The Adoption of Operational Environmental Sustainability Approaches in the Thai Manufacturing sector

Abstract

Evidence suggests that manufacturing companies have tried to address the current environmental challenges derived from their operations by implementing various operational environmental sustainability approaches, including green manufacturing (GM), cleaner production (CP), green lean (GL), green supply chain management (GSCM), reverse logistics (RLs) and circular economy (CE). However, although their adoption is well documented in developed nations and few other countries, very little has been done to understand such phenomenon in a rapid developing country such as Thailand. This paper aims at filling this gap by providing light into some fundamental issues regarding the implementation of these approaches in the manufacturing sector of Thailand. A survey-based exploratory research was carried out based on 287 Thai manufacturing companies. The data was analysed using a combination of descriptive and inferential statics. The study revealed that a large amount of investment capacity, and proper training & knowledge are needed to fully implement the studied operational approaches. This resulted in some of the weakest elements of Thai manufacturing firms and hence the main barriers to their implementation. The study also showed that Thai manufacturing firms consider the impact on the environment and benefits from adopting these operational approaches as company's policy and own initiative, environmental awareness, and cost saving from conservation of energy as the main reasons for adopting the studied operational approaches. Finally, the findings also indicate that Thai manufacturing firms tend to implement them because of internal factors and that they lack of motivation from external factors and involvement from other stakeholders. The paper extends the current limited knowledge on the deployment of operational environmental sustainability approaches in Asia, and its results can be beneficial for organisations that aim at effectively adopting them to improve their operation's sustainability.

Keywords: Environmental sustainability, manufacturing, operations improvement, implementation.

1. Introduction

Environmental degradation is arguably the biggest challenge facing mankind and the planet. Despite being one of the main driving sectors of economic development and growth, the manufacturing industry is also a main contributor to such degradation as well as other environmental problems, such as climate change and natural resources scarcity (Alam et al., 2016). Thus, over the last decades, manufacturing organisations have responded to pressures from governments, customers, investors and local communities to reduce the environmental impact of their operations by adopting operational environmental sustainability approaches that include green manufacturing (GM), cleaner production (CP), green lean (GL), green supply chain management (GSCM), reverse logistics (RLs) and circular economy (CE).

GM is a method to manufacture which aims to minimise waste and pollution through two main practices, namely: pollution prevention and product stewardship (Chiarini, 2014). Pollution prevention refers to capturing the pollution prior it enters the environment and eliminating its root cause. Product stewardship consists in companies extending the 'greening' of processes to the whole phases of the product lifecycle, from the extraction of raw material to disposal at the end of product life (Bhupendra and Sangle, 2016). On the other hand, CP is a strategy that intends to minimise/eliminate the negative impact of production processes and products on the environment (Daylan et al., 2013). CP is mainly underpinned by practices such as reducing the use of resources and waste, life cycle analysis (LCA), eco-design and pollution prevention (Silva et al., 2017; Luken et al., 2016). Reduction of resources in CP is mainly focused on minimising material consumption and energy through better integration of and more efficient processes (Silva et al., 2017). LCA is a tool commonly employed to compare and quantify the environmental impact of products or activities over their entire life cycle (Salmoral and Yan, 2018). Eco-design aims at designing products taking into consideration their environmental effect during their whole life cycle (Cimatti et al., 2017).

Moreover, GL is an integrated approach that combines lean management and green principles and initiatives to optimise processes not only in terms of efficiency but also environmental performance. Fercoq et al. (2016) suggest that the 3Rs of waste management, i.e. reduce, reuse and recycle, can greatly contribute to the management and elimination of the seven lean wastes, i.e. over-production, inventory, transportation/motion, defects, defects, over-processing and waiting. Thus, Fercoq et al. (2016) consider waste elimination as the main GL practice.

Conversely, GSCM is referred by Adarsha and Parthap (2013) as the combination of green procurement, green manufacturing, green distribution and RLs. Vanalle et al. (2017) classified GSCM practices into internal and external practices, including internal environmental management and eco-design as internal practices and green purchasing, customer cooperation with environmental concern, and investment recovery as external practices. Internal environmental management considers the environmental management system that supports and monitors environmental issues, e.g. ISO 14000 or Total Quality Environmental Management (Vanalle et al., 2017). Green purchasing is the procurement process of products and services taking into consideration the environment, unlike the traditional procurement method (Liobikienė et al., 2016), whereas a close cooperation with customers, in green terms, has been identified as a main promoter of an enhanced environmental performance of supply chains (Vanalle et al., 2017). Investment recovery is considered a GSCM practice as it promotes the selling of excess inventories/materials, reducing equipment and machines' energy consumption and/or recycling used and scrapped. These actions also have a positive environmental effect as in many cases excess materials and surplus equipment from companies can be redirected to other companies, extending their life cycle and usability (Mitra, 2009).

RLs address concerns about expired products and what is done with these at their end of their life cycle (Rahimi et al., 2016). Thus, RLs refers to moving products from their final destination, once that their life cycle has ended, for the purpose of capturing extra value (e.g. through repair, reconditioning, recycling, etc.) or appropriate disposal. Practices associated to RLs include recycling, product upgrades and waste management (Fernández-González et al., 2017; Xiong et al., 2016). Finally, CE proposes the development of a total economic model that restores and regenerates by intention and design (Ellen MacArthur Foundation, 2013). According to Masi et al. (2018), CE is underpinned by ten practices, namely; pollution prevention, product stewardship, reducing the use of resources, 3Rs, life cycle analysis, eco-design, internal environmental management, green purchasing, cooperation with customers including environmental requirements, and investment recovery. The six operational environmental sustainability approaches considered in this study and their associated practices are summarised in Table 1.

Despite the popularity of the aforementioned approaches within the manufacturing sector, there is still a recognised difficulty on the adoption of these in developing countries (Hens et al., 2017). In particular, the manufacturing sector plays an important role in driving economic growth in Thailand (Al-Swidi and Shahzad, 2014). However, the rapid economic development and capitalisation of this industry has led to quick resources depletion and environmental problems in this nation (Wirutskulshai et al., 2011). To attain sustainable growth which do not only consider economic profits but also the environmental impact of their operations, it is necessary to firstly establish how far manufacturing companies in Thailand have gone in the implementation of GM, CP, GL, GSCM, RLs and CE. Thus, this paper addresses the following fundamental research questions:

Have companies in the manufacturing sector of Thailand adopted GM, CP, GL, GSCM, RLs and CE to improve the environmental sustainability of their operations?

What have been the main reasons that have contributed for Thai manufacturing companies to implement GM, CP, GL, GSCM, RLs and CE?

What barriers have manufacturing companies in Thailand faced when implementing GM, CP, GL, GSCM, RLs and CE?

Table 1. Operational environmental sustainability approaches and their associated practices

<table>
<tr><th colspan="2" rowspan="2">Practices</th><th colspan="6">Operational Environmental Sustainability Approaches</th></tr>
<tr><th>Green Manufacturing</th><th>Cleaner Production</th><th>Green Lean</th><th>Green Supply Chain Management</th><th>Reverse Logistics</th><th>Circular Economy</th></tr>
<tr><td colspan="2"></td><td>Chiarini (2014); Bhupendra and Sangle (2016)</td><td>Daylan et al. (2013); Silva et al. (2017); Luken et al. (2016); Salmoral and Yan (2018)</td><td>Fercoq et al. (2016)</td><td>Adarsha and Parthap (2013); Vanalle et al. (2017); Liobikienė et al., (2016); Mitra (2009)</td><td>Rahimi et al. (2016); Fernández-González et al. (2017); Xiong et al. (2016)</td><td>Ellen MacArthur Foundation (2013); Masi et al. (2018)</td></tr>
<tr><td colspan="2">Pollution Prevention</td><td>✓</td><td>✓</td><td></td><td>✓</td><td></td><td>✓</td></tr>
<tr><td colspan="2">Product Stewardship</td><td>✓</td><td></td><td></td><td>✓</td><td></td><td>✓</td></tr>
<tr><td colspan="2">Reducing the use of resources</td><td></td><td>✓</td><td></td><td></td><td></td><td>✓</td></tr>
<tr><td rowspan="3">Waste reduction 3R</td><td>Reduce</td><td></td><td></td><td>✓</td><td>✓</td><td></td><td>✓</td></tr>
<tr><td>Reuse</td><td></td><td></td><td>✓</td><td>✓</td><td></td><td>✓</td></tr>
<tr><td>Recycle</td><td></td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td colspan="2">Life Cycle Analysis</td><td></td><td>✓</td><td></td><td>✓</td><td></td><td>✓</td></tr>
<tr><td colspan="2">Eco-design</td><td></td><td>✓</td><td></td><td>✓</td><td></td><td>✓</td></tr>
<tr><td colspan="2">Internal Environmental Management</td><td></td><td></td><td></td><td>✓</td><td></td><td>✓</td></tr>
<tr><td colspan="2">Green Purchasing</td><td></td><td></td><td></td><td>✓</td><td></td><td>✓</td></tr>
<tr><td colspan="2">Cooperation with customers including environmental requirements</td><td></td><td></td><td></td><td>✓</td><td></td><td>✓</td></tr>
<tr><td colspan="2">Investment Recovery</td><td></td><td></td><td></td><td>✓</td><td></td><td>✓</td></tr>
</table>

Product upgrade					✓	
Waste Management				✓	✓	

Previous studies have focused on the implementation of operational approaches to achieve environmental sustainability in the manufacturing sectors of European countries, BRIC countries, the US and China (e.g. Caniëls et al., 2013; Feng et al., 2017; Gabaldón-Estevan et al., 2014; Johansson and Sundin, 2014; Kong et al., 2016; Pao and Tsai, 2011; Rusinko, 2007; Severo et al., 2017). However, no similar study has centred on investigating such phenomenon on a rapidly developing country such as Thailand. For this reason, the main contribution of this paper lies in filling this research gap by providing evidence of the adoption of operational environmental sustainability approaches in the Thai manufacturing sector. In addition, the operational environmental sustainability approaches considered in this research have traditionally been studied as separated strategies to improve environmental performance. Thus, this paper also contributes by studying these within the same contextual setting so a wider comparative perspective can be drawn.

The rest of the paper is structured as follows: the literature review and formulation of hypotheses and complementary research questions are included in Section 2; Section 3 presents the research methodology and data collection methods, whereas the analyses and discussion of findings are presented in Section 4; finally, Section 5 draws the conclusions derived from this research as well as identifies its limitations and proposes future research directions.

2. Literature review – formulation of hypotheses and complementary research questions

2.1 Implementation of Green Manufacturing in the Thai manufacturing sector

Green manufacturing (GM) is an approach commonly used in the manufacturing industry, especially in developed countries such as the USA and EU, where strict policies and regulations regarding the environment exist (Dilip Maruthi and Rashmi, 2015; Govindan et al., 2015a). For example, Rusinko (2007) suggests that many manufacturing companies in the US have already used GM. Due to the strong environmental regulations in the EU, manufacturing firms are characterised by the rise of pressure from these regulations, which have led to strong relationships between industries and environmental control, resulting in the use of the GM (Gabaldón-Estevan et al., 2014). Furthermore, developing nations such as BRIC countries including Brazil, Russia, India and China have also increased their awareness of the environmental impacts of their industries on humans and the planet. Thus, demand for GM in these countries has increased (Pao and Tsai, 2011).

In Asia, GM has been adopted in China. China is recognised as the world's manufacturing hub and its government has implemented a series of environmental control policies (Kong et al., 2016; Liu et al., 2017). These policies aim to develop and improve GM technologies. According to Kong et al. (2016), there is evidence that manufacturing firms in China have adopted GM. In Southeast Asia, most of the countries are victims of severe poverty and lack of awareness of environmental concerns, these countries require investment in basic facilities and infrastructures; hence, environmental problems are not their primary concern (Rao, 2004). Manufacturing firms in Malaysia, located in the same continental region as Thailand, have encountered barriers that inhibit the implementation of GM practices (Ghazilla et al., 2015; Masoumik et al., 2015), which may have been a reasons as to why GM has received little attention in the region. According to Ghazilla et al. (2015), Masoumik et al. (2015), and

Rao (2004), there is no empirical evidence to suggest that GM is a widely used approach by Thai manufacturing organisations. From this basis, the following hypothesis was formulated.

Hypothesis 1: *Thai manufacturing organisations do not implement Green Manufacturing.*

In order to complement the investigation of H1, the following Complementary Research Question 1 (CRQ1) was proposed.

CRQ 1: *What are the reasons as to why Thai manufacturing organisations adopt, or do not adopt, Green Manufacturing?*

2.2 Implementation of Cleaner Production in the Thai manufacturing sector

Due to the increase in energy demand, various countries and regions have prioritised the sustainability of energy and focused on reducing environmental impact through Cleaner Production (CP) (Saez-Martínez et al., 2016). In 2011, the launch of the Eco-Innovation Action Plan (EcoAP) by the European Commission moved the EU towards green technologies, which resulted in environmental concerns to be more common in the manufacturing sector (Leach et al., 2012). Hence, CP practices have been adopted by manufacturing firms in the EU. Severo et al. (2017) indicate that Brazilian industries have adopted CP practices as they are important to promote sustainable production. In the same way, CP has also been adopted by companies in Cuba (Hens et al., 2017). By adopting the CP approach, environmental performance is promoted and improved as its practices aim to integrate environmental objectives with manufacturers' production processes to reduce wastes and emissions (Guimaraes et al., 2017). However, Hens et al. (2017) recognise that there are difficulties to adopt CP in developing countries, mainly due to the funding problems.

