
| | Supply Chain Manager | 19 | 13.3 | 13.3 | 88.1 |
| | Logistics Manager | 13 | 9.1 | 9.1 | 97.2 |
| | R&D Director/Manager | 4 | 2.8 | 2.8 | 100.0 |
| | Total | 143 | 100.0 | 100.0 | |

**F2. Years in firm**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 11 to 15 years | 40 | 28.0 | 28.0 | 28.0 |
| | 6 to 10 years | 49 | 34.3 | 34.3 | 62.2 |
| | Less than 5 years | 21 | 14.7 | 14.7 | 76.9 |
| | More than 15 years | 33 | 23.1 | 23.1 | 100.0 |
| | Total | 143 | 100.0 | 100.0 | |

**F3. Qualification of respondent**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Doctorate Degree | 5 | 3.5 | 3.5 | 3.5 |
| | Master's Degree | 74 | 51.7 | 51.7 | 55.2 |
| | Professional Certificate | 56 | 39.2 | 39.2 | 94.4 |
| | Undergraduate Degree | 8 | 5.6 | 5.6 | 100.0 |
| | Total | 143 | 100.0 | 100.0 | |

**F4. Gender of respondent**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Female | 49 | 34.3 | 34.3 | 34.3 |
| | Male | 94 | 65.7 | 65.7 | 100.0 |
| | Total | 143 | 100.0 | 100.0 | |

**F5. Age of respondent**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 31 to 40 years old | 36 | 25.2 | 25.2 | 25.2 |
| | 41 to 50 years old | 60 | 42.0 | 42.0 | 67.1 |
| | Less than 30 years old | 4 | 2.8 | 2.8 | 69.9 |
| | More than 50 years old | 43 | 30.1 | 30.1 | 100.0 |
| | Total | 143 | 100.0 | 100.0 | |

| | Cronbach's Alpha | rho_A | Composite Reliability | Average Variance Extracted (AVE) |
|---|---|---|---|---|
| COST | 0.865 | 0.87 | 0.903 | 0.65 |
| CUST | 0.952 | 0.96 | 0.965 | 0.873 |
| ENGO | 0.917 | 0.949 | 0.941 | 0.8 |
| ENVF | 0.915 | 0.918 | 0.94 | 0.796 |
| FLEX | 0.921 | 0.922 | 0.944 | 0.809 |
| GOV | 0.869 | 0.928 | 0.907 | 0.712 |
| GT | 0.832 | 0.895 | 0.881 | 0.657 |
| LCDIS | 0.89 | 0.894 | 0.92 | 0.697 |
| LCLOG | 0.91 | 0.912 | 0.937 | 0.787 |
| LCP | 0.896 | 0.903 | 0.935 | 0.827 |
| LCPROC | 0.96 | 0.961 | 0.969 | 0.861 |
| LCPROD | 0.929 | 0.937 | 0.95 | 0.827 |
| LCPROS | 0.925 | 0.948 | 0.948 | 0.823 |
| RESP | 0.878 | 0.88 | 0.911 | 0.673 |
| TPM | 0.773 | 0.807 | 0.852 | 0.593 |

| | R Square | R Square Adjusted |
|---|---|---|
| COST | 0.705 | 0.683 |
| ENVF | 0.743 | 0.723 |
| FLEX | 0.750 | 0.731 |
| LCDIS | 0.682 | 0.67 |
| LCLOG | 0.556 | 0.54 |
| LCP | 0.767 | 0.742 |
| LCPROC | 0.560 | 0.544 |
| LCPROD | 0.415 | 0.392 |
| LCPROS | 0.333 | 0.308 |
| RESP | 0.674 | 0.649 |

