Effective green supply chain practices for business performance improvement of Thai electronics industry

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Abstract: This study aims to identify the potential correlation between green supply chain management (GSCM) practices and business performance of firms in the Thai electronics industry to find the effective GSCM practices. Structured questionnaires were sent by mail to 67 of the electronics firms in Thailand that have joined the Green Industry Project. Canonical correlation analysis was used to test hypotheses. GSCM practices lead to improvement of business performance in the following aspects: environmental, competitive, operational and economic performances. The effective GSCM practices that have strong influence on business performances are clean manufacturing technologies, ISO 14001, and commitment to GSCM of senior managers. This study presents GSCM practices and business performances that cover all activities in the supply chain. Moreover, it aims to explore the relationships between GSCM practices and main business performances. Effective GSCM practices for Thai electronics industry are shown. Guidelines for improvement of each business performance are presented.

Keywords: green supply chain management; GSCM; business performance; electronics industry; green industry; canonical correlation analysis; CCA.

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1 Introduction

Green supply chain management (GSCM) has been commonly applied by many manufacturers. It is regarded as the environmental mission of businesses and aims to reduce the environmental impact of supply chain operations. The concept of GSCM integrates environmental concerns into the supply chain, starting from suppliers, manufacturers, customers, and reverse logistics.

The electronics and electrical appliance industry (hereafter referred to as E&E) is important to Thailand since the country has a dynamic income from manufacturing and exporting to markets around the world. This industry also creates employment opportunities in Thailand. Currently, there are 2,373 firms, and most of them are small businesses. There are 1,480 small to medium electronic parts manufacturers in E&E industry, which have high potential export businesses. The competitive advantages of Thai manpower are skills and precision. Thai E&E industry mainly serves demand from China, Japan, and the expanding ASEAN market, especially in the CLMV countries (Cambodia, Laos Myanmar and Vietnam) (Electrical and Electronics Institute, 2018). The export value of electrical products is still rising in 2019. These products are exported to China, Japan, ASEAN, EU, and USA markets. Electronic components and electrical circuits are the highest valued export product of Thailand. Global electronics exports are likely to expand further, driven by the advancement of technology. Countries in East Asia and Pacific have benefited disproportionally. Global market share of Thai electronic industry is relatively low comparing with its neighbours, but it tends to increase every year. In 2018, export value was 5,098 million US dollar, increased 17.29% from the previous year (Office of Industrial Economics, The Ministry of Industry, 2018).

In contrast to an unceasing expansion of international trade, E&E industry is also impacted by increasing environmental problems. As a result, environmental concerns have been discussed between governments, private sectors and consumers. The environmental problems are mainly caused by expired products in E&E industry. These wastes are contaminated with toxic substances, in other words, hazardous wastes, which lead to environmental damage. This is challenging for a properly controlled waste treatment. Waste segregation is essential in avoiding any contamination to soil, water and air. Improper waste management can cause waste of resources as well as toxic leakage that gives lethal impacts on people and the environment (Goodman, 2008; Schneiderman, 2009).

Consequently, E&E manufacturers must follow environmental regulations of the importing countries' standards. Some of the rules and regulations give both direct and indirect effects on production as well as trading. EU countries impose several environment and safety regulations, which illustrate the strong impact on E&E business, for example, Directive 2002/96/EC: Waste Electrical and Electronics Equipment (WEEE)

and Directive 2002/95/EC: Restriction of Hazardous Substances in Electrical and Electronics Equipment (RoHS). However, in the US market, the regulation is enacted by Environmental Protection Agency (EPA), the organisation monitoring, setting standards and enforcing activities to ensure environmental protection, and has become a model for other countries. Therefore, it is important that Thai manufacturers and importers understand these regulations very well to enhance the opportunity of market expansion. These regulations have encouraged the manufacturers to be concerned about environmental standards for the products, starting from product R&D stage, through production stage until expired stage.

Due to the government's awareness of the effect of changes in society, economics, environment, and natural disasters on economics and quality of life, there has been an initiative of government's preparation in the national economic system by creating competitive opportunity in economic development. This opportunity is classified as manpower development, knowledge creation, technology, innovation and creativity based on environmental friendly production in the industry.

Green industry in Thailand was started to support industrial organisations to operate an environmental-friendly business (Green Industry Project, 2014). There are five levels:

- Level 1 – Green commitment, demonstrated by policy, goals and action plans to reduce environmental impacts, and effective internal organisational communication.
- Level 2 – Green activity, the development of environmental activities in compliance with policy, goals and plans.
- Level 3 – Green system, the systematic environmental management, including assessment and revision aimed toward sustainable development, award recognition on the environment, accreditation on a variety of environmental concerns and substantial reduction of environmental impacts as in the commitment.
- Level 4 – Green culture, the cooperation of employees at all levels of the organisation in implementation of a friendly environment in all aspects of business operation and creating the concept to be as a value of organisation culture.
- Level 5 – Green network, the demonstration of network extension throughout green demand chains by promoting cooperation with business partners and allies entering into accredited green industrial processes.