The Chinese Cleaner Production Promotion Law requires a mandatory audit for the implementation and use of Cleaner Production (Bai et al., 2015). Hence, this law promotes the use of CP in China. In Malaysia, CP is not widely adopted as manufacturing firms still lack of the main driver, which is the requirement to comply with environmental protection rules and regulations (Yusup et al., 2015). Moreover, there are also barriers for the implementation of this operational approach in developing countries, including the absence of economic incentive policies, weak public awareness and pressure, financial and economic barriers, technical and information barriers, and managerial resistance to change (Hens et al., 2017; Shi et al., 2008; Vieira and Amaral, 2016). Despite the lack of evidence of the implementation of CP in Thailand, its similar characteristics to Malaysia and other developing countries suggest that the same barriers applicable to them may also apply to Thailand. However, the contradictory evidence of the adoption of CP in various countries call for further research regarding the following hypothesis:

Hypothesis 2: *Thai manufacturing organisations do not implement Cleaner Production.*

A CRQ2 was proposed to gain a better understanding of the deployment of CP by Thai manufacturers.

CRQ 2: *What are the reasons as to why Thai manufacturing organisations adopt, or do not adopt, Cleaner Production?*

2.3 Implementation of Green Lean in the Thai manufacturing sector

Industrial globalisation has brought regulations and restrictions, in terms of environmental responsibility, to the manufacturing sector. In this context, Green Lean (GL) has emerged as an approach that helps organisations to achieve their environmental, financial and regulatory targets (Zhan et al., 2018). GL has not only been widely used in the USA manufacturing sector to enable sustainable production but also in product development (Johansson and Sundin, 2014). EU environmental laws focusing on pollution emissions in the manufacturing sector promote the use of GL (Chiarini, 2014). In the Swedish industry, ISO 9001 and ISO 14001 have been integrated through environmental management systems in daily operations, enabling the use of GL (Kurdve et al., 2014). However, Garza-Reyes (2015) mention that GL is relatively new and that it still lacks of a clear structure. Moreover, there are also some barriers to the implementation of GL (Cherrafi et al., 2017). Cherrafi et al. (2017) conclude that environmental awareness and lack of government support are the main barriers for implementing GL as they contribute to many other barriers. These also align to the barriers defined by Marhani et al. (2013).

In developing countries, there is a need for manufacturing firms to survive and create short-term profitability. These conditions can be considered as barriers for the implementation of GL practices (Fu et al., 2017). Moreover, developing countries lack of funding support for adopting green practices, and also lack of government support for integrating these into manufacturing processes (Cherrafi et al., 2017; Fu et al., 2017; Marhani et al., 2013). The wide applicability of GL in some countries, but its limited deployment in developing nations calls for the formulation of the following hypothesis.

Hypothesis 3: *Thai manufacturing organisations do not implement Green Lean.*

In order to complement the investigation of GL in the manufacturing sector of Thailand, the following CRQ3 was derived.

CRQ 3: *What are the reasons as to why Thai manufacturing organisations adopt, or do not adopt, Green Lean?*

2.4 Implementation of Green Supply Chain Management in the Thai manufacturing sector

Competition in the manufacturing sector is increasing, and green supply chains can provide a competitive advantage to organisations (Caniëls et al., 2013). However, all supply chain members need to align to the same goal of improving environmental management, so there is a need for green supply chain management (GSCM) (Islam et al., 2018). GSCM has been applied in a wide range of industries, including food, hotel, and automotive (Al-Aomar and Hussain, 2017; Azevedo et al., 2011; Miranda-Ackerman et al., 2017). Consequently, it has been considered as a feasible option for manufacturing companies to improve their environmental performance. Thus, GSCM has been widely deployed in automotive supply chains in Germany, Brazil, and India (Caniëls et al., 2013; Mathivathanan et al., 2017; Vanalle et al., 2017). In Finland, manufacturing firms have adopted GSCM to promote environmental collaboration with their suppliers (Laari et al., 2017).

Pressures including regulations, external sources, financial factors, and production and operational factors have contributed on putting pressure on manufacturing companies to adopt GSCM (Jayant and Azhar, 2014; Mathiyazhagan et al., 2015). However, in some countries this has been a challenge. For instance, in India, manufacturing firms are lacking knowledge on green practices, technical expertise, and financial support, which are the main challenges for the implementation of the GSCM (Jayant and Azhar, 2014). Panya et al. (2017) studied the environmental performance of local governments in Thailand, and found that it is at a moderate level, mainly due to the lack of long-term environmental policies, a sustainable culture, environmental learning organisations, and environmental budget. According to the work of Jayant and Azhar (2014), Mathiyazhagan et al. (2015), and Panya et al. (2017), it can be implied that despite its significance and wide application in other nations, Thai manufacturing organisations lack of appropriate factors to adopt GSCM; thus, the following hypothesis was proposed.

Hypothesis 4: *Thai manufacturing organisations do not implement Green Supply Chain Management.*

To complement H4, the following CRQ4 was formulated to determine the motivations and challenges for implementing GSCM.

CRQ 4: *What are the reasons as to why Thai manufacturing organisations adopt, or do not adopt, Green Supply Chain Management?*

2.5 Implementation of Reverse Logistics in the Thai manufacturing sector

Growing concerns in the recovery of end-of-life products has raised the need for reverse logistics (RLs) (Lipan et al., 2017). RLs has been used in industries such as construction and manufacturing (Chinda, 2017). There is also a major concern regarding wastes of electrical and electronic equipment due to hazardous substances, and RLs has played an essential role to deal with these wastes (Li and Tee, 2012). Moreover, manufacturers in Mexico have also used RLs to deal with end-of-life vehicles (Cruz-Rivera and Ertel, 2009). In Europe, government regulations have forced manufacturers to take care of their end-of-life products. For example, the European Waste Electrical and Electronic Equipment (WEEE) law contains mandatory requirements to collect, recycle, and recover electronic goods (Govindan et al., 2015b; Schultmann et al., 2006). Hence, manufacturing organisations in European countries are adopting RLs to comply with the requirements of these laws and regulations.

Demajorovic et al. (2016) and Li and Tee (2012) suggest that developing countries lack of a formal waste sector that focuses on RLs. In Brazil, wastes from manufacturing industries have been a major concern for the government and private sectors. Nevertheless, RLs has not been fully adopted because there is no legal support, no organisation to control, and no governmental support (Caiado et al., 2017). In India, there are barriers for the adoption of RLs practices, including lack of proper training, lack of infrastructure facilities, resistance to change, and high initial and operating costs (Prakash et al., 2015). Despite the implementation of RLs in various industries and research studies into its status in various developing countries, no evidence exist of its practice in the manufacturing sector of Thailand. Based on this evidence, the following hypothesis was formulated.

Hypothesis 5: *Thai manufacturing organisations do not implement Reverse Logistics.*

To complement the investigation of H5, the following CRQ5 was derived.

Complementary Research Question 5: *What are the reasons as to why Thai manufacturing organisations adopt, or do not adopt, Reverse Logistics?*

2.6 Implementation of Circular Economy (CE) in the Thai manufacturing sector

The concept of circular economy (CE) has been gaining wide popularity in various countries and industrial sectors (Di et al., 2017; Veleva et al., 2017). In Europe, Waste Electrical and Electronic Equipment (WEEE) is divided into ten categories (Parajuly and Wenzel, 2017).

The purpose of dividing wastes into ten categories is to promote CE, which emphasises the reuse, remanufacturing, and recycling of wastes. CE has been adopted by industries in South Africa, Austria and India since it promotes cost reduction (Mativenga et al., 2017a; Jacobi et al., 2018; Singh et al., 2018). In the UK, CE is known as an approach to maximise the useful life of resources by using them for as long as possible to exploit their maximum value. This can be done by a recovery process after the end of service life (Mativenga et al., 2017a). Moving toward a CE requires a major fundamental change that affects the whole organisation and its stakeholders (Ritzén and Sandström, 2017). Therefore, organisations are required to manage the innovation as implementing CE practices increases the complexity from integrating sustainability with 'normal' business activities.

In China, the concept of CE is represented as a comprehensive strategy as the government is intending to move industries toward sustainable development (Jiao and Boons, 2015). Barriers for the adoption of CE consist of lack of allocated resources, lack of expert knowledge, and lack of information on environmental impacts (Bey et al., 2013; Mativenga et al., 2017b; Ritzén and Sandström, 2017). Mativenga et al. (2017a) suggest that drives such as expert knowledge and allocated resources are required to enable a transition towards CE. However, Thailand still lacks of formal education on environmental issues, which is a major barrier for the implementation of CE (Chankrajang and Muttarak, 2017). Therefore, the following hypothesis was proposed to investigate the application of CE practices in Thai manufacturing firms.

Hypothesis 6: *Thai manufacturing organisations do not implement Circular Economy practices.*

To complement H6, the following CRQ6 was set.

CRQ 6: *What are the reasons as to why Thai manufacturing organisations adopt, or do not adopt, Circular Economy?*

2.7 Environmental sustainability improvement through the various practices studied

Improvements in environmental performance lead to cost reduction and enhancement of quality performance (Pullman et al., 2009). However, it is difficult to recognise the performance benefits obtained from sustainability practices. Marcon et al. (2017) studied the best practices which have the most positive impact on environmental sustainability. They found that practices such as material saving, energy saving, use of cleaner technologies, and less resources consumption have a direct and positive impact on the improvement of environmental performance. Pimenta and Ball (2015) indicate that it is difficult to understand environmental sustainability practices, and that there is a strong effort to assess the improvement in overall performance of companies from environmental practices. The work of To et al. (2015) suggest that organisations do not fully understand the green concept, which makes the identification of the best environmental practices difficult.

In the ASEAN region, economic growth has led to environmental decline and hence manufacturing firms should adopt practices that can reduce the negative effects of their operations (Saufi et al., 2016). Nevertheless, the implementation of sustainable manufacturing practices usually has high implementation costs at the beginning, but it results in cost savings in the long-run. Furthermore, the ASEAN region, where Thailand is located, consists of several developing countries and manufacturing firms that require short-term profitability for survival (Fu et al., 2017). The general influence for the adoption of environmental practices in developing countries mainly come from stakeholders as they put pressure on firms (Ferrn Vilchez et al., 2017; Riillo, 2017). Moreover, the literature does not show a convincing indication on the best practices that can promote environmental performance. Hence, the following hypothesis was formulated in order to determine the difference, and their importance, in the improvement of environmental sustainability performance among the 14 practices of the operational approaches studied, particularly within the context of manufacturing companies in Thailand, see Table 1.

***Hypothesis** 7: There is no difference on the improvement of environmental sustainability performance among the practices of the operational approaches studied, i.e. pollution prevention, product stewardship, reducing the use of resources, waste reduction (reduce), waste reduction (reuse), waste reduction (recycle), life cycle analysis, eco-design, internal environmental management, green purchasing, cooperation with customers including environmental requirements, investment recovery, product upgrade, and waste management.*

3. Research Methodology

3.1 Data Collection Method – Survey Questionnaire

To test the hypotheses and answer the CRQs previously formulated, a self-completed questionnaire was adopted as a data collection method. The questionnaire was developed using Qualtrics software as it offered a reliable and convenient access to the questionnaire via web browsers or mobile phones/tablets and from where results could be directly organised into an Excel spreadsheet for an easy import to specialised statistical software. Nominal and ordinal data were collected through the three sections and twenty one questions that the questionnaire consisted of. Figure 1 illustrates the questionnaire structure in relation to the hypotheses and research questions, whereas Appendix A presents the questionnaire instrument. The data was analysed using both descriptive and statistical methods.

3.2 Questionnaire validity and reliability

Johanson and Brooks (2010) suggests that a pilot study is required to address potential issues including subject or participant error, subject or participant bias, observer error and observer bias. Thus, a small-scale pilot test was conducted to ensure both reliability and validity of the data collection instrument. The questionnaire was distributed to six participants, including three academics and three industrial experts from the Federation of Thai Industries. The questions, format, readability and logic of the questionnaire were improved/amended based on the feedback of the experts to eliminate participant errors and bias.

3.3 Questionnaire distribution

The study targeted Thai manufacturing companies operating in various sectors that included automotive, aerospace, apparel, chemical, among others, and were specifically addressed to people with knowledge on the operations of the participant companies, e.g. CEOs, Managing Directors, Directors and Senior Managers, Managers and Team Leaders/Members in relevant departments, e.g. Production, Operations, Manufacturing, etc. The respondent organisations were identified through the databases of the Federation of Thai Industries and the Ministry of Industry of the Kingdom of Thailand.

The questionnaire was mainly distributed by using e-mail and social media channels such as LinkedIn and Line application. Moreover, some of them were sent via direct post mail to selected participants. Out of 1,100 questionnaires distributed, 287 responses were collected, representing a 26.09% response rate. Based on comparative studies, e.g. Johansson and

Sundin (2014) and Vanalle et al. (2017), 287 responses were considered as an acceptable sample to provide some initial insights into the adoption of the operational environmental sustainability practices studied in the Thai manufacturing sector.

The data collected was examined through a combination of descriptive and inferential statistical analyses that included Z-test, One-way ANOVA and Turkey Pairwise Comparison, see Section 4.2 onwards.