| $f^2$ | COST | ENVF | FLEX | LCDIS | LCLOG | LCP | LCPROC | LCPROD | LCPROS | RESP |
|---|---|---|---|---|---|---|---|---|---|---|
| COST | | | | | | 0.027 | | | | |
| CUST | 0.575 | 0.081 | 0.001 | 0.091 | 0.109 | 0.042 | 0.085 | 0.028 | 0.135 | 0.093 |
| ENGO | 0.002 | 0.014 | 0.102 | 0.059 | 0.087 | 0.008 | 0.03 | 0 | 0.022 | 0.001 |
| ENVF | | | | | | 0.085 | | | | |
| FLEX | | | | | | 0.057 | | | | |
| GOV | 0.001 | 0.01 | 0.036 | 0.007 | 0.055 | 0.003 | 0.028 | 0 | 0.001 | 0.003 |
| GT | 0 | 0 | 0.021 | 0.17 | 0.003 | 0.001 | 0.032 | 0.007 | 0.017 | 0.001 |
| LCDIS | 0.081 | 0.001 | 0.008 | | | 0.096 | | | | 0.096 |
| LCLOG | 0.013 | 0.001 | 0.006 | | | 0.06 | | | | 0.039 |
| LCP | | | | | | | | | | |
| LCPROC | 0.017 | 0 | 0.023 | | | 0.023 | | | | 0.006 |
| LCPROD | 0.004 | 0.492 | 0.224 | | | 0.027 | | | | 0.085 |
| LCPROS | 0.002 | 0 | 0.013 | | | 0.013 | | | | 0 |
| RESP | | | | | | 0.068 | | | | |
| TPM | 0.018 | 0.144 | 0.284 | 0.12 | 0.157 | 0.008 | 0.151 | 0.294 | 0 | 0.007 |

| **Loadings** | COST | CUST | ENGO | ENVF | FLEX | GOV | GT | LCDIS | LCLOG | LCP | LCPROC | LCPROD | LCPROS | RESP | TPM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| COST1 | 0.788 | | | | | | | | | | | | | | |
| COST2 | 0.85 | | | | | | | | | | | | | | |
| COST3 | 0.81 | | | | | | | | | | | | | | |
| COST4 | 0.832 | | | | | | | | | | | | | | |
| COST5 | 0.748 | | | | | | | | | | | | | | |
| CUST1 | | 0.965 | | | | | | | | | | | | | |
| CUST2 | | 0.921 | | | | | | | | | | | | | |
| CUST3 | | 0.949 | | | | | | | | | | | | | |
| CUST4 | | 0.902 | | | | | | | | | | | | | |
| ENGO1 | | | 0.838 | | | | | | | | | | | | |
| ENGO2 | | | 0.887 | | | | | | | | | | | | |
| ENGO3 | | | 0.929 | | | | | | | | | | | | |
| ENGO4 | | | 0.92 | | | | | | | | | | | | |
| ENVF1 | | | | 0.911 | | | | | | | | | | | |
| ENVF2 | | | | 0.868 | | | | | | | | | | | |
| ENVF3 | | | | 0.901 | | | | | | | | | | | |
| ENVF4 | | | | 0.889 | | | | | | | | | | | |
| FLEX1 | | | | | 0.902 | | | | | | | | | | |
| FLEX2 | | | | | 0.925 | | | | | | | | | | |
| FLEX3 | | | | | 0.891 | | | | | | | | | | |
| FLEX4 | | | | | 0.88 | | | | | | | | | | |
| GOV1 | | | | | | 0.936 | | | | | | | | | |
| GOV2 | | | | | | 0.866 | | | | | | | | | |
| GOV3 | | | | | | 0.79 | | | | | | | | | |
| GOV4 | | | | | | 0.773 | | | | | | | | | |
| GT1 | | | | | | | 0.819 | | | | | | | | |

| **Loadings** | COST | CUST | ENGO | ENVF | FLEX | GOV | GT | LCDIS | LCLOG | LCP | LCPROC | LCPROD | LCPROS | RESP | TPM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GT2 | | | | | | | 0.918 | | | | | | | | |
| GT3 | | | | | | | 0.586 | | | | | | | | |
| GT4 | | | | | | | 0.877 | | | | | | | | |
| LCDIS1 | | | | | | | | 0.818 | | | | | | | |
| LCDIS2 | | | | | | | | 0.901 | | | | | | | |
| LCDIS3 | | | | | | | | 0.876 | | | | | | | |
| LCDIS4 | | | | | | | | 0.74 | | | | | | | |
| LCDIS5 | | | | | | | | 0.831 | | | | | | | |
| LCLOG1 | | | | | | | | | 0.877 | | | | | | |
| LCLOG2 | | | | | | | | | 0.845 | | | | | | |
| LCLOG3 | | | | | | | | | 0.927 | | | | | | |
| LCLOG4 | | | | | | | | | 0.898 | | | | | | |
| LCP1 | | | | | | | | | | 0.905 | | | | | |
| LCP2 | | | | | | | | | | 0.9 | | | | | |
| LCP3 | | | | | | | | | | 0.923 | | | | | |
| LCPROC1 | | | | | | | | | | | 0.922 | | | | |
| LCPROC2 | | | | | | | | | | | 0.911 | | | | |
| LCPROC3 | | | | | | | | | | | 0.954 | | | | |
| LCPROC4 | | | | | | | | | | | 0.927 | | | | |
| LCPROC5 | | | | | | | | | | | 0.926 | | | | |
| LCPROD1 | | | | | | | | | | | | 0.95 | | | |
| LCPROD2 | | | | | | | | | | | | 0.821 | | | |
| LCPROD3 | | | | | | | | | | | | 0.945 | | | |
| LCPROD4 | | | | | | | | | | | | 0.914 | | | |
| LCPROS1 | | | | | | | | | | | | | 0.939 | | |
| LCPROS2 | | | | | | | | | | | | | 0.954 | | |