It has been indicated in prior researches that SCM and environment are the fastest growing areas in the developing countries. Supply chains have focused more on the environment and its impact on organisational performances. This change in the focus of supply chains has resulted from growing social pressure, product life cycle, supply chain risks, and increasing use of the environment (Vijayvargy and Agarwal, 2013). However, not all activities have been covered by the concept. Thus, in this research, all variables in all activities of Thai electronics industry SCM have been synthesised. Generally, different countries have different pressures for the adoption of GSCM (Zhu et al., 2007a, 2007b, 2007c). In Thailand, there are few studies relating to GSCM. Moreover, relationships of GSCM practices and business performances have not been deeply investigated. Gathering all information related to effective practices will be very useful. It

is important to be able to statistically test the influences of green practice adoption (Kuei et al., 2015). Thus, this work aims to fill this research gap by exploring the relationship between GSCM practices and business performances, and highlight the benefits of the critical GSCM practices to manufacturers in the electronics industry and others industries.

2 Background literature

From the literature review, GSCM practices have been synthesised into seven activities; internal environmental management (X1), green purchasing (X2), eco-design (X3), green manufacturing (X4), cooperation with customers (X5), green distribution (X6), and investment recovery (X7). These seven activities are gathered from many research works and rearranged based on SCM activities. Similar practices are grouped to the main practice. Some research works may focus on a specific practice (Rahman et al., 2014; Eltayeb et al., 2011), but in this research existing practices are investigated to find the effective one. Additionally, the benefits of GSCM on business performances can be divided into four categories. These are economic performance (Y1), environmental performance (Y2), operational performance (Y3), and competitive performance (Y4). These business performances are also from existing research works. Different research works may have a different objective and may focus on different business performance. For example, Rao and Holt (2005) focus on competitiveness and economic performance, and Zhu et al. (2007b) emphasise on environmental and operational performance. These are discussed in the following subsection.

2.1 Green supply chain management

GSCM is the integration of environmental concepts and the SCM. The main activities and their descriptions are shown in Table 1.

Table 1 Summary of GSCM practices for electronics industry in Thailand

GSCM practices	*Description*	*Reference*
Internal environmental management (X1)	Commitment of senior managers to GSCM	Zhu et al. (2007a, 2010), Khiewnavawongsa (2011), Kim (2010) and Agyemang et al. (2018)
	Support for GSCM by mid-level managers	Zhu et al. (2007a, 2010), Khiewnavawongsa (2011) and Kim (2010)
	Cross-functional cooperation for environmental improvements	Zhu et al. (2007b, 2010), Khiewnavawongsa (2011) and Kim (2010)
	Environmental compliance and auditing program	Zhu et al. (2007b, 2010), Khiewnavawongsa (2011) and Kim (2010)
	ISO 14001 certification	Zhu et al. (2007c, 2010), Kim (2010), Khiewnavawongsa (2011) and Diabat and Govindan (2011)

Table 1 Summary of GSCM practices for electronics industry in Thailand (continued)

GSCM practices	*Description*	*Reference*
Green purchasing (X2)	Providing design specification to suppliers that includes environmental requirements for purchased items	Zhu et al. (2010), Youn et al. (2013), Kim (2010) and Agyemang et al. (2018)
	Cooperation with suppliers to meet environmental objectives	Zhu et al. (2010), Eltayeb et al. (2011), Bhateja et al. (2011), Khiewnavawongsa (2011), Kim (2010) and Rao and Holt (2005)
	Environmental audit for suppliers' internal management	Zhu et al. (2005, 2010), Khiewnavawongsa (2011) and Kim (2010)
	Suppliers ISO 14001 certification	Zhu et al. (2005, 2010), Khiewnavawongsa (2011), Kim (2010) and Diabat and Govindan (2011)
Eco-design (X3)	Design of products for reduced consumption of materials/energy	Zhu et al. (2005, 2013), Bhateja et al. (2011), Khiewnavawongsa (2011), Kim (2010) and Diabat and Govindan (2011)
	Design of products for reuse, recycle, recovery of materials and component parts	Zhu et al. (2005, 2010), Eltayeb et al. (2011), Khiewnavawongsa (2011), Kim (2010) and Diabat and Govindan (2011)
	Design of products to avoid or reduce use of hazardous products and/or their manufacturing processes	Zhu et al. (2007c, 2010), Eltayeb et al. (2011), Youn et al. (2013), Bhateja et al. (2011), Kim (2010), Khiewnavawongsa (2011) and Diabat and Govindan (2011)
Green manufacturing (X4)	Clean manufacturing technologies are applied	Rao and Holt (2005)
	Substitution of hazardous materials	Rao and Holt (2005)
	Use eco-friendly energy production, reduce water usage and keep control of pollution source	Rao and Holt (2005)
Cooperation with customers (X5)	Cooperation with customers for eco-design	Zhu et al. (2007c, 2010), Kim (2010), Agyemang et al. (2018) and Wang et al. (2018)
	Cooperation with customers for cleaner production	Zhu et al. (2007a, 2010) and Kim (2010)
	Cooperation with customers for green packaging	Zhu et al. (2007a, 2010) and Kim (2010)
Green distribution (X6)	The return or take-back of a product or packaging	Rao and Holt (2005), Eltayeb et al. (2011) and Bhateja et al. (2011)
	The company received the environmental certification	Rao and Holt (2005) and Bhateja et al. (2011)
	Environmentally friendly transportation	Rao and Holt (2005), Bhateja et al. (2011), Holt and Ghobadian (2009), Tsoulfasr and Pappis (2006) and Wu and Dunn (1995)
Investment recovery (X7)	Investment recovery (sale) of excess inventories/materials	Zhu et al. (2007b, 2010), Khiewnavawongsa (2011) and Tsoulfasr and Pappis (2006)
	Sale of scraps and used materials/ capital equipment	Zhu et al. (2007b, 2010) and Khiewnavawongsa (2011)