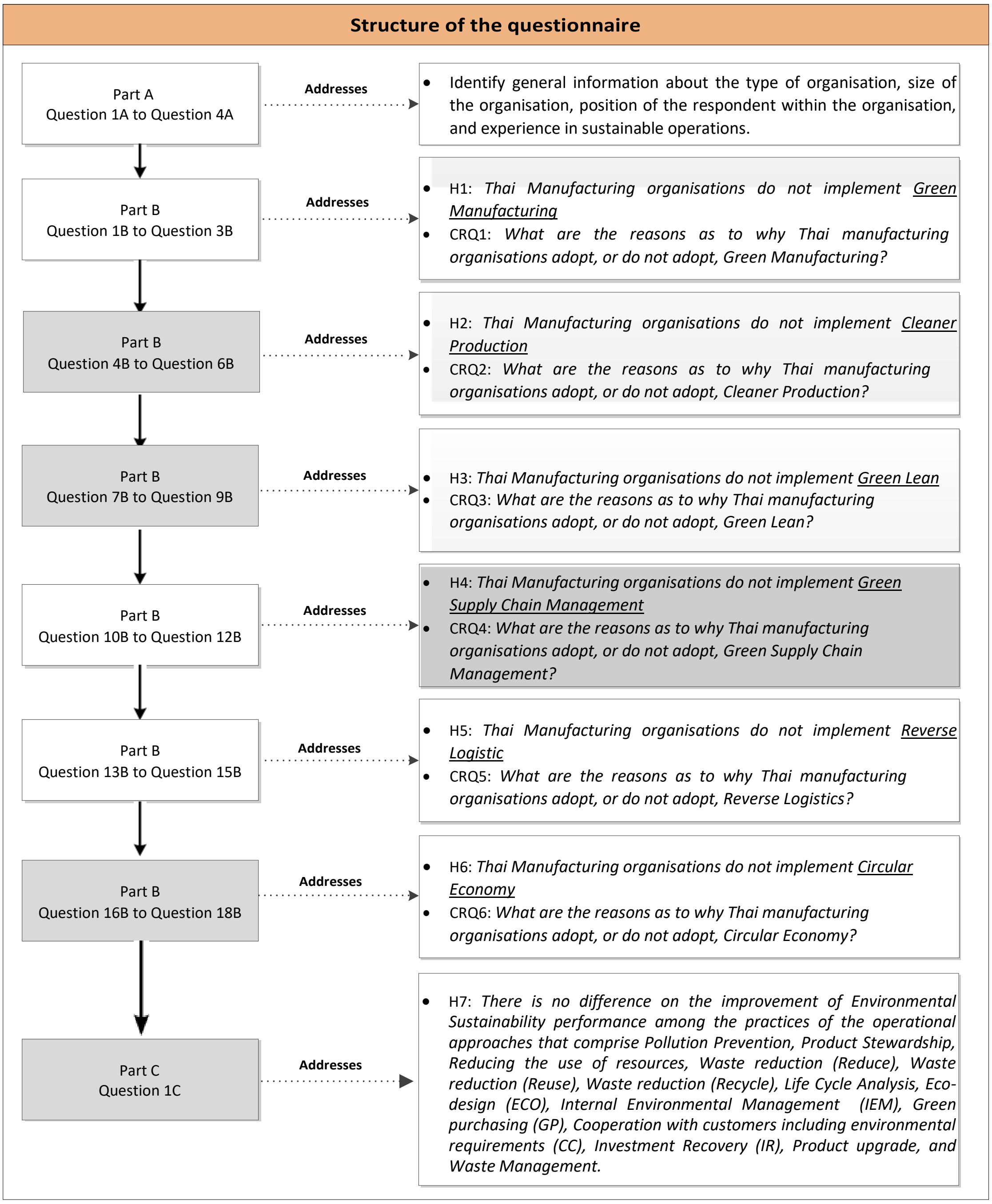


Figure 1. Questionnaire structure alignment to hypotheses and CRQs

4. Study results and discussion

4.1 Respondents and companies' profile

Table 2 presents the companies and respondents' profile who participated in the study.

Table 2. Respondents and organisations' profiles

Company profile		Respondent profile	
Company size		***Experience on Sustainable Operations***	
Large (>200 employees)	53.17%	Very High	5.28%
Medium (50-200 employees)	23.94%	High	15.14%
Small (<50 employees)	22.89%	Medium	31.69%
		Low	23.94%
Manufacturing industries		Very Low	17.61%
Steel Industry	14.44%	No experience	6.34%
Pharmaceutical Industry	13.38%		
Automotive Industry	12.68%	***Position of Respondents***	
Electronics Industry	10.21%	Team member	30.63%
Food Industry	9.86%	Manager	17.96%
Textile Industry	7.75%	Team Leader	16.20%
Others	5.28%	Senior Manager	11.62%
Chemical Industry	5.28%	Director	7.75%
Machinery Manufacturing	4.93%	Others	5.63%
Fast Moving Consumer Goods	4.58%	Managing Director	5.28%
Transportation Products or Components Manufacturing	4.23%	CEO	4.93%
Paper Manufacturing	3.87%		
Plastic Industry	2.11%		
Apparel Manufacturing	1.41%		
Aerospace Industry	0%		
Defence Industry	0%		

4.2 Hypotheses and CRQs - Results and discussion

Hypothesis 1: *Thai manufacturing organisations do not implement Green Manufacturing*

This hypothesis aimed at determining whether the implementation of GM is a common phenomenon among Thai manufacturing companies. The results of the study indicated that 67.61% of the participant organisations had already implemented GM practices. Since the P-value of the Z-test, see Table 3, was less than 0.05 ($P<0.0001$), the null hypothesis was rejected, indicating that GM is an approach commonly adopted by manufacturers in Thailand. This suggests that similarly as the US and EU countries, the Thai manufacturing sector is also concerned about the impact of their operations on the environment (Dilip Maruthi and Rashmi, 2015; Govindan et al., 2015a). The results also indicate that such companies may not experience, or have learnt to overcome, the GM barriers indicated by Ghazilla et al. (2015) and Masoumik et al. (2015) traditionally found in Southeast Asia countries when deploying GM practices.

Table 3. Z-test for the implementation of GM practices

Hypothesis 0: There is no statistical difference on mean as Thai manufacturing organisations do not implement Green Manufacturing (μ=0).
Hypothesis 1: There is a statistical difference on mean as Thai manufacturing organisations implement Green Manufacturing (μ>0).

One-Sample Z: Green Manufacturing
Descriptive Statistics

N	Mean	StDev	SE Mean	95% Lower Bound for μ
84	0.6761	0.4688	0.0278	0.6303

μ: mean of Green Manufacturing
Known standard deviation = 0.4688

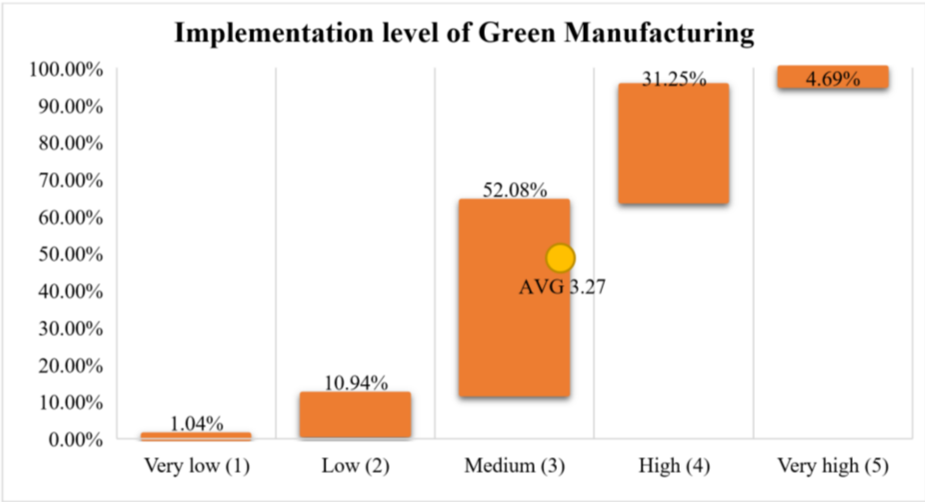
Z-Test

Null hypothesis	H_0: $\mu = 0$
Alternative hypothesis	H_1: $\mu > 0$

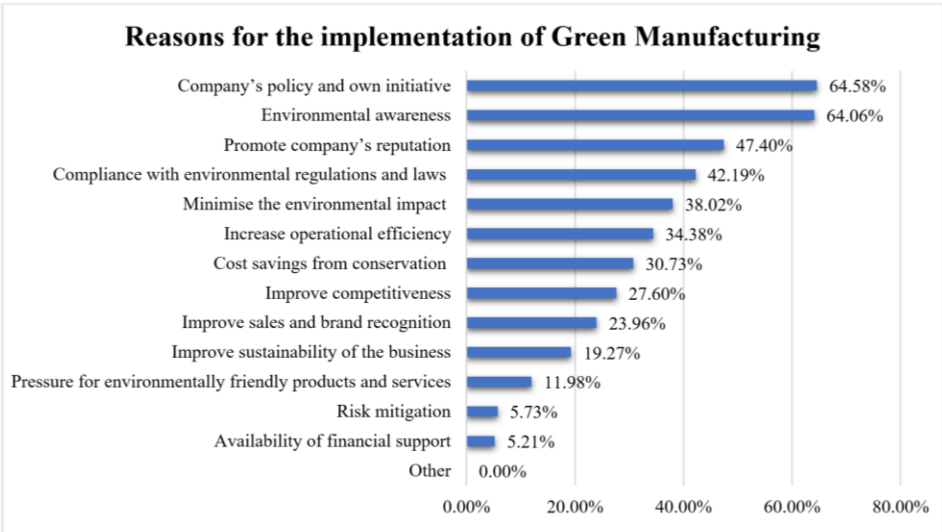
Z-Value	P-Value
24.30	$P<0.0001$

***CRQ1:** What are the reasons as to why Thai manufacturing organisations adopt, or do not adopt, Green Manufacturing?*

A 1-5 Likert scale was employed to determine the implementation level of GM, see Figure 2(a). As shown by this figure, Thai manufacturing organisations have implemented GM at a medium level, i.e. in not all their operations. Gabaldón-Estevan et al. (2014) and Ghinmine and Sangotra (2015) state that manufacturing organisations tend to implement GM practices in all their processes and operations due to ever more intensive pressures for environmentally friendly products and business sustainability. However, Thai manufacturers seem currently not to be intensively subjected to these pressures, see Figure 2(b). Moreover, they also lack of training & knowledge to implement GM practices, see Figure 2(c). Overall, the implementation level of GM deployment in Thai manufacturing organisations is limited by various factors as indicated by Figure 2(c). On the other hand, Govindan et al. (2015a) suggest that pressure from competitors, brand positioning, and social aspects are the main drivers for GM. This is supported by the results obtained by this study as they indicate that Thai manufacturing firms are motivated to implement GM practices mainly due to internal aspects such as company's policy and environmental awareness to promote their reputation. For companies that have not adopted GM, lack of training & knowledge is the major barrier they have encountered.



(a)



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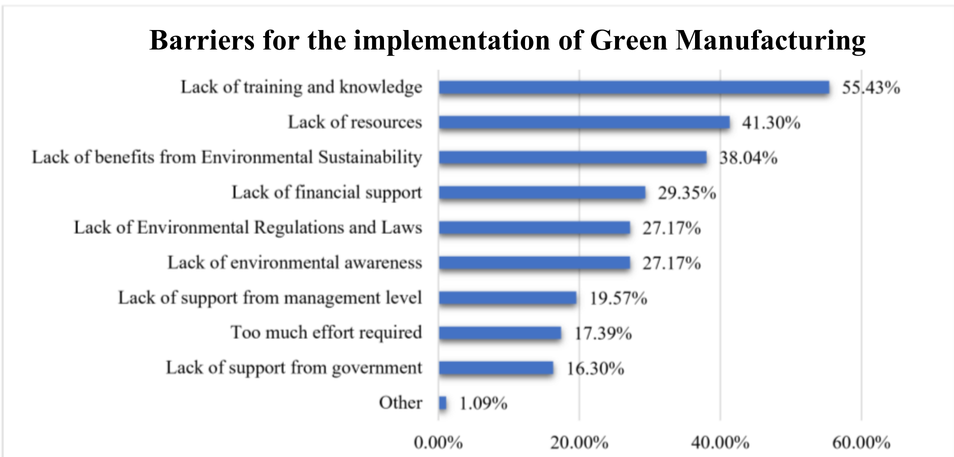


(c)

Figure 2. (a) Implementation level of GM, (b) Reasons for the implementation of GM, (c) Barriers for the implementation of GM

Hypothesis 2: *Thai manufacturing organisations do not implement Cleaner Production*

As various factors such as absence of economic incentive policies, weak public awareness and pressure, and funding problems have made the implementation of CP challenging in developing countries (Hens et al., 2017; Shi et al., 2008; Guimaraes et al., 2017), this hypothesis explores this phenomenon within the context of the Thai manufacturing sector. According to the collected data, 75.70% of the respondent organisations have already implemented CP in their operations. Table 4 presents the results of the Z-test, showing a P-value of less than 0.05 ($P<0.0001$), resulting in the rejection of the null hypothesis. This suggests that similarly as in EU countries (Leach et al., 2012), Brazil (Severo et al., 2012), Cuba (Hens et al., 2017) and China (Bai et al., 2015), and unlike Malaysia (Yusup et al., 2015), CP is an approach commonly adopted by Thai manufacturing companies.

Table 4. Z-test for the implementation of CP practices

Hypothesis 0: There is no statistical difference on mean as Thai manufacturing organisations do not implement Cleaner Production ($\mu=0$).
Hypothesis 1: There is a statistical difference on mean as Thai manufacturing organisations implement Cleaner Production ($\mu>0$).