| **Loadings** | COST | CUST | ENGO | ENVF | FLEX | GOV | GT | LCDIS | LCLOG | LCP | LCPROC | LCPROD | LCPROS | RESP | TPM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LCPROS3 | | | | | | | | | | | | | 0.966 | | |
| LCPROS4 | | | | | | | | | | | | | 0.752 | | |
| RESP1 | | | | | | | | | | | | | | 0.756 | |
| RESP2 | | | | | | | | | | | | | | 0.8 | |
| RESP3 | | | | | | | | | | | | | | 0.842 | |
| RESP4 | | | | | | | | | | | | | | 0.839 | |
| RESP5 | | | | | | | | | | | | | | 0.86 | |
| TPM1 | | | | | | | | | | | | | | | 0.686 |
| TPM2 | | | | | | | | | | | | | | | 0.664 |
| TPM3 | | | | | | | | | | | | | | | 0.827 |
| TPM4 | | | | | | | | | | | | | | | 0.882 |

| **VIF** | GOV | CUST | ENGO | GT | TPM | LCPROC | LCPROD | LCPROS | LCDIS | LCLOG | COST | FLEX | RESP | ENVF | LCP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| COST | | | | | | | | | | | | | | | 4.035 |
| CUST | | | | | | 1.573 | 1.573 | 1.573 | 1.573 | 1.573 | 2.059 | 2.059 | 2.059 | 2.059 | 3.288 |
| ENGO | | | | | | 1.717 | 1.717 | 1.717 | 1.717 | 1.717 | 1.967 | 1.967 | 1.967 | 1.967 | 2.193 |
| ENVF | | | | | | | | | | | | | | | 4.921 |
| FLEX | | | | | | | | | | | | | | | 4.306 |
| GOV | | | | | | 1.404 | 1.404 | 1.404 | 1.404 | 1.404 | 1.514 | 1.514 | 1.514 | 1.514 | 1.607 |
| GT | | | | | | 2.233 | 2.233 | 2.233 | 2.233 | 2.233 | 2.728 | 2.728 | 2.728 | 2.728 | 2.792 |
| LCDIS | | | | | | | | | | | 3.665 | 3.665 | 3.665 | 3.665 | 4.228 |
| LCLOG | | | | | | | | | | | 2.691 | 2.691 | 2.691 | 2.691 | 2.858 |
| LCP | | | | | | | | | | | | | | | |
| LCPROC | | | | | | | | | | | 2.752 | 2.752 | 2.752 | 2.752 | 2.902 |
| LCPROD | | | | | | | | | | | 1.798 | 1.798 | 1.798 | 1.798 | 3.122 |
| LCPROS | | | | | | | | | | | 1.671 | 1.671 | 1.671 | 1.671 | 1.7 |
| RESP | | | | | | | | | | | | | | | 4.135 |
| TPM | | | | | | 2.395 | 2.395 | 2.395 | 2.395 | 2.395 | 3.969 | 3.969 | 3.969 | 3.969 | 4.605 |