2.2 Business performances

The outcomes of business can be classified into four categories as the results of GSCM initiatives adopted by manufacturing firms. They are shown in Table 2.

Table 2 Summary of business performances for electronics industry in Thailand

GSCM performances	*Description*	*Reference*
Economic performance (Y1)	New market opportunities	Rao and Holt (2005) and Lin et al. (2013)
	Product price increase	Rao and Holt (2005)
	Profit margin	Rao and Holt (2005) and Eltayeb et al. (2011)
	Sales	Rao and Holt (2005), Eltayeb et al. (2011), Kuei et al. (2015) and Robinson (2012)
	Market share	Rao and Holt (2005) and Robinson (2012)
	Customer satisfaction	Sambasivan et al. (2013), Robinson (2012) and Kuei et al. (2015)
	Decrease of fees for waste discharge and waste treatment	Zhu et al. (2007a)
	Increase of operating cost and training cost	Zhu et al. (2007a) and Lin et al. (2013)
Environmental performance (Y2)	Reduction of solid/liquid waste and air emission	Zhu et al. (2007b), Sambasivan et al. (2013), Lin et al. (2013), Khiewnavawongsa (2011), Robinson (2012) and Wang et al. (2018)
	Decrease of consumption of hazardous/harmful/toxic materials	Zhu et al. (2007b), Eltayeb et al. (2011), Sambasivan et al. (2013), Lin et al. (2013), Khiewnavawongsa (2011) and Robinson (2012)
	Use of environmentally friendly technology	Lin et al. (2013)
	Environmental certification	Robinson (2012)
	Partnership with green organisations and suppliers	Lin et al. (2013) and Kuei et al. (2015)
Operational performance (Y3)	Increase amount of goods delivered on time	Eltayeb et al. (2011), Sambasivan et al. (2013), Khiewnavawongsa (2011) and Robinson (2012)
	Improved utilisation	Eltayeb et al. (2011) and Khiewnavawongsa (2011)
	Decrease inventory levels	Khiewnavawongsa (2011)
	Increased production capacity	Lin et al. (2013)
Competitive performance (Y4)	Quality improvement	Eltayeb et al. (2011), Kuei et al. (2015), Sambasivan et al. (2013), Lin et al. (2013) and Khiewnavawongsa (2011)
	Cost saving	Zhu et al. (2007c), Robinson (2012), Sambasivan et al. (2013), Kuei et al. (2015) and Wang et al. (2018)
	Corporate image improvement	Kuei et al. (2015) and Lin et al. (2013)

3 Hypothesis development

The hypotheses in this research are listed as follows:

3.1 GSCM practices and economic performance

The financial benefit to firms relates to environmental practices in a variety of ways due to the reduction of production waste and selection of non-hazardous raw materials. GSCM practices cause an improvement in the efficiency of resource usage. They can increase productivity and reduce operating costs. The key indicators of economic performance are new market opportunities, product price increase, profit margin, sales, and market share, etc. (Rao and Holt, 2005; Zhu et al., 2007a, 2007b; Kuei et al., 2015; Eltayeb et al., 2011; Lin, 2013; Robinson, 2012; Ramanathan et al., 2014). Then, the following hypothesis is proposed:

H1 GSCM practices are positively associated with economic performance.

3.2 GSCM practices and environmental performance

A few studies have investigated the impact of environmental practices on environmental performance. Some researchers have noted that some indicators of environmental performance, such as ISO 14001 certification do not fit with good environmental performance (Sambasivan et al., 2013). However, environmental performance is important to evaluate the GSCM in the entire supply chain (Lin et al., 2013; Kuei et al., 2015; Zhu et al., 2007b, 2007c; Eltayeb et al., 2011). Particular GSCM practices that involve strategic procurement of environmentally friendly raw material may lead to reductions in waste disposal process, thus improving environmental performance (Youn et al., 2013). Then, the following hypothesis is proposed:

H2 GSCM practices are positively associated with environmental performance.