One-Sample Z: Cleaner Production
Descriptive Statistics

N	Mean	StDev	SE Mean	95% Lower Bound for μ
284	0.7570	0.4296	0.0255	0.7151

μ: mean of Cleaner Production
Known standard deviation = 0.4296

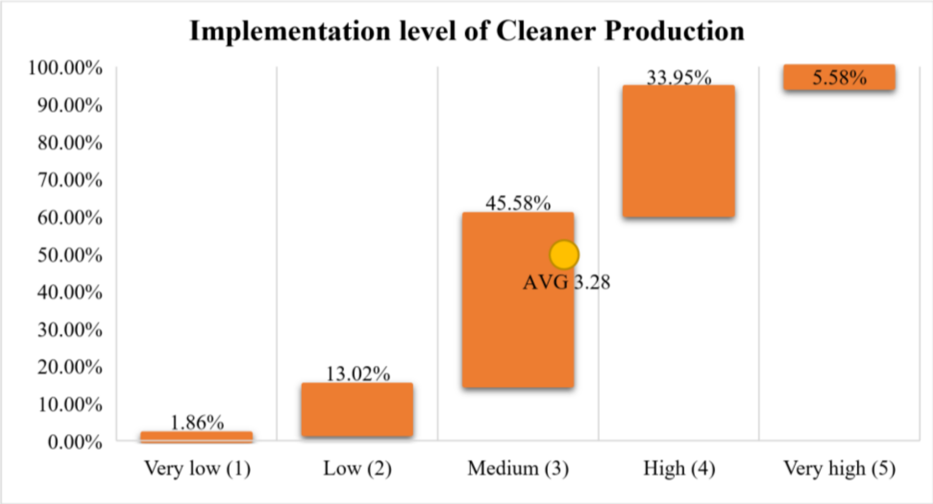
Z-Test

Null hypothesis	H_0: $\mu = 0$
Alternative hypothesis	H_1: $\mu > 0$

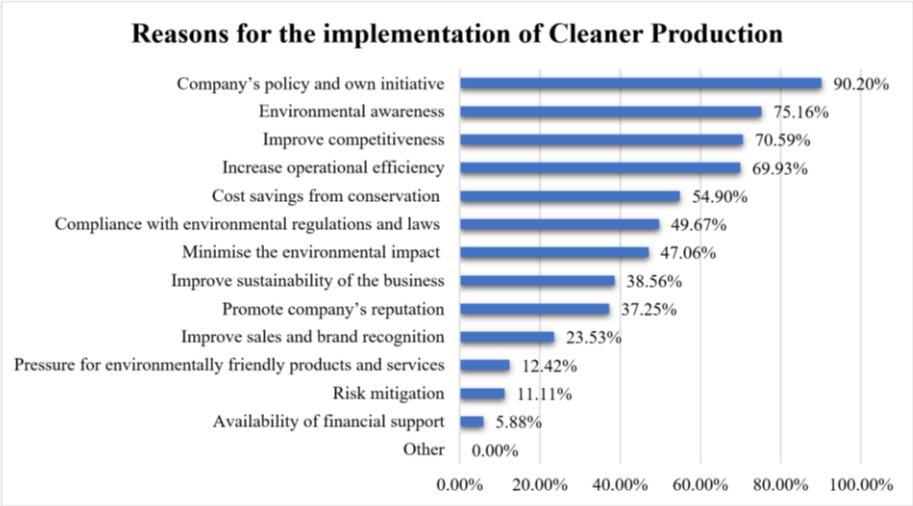
Z-Value	P-Value
29.70	P<0.0001

CRQ 2: *What are the reasons as to why Thai manufacturing organisations adopt, or do not adopt, Cleaner Production?*

The results of this study indicate that the implementation level of CP in the Thai manufacturing sector is at a moderate level, suggesting that companies implement these practices in some of their operations only, see Figure 3(a). This is in line with the work of Hens et al. (2017), which suggests that companies in developing countries have found difficult the implementation of CP in all their processes and operations. Moreover, the literature suggests that companies are driven to CP mainly due to increases in energy demand as it helps to reduce the environmental impact through the prioritisation of energy sustainability, and promotes financial performance through sustainable production (Saez-Martínez et al., 2016; Severo et al., 2017). These benefits align to the main motivational drivers in the Thai manufacturing sector, see Figure 3(b), as they implement CP to improve environmental performance, competitiveness, and operational efficiency. In terms of the barriers, Shi et al. (2008) found that technical and information barriers, additional infrastructure requirements, and difficulty in accessing financial capital are the main challenges to adopt CP. It is not surprising that these barriers are also in line with the challenges illustrated in Figure 3(c), since Thai manufacturing firms still lack access to training & knowledge, resources, and financial support.



(a)



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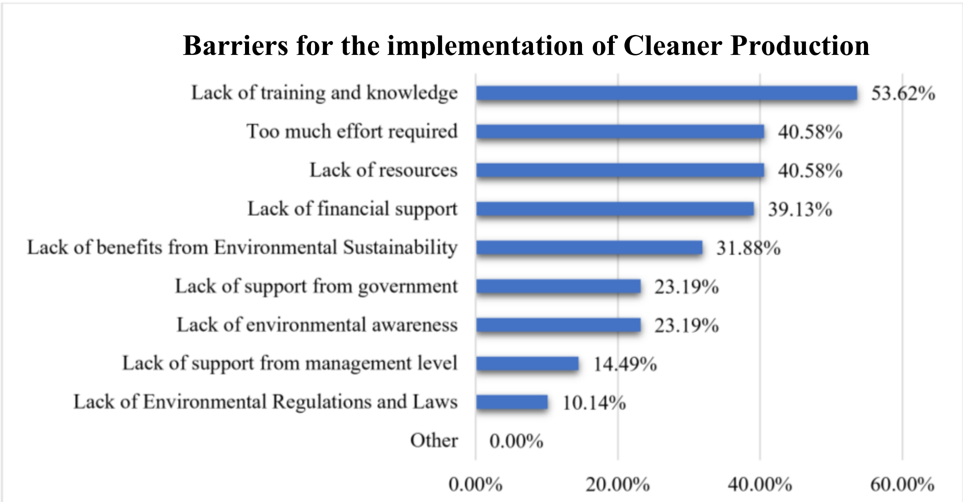


(c)

Figure 3. (a) Implementation level of the CP, (b) Reasons for the implementation of CP, (c) Barriers for the implementation of CP

Hypothesis 3: *Thai manufacturing organisations do not implement Green Lean*

Strong evidence suggests that GL is an approach commonly implemented by manufacturing firms in developing countries (Ribeiro Ramos et al., 2018; Chiarini, 2014; Johansson and Sundin, 2014). This is also the case in Thailand as the collected data indicated that 72.10% of the participant companies had deployed GL practices, resulting in the rejection of the null hypothesis through the Z-test, P-value of less than 0.05 ($P<0.0001$), see Table 5. Cherrafi et al. (2017) highlighted that GL implementation barriers include fund constraints, poor quality of human resources, and lack of top management involvement. Furthermore, Fu et al. (2017) mentioned that short-term profitability is crucial for manufacturing firms in developing countries to survive. From this study's results, it can be concluded that a large proportion of Thai manufacturer have overcome these barriers and hence successfully implemented GL.

Table 5. Z-test for the implementation of GL practices

Hypothesis 0: There is no statistical difference on mean as Thai manufacturing organisations do not implement Green Lean ($\mu=0$).
Hypothesis 1: There is a statistical difference on mean as Thai manufacturing organisations implement Green Lean ($\mu>0$).

One-Sample Z: Cleaner Production
Descriptive Statistics

N	Mean	StDev	SE Mean	95% Lower Bound for μ
284	0.7218	0.4489	0.0266	0.6780

μ: mean of Cleaner Production
Known standard deviation = 0.4489

Z-Test

Null hypothesis	H_0: $\mu = 0$
Alternative hypothesis	H_1: $\mu > 0$

Z-Value	P-Value
27.10	P<0.0001

CRQ3: *What are the reasons as to why Thai manufacturing organisations adopt, or do not adopt, Green Lean?*

In regards to the implementation level of GL, the results illustrated in Figure 4(a) indicate that Thai manufacturing organisations have adopted GL at a moderate level only. Fu et al. (2017) also mention that financial support is a vital factor for implementing GL while Chiarini (2014) comment that pressure for environmentally friendly products promotes the use of GL. Therefore, the literature confirms the obtained results, which also clarify why Thai manufacturing firms have implemented GL only at a medium level. Johansson and Sundin (2014) mention that implementing GL practices not only brings environmental benefits, but also promotes the efficiency of production processes. This supports the results illustrated in Figure 4(b) as Thai manufacturing firms implement GL in order to get benefits from cost savings and achieve improvements in operational efficiency. However, Cherrafi et al. (2017) determined that lack of expert training & education, high cost, fund constraints, poor quality of human resources, and resistance to change are the main challenges to adopt GL. These barriers line up with the challenges presented in Figure 4(c) as Thai manufacturing organisations still lack of knowledge, effort, resources, and financial support to more widely implementing GL in their operations.

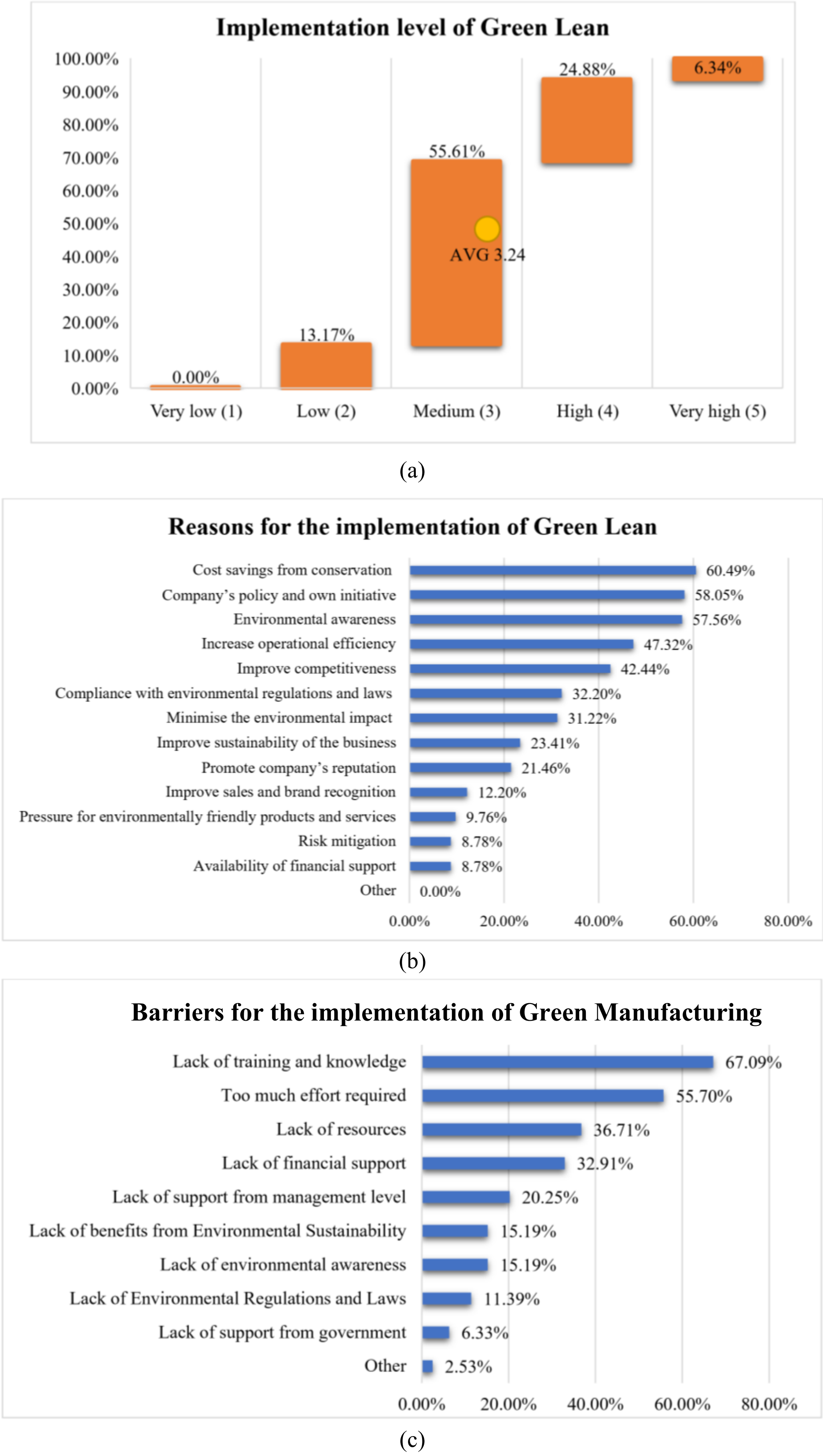


Figure 4. (a) Implementation level of GL (b) Reasons for the implementation of GL (c) Barriers for the implementation of GL

Hypothesis 4: *Thai manufacturing organisations do not implement Green Supply Chain Management*

Mathiyazhagan et al. (2015) state that environmental regulations, financial factors, and production and operational factors are putting pressures on manufacturing companies to adopt GSCM practices. However, Panya et al. (2017) explored the environmental commitment of Thai manufacturing firms and found that they do not suffer from such pressures. Nevertheless, the results suggest that Thai manufacturing companies are nowadays more concious of their environmental impact as 50.35% of the participant firms had implemented GSCM practices. Since the Z-test showed a P-value of less than 0.05 (P<0.0001), see Table 6, the null hypothesis was rejected, indicating that the adoption of GSCM is a common practice in the Thai manufacturing sector.

Table 6. Z-test for the implementation of GSCM practices

Hypothesis 0: There is no statistical difference on mean as Thai manufacturing organisations do not implement Green Supply Chain Management (μ=0).
Hypothesis 1: There is a statistical difference on mean as Thai manufacturing organisations implement Green Supply Chain Management (μ>0).