| **HTMT** | COST | CUST | ENGO | ENVF | FLEX | GOV | GT | LCDIS | LCLOG | LCP | LCPROC | LCPROD | LCPROS | RESP | TPM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| COST | | | | | | | | | | | | | | | |
| CUST | 0.838 | | | | | | | | | | | | | | |
| ENGO | 0.496 | 0.495 | | | | | | | | | | | | | |
| ENVF | 0.659 | 0.538 | 0.357 | | | | | | | | | | | | |
| FLEX | 0.518 | 0.396 | 0.231 | 0.812 | | | | | | | | | | | |
| GOV | 0.285 | 0.25 | 0.508 | 0.241 | 0.192 | | | | | | | | | | |
| GT | 0.506 | 0.438 | 0.504 | 0.572 | 0.671 | 0.447 | | | | | | | | | |
| LCDIS | 0.764 | 0.635 | 0.615 | 0.615 | 0.635 | 0.356 | 0.746 | | | | | | | | |
| LCLOG | 0.658 | 0.632 | 0.563 | 0.589 | 0.529 | 0.221 | 0.542 | 0.684 | | | | | | | |
| LCP | 0.707 | 0.475 | 0.433 | 0.846 | 0.781 | 0.356 | 0.647 | 0.741 | 0.476 | | | | | | |
| LCPROC | 0.593 | 0.594 | 0.502 | 0.612 | 0.636 | 0.234 | 0.573 | 0.784 | 0.716 | 0.564 | | | | | |
| LCPROD | 0.279 | 0.232 | 0.29 | 0.798 | 0.744 | 0.242 | 0.531 | 0.401 | 0.391 | 0.644 | 0.458 | | | | |
| LCPROS | 0.477 | 0.549 | 0.452 | 0.371 | 0.34 | 0.269 | 0.404 | 0.441 | 0.597 | 0.309 | 0.427 | 0.214 | | | |
| RESP | 0.838 | 0.687 | 0.535 | 0.837 | 0.73 | 0.351 | 0.613 | 0.81 | 0.719 | 0.844 | 0.668 | 0.568 | 0.472 | | |
| TPM | 0.736 | 0.64 | 0.623 | 0.842 | 0.845 | 0.471 | 0.788 | 0.832 | 0.777 | 0.85 | 0.785 | 0.686 | 0.481 | 0.843 | |

| **Q²** | SSO | SSE | Q² (=1-SSE/SSO) |
|---|---|---|---|
| COST | 710 | 413.139 | 0.418 |
| CUST | 568 | 568 | |
| ENGO | 568 | 568 | |
| ENVF | 568 | 262.168 | 0.539 |
| FLEX | 568 | 253.7 | 0.554 |
| GOV | 568 | 568 | |
| GT | 568 | 568 | |
| LCDIS | 710 | 398.187 | 0.439 |
| LCLOG | 568 | 340.862 | 0.4 |
| LCP | 426 | 186.361 | 0.556 |
| LCPROC | 710 | 393.669 | 0.445 |
| LCPROD | 568 | 390.768 | 0.311 |
| LCPROS | 568 | 428.193 | 0.246 |
| RESP | 710 | 418.515 | 0.411 |
| TPM | 568 | 568 | |

| **Bootstrapping (Path Coefficient)** | Original Sample (O) | Sample Mean (M) | Standard Deviation (STDEV) | T Statistics (\|O/STDEV\|) | P Values |
|---|---|---|---|---|---|
| COST -> LCP | 0.133 | 0.239 | 0.058 | 2.282 | 0.011 |
| CUST -> COST | 0.179 | 0.592 | 0.096 | 1.859 | 0.032 |
| CUST -> ENVF | 0.213 | 0.214 | 0.107 | 1.994 | 0.023 |
| CUST -> FLEX | 0.388 | 0.023 | 0.085 | 4.56 | 0 |
| CUST -> LCDIS | 0.218 | 0.219 | 0.047 | 4.674 | 0 |
| CUST -> LCLOG | 0.28 | 0.274 | 0.065 | 4.325 | 0 |
| CUST -> LCP | 0.346 | 0.18 | 0.069 | 5.035 | 0 |
| CUST -> LCPROC | 0.211 | 0.237 | 0.049 | 4.316 | 0 |
| CUST -> LCPROD | 0.173 | 0.173 | 0.067 | 2.604 | 0.005 |
| CUST -> LCPROS | 0.337 | 0.37 | 0.056 | 5.985 | 0 |
| CUST -> RESP | 0.135 | 0.252 | 0.084 | 1.61 | 0.054 |
| ENGO -> COST | 0.556 | 0.037 | 0.068 | 8.159 | 0 |
| ENGO -> ENVF | 0.379 | 0.083 | 0.084 | 4.521 | 0 |
| ENGO -> FLEX | -0.003 | 0.226 | 0.081 | 0.036 | 0.486 |
| ENGO -> LCDIS | 0.326 | 0.181 | 0.057 | 5.766 | 0 |
| ENGO -> LCLOG | 0.388 | 0.261 | 0.065 | 5.943 | 0 |
| ENGO -> LCP | 0.154 | 0.064 | 0.077 | 1.985 | 0.024 |
| ENGO -> LCPROC | -0.032 | 0.165 | 0.066 | 0.481 | 0.315 |
| ENGO -> LCPROD | 0.147 | 0.015 | 0.087 | 1.692 | 0.046 |
| ENGO -> LCPROS | 0.262 | 0.165 | 0.054 | 4.819 | 0 |
| ENGO -> RESP | 0.041 | 0.034 | 0.08 | 0.511 | 0.305 |
| ENVF -> LCP | 0.3 | 0.304 | 0.087 | 3.442 | 0 |
| FLEX -> LCP | 0.247 | 0.186 | 0.07 | 3.505 | 0 |