3.3 GSCM practices and operational performance

Green principles in the supply chain have been defined from the organisation's capacity. An environmental management system is an innovative environmental policy and information management tool for industry to improve the organisation's operational performance in order to serve its clients in terms of delivered on time, process improvements, or increased production capacity, etc. (Zhu et al., 2007a, 2007b, 2010; Eltayeb et al., 2011). So, the following hypothesis is proposed:

H3 GSCM practices are positively associated with operation performance.

3.4 GSCM practices and competitive performance

The benefits of green practices lead to the improvement of competitive advantage, enhancing the green reputation of the firm, improving corporate image, product quality and obtaining higher customer satisfaction (Rao and Holt, 2005; Zhu et al., 2007b, 2010; Eltayeb et al., 2011; Kuei et al., 2015). These can also increase customer loyalty (Youn et al., 2013). Then, the following hypothesis is proposed:

H4 GSCM practices are positively associated with competitive performance.

4 Research methods

This research employs multiple case studies from Thai electronics companies, which are involved in the Green Industry Project. There are three stages: design, data collection, and analysis. Canonical correlation analysis (CCA) is used to analyse the relationships of GSCM and each business performance because it is suitable for metric predictor variables and multiple dependent variables with a single relationship (Hair et al., 1995). The details of each stage are discussed in the following subsections.

4.1 Research design

The main objective of this research is to explore and understand the influence of GSCM practices on business performances. In this study, all of the main activities in the supply chain from many literatures were collected. All of the GSCM business performances for the organisations concerned are covered and can be classified into four categories: economic, environmental, operational, and competitive performances. Then, these four groups of variables are integrated in the proposed research model.

Figure 1 Research framework

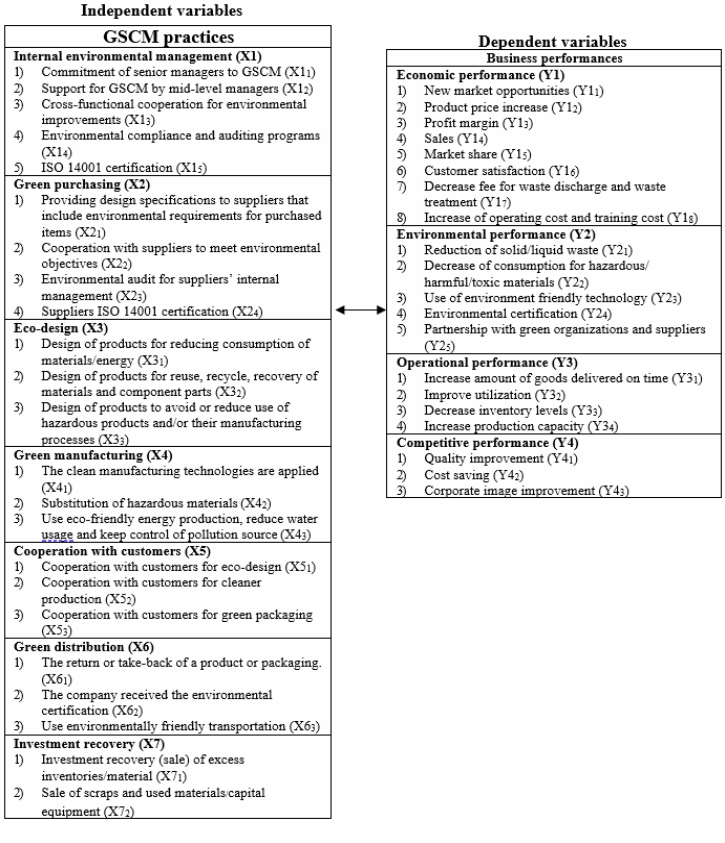


Figure 1 depicts the research model, which emphasises the relationships between GSCM practices and business performances of the Thai electronics industry.

4.2 Data collection

A questionnaire was the tool for the data collection. 81 electronics manufacturing firms have joined the Green Industry Project; however, in this study 67 of those were selected as the target respondents by the simple random sampling method. Respondents were logistics and supply chain managers or environmental managers, with 21–25 years of working experience in the firms. The questionnaire was verified and validated. Index of item-objective congruence (IOC) was checked by five experts. Reliability and validity were assessed by Cronbach's alpha for 30 pre-test samples, which have a value above 0.7 (Diab et al., 2015). It is relevant to the study. Each item was measured by a Likert's scale ranging from 1–5. Survey data were collected by mailing, then analysed through the SPSS statistical program and tested through CCA. This procedure produced a 100% response.