One-Sample Z: Green Supply Chain Management
Descriptive Statistics

N	Mean	StDev	SE Mean	95% Lower Bound for μ
284	0.5035	0.5009	0.0297	0.4546

μ: mean of Green Supply Chain Management
Known standard deviation = 0.5009

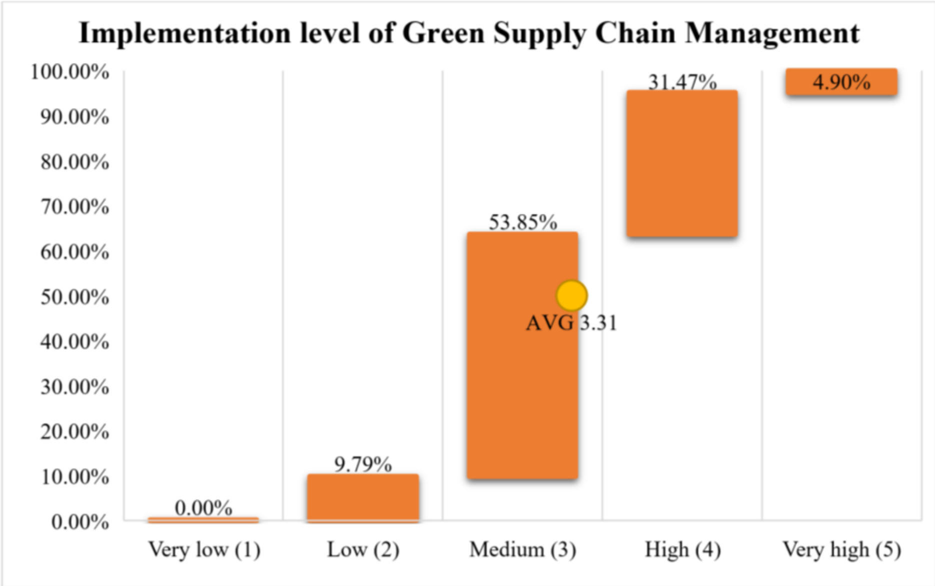
Z-Test

Null hypothesis	H_0: $\mu = 0$
Alternative hypothesis	H_1: $\mu > 0$

Z-Value	P-Value
16.94	P<0.0001

CRQ 4: *What are the reasons as to why Thai manufacturing organisations adopt, or do not adopt, Green Supply Chain Management?*

Despite the fact that the Thai manufacturing sector has implemented GSCM, the present study suggests that this has been done at a moderate level, see Figure 5(a). This indicates that such sector in Thailand may be experiencing various pressures to have more environmentally friendly operations as indicated by Mathiyazhagan et al. (2015). Jayant and Azhar (2014) and Panya et al. (2017) state that the lack of an implementation budget and customers' awareness about GSCM limit the deployment level of this operational approach, which aligns with the results presented in Figure 5(b). Vanalle et al. (2017) comment that GSCM can help manufacturing firms to reduce their production cost as this approach improves operational efficiency. Moreover, Mathivathanan et al. (2017) suggest that GSCM is a feasible option to improve environmental performance and competitive advantage. From Figure 5(b), it can be seen that Thai manufacturing firms have considered these advantages and used them as their motivation to deploy GSCM practices. On the other hand, Jayant and Azhar (2014) found out that adopting this approach requires a sustainable culture, knowledge about green practices, and having an environmental budget. In the case of the Thai manufacturing firms, the present study advocates that they still lack of these factors, see Figure 5(c).



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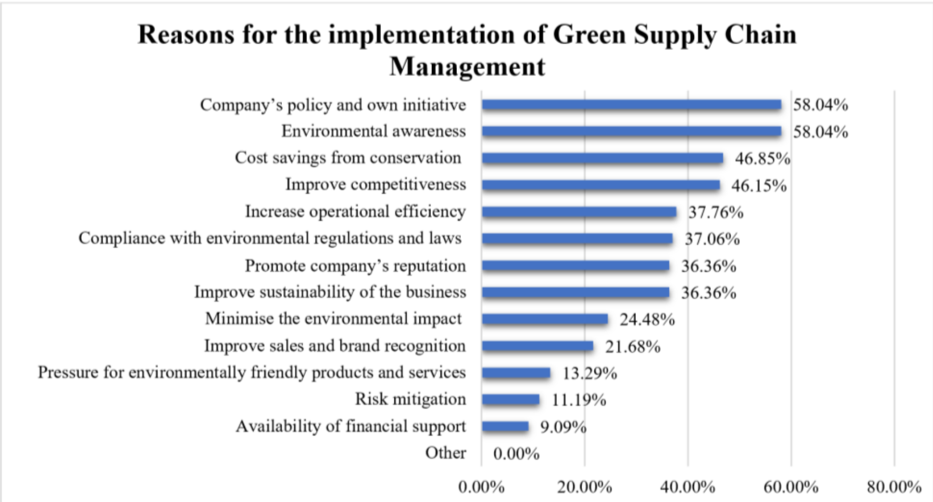

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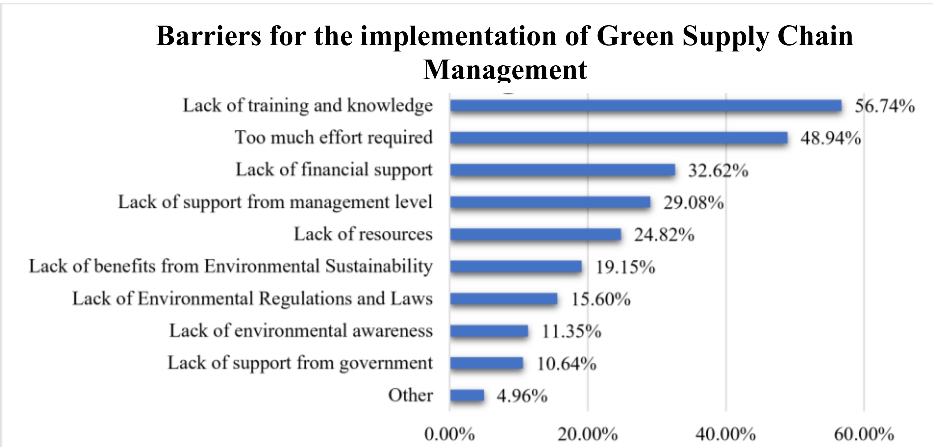


(c)

Figure 5. (a) Implementation level of GSCM, (b) Reasons for the implementation of GSCM, (c) Barriers for the implementation of GSCM

Hypothesis 5: *Thai manufacturing organisations do not implement Reverse Logistics*

Reverse Logistics (RLs) emerged to address the growing concern in the recovery of end-of-life products (Lipan et al., 2017). Nevertheless, Li and Tee (2012) found that developing countries commonly lack of a formal waste control that prioritises RLs. Hypothesis 5 was formulated to assert this evidence, particularly, within the context of the Thai manufacturing sector. In this line, the results of the present study indicated that the percentage of Thai manufacturing companies that had not implemented RLs was higher, i.e. 53.87%, than those that had adopted these in their operations, i.e. 46.13%. However, the results of the Z-test statistically confirmed that generally, the Thai manufacturing sector can still be considered as an industry which has integrated RLs in their operations as it showed a P-value of less than 0.05 ($P<0.0001$), see Table 7. This resulted in the rejection of the null hypothesis and alignment of the popularity and acceptance of RLs in Thailand to those found in Europe and Mexico (Govindan et al., 2015b; Schultmann et al., 2006; Cruz-Rivera and Ertel, 2009).

Table 7. Z-test for the implementation of RLs practices

Hypothesis 0: There is no statistical difference on mean as Thai manufacturing organisations do not implement Reverse Logistics ($\mu=0$).
Hypothesis 1: There is a statistical difference on mean as Thai manufacturing organisations implement Reverse Logistics ($\mu>0$).

One-Sample Z: Reverse Logistics
Descriptive Statistics

N	Mean	StDev	SE Mean	95% Lower Bound for μ
284	0.4613	0.4994	0.0296	0.4125

μ: mean of Reverse Logistics
Known standard deviation = 0.4994

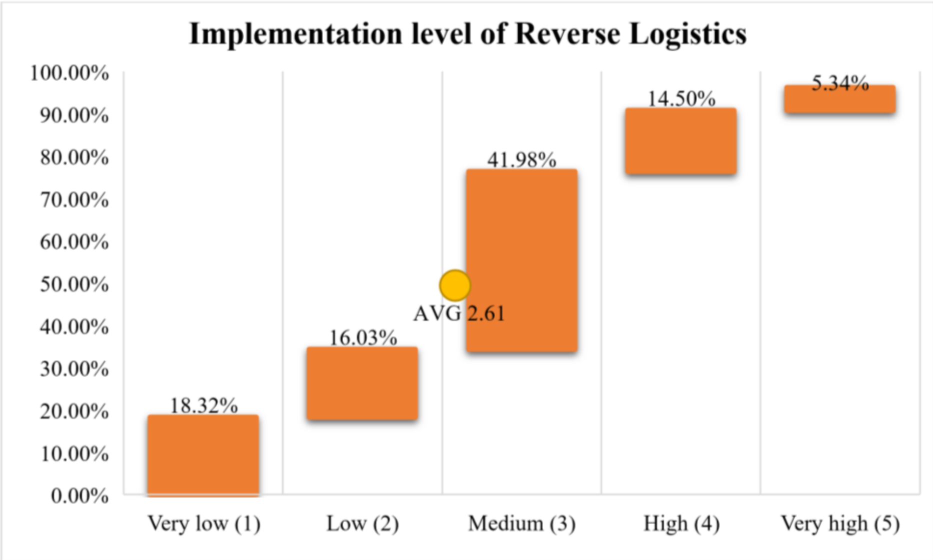
Z-Test

Null hypothesis	H_0: $\mu = 0$
Alternative hypothesis	H_1: $\mu > 0$

Z-Value	P-Value
15.57	$P<0.0001$

CRQ 5: *What are the reasons as to why Thai manufacturing organisations adopt, or do not adopt, Reverse Logistics?*

This study exhorted that despite RLs has been implemented by Thai manufacturing companies, this has been done at a moderate level only, see Figure 6(a). This has mainly been as a consequence of the lack of financial support and pressure for more environmentally friendly products, see Figure 6(b). Li and Tee (2012) acknowledge that availability of an environmental budget and demand for environmentally friendly products are the main factors that drive the implementation of RLs, whereas Ravi and Shankar (2005) remark that company policies and awareness about environmental impact from end-of-life product are the main internal reasons for companies to adopt RLs. From Figure 6(b), it can be seen that Thai manufacturing organisations have mainly adopted RLs due to internal factors and the benefits that it can contribute in achieving, i.e. cost reduction and improvement in competitiveness, which align to the works of Li and Tee (2012) and Ravi and Shankar (2005). Chileshe et al. (2015) established that the main barriers for the implementation of RLs are the lack of technical guidance, administrative resources, top-management support, and cost-effective technologies. These are all aligned with the findings of this study as illustrated in Figure 6(c).



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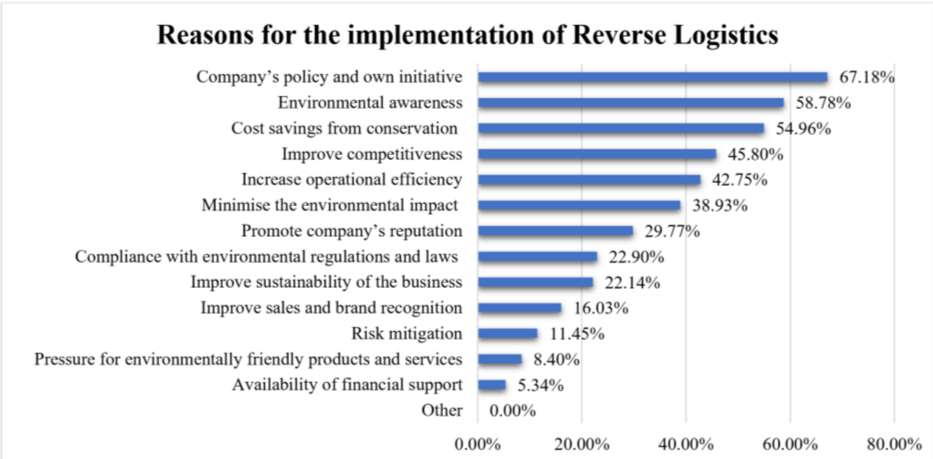

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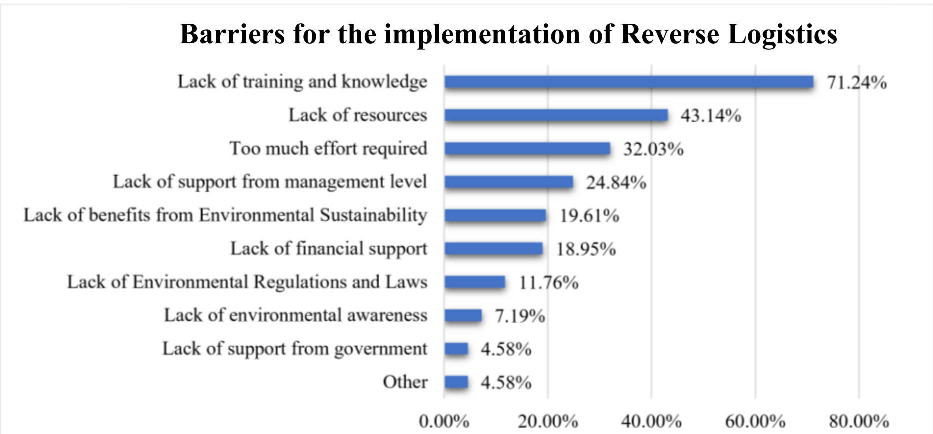


(c)

Figure 6. (a) Implementation level of RLs, (b) Reasons for the implementation of RLs, (c) Barriers for the implementation of RLs

Hypothesis 6: *Thai manufacturing organisations do not implement Circular Economy*

This hypothesis aimed at exploring whether Thai manufacturing companies had adopted the concept of Circular Economy (CE). The result of the study indicated that 51.76% of the participant organisations had implemented CE. Consequently, the Z-test statistically confirmed, through a P-Value of less than 0.05 ($P<0.0001$) and hence rejection of the null hypothesis, that CE is a widely deployed approach among manufacturing companies in Thailand, see Table 8. This confirms that the rapid widespread of CE has not only reached European countries (Di et al., 2017; Veleva et al., 2017), South Africa (Mativenga et al., 2017a), Austria (Jacobi et al., 2018), India (Singh et al., 2018), China (Jiao and Boons, 2015), among others, but also Thailand, suggesting that this country, and more specifically its manufacturing sector, is aligning to the environmental awareness shown by other nations around the world.