| **Bootstrapping (Path Coefficient)** | Original Sample (O) | Sample Mean (M) | Standard Deviation (STDEV) | T Statistics (\|O/STDEV\|) | P Value s |
|---|---|---|---|---|---|
| GOV -> COST | 0.225 | 0.029 | 0.083 | 2.694 | 0.004 |
| GOV -> ENVF | 0.302 | 0.057 | 0.099 | 3.046 | 0.001 |
| GOV -> FLEX | 0.46 | 0.11 | 0.079 | 5.848 | 0 |
| GOV -> LCDIS | 0.125 | 0.063 | 0.062 | 2.019 | 0.022 |
| GOV -> LCLOG | 0.18 | 0.185 | 0.073 | 2.472 | 0.007 |
| GOV -> LCP | 0.35 | 0.042 | 0.078 | 4.459 | 0 |
| GOV -> LCPROC | 0.127 | 0.141 | 0.067 | 1.904 | 0.029 |
| GOV -> LCPROD | -0.038 | -0.004 | 0.08 | 0.481 | 0.316 |
| GOV -> LCPROS | 0.09 | 0.016 | 0.044 | 2.023 | 0.022 |
| GOV -> RESP | -0.091 | -0.041 | 0.084 | 1.077 | 0.141 |
| GT -> COST | 0.084 | 0.02 | 0.07 | 1.203 | 0.115 |
| GT -> ENVF | 0.193 | 0.011 | 0.074 | 2.599 | 0.005 |
| GT -> FLEX | -0.012 | -0.121 | 0.055 | 0.225 | 0.411 |
| GT -> LCDIS | 0.347 | 0.351 | 0.057 | 6.115 | 0 |
| GT -> LCLOG | 0.042 | 0.049 | 0.061 | 0.684 | 0.247 |
| GT -> LCP | 0.109 | 0.033 | 0.063 | 1.728 | 0.042 |
| GT -> LCPROC | 0.748 | 0.173 | 0.059 | 12.662 | 0 |
| GT -> LCPROD | 0.176 | 0.092 | 0.082 | 2.162 | 0.016 |
| GT -> LCPROS | 0.318 | 0.159 | 0.064 | 4.947 | 0 |
| GT -> RESP | 0.255 | 0.022 | 0.059 | 4.3 | 0 |
| LCDIS -> COST | 0.309 | 0.302 | 0.09 | 3.415 | 0 |
| LCDIS -> ENVF | 0.564 | 0.022 | 0.072 | 7.816 | 0 |
| LCDIS -> FLEX | 0.184 | 0.092 | 0.091 | 2.018 | 0.022 |
| LCDIS -> LCP | 0.225 | 0.181 | 0.097 | 2.313 | 0.011 |
| LCDIS -> RESP | 0.381 | 0.344 | 0.057 | 6.637 | 0 |
| LCLOG -> COST | 0.189 | 0.102 | 0.099 | 1.905 | 0.029 |
| LCLOG -> ENVF | -0.035 | -0.031 | 0.077 | 0.45 | 0.327 |
| LCLOG -> FLEX | 0.06 | 0.061 | 0.087 | 0.688 | 0.246 |
| LCLOG -> LCP | 0.248 | 0.212 | 0.105 | 2.374 | 0.009 |
| LCLOG -> RESP | 0.235 | 0.18 | 0.053 | 4.398 | 0 |
| LCPROC -> COST | 0.189 | 0.117 | 0.101 | 1.88 | 0.03 |
| LCPROC -> ENVF | 0.028 | 0.004 | 0.093 | 0.299 | 0.382 |
| LCPROC -> FLEX | 0.194 | 0.12 | 0.101 | 1.909 | 0.028 |
| LCPROC -> LCP | 0.15 | 0.052 | 0.103 | 1.455 | 0.073 |
| LCPROC -> RESP | 0.156 | 0.074 | 0.083 | 1.889 | 0.03 |
| LCPROD -> COST | 0.009 | 0.046 | 0.063 | 0.137 | 0.445 |
| LCPROD -> ENVF | 0.26 | 0.481 | 0.081 | 3.228 | 0.001 |
| LCPROD -> FLEX | 0.52 | 0.304 | 0.045 | 11.605 | 0 |
| LCPROD -> LCP | 0.189 | 0.032 | 0.058 | 3.261 | 0.001 |
| LCPROD -> RESP | 0.141 | 0.224 | 0.049 | 2.877 | 0.002 |
| LCPROS -> COST | 0.203 | 0.035 | 0.082 | 2.466 | 0.007 |
| LCPROS -> ENVF | 0.121 | 0.001 | 0.066 | 1.835 | 0.034 |