4.3 Methods for data analysis

The relationships between GSCM practices and business performances were investigated using CCA, which is a multivariate statistical model that enables the study of interrelationships among sets of multiple criterion variables and multiple predictor variables. The single or overall relationship is studied in this research. The general form of canonical analysis is expressed as

$$\underset{\text{(metric, non-metric)}}{Y1 + Y2 + Y3 + \ldots + Yn} = \underset{\text{(metric, non-metric)}}{X1 + X2 + X3 \ldots + Xn + \ldots} \quad (1)$$

In situations with multiple dependent and independent variables, CCA is the most proper and powerful multivariate technique. This study also used the CCA technique to analyse sets of GSCM variables and business performance variables. Canonical variables, found to have maximum correlations, can be examined with canonical loadings. These loadings are the correlations between the primitive variables and canonical variables (Hair et al., 1995).

5 Results and discussion

The results are demonstrated in descriptive statistics and the analysis of canonical correlation between GSCM practices and business performances.

5.1 Descriptive statistics

The result of statistical analysis of GSCM practices variables are shown in Table 3.

The Pearson's correlations between GSCM practices and business performances are shown in Table 3. They reveal bi-variate relationships. The correlations among GSCM practices are generally positive, except the relationship of cooperation with customers (X5) and investment recovery (X7) is not statistically correlated. The correlations among business performances are very high and all relationships of the business performances

are positive. The internal correlations between each GSCM practice and each business performance are positive too, except the relationship between investment recovery (X7) and competitive performance (Y4) is not statistically correlated.

Table 3 Correlation between GSCM practices and business performances

	X1	*X2*	*X3*	*X4*	*X5*	*X6*	*X7*	*Y1*	*Y2*	*Y3*	*Y4*	*Cronbach's alpha*
X1	1.00											0.87
X2	0.53*	1.00										0.83
X3	0.56*	0.31*	1.00									0.83
X4	0.70*	0.63*	0.73*	1.00								0.91
X5	0.34*	0.55*	0.51*	0.58*	1.00							0.81
X6	0.56*	0.64*	0.36*	0.47*	0.52*	1.00						0.77
X7	0.51*	0.49*	0.24*	0.35*	0.10	0.47*	1.00					0.70
Y1	0.47*	0.43*	0.63*	0.68*	0.62*	0.37*	0.24*	1.00				0.86
Y2	0.75*	0.58*	0.65*	0.75*	0.51*	0.60*	0.43*	0.74*	1.00			0.91
Y3	0.63*	0.53*	0.68*	0.68*	0.47*	0.48*	0.33*	0.75*	0.82*	1.00		0.91
Y4	0.69*	0.49*	0.61*	0.58*	0.54*	0.55*	0.21	0.73*	0.83*	0.86*	1.00	0.93
Mean	4.39	3.69	3.93	4.03	3.74	4.02	3.98	3.69	4.26	3.98	4.21	
Standard deviation	0.43	0.64	0.69	0.64	0.75	0.57	0.81	0.58	0.52	0.65	0.55	

Note: *$p < 0.05$.

Internal environmental management (X1) has the highest mean value among GSCM practices, which is 4.39. This result showed that the Thai electronics industry has experienced high pressure for regulatory compliance and has strong internal drivers for GSCM practice adoption, which is similar to Malaysian, Vietnamese, and Indonesian industries (Rahman et al., 2014; Pham and Pham, 2017; Djunaidi et al., 2018). The result of Diab et al. (2015) also confirms that internal environmental management has a strong influence on GSCM practices.

Green manufacturing (X4) and green distribution (X6) have also been implemented at a significantly high level with 4.03 and 4.02, respectively. Thai electronics industry has implemented GSCM mainly in manufacturing and distribution processes using clean technologies, substitution of hazardous materials, energy saving, water saving, using eco-friendly energy production, keeping control of pollution source, and environmentally friendly transportation. Three GSCM practices, which are green purchasing, eco-design, and reverse logistics were studied with Malaysian industry and found that eco-design was the main practice among the three practices (Eltayeb et al., 2011). This means that the firm tries to improve environmental outcome of its products internally, with little cooperation or interaction with external parties. Sundram et al. (2017) found that it is not only eco-design but also inventory recovery and packaging practices were important practices for Malaysian industry that influenced environmental and operational outcomes. For Vietnamese industry, green manufacturing is the most significant practice for competitiveness (Nguyen and Le, 2020). Implementation of GSCM practices for ASEAN countries mainly started from internal operations in various ways.

Environmental performance has the highest mean value among business performances, which is 4.26. This performance can be seen from the reduction of waste and toxic materials, environmental certifications, and partnership with green organisations and suppliers. Competitive performance is also high at the level of 4.21. It indicates high quality improvement, cost saving, and corporate image improvement. These results are similar to the works of Zhu et al. (2007a), Kuei et al. (2015), Diab et al. (2015) and Rao and Holt (2005). Eltayeb et al. (2011) studied GSCM practices that affect business performance from certified companies in Malaysia, they found that environmental outcomes value is the highest among economic outcomes, cost reductions, intangible outcomes. Nguyen and Le (2020) also found that GSCM practices have a positive impact on environmental, competitive, and financial performances for Vietnamese businesses. These results are similar to Thai industry. Next, CCA was employed to examine the types of interaction. All factors for GSCM practices and business performances have reliability values (Cronbach's alpha) above or equal to 0.7, the threshold value (Zhu et al., 2007a).