Table 8. Z-test for the implementation of CE

Hypothesis 0: There is no statistical difference on mean as Thai manufacturing organisations do not implement Circular Economy ($\mu=0$).
Hypothesis 1: There is a statistical difference on mean as Thai manufacturing organisations implement Circular Economy ($\mu>0$).

One-Sample Z: Circular Economy
Descriptive Statistics

N	Mean	StDev	SE Mean	95% Lower Bound for μ
284	0.5176	0.5006	0.0297	0.4687

μ: mean of Circular Economy
Known standard deviation = 0.5006

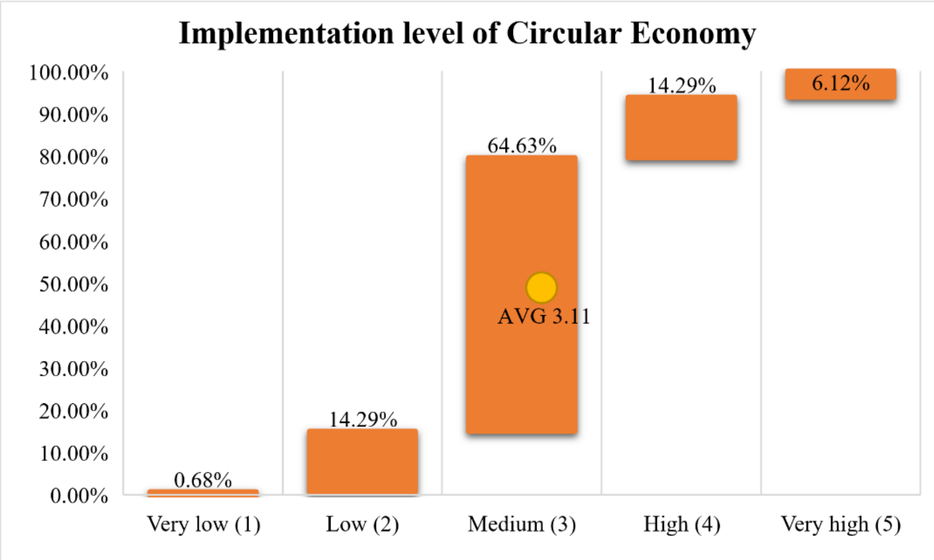
Z-Test

Null hypothesis	H_0: $\mu = 0$
Alternative hypothesis	H_1: $\mu > 0$

Z-Value	P-Value
17.42	P<0.0001

CRQ 6: *What are the reasons as to why Thai manufacturing organisations adopt, or do not adopt, Circular Economy?*

The study found that Thai manufcaturing companies tend to implement CE at a moderate level, see Figure 7(a). In this vein, the lack of financial suppport, see Figure 7(b), seems to have been the main reason as to why these companies have not implementing it across their entire operations. Bey et al. (2013) and Mativenga et al. (2017b) state that a dedicated financial budget for environmental improvement is essential for successfully implementing CE, which aligns to the findings of this study. Veleva et al. (2017) mention that organisations that are aware of their environmental impact and move towards zero waste are those that tend to adopt CE. Besides being oriented towards environmental sustainability improvement and since CE maximises the useful life of resources, it contributes in improving the operational efficiency of entire processes, which results in cost reduction (Mativenga et al., 2017a). Hence, the motivations for implementing CE by the Thai manufacturing sector seen in Figure 7(b) are the same as those confirmed by the literature. However, Geng and Doberstein (2008) remark that implementing CE requires high skills technical training, effective planning and management, environmentally superior technologies, technical capabilities, and financial resources. As discussed in Section 1 and shown by Table 1, most of the practices of the studied operational approaches are related to CE. Therefore, it is not surprising that implementing this operational approach requires high skills technical training. The barriers defined through the work of Geng and Doberstein (2008) support the research findings of this study illustrated in Figure 7(c).



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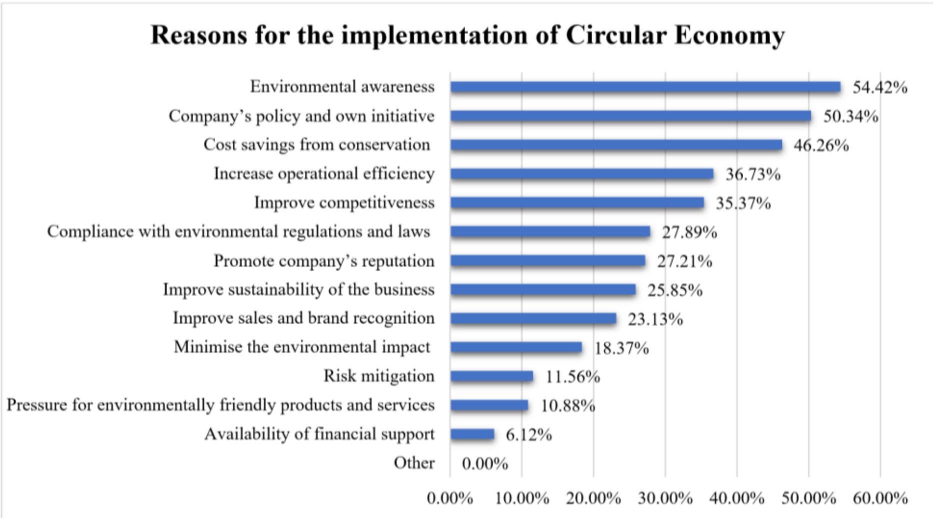

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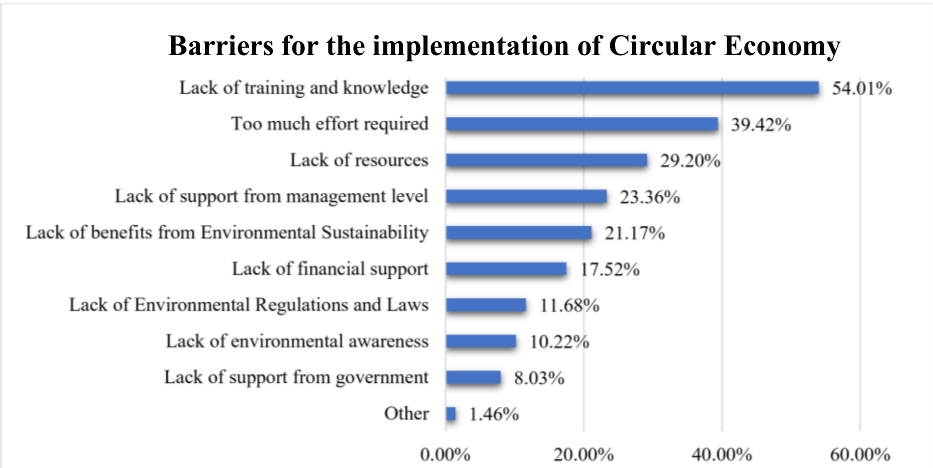

(c)

Figure 7. (a) Implementation level of CE, (b) Reason for the implementation of CE, (c) Barriers to the implementation of CE

Hypothesis 7: *There is no difference on the improvement of environmental sustainability performance among the practices of the operational approaches studied, i.e. pollution prevention, product stewardship, reducing the use of resources, waste reduction (reduce), waste reduction (reuse), waste reduction (recycle), life cycle analysis, eco-design, internal environmental management, green purchasing, cooperation with customers including environmental requirements, investment recovery, product upgrade, and waste management.*

The testing of this hypothesis will contribute in understanding whether the practices that comprise the studied operational environmental sustainability approaches, see Table 1, have the same impact on the environmental sustainability improvement of Thai manufacturing companies. To explore this phenomenon, the respondents were asked to estimate, from 0 to 100%, based on their experience and expertise on the subject and view on how these practices have impacted the operations of their companies, the effect of every one of the fourteen practices on environmental performance. Figure 8 shows a tendency of responses towards 'pollution prevention', 'waste reduction' and 'waste management' as the most significant practices.

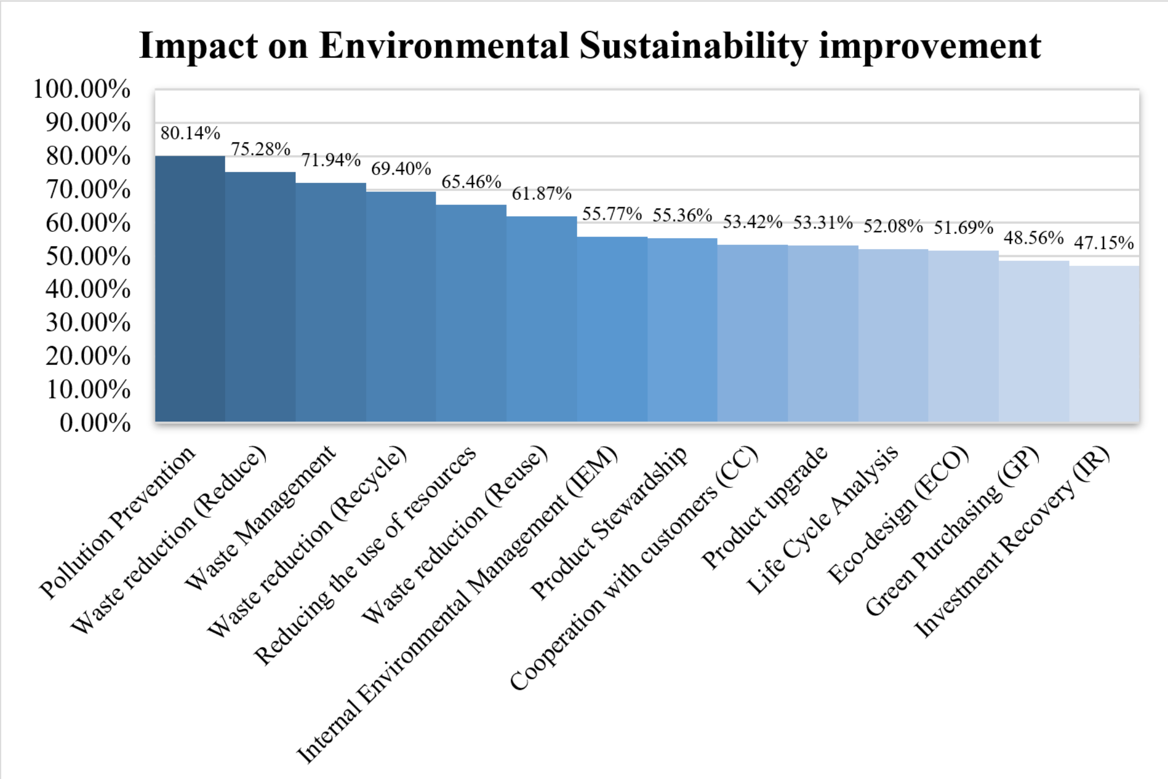

Figure 8. Practices effect on environmental sustainability improvement

A One-way ANOVA was conducted to validate the significance of these conclusions, see Table 9. The ANOVA test revealed a P-value of less than 0.05 ($P<0.0001$), indicating the rejection of the null hypothesis, which consequently suggested that there is a statistically significant difference in the improvement of environmental sustainability performance among the practices of the studied approaches. In order to determine which practice(s) have the strongest contribution to environmental performance, a Tukey-Pairwise Comparison test was performed, see Table 10.

Table 9. ANOVA test for Hypothesis 7

Hypothesis 0: There is no statistical difference on the mean as all practices of the operational approaches contribute equally to improve environmental sustainability.
Hypothesis 1: There is a statistical difference on the mean as all practices of the operational approaches contribute differently to improve environmental sustainability.

One-way ANOVA:
Method

Null hypothesis	All means are equal
Alternative hypothesis	Not all means are equal
Significance level	α = 0.05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Factor	14	Pollution Prevention, Product Stewardship, Reducing the use of resources, Waste reduction (Reduce), Waste reduction (Reuse), Waste reduction (Recycle), Life Cycle Analysis, Eco-design (ECO), Internal Environmental Management, Green Purchasing (GP), Cooperation with customers , Investment Recovery (IR), Product upgrade, Waste Management

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	13	414121	31855.5	50.00	P<0.0001
Error	3956	2520336	637.1		
Total	3969	2934458			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
25.2407	14.11%	13.83%	13.50%

Means

Factor	N	Mean	StDev	95% CI
Pollution Prevention	284	80.14	24.28	(77.20, 83.08)
Product Stewardship	284	55.36	23.11	(52.40, 58.31)
Reducing the use of resources	284	65.46	21.43	(62.51, 68.41)
Waste reduction (Reduce)	284	75.28	22.04	(72.35, 78.22)
Waste reduction (Reuse)	284	61.87	24.15	(58.93, 64.80)
Waste reduction (Recycle)	284	69.40	24.74	(66.46, 72.34)
Life Cycle Analysis	284	52.08	26.31	(49.14, 55.01)
Eco-design (ECO)	284	51.69	25.48	(48.75, 54.63)
Internal Environmental Management	284	55.77	26.43	(52.84, 58.71)
Green Purchasing (GP)	284	48.56	27.76	(45.62, 51.49)
Cooperation with customers	284	53.42	26.60	(50.48, 56.35)
Investment Recovery (IR)	284	47.15	27.49	(44.21, 50.08)
Product upgrade	284	53.31	27.47	(50.37, 56.25)
Waste Management	284	71.94	25.00	(69.00, 74.87)

Pooled StDev = 25.2407

Table 10 shows that pollution prevention, waste reduction (reduce), waste management, waste reduction (recycle), and reducing the use of resources are the practices that have the strongest effect on the improvement of sustainability performance, i.e. Groups A, B and C. Bhupendra and Sangle (2016) and Harrington (2012) advocate that pollution prevention is one of the most effective environmental practices to be adopted by organisations since it addresses the creation of pollution at its source. Furthermore, Fercoq et al. (2016), Jibril et al. (2012) and Ye et al. (2011) suggest that waste reduction (reduce) is a critical success factor in improving environmental and financial performance as it promotes energy conservation, reduces the potential risk to humans, and eliminates waste from overproduction. In the same way, Fruergaard et al. (2009) indicate that effective waste management can recover value from the waste since energy can be recovered in the form of electricity, heat, biogas, and landfill gas. Waste reduction (recycle) is another important practice since it promotes sustainability by treating waste as an economic resources through recycling processes (George et al., 2015; Ghisellini et al., 2016). Lastly, the use of natural resources or fossil fuels is not sustainable due to the limitation of available resources. Geldermann et al. (2016), Yue et al. (2015), and Mikulcic et al. (2016) all agreed that reducing the use of these resources helps to prevent environmental problems. Therefore, the result of this study corroborates the high importance of these practices emphasised in the academic literature, indicating that these are also highly applicable to the Thai manufacturing sector.