| **Bootstrapping (Path Coefficient)** | Original Sample (O) | Sample Mean (M) | Standard Deviation (STDEV) | T Statistics (\|O/STDEV\|) | P Values |
|---|---|---|---|---|---|
| LCPROS -> FLEX | 0.003 | 0.071 | 0.062 | 0.045 | 0.482 |
| LCPROS -> LCP | 0.119 | 0.021 | 0.077 | 1.553 | 0.061 |
| LCPROS -> RESP | 0.147 | 0.004 | 0.055 | 2.653 | 0.004 |
| RESP -> LCP | 0.277 | 0.252 | 0.091 | 3.039 | 0.001 |
| TPM -> COST | 0.105 | 0.134 | 0.084 | 1.255 | 0.105 |
| TPM -> ENVF | 0.213 | 0.378 | 0.092 | 2.309 | 0.011 |
| TPM -> FLEX | 0.102 | 0.541 | 0.078 | 1.295 | 0.098 |
| TPM -> LCDIS | 0.314 | 0.301 | 0.058 | 5.371 | 0 |
| TPM -> LCLOG | 0.36 | 0.412 | 0.056 | 6.489 | 0 |
| TPM -> LCP | 0.188 | 0.085 | 0.065 | 2.905 | 0.002 |
| TPM -> LCPROC | 0.121 | 0.405 | 0.059 | 2.056 | 0.02 |
| TPM -> LCPROD | 0.467 | 0.654 | 0.062 | 7.523 | 0 |
| TPM -> LCPROS | 0.143 | 0.004 | 0.057 | 2.488 | 0.007 |
| TPM -> RESP | 0.611 | 0.098 | 0.077 | 7.896 | 0 |

| **Bootstrapping (Specific Indirect Effects)** | Original Sample (O) | Sample Mean (M) | Standard Deviation (STDEV) | T Statistics (\|O/STDEV\|) | P Values |
|---|---|---|---|---|---|
| LCPROC -> COST -> LCP | 0.026 | 0.029 | 0.019 | 1.384 | 0.083 |
| LCPROC -> FLEX -> LCP | 0.115 | 0.021 | 0.039 | 2.953 | 0.002 |
| LCPROC -> RESP -> LCP | 0.054 | 0.019 | 0.025 | 2.166 | 0.015 |
| LCPROC -> ENVF -> LCP | 0.101 | 0 | 0.04 | 2.489 | 0.007 |
| LCPROD -> COST -> LCP | 0.011 | 0.011 | 0.012 | 0.922 | 0.179 |
| LCPROD -> FLEX -> LCP | -0.009 | -0.056 | 0.022 | 0.407 | 0.342 |
| LCPROD -> RESP -> LCP | 0.013 | 0.056 | 0.02 | 0.613 | 0.27 |
| LCPROD -> ENVF -> LCP | 0.004 | 0.145 | 0.026 | 0.161 | 0.436 |
| LCPROS -> COST -> LCP | 0.123 | 0.009 | 0.048 | 2.529 | 0.006 |
| LCPROS -> FLEX -> LCP | 0.022 | 0.012 | 0.026 | 0.831 | 0.203 |
| LCPROS -> RESP -> LCP | 0.096 | 0.002 | 0.034 | 2.831 | 0.002 |
| LCPROS -> ENVF -> LCP | 0.085 | 0.001 | 0.043 | 1.997 | 0.023 |
| LCDIS -> COST -> LCP | -0.01 | -0.072 | 0.018 | 0.571 | 0.284 |
| LCDIS -> FLEX -> LCP | 0.071 | 0.017 | 0.029 | 2.454 | 0.007 |
| LCDIS -> RESP -> LCP | 0.017 | 0.087 | 0.026 | 0.638 | 0.262 |
| LCDIS -> ENVF -> LCP | -0.034 | -0.006 | 0.034 | 1.02 | 0.154 |
| LCLOG -> COST -> LCP | 0.171 | 0.025 | 0.068 | 2.521 | 0.006 |
| LCLOG -> FLEX -> LCP | 0.132 | 0.012 | 0.042 | 3.167 | 0.001 |
| LCLOG -> RESP -> LCP | 0.073 | 0.046 | 0.029 | 2.464 | 0.007 |
| LCLOG -> ENVF -> LCP | 0.108 | 0.01 | 0.037 | 2.904 | 0.002 |

```
Sample size:  143
Number of variables:  63

Univariate skewness and kurtosis
```