5.2 Correlations between GSCM practices and business performances

The analysis of canonical correlation is separated into the analysis between the overall GSCM practices and business performances, the analysis between main groups of GSCM practices and business performances, the analysis of sub-criteria in each group of GSCM practices and each business performance, and the analysis of each sub-criteria of business performance and each group of GSCM practices. The relationships between GSCM practices and business performances were analysed and demonstrated as follows.

5.2.1 Canonical correlation between GSCM practices and business performances

Initially, main factors of GSCM practices and main factors of business performances were analysed. Then, each pair of GSCM practices and business performances were investigated.

Table 4 Discriminant analysis of the main factors

Function (F)	*Eigenvalue*	*% of variance*	*Cumulative %*	*Canonical correlation*
1	*3.959*	*81.09%*	*81.09%*	*0.894***
2	*0.662*	*13.55*	*94.64*	*0.631***
3	0.181	3.70	98.34	0.391
4	0.081	1.66	100.00	0.274

Notes: *p < 0.05; **p < 0.01.

Table 4 shows canonical correlation between main factors of GSCM practices (internal environmental management (X1), green purchasing (X2), eco-design (X3), green manufacturing (X4), cooperation with customers (X5), green distribution (X6), and investment recovery (X7) and main factors of business performance (economic performance (Y1), environmental performance (Y2), operation performance (Y3), and competitive performance (Y4) with eigenvalues 3.959, 0.662, 0.181 and 0.081

respectively. Two functions are statistically significant at canonical correlation 0.894 and 0.631, respectively.

Table 5 Canonical redundancy indices for significant canonical function

Functions	*Average loading squared*	*Canonical* R_c^2	*Redundancy index*[a]	*Cumulative proportion*
Independent variables: GSCM practices				
1	0.458	0.797	0.365	0.365
2	0.252	0.382	0.096	0.461
Dependent variables: business performance				
1	0.792	0.797	0.631	0.631
2	0.610	0.382	0.233	0.864

Note: [a]Redundancy index calculated by average loading squared × canonical R_c^2.

Canonical redundancy indices, shown in Table 5, measure the proportion of the GSCM practice variables shared with business performance variables. For function 1, redundancy index for the criterion variate is substantial (0.365) and the predictor variate has a substantially higher redundancy index (0.631). Redundancy indices for both criterion variate and predictor variate of the second function have substantially lower values (0.096 and 0.233), so only the first function is accepted.

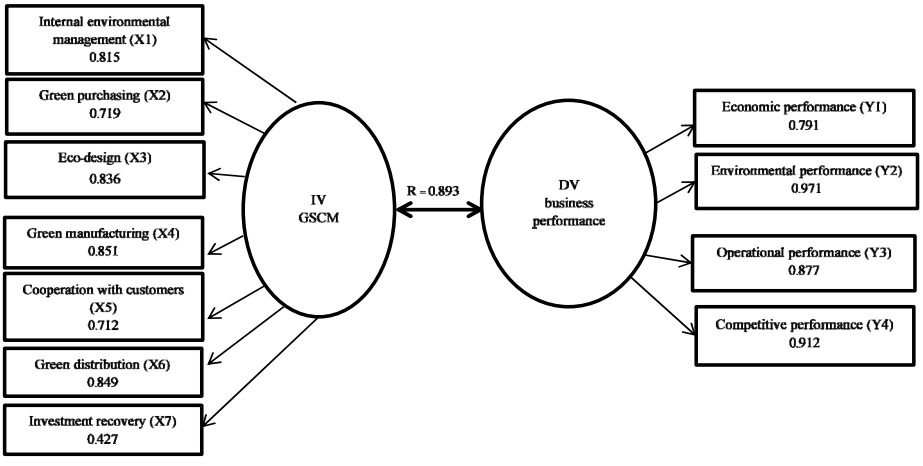
Table 6 Canonical structure of the canonical function

	Function 1
Canonical correlation	0.893
Bartlett test of residual correlation (p-value)	0.000
Canonical loading (r): GSCM (independent variable)	
Internal environmental management (X1)	0.815[a]
Green purchasing (X2)	0.719[a]
Eco-design (X3)	0.836[a]
Green manufacturing (X4)	0.851[a]
Cooperation with customers (X5)	0.712[a]
Green distribution (X6)	0.849[a]
Investment recovery (X7)	0.427[a]
Redundancy index	0.365
Canonical loading (r): business performance (dependent variable)	
Economic performance (Y1)	0.791[a]
Environmental performance (Y2)	0.971[a]
Operation performance (Y3)	0.877[a]
Competitive performance (Y4)	0.912[a]
Redundancy index	0.631

Note: [a]The absolute value of canonical loading greater than 0.30 were used in this study (Hair et al., 1995).