Table 10. Tukey Pairwise Comparisons test for Hypothesis 7

Tukey Pairwise Comparisons
Grouping Information Using the Tukey Method and 95% Confidence

Factor	N	Mean	Grouping							
Pollution Prevention	284	80.14	A							
Waste reduction (Reduce)	284	75.28	A	B						
Waste Management	284	71.94		B	C					
Waste reduction (Recycle)	284	69.40		B	C					
Reducing the use of resources	284	65.46			C	D				
Waste reduction (Reuse)	284	61.87				D	E			
Internal Environmental Management	284	55.77					E	F		
Product Stewardship	284	55.36					E	F	G	
Cooperation with customers	284	53.42						F	G	H
Product upgrade	284	53.31						F	G	H
Life Cycle Analysis	284	52.08						F	G	H
Eco-design (ECO)	284	51.69						F	G	H
Green Purchasing (GP)	284	48.56							G	H
Investment Recovery (IR)	284	47.15								H

Means that do not share a letter are significantly different.

5. Concluding remarks, limitations and future research

Undoubtedly, the manufacturing sector has served as an engine for the economic and social expansion of countries, but specially developing nations. This expansion, however, has been convoyed by serious environmental problems that include the degradation and scarcity of natural resources, extreme pollution, climate change, among others. To address these challenges, manufacturing companies have implemented operational environmental sustainability approaches that include green manufacturing (GM), cleaner production (CP), green lean (GL), green supply chain management (GSCM), reverse logistics (RLs) and circular economy (CE). Nevertheless, despite their wide application in various countries, specially developed nations, there is still a recognised difficulty on their adoption in developing countries. Form a theoretical viewpoint, various studies have focused on the implementation of these approaches in the manufacturing sectors of European countries, BRIC countries, the US and China, but no similar study has concentrated on investigating such adoption on a fast developing country like Thailand. In this line, the present paper fills this research gap and expands our knowledge in the field of operations and environmental sustainability by:

- Investigating the adoption of GM, CP, GL, GSCM, RLs and CE in the manufacturing industry of Thailand;
- Helping us to understand the drivers that have motivated manufacturing companies in this country to implement operational environmental sustainability approaches;
- Exploring the impending factors that have stopped these companies from more widely adopting the approaches studied; and
- Providing an insight into which of the practices that comprise the approaches studied have the strongest effect on the improvement of environmental sustainability.

Alongside these theoretical contributions, the paper also contributes to the industrial practice as these are important for managers who aim at improving the environmental performance of their organisations. From the research findings, it was concluded that all operational environmental sustainability approaches have very similar implementation statuses and characteristics. For instance, all of them were considered to be commonly used by Thai manufacturing companies, with RL being probably the least applied, and implemented at a moderate level. In the same way, it was also found that fully implementing all of the studied operational approaches requires a large amount of investment capacity, and proper training & knowledge, which resulted in some of the weakest elements of Thai manufacturing firms. Thus, it is not surprising that the main barriers for their implementation were those two factors, which were also a common denominator for all of the studied approaches. However, the study showed that Thai manufacturing firms also consider the impact on the environment and benefits from adopting these operational approaches as company's policy and own initiative, environmental awareness, and cost saving from conservation of energy as the main reasons for adopting the studied operational approaches. The findings also indicate that Thai manufacturing firms tend to implement the approaches because of internal factors and that they lack of motivation from external factors and involvement from other stakeholders. This calls for the Thai government to formulate appropriate strategies, policies and regulations as well as provide financial support to create external motivations to drive manufacturing organisations to adopt operational approaches that can support them in achieving long-term sustainable development.

Even through the study was particularly centred on the manufacturing industry of Thailand, other sector such as healthcare, logistics and transport, services, etc. may also benefit from this study due to the wide applicability of the environmental sustainability approaches studied. These other sectors are also having pressures from stakeholders to be more sustainable.

The study provides some interesting views into the adoption of environmental sustainability approaches in the Thai manufacturing sector. We hope this study motivates Thai organisations, and companies from the region, to contemplate the benefits and embark in the implementation of some of the approaches studied in this paper to make their operations sustainable.

This present study has a number of limitations. Although this research was able to conduct a study with 284 responses, the sample came from different manufacturing sectors. This may hinder the reflection of an overall picture regarding the state of the industry and cause biases. Thus, a larger and more specific study is recommended to get a better insight into the state of the studied approaches in the Thai manufacturing sector. Similarly, the study adopted a positivist and deductive approach through hypothesis building and statistical testing. Complementing this research method with a qualitative analysis, for example, through interviews, case studies or action research will provide further robustness to the research and validation of findings. Additionally, this research has been mainly contained to an exploratory study which offers light into the application of some commonly used operational approaches. Future research can consider the findings of this research to develop a framework to facilitate their implementation in Thailand. Finally, as this research distinctively focuses in the Thai manufacturing sector, future researchers could adopt this study as a guide to explore the implementation of operational environmental sustainability approaches, including motivations and barriers, in other countries and industrial sectors as well as consider the social pillar of sustainability not contemplated in the present study.

References

Al-Aomar, R. and Hussain, M. (2017). An assessment of green practices in a hotel supply chain: A study of UAE hotels. *Journal of Hospitality and Tourism Management*, 32, pp.71–81.

Al-Swidi, A.K., Shahzad, A. (2014). The Business Competitiveness of Thailand in the ASEAN Region. *Business and Economic Research*, 4(1), pp.48–69.

Adarsha, K., Parthap, B.N. (2013). Green Supply Chain Management Practices : A Case Study from Indian Manufacturing Industry. *Asia Pacific Journal of Research*, 3, pp.1–13.

Alam, M.M., Murad, M.W., Noman, A.H.M., Ozturk, I. (2016). Relationships among carbon emissions, economic growth, energy consumption and population growth: Testing Environmental Kuznets Curve hypothesis for Brazil, China, India and Indonesia. *Ecological Indicators*, 70, pp.466–479.

Azevedo, S.G., Carvalho, H. and Cruz Machado, V. (2011). The influence of green practices on supply chain performance: A case study approach. *Transportation Research Part E: Logistics and Transportation Review*, 47(6), pp.850–871.

Bai, Y., Yin, J., Yuan, Y., Guo, Y. and Song, D., 2015. An innovative system for promoting cleaner production: Mandatory cleaner production audits in China. *Journal of Cleaner Production*, 108, pp.883–890.

Bey, N., Hauschild, M.Z. and McAloone, T.C. (2013). Drivers and barriers for implementation of environmental strategies in manufacturing companies. *CIRP Annals - Manufacturing Technology*, 62(1), pp.43–46.

Bhupendra, K.V., Sangle, S. (2016). Pollution prevention strategy: a study of Indian firms. *Journal of Cleaner Production*, 133, pp.795–802.

Caiado, N., Guarnieri, P., Xavier, L.H. and de Lorena Diniz Chaves, G. (2017). A characterization of the Brazilian market of reverse logistic credits (RLC) and an analogy with the existing carbon credit market. *Resources, Conservation and Recycling*, 118, pp.47–59.

Caniëls, M.C.J., Gehrsitz, M.H., Semeijn, J. (2013). Participation of suppliers in greening supply chains: An empirical analysis of German automotive suppliers. *Journal of Purchasing and Supply Management*, 19(3), pp.134–143.

Chankrajang, T., Muttarak, R., 2017. Green Returns to Education: Does Schooling Contribute to Pro-Environmental Behaviours? Evidence from Thailand. *Ecological Economics*, 131, pp.434–448.

Cherrafi, A., Elfezazi, S., Garza-Reyes, J.A., Benhida, K. and Mokhlis, A. (2017). Barriers in Green Lean implementation: a combined systematic literature review and interpretive structural modelling approach. *Production Planning & Control*, 28(10), pp.829–842.

Chiarini, A. (2014). Sustainable manufacturing-greening processes using specific Lean Production tools: An empirical observation from European motorcycle component manufacturers. *Journal of Cleaner Production*, 85, pp.226–233.

Chileshe, N., Rameezdeen, R., Hosseini, M.R., Lehmann, S. (2015). Barriers to implementing reverse logistics in South Australian construction organisations. *Supply Chain Management-an International Journal*, 20(2), pp.179–204.

Cimatti, B., Campana, G. and Carluccio, L. (2017). Eco Design and Sustainable Manufacturing in Fashion: A Case Study in the Luxury Personal Accessories Industry. *Procedia Manufacturing*, 8, pp.393–400.

Chinda, T. (2017). Examination of Factors Influencing the Successful Implementation of Reverse Logistics in the Construction Industry: Pilot Study. *Procedia Engineering*, 182, pp.99–105.

Cruz-Rivera, R., Ertel, J. (2009). Reverse logistics network design for the collection of End-of-Life Vehicles in Mexico. *European Journal of Operational Research*, 196(3), pp.930–939.

Daylan, B., Ciliz, N., Mammodov, A., (2013). Hazardous process chemical and water consumption reduction through cleaner production application for a zinc electroplating industry in Istanbul. *Resources, Conservation and Recycling*, 81, pp.1-7.

Demajorovic, J., Augusto, E.E.F., Souza, M.T.S. De, (2016). Reverse Logistics of E-Waste in Developing Countries: Challenges and Prospects for the Brazilian Model. *Ambiente & Sociedade*, 19(2), pp.117–136.

Di, F., Carlo, P., Baldé, K., Polder, M. (2017). Measuring resource efficiency and circular economy : A market value approach. *Resources, Conservation & Recycling*, 122, pp.163–171.

Dilip Maruthi, G. and Rashmi, R., 2015. Green Manufacturing: It's Tools and Techniques that can be implemented in Manufacturing Sectors. *Materials Today: Proceedings*, 2, pp.3350–3355.

Ellen MacArthur Foundation. 2013. *Towards the Circular Economy: Opportunities for the Consumer Goods Sector*. Geneva: Ellen MacArthur Foundation.

Feng, C., Wang, M., Liu, G.C. and Huang, J.B. (2017). Green development performance and its influencing factors: A global perspective. *Journal of Cleaner Production*, 144, pp.323–333.

Fercoq, A., Lamouri, S. and Carbone, V. (2016). Lean/Green integration focused on waste reduction techniques. *Journal of Cleaner Production*, 137, pp.567–578.

Fernández-González, J.M., Grindlay, A.L., Serrano-Bernardo, F., Rodríguez-Rojas, M.I. and Zamorano, M. (2017). Economic and environmental review of Waste-to-Energy systems for municipal solid waste management in medium and small municipalities, *Waste Management*, 67, pp.360–374.

Ferrn Vilchez, V., Darnall, N. and Aragon Correa, J.A. (2017). Stakeholder influences on the design of firms' environmental practices. *Journal of Cleaner Production*, 142, pp.3370–3381.

Fruergaard, T., Astrup, T., Ekvall, T. (2009). Energy use and recovery in waste management and implications for accounting of greenhouse gases and global warming contributions. *Waste management & research : The journal of the International Solid Wastes and Public Cleansing Association*, 27(8), pp.724–737.

Fu, X., Guo, M. and Zhanwen, N. (2017). Applying the green Embedded lean production model in developing countries: A case study of china. *Environmental Development*, 23, pp.1–14.

Gabaldón-Estevan, D., Criado, E., Monfort, E. (2014). The green factor in European manufacturing: A case study of the Spanish ceramic tile industry. *Journal of Cleaner Production*, 70, pp.242–250.

Garza-Reyes, J.A., 2015. Lean and green-a systematic review of the state of the art literature. *Journal of Cleaner Production*, 102, pp.18–29.

Geldermann, J., Kolbe, L.M., Krause, A., Mai, C., Militz, H., Osburg, V.S., Schöbel, A., Schumann, M., Toporowski, W. and Westphal, S., 2016. Improved resource efficiency and cascading utilisation of renewable materials. *Journal of Cleaner Production*, 110, pp.1–8.

Geng, Y., Doberstein, B. (2008). Developing the circular economy in China: Challenges and opportunities for achieving 'leapfrog development'. *International Journal of Sustainable Development & World Ecology*, 15, pp.231–239.

George, D.A.R., Lin, B.C., Chen, Y. (2015). A circular economy model of economic growth. *Environmental Modelling and Software*, 73, pp.60–63.

Ghazilla, R.A.R., Sakundarini, N., Abdul-Rashid, S.H., Ayub, N.S., Olugu, E.U., Musa, S.N., (2015). Drivers and barriers analysis for green manufacturing practices in Malaysian smes: A preliminary findings. *Procedia CIRP*, 26, pp.658–663.

Ghinmine, S.V., Sangotra, D.I. (2015). Implementation of Green Manufacturing in Industry - A Case Study. *International Journal of Research in Engineering and Technology*, 4(4), pp.42–45.

Ghisellini, P., Cialani, C., Ulgiati, S. (2016). A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production*, 114, pp.11–32.

Govindan, K., Diabat, A., Madan Shankar, K. (2015a). Analyzing the drivers of green manufacturing with fuzzy approach. *Journal of Cleaner Production*, 96, pp.182–193.

Govindan, K., Soleimani, H., Kannan, D. (2015b). Reverse logistics and closed-loop supply chain: A comprehensive review to explore the future. *European Journal of Operational Research*, 240(3), pp.603–626.