| | Skewness | SE_skew | Kurtosis | SE_kurt |
|---|---|---|---|---|
| GOV1 | -0.127465129 | 0.2027312 | -2.012093587 | 0.4027923 |
| GOV2 | -0.448849900 | 0.2027312 | -1.824247234 | 0.4027923 |
| GOV3 | -0.771611109 | 0.2027312 | -1.424741723 | 0.4027923 |
| GOV4 | -0.670106183 | 0.2027312 | -1.573159101 | 0.4027923 |
| CUST1 | -0.466322741 | 0.2027312 | -0.974676075 | 0.4027923 |
| CUST2 | -0.842890074 | 0.2027312 | -0.040127421 | 0.4027923 |
| CUST3 | -0.560147286 | 0.2027312 | -0.595002172 | 0.4027923 |
| CUST4 | -0.834519682 | 0.2027312 | -0.127448796 | 0.4027923 |
| GT1 | -0.410410079 | 0.2027312 | -0.401747717 | 0.4027923 |
| GT2 | -0.351059597 | 0.2027312 | 0.788015089 | 0.4027923 |
| GT3 | 0.015478303 | 0.2027312 | -1.321095501 | 0.4027923 |
| GT4 | -0.159523802 | 0.2027312 | 0.001108746 | 0.4027923 |
| ENGO1 | -0.236703448 | 0.2027312 | -0.968385117 | 0.4027923 |
| ENGO2 | -0.333578785 | 0.2027312 | -0.618610275 | 0.4027923 |
| ENGO3 | -0.066254114 | 0.2027312 | -1.377174531 | 0.4027923 |
| ENGO4 | -0.177008989 | 0.2027312 | -0.673121375 | 0.4027923 |
| TPM1 | 0.074606026 | 0.2027312 | -0.589329353 | 0.4027923 |
| TPM2 | 0.187177503 | 0.2027312 | -0.708863449 | 0.4027923 |
| TPM3 | -0.305652646 | 0.2027312 | 0.493175420 | 0.4027923 |
| TPM4 | -0.405435532 | 0.2027312 | 0.192270004 | 0.4027923 |
| LCPROC1 | -0.153230019 | 0.2027312 | -0.685442617 | 0.4027923 |
| LCPROC2 | -0.136230828 | 0.2027312 | -0.575601824 | 0.4027923 |
| LCPROC3 | -0.062304156 | 0.2027312 | -0.844432783 | 0.4027923 |
| LCPROC4 | -0.110428160 | 0.2027312 | -0.717048240 | 0.4027923 |
| LCPROC5 | -0.114474387 | 0.2027312 | -0.822492809 | 0.4027923 |
| LCPROD1 | 0.878483697 | 0.2027312 | -1.245890153 | 0.4027923 |
| LCPROD2 | 1.031472044 | 0.2027312 | -0.949544073 | 0.4027923 |
| LCPROD3 | 0.703409962 | 0.2027312 | -1.526766917 | 0.4027923 |
| LCPROD4 | 1.071967042 | 0.2027312 | -0.863156981 | 0.4027923 |
| LCPROS1 | -0.461818114 | 0.2027312 | -0.637297193 | 0.4027923 |
| LCPROS2 | -0.337354425 | 0.2027312 | -1.052631948 | 0.4027923 |
| LCPROS3 | -0.133281880 | 0.2027312 | -1.228394961 | 0.4027923 |
| LCPROS4 | -0.044654984 | 0.2027312 | -0.309308147 | 0.4027923 |
| LCDIS1 | -0.608196872 | 0.2027312 | 1.055555509 | 0.4027923 |
| LCDIS2 | -0.616294669 | 0.2027312 | 0.446446103 | 0.4027923 |
| LCDIS3 | -0.550559570 | 0.2027312 | -0.084547314 | 0.4027923 |
| LCDIS4 | -0.508232883 | 0.2027312 | -0.238182263 | 0.4027923 |
| LCDIS5 | -0.248305242 | 0.2027312 | -0.665747944 | 0.4027923 |
| LCLOG1 | -0.579928136 | 0.2027312 | -0.147340049 | 0.4027923 |
| LCLOG2 | -0.463563433 | 0.2027312 | -0.269864014 | 0.4027923 |
| LCLOG3 | -0.348162760 | 0.2027312 | -0.437225944 | 0.4027923 |
| LCLOG4 | -0.629120546 | 0.2027312 | -0.310683468 | 0.4027923 |

```
         Skewness   SE_skew    Kurtosis   SE_kurt
COST1  -0.379470556 0.2027312 -0.731068168 0.4027923
COST2  -0.507123875 0.2027312 -0.935851952 0.4027923
COST3  -0.177872714 0.2027312 -0.812651622 0.4027923
COST4  -0.379470556 0.2027312 -0.731068168 0.4027923
COST5  -0.371383450 0.2027312 -0.818275389 0.4027923
FLEX1  -0.054643177 0.2027312 -0.355385423 0.4027923
FLEX2  -0.026683972 0.2027312 -0.209755833 0.4027923
FLEX3   0.009018893 0.2027312  0.154317626 0.4027923
FLEX4  -0.122697630 0.2027312 -0.543429657 0.4027923
RESP1  -0.223119006 0.2027312 -0.839321758 0.4027923
RESP2  -0.125509814 0.2027312 -0.585232231 0.4027923
RESP3  -0.239526997 0.2027312 -0.749451643 0.4027923
RESP4  -0.225042192 0.2027312 -0.766353198 0.4027923
RESP5  -0.177872714 0.2027312 -0.812651622 0.4027923
ENVF1  -0.092497901 0.2027312 -0.375767963 0.4027923
ENVF2  -0.060643620 0.2027312 -0.298519197 0.4027923
ENVF3  -0.160576458 0.2027312 -0.595028211 0.4027923
ENVF4  -0.089876558 0.2027312 -0.524389145 0.4027923
LCP1   -0.166958884 0.2027312 -0.712232171 0.4027923
LCP2   -0.180635552 0.2027312 -0.699094445 0.4027923
LCP3   -0.029651925 0.2027312 -0.976305780 0.4027923

Mardia's multivariate skewness and kurtosis
                b           z p-value
Skewness 2527.240 60232.54331       0
Kurtosis 4407.212    20.62745       0
```