In Table 6, the research results show the important weights of canonical function for both GSCM practices and business performances as shown in the diagram of Figure 2. The GSCM practices effectively influence all of the business performance indicators except investment recovery (X7). Green manufacturing (X4), green distribution (X6), eco-design (X3), internal environmental management (X1), green purchasing (X2), and cooperation with customers (X5) are main factors, which have strongly influenced all of the business performances with the values of 0.851, 0.849, 0.836, 0.815, 0.719, 0.712, respectively. These practices affect the environmental, competitive, operational, and economic performances (Y2, Y4, Y3, Y1), with canonical loading 0.971, 0.912, 0.877, and 0.791, respectively.

Figure 2 The relationships between GSCM practices and business performances of electronics industry in Thailand



Green industry in Thailand has been initiated to support the electronics industry to operate an environmental-friendly business. Moreover, the electronics industry was forced by environmental regulations of the importing countries' standards to improve environmental aspect in all activities of the supply chain, which was similar for other counties (Diabat and Govindan, 2011). Thai electronics industry started going green by implementing green manufacturing, green distribution and eco-design with the support from internal management. After implementing GSCM practices, improved environmental performance, such as waste reduction, decrease of energy and toxic consumption, and environmental certification were evident. Cost of the products could also be reduced, and corporate image is improved. Environmental performance of electronic industry in Thailand is rated as satisfactory. Tippayawong et al. (2015) also found that green manufacturing is the most important factor for the electronics industry in Thailand. They suggested that setting systematic manufacturing and technology can reduce the production of wastes or can increase the factory's highest capability.

Eltayeb et al. (2011) studied three practices in Malaysian industry. The result showed that eco-design is the highest adopted green supply chain initiative, followed by green purchasing and reverse logistics. For Vietnamese industry, green manufacturing has a strong relationship with global collaborative capability, which can increase

competitiveness performance (Nguyen and Le, 2020). Effective GSCM practices of ASEAN countries are green manufacturing, green distribution, and eco-design.

The result of Thai manufacturers' performance contrasts with Malaysia manufacturers, which found that GSCM practices are not significant to environmental performance (Rahman et al., 2014), but it is consistent with many research works (Cote et al., 2008; Zhu et al., 2007a, 2010). GSCM initiatives have positive effects on environmental and operational outcomes for both Malaysia and Vietnam industries (Eltayeb et al., 2011; Sundram et al., 2017; Nguyen and Le, 2020). GSCM makes Thai companies able to compete with other export countries with high quality, cost-saving, and corporate image. Operational and economic performances are also improved by applying green manufacturing, green distribution, green purchasing, and eco-design. Manufacturing plants should consider and develop all steps to reduce environmental pollution. The case studies in Zhu et al. (2007a, 2010) also showed the result in the same direction by implementing internal environmental management, cleaner production, green purchasing, green marketing, and eco-design program. It found that large Japanese manufacturers have achieved significant environmental and economic performances, while operational performance improvement is not significant. GSCM practices in China have resulted in environmental performance improvement, but most of their improvements are not significant. Competitive performance is also highly affected. Kuei et al. (2015) found that this performance has a high correlation with upstream firms. On the other hand, economic performance is the least affected; however, it is at quite a high level. Thai electronics industry is still in the initial stage of becoming a green industry.

Each GSCM practice may have a relationship with each business performance differently. In the next section, the relationships of all pairs of GSCM practices and business performances have been investigated.

5.2.2 Correlations of each group of GSCM practices and business performance

The result of significant canonical functions is shown in Table 7.

Table 7 Discriminant analysis of each GSCM practice and business performance

GSCM	*Business performance*	*Function (F)*	*Eigenvalue*	*% of variance*	*Cumulative %*	*Canonical correlation*
Internal environmental management (X1)	Y1	1	0.621	47.64%	47.64%	0.619**
	Y2	1	4.921	84.55%	84.55%	0.912**
		2	0.721	12.38	96.93	0.647**
	Y3	1	0.793	63.38%	63.38%	0.665**
		2	0.206	16.48	79.86	0.413*
	Y4	1	2.491	86.69%	86.89%	0.845**
		2	0.342	11.89	98.78	0.505**
Green purchasing (X2)	Y1	1	1.098	70.66%	70.66%	0.723**
	Y2	1	1.050	67.91%	67.91%	0.716**
		2	0.337	21.77	89.68	0.502**
	Y3	1	1.552	80.13%	80.13%	0.780**
		2	0.265	13.70	93.83	0.458*
	Y4	1	0.911	87.06%	87.06	0.691**

Notes: *p < 0.05; **p < 0.01; economic performance (Y1), environmental performance (Y2), operational performance (Y3) and competitive performance (Y4).