Guimaraes, J.C.F., Severo, E.A., Vieira, P.S. (2017). Cleaner production, project management and Strategic Drivers: An empirical study. *Journal of Cleaner Production*, 141, pp.881–890.

Hens, L., Cabello-Eras, J.J., Sagastume-Gutierez, A., Garcia-Lorenzo, D., Cogollos-Martinez, J.B., Vandecasteele, C., (2017). University-industry interaction on cleaner production. The case of the Cleaner Production Center at the University of Cienfuegos in Cuba, a country in transition. *Journal of Cleaner Production*, 142, pp.63–68.

Harrington, D.R. (2012). Two-stage adoption of different types of pollution prevention (P2) activities. *Resource and Energy Economics*, 34(3), pp.349–373.

Islam, S., Tseng, M., Karia, N., Lee, C. (2018). Assessing green supply chain practices in Bangladesh using fuzzy importance and performance approach. *Resources, Conservation & Recycling*, 131, pp.134–145.

Jacobi, N., Haas, W., Wiedenhofer, D., Mayer, A. (2018). Providing an economy-wide monitoring framework for the circular economy in Austria: Status quo and challenges. *Resources, Conservation and Recycling*, 137, pp.156-166.

Jayant, A. and Azhar, M., 2014. Analysis of the barriers for implementing green supply chain management (GSCM) Practices: An Interpretive Structural Modeling (ISM) Approach. *Procedia Engineering*, 97, pp.2157–2166.

Jiao, W., Boons, F. (2015). Policy durability of Circular Economy in China: A process analysis of policy translation. *Resources, Conservation and Recycling*, 117, pp.12–24.

Jibril, J.D., Sipan, I.B., Sapri, M., Shika, S.A., Isa, M., Abdullah, S. (2012). 3R s Critical Success Factor in Solid Waste Management System for Higher Educational Institutions. *Procedia - Social and Behavioral Sciences*, 65, pp.626–631.

Johanson, G.A., Brooks, G.P. (2010). Initial Scale Development: Sample Size for Pilot Studies. *Educational and Psychological Measurement*, 70(3), pp.394–400.

Johansson, G., Sundin, E. (2014). Lean and green product development: Two sides of the same coin. *Journal of Cleaner Production*, 85, pp.104–121.

Kong, D., Feng, Q., Zhou, Y., Xue, L. (2016). Local implementation for green-manufacturing technology diffusion policy in China: From the user firms' perspectives, *Journal of Cleaner Production*, 129, pp.113–124.

Kurdve, M., Zackrisson, M., Wiktorsson, M., Harlin, U. (2014). Lean and green integration into production system models - Experiences from Swedish industry. *Journal of Cleaner Production*, 85, pp.180–190.

Laari, S., Töyli, J., Ojala, L. (2017). Supply chain perspective on competitive strategies and green supply chain management strategies. *Journal of Cleaner Production*, 141, pp.1303–1315.

Leach, M., Rockström, J., Raskin, P., Scoones, I., Stirling, A.C., Smith, A., Thompson, J., Millstone, E., Ely, A., Arond, E., Folke, C., Olsson, P. (2012). Transforming innovation for sustainability. *Ecology and Society*, 17(2), pp.1–6.

Li, R.C., Tee, T.J.C., 2012. A Reverse Logistics Model for Recovery Options Of E-waste Considering the Integration of the Formal and Informal Waste Sectors. *Procedia - Social and Behavioral Sciences*, 40, pp.788–816.

Liobikienė, G., Grincevičienė, Š. and Bernatonienė, J. (2016). Environmentally friendly behaviour and green purchase in Austria and Lithuania. *Journal of Cleaner Production*, 142, pp.3789–3797.

Lipan, F., Govindan, K., Chunfa, L. (2017). Strategic planning: Design and coordination for dual-recycling channel reverse supply chain considering consumer behavior. *European Journal of Operational Research*, 260(2), pp.601–612.

Liu, P., Zhou, Y., Zhou, D.K., Xue, L. (2017). Energy Performance Contract models for the diffusion of green-manufacturing technologies in China: A stakeholder analysis from SMEs' perspective. *Energy Policy*, 106, pp.59–67.

Luken, R.A., Van Berkel, R., Leuenberger, H., Schwager, P. (2016). A 20-year retrospective of the National Cleaner Production Centres programme. *Journal of Cleaner Production*, 112, pp.1165–1174.

Marcon, A., de Medeiros, J.F., Ribeiro, J.L.D. (2017). Innovation and environmentally sustainable economy: Identifying the best practices developed by multinationals in Brazil. *Journal of Cleaner Production*, 160, pp.83–97.

Marhani, M.A., Jaapar, A., Azmi, N., Bari, A., Zawawi, M. (2013). Sustainability through Lean Construction Approach: A literature review. *Procedia - Social and Behavioral Sciences*, 101, pp.90–99.

Masi, D., Kumar, V., Garza-Reyes, J.A., Godsell, J. (2018). Towards a Circular Economy: An investigation into the awareness, practices, and barriers at a firm level. *Production Planning & Control: The Management of Operations*, 29(6), 539-550.

Masoumik, S.M., Abdul-Rashid, S.H., Olugu, E.U. (2015). Importance-performance analysis of green strategy adoption within the Malaysian manufacturing industry. *Procedia CIRP*, 26, pp.646–652.

Mathivathanan, D., Kannan, D., Haq, A.N. (2017). *Sustainable supply chain management practices in Indian automotive industry: A multi-stakeholder view. Resources, Conservation and Recycling*, 128, pp.1–22.

Mathiyazhagan, K., Diabat, A., Al-Refaie, A., Xu, L. (2015). Application of analytical hierarchy process to evaluate pressures to implement green supply chain management. *Journal of Cleaner Production*, 107, pp.229–236.

Mativenga, P.T., Agwa-Ejon, J., Mbohwa, C., Sultan, A.A.M., Shuaib, N.A. (2017a). Circular Economy Ownership Models: A view from South Africa Industry. *Procedia Manufacturing*, 8, pp.284–291.

Mativenga, P.T., Amin, A., Sultan, M., Agwa-Ejon, J., Mbohwa, C. (2017b). Composites in a Circular Economy : A study of United Kingdom and South Africa. *Procedia CIRP*, 61, pp.691–696.

Mikulcic, H., Klemes, J.J., Vujanovic, M., Urbaniec, K., Duic, N. (2016). Reducing greenhouse gasses emissions by fostering the deployment of alternative raw materials and energy sources in the cleaner cement manufacturing process. *Journal of Cleaner Production*, 136, pp.119–132.

Miranda-Ackerman, M.A., Azzaro-Pantel, C., Aguilar-Lasserre, A.A. (2017). A green supply chain network design framework for the processed food industry: Application to the orange juice agrofood cluster. *Computers & Industrial Engineering*, 109, pp.369–389.

Mitra, S. (2009). Analysis of a two-echelon inventory system with returns. *Omega*, 37(1), pp.106–115.

Panya, N., Poboon, C., Phoochinda, W., Teungfung, R. (2017). The performance of the environmental management of local governments in Thailand. *Kasetsart Journal of Social Sciences*, 38(1), pp.1–9.

Pao, H.T., Tsai, C.M. (2011), Multivariate Granger causality between CO2 emissions, energy consumption, FDI (foreign direct investment) and GDP (gross domestic product):

Evidence from a panel of BRIC (Brazil, Russian Federation, India, and China) countries. *Energy*, 36, pp.685–693.

Parajuly, K., Wenzel, H. (2017). Potential for circular economy in household WEEE management. *Journal of Cleaner Production*, 151, pp.272–285.

Pimenta, H.C.D., Ball, P.D. (2015). Analysis of Environmental Sustainability Practices Across Upstream Supply Chain Management. *Procedia CIRP*, 26, pp.677–682.

Prakash, C., Barua, M.K., Pandya, K.V. (2015). Barriers Analysis for Reverse Logistics Implementation in Indian Electronics Industry using Fuzzy Analytic Hierarchy Process. *Procedia - Social and Behavioral Sciences*, 189, pp.91–102.

Pullman, M.E., Maloni, M.J., Carter, C.R. (2009). Food for thought: Social versus environmental sustainability practices and performance outcomes. *Journal of Supply Chain Management*, 45(4), pp.38–54.

Rahimi, M., Baboli, A., Rekik, Y. (2016). Sustainable Inventory Routing Problem for Perishable Products by Considering Reverse Logistic. *Proceedings of the IFAC Conference on Manufacturing Modelling, Management and Control MIM 2016*, Troyes, France, 28—30 June, 49(12), pp.949–954.

Rao, P. (2004). Greening production: a South-East Asian experience. *International Journal of Operations & Production Management*, 24(3), pp.289–320.

Ravi, V., Shankar, R. (2005). Analysis of interactions among the barriers of reverse logistics. *Technological Forecasting & Social Change*, 72(8), pp.1011–1029.

Ribeiro Ramos, A., Espíndola Ferreira, J.C., Kumar, V., Garza-Reyes, J.A., Cherrafi, A. (2018). A lean and cleaner production benchmarking method for sustainability assessment: A study of manufacturing companies in Brazil. *Journal of Cleaner Production*, 177, pp.218-231.

Riillo, C.A.F. (2017). Beyond the question 'Does it pay to be green?': How much green? and when? *Journal of Cleaner Production*, 141, pp.626–640.

Ritzén, S., Sandström, G.Ö. (2017). Barriers to the Circular Economy – Integration of Perspectives and Domains. *Procedia CIRP*, 64, pp.7–12.

Rusinko, C.A. (2007). Green manufacturing: An evaluation of environmentally sustainable manufacturing practices and their impact on competitive outcomes, *IEEE Transactions on Engineering Management*, 54(3), pp.445–454.

Saez-Martínez, F.J., Lefebvre, G., Hernandez, J.J., Clark, J.H. (2016). Drivers of sustainable cleaner production and sustainable energy options. *Journal of Cleaner Production*, 138, pp.1–7.

Salmoral, G., Yan, Y. (2018). Food-energy-water nexus: A life cycle analysis on virtual water and embodied energy in food consumption in the Tamar catchment, UK. *Resources, Conservation and Recycling*, 133, pp.320-330.

Saufi, N.A.A., Daud, S., Hassan, H. (2016). Green Growth and Corporate Sustainability Performance. *Procedia Economics and Finance*, 35, pp.374–378.

Schultmann, F., Zumkeller, M., Rentz, O. (2006). Modeling reverse logistic tasks within closed-loop supply chains: An example from the automotive industry. *European Journal of Operational Research*, 171(3), pp.1033–1050.

Severo, E.A., Guimaraes, J.C.F. and Dorion, E.C.H. (2017), Cleaner production and environmental management as sustainable product innovation antecedents: A survey in Brazilian industries, *Journal of Cleaner Production*, 142, pp.87–97.

Shi, H., Peng, S.Z., Liu, Y., Zhong, P. (2008). Barriers to the implementation of cleaner production in Chinese SMEs: government, industry and expert stakeholders' perspectives. *Journal of Cleaner Production*, 16(7), pp.842–852.

Silva, A.S., Medeiros, C.F., Kennedy Vieira, R. (2017). Cleaner Production and PDCA cycle: Practical application for reducing the Cans Loss Index in a beverage company. *Journal of Cleaner Production*, 150, pp.324–338.

Singh, M.P., Chakraborty, A., Roy, M. (2018). Developing an extended theory of planned behavior model to explore circular economy readiness in manufacturing MSMEs, India. *Resources, Conservation and Recycling*, 131, 146-147.

To, W.M., Lam, K.H., Lai, T.M. (2015). Importance-performance ratings for environmental practices among Hong Kong professional-level employees. *Journal of Cleaner Production*, 108, pp.699–706.

Vanalle, R.M., Ganga, G.M.D., Filho, M.G. and Lucato, W.C. (2017). Green supply chain management: An investigation of pressures, practices, and performance within the Brazilian automotive supply chain. *Journal of Cleaner Production*, 151, pp.250–259.

Veleva, V., Bodkin, G., Todorova, S. (2017). The need for better measurement and employee engagement to advance a circular economy: Lessons from Biogen's 'Zero Waste' journey. *Journal of Cleaner Production*, 154, pp.517–529.

Vieira, L.C., Amaral, F.G. (2016). Barriers and strategies applying Cleaner Production: A systematic review. *Journal of Cleaner Production*, 113, pp.5–16.

Wirutskulshai, U., Sajor, E., Coowanitwong, N. (2011). Importance of context in adoption and progress in application of strategic environmental assessment: Experience of Thailand. *Environmental Impact Assessment Review*, 31(3), pp.352–359.

Xiong, Y., Zhao, P., Xiong, Z., Li, G. (2016). The impact of product upgrading on the decision of entrance to a secondary market. *European Journal of Operational Research*, 252(2), pp.443–454.

Yang, H. (2011). Research on the construction and management of green supply chain based on circular economy. *2011 International Conference on Business Management and Electronic Information*, 3, pp.171–174.

Ye, S., Jiang, B., Li, C. (2011). The tentative idea of energy recovery based on '3R' principle. *Procedia Engineering*, 21, pp.1188–1192.

Ying, J., Li-jun, Z. (2012). Study on Green Supply Chain Management Based on Circular Economy. *Physics Procedia*, 25, pp.1682–1688.

Yue, Q., Wang, H., Gao, C., Du, T., Liu, L., Lu, Z. (2015). Resources saving and emissions reduction of the aluminum industry in China. *Resources, Conservation and Recycling*, 104, pp.68–75.

Yusup, M.Z., Wan Mahmood, W.H., Salleh, M.R., Ab Rahman, M.N. (2015). The implementation of cleaner production practices from Malaysian manufacturers' perspectives. *Journal of Cleaner Production*, 108, pp.659–672.

Zhan, Y., Hua, K., Ji, G., Chung, L. and Chiu, A.S.F. (2018). Green and lean sustainable development path in China : Guanxi, practices and performance. *Resources, Conservation & Recycling*, 128, pp.240–249.