**Test Statistics[a]**

| Mann-Whitney test | LCP |
|---|---|
| Mann-Whitney U | 2022.500 |
| Wilcoxon W | 7482.500 |
| Z | -.028 |
| Asymp. Sig. (2-tailed) | .978 |

a. Grouping Variable: Group

**Ranks**

| | Group | N | Mean Rank | Sum of Ranks |
|---|---|---|---|---|
| LCP | Early | 39 | 72.14 | 2813.50 |
| | Late | 104 | 71.95 | 7482.50 |
| | Total | 143 | | |

## APPENDIX C

## LIST OF PUBLICATIONS

Fernando, Y., Shaharudin, M. S., & Wah, W. X. (2015). *Eco-Innovation Enablers and Typology in Green Furniture Manufacturing*. (B. Christiansen, Ed.), *Handbook of Research on Global Business Opportunities*. IGI Global. doi:10.4018/978-1-4666-6551-4

Shaharudin, M. S., & Fernando, Y. (2015). Low Carbon Footprint: The Supply Chain Agenda in Malaysian Manufacturing Firms. *Promoting Sustainable Practices through Energy Engineering and Asset Management*, 324–347.

Fernando, Y., Shaharudin, M. S., & Wahid, N. A. (2016). Eco-innovation practices: A case study of green furniture manufacturers in Indonesia. *International Journal of Services and Operations Management*, *23*, 43–58.

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Shaharudin, M. S., & Fernando, Y. (2017). *Measuring Low Carbon Supply Chain*. (M. Khosrow-Pour, Ed.), *Measuring Low Carbon Supply Chain*. IGI Global.

Fernando, Y., Shaharudin, M. S., Haron, H., Karim, N. A., & Ganesan, Y. (2018). A Moderating Impact of ISO 14001 Certified Firms on Reverse Logistics Implementation: Analysis of A Second-Order Model. In *8th International Borneo Business Conference* (pp. 31–43). Kuching, Sarawak.

Fernando, Y., Shaharudin, M. S., Ismail, I., Yew, S. Q., & Ganesan, Y. (2018). A Mediating Model of Resource Commitment, Reverse Logistics and Financial Performance: Importance-Performance Map Analysis. In *8th International Borneo Business Conference* (pp. 20–30). Kuching, Sarawak.

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