Table 7 Discriminant analysis of each GSCM practice and business performance (continued)

GSCM	*Business performance*	*Function (F)*	*Eigenvalue*	*% of variance*	*Cumulative %*	*Canonical correlation*
Eco-design (X3)	Y1	1	1.328	84.90%	84.90%	0.755**
	Y2	1	1.666	84.14%	84.14%	0.791**
		2	0.300	15.15	99.29	0.480**
	Y3	1	1.188	89.23%	89.23%	0.737**
	Y4	1	1.264	93.85%	93.85%	0.747**
Green manufacturing (X4)	Y1	1	1.786	82.59%	82.59%	0.801**
	Y2	1	8.210	92.99%	92.99%	0.944**
		2	0.555	6.29	99.28	0.597**
	Y3	1	1.016	82.12%	82.12%	0.710**
		2	0.196	15.81	97.93	0.405*
	Y4	1	0.756	87.83%	87.83%	0.656**
Cooperation with customers (X5)	Y1	1	1.874	73.05%	73.05%	0.808**
		2	0.555	21.63	94.68	0.597**
	Y2	1	2.023	86.15%	86.15%	0.818**
		2	0.264	11.22	97.37	0.457*
	Y3	1	0.982	92.53%	92.53%	0.704**
	Y4	1	0.910	75.76%	75.76%	0.690**
		2	0.275	22.87	98.63	0.464**
Green distribution (X6)	Y1	1	1.848	85.38%	85.38%	0.806**
	Y2	1	1.313	74.17%	74.17%	0.753**
		2	0.378	21.36	95.53	0.524**
	Y3	1	1.220	91.70%	91.70%	0.741**
	Y4	1	1.448	85.12%	85.12%	0.769**
		2	0.228	13.42	98.54	0.431**
Investment recovery (X7)	Y1	1	0.428	77.86%	77.86	0.329*
	Y2	1	0.373	76.66%	76.66%	0.521**
	Y3	1	0.252	76.40%	76.40%	0.449*

Notes: *p < 0.05; **p < 0.01; economic performance (Y1), environmental performance (Y2), operational performance (Y3) and competitive performance (Y4).

Table 7 shows the analysis of canonical relationships between each GSCM practice variable and the business performance variables. Then, the redundancy index for each GSCM practice was checked; it was found that most of the GSCM practice variables were statistically significant with almost all business performance variables except investment recovery (X7). In this research, competitive performance (Y4) has not been found to be significant to investment recovery (X7). The result differs from Zhu et al. (2010) who found that investment recovery was significant from green implementation in large Japanese manufacturing companies that may result from Japanese laws and policies on reuse, recycling, and recovery, which are active and critical. However, Thailand still lacks external cooperation and diffusion on green practices.

Next, the most to the least important practices, according to canonical loading are discussed. Only strong canonical correlations (>0.7) are mentioned. Green manufacturing (X4) affects environmental, economic, and operational performances (Y1, Y2, Y3). Green distribution (X6) and eco-design (X3) influence all business performances. Next, internal environmental management (X1) has a high canonical correlation with environmental and competitive performances (Y2, Y4). Moreover, green purchasing (X2) influences economic and operational performances (Y1, Y3) and cooperation with customers (X5) affects economic, environmental, and operational performances (Y1, Y2, Y3).

Green manufacturing is a critical practice in the Jordanian food industry (Diab et al., 2015). Muma et al. (2014) also found that green manufacturing has a positive effect on environmental performance. It is an effective practice in many industries. Eco-design has a significant effect on environmental, economic, and competitive performance in Malaysia (Eltayeb et al., 2011). The finding in this research is also confirmed in the same direction. Moreover, eco-design also affects operational performance. Internal environmental management and green purchasing are crucial factors for all types of industry (Zhu et al., 2007a). Green the inbound function and greening production lead to greening outbound, as well as improving to competitiveness and economic performance (Rao and Holt, 2005). Those research results are supported by the outcome of this research.

5.2.3 Correlations between sub-criteria of each GSCM practices group and each business performance

Next, the relationship of each GSCM practice was analysed with respect to each business performance, illustrated in Appendix. To identify the significant canonical function, the absolute values of canonical loading greater than 0.30 were used in this study (Hair et al., 1995).

From Table 8 canonical loadings of each variable in GSCM practices and those in business performance variables are used to interpret the meaning of the relationship between GSCM practices and business performances. Almost all items of GSCM practices relate to business performance indicators at medium to high level, except sub-criteria of green purchasing (X2), providing design specifications to suppliers that include environmental requirements for purchased items ($X2_1$) and cooperation with suppliers to meet environmental objectives ($X2_2$), at the values of –0.236 and –0.090, respectively, which means that these practices do not have sufficient evidence to show that they influence economic performance.

The effective correlation of each sub-criterion is calculated by multiplying canonical correlation of group with individual correlation. Next, sub-criteria of GSCM practices in each group in Table 8, which have a strong effect, correlation greater than 0.65 are discussed, according to the importance of group in descending order. The most effective practice is clean manufacturing technologies applied ($X4_1$). The second rank is ISO 14001 certification ($X1_5$), and the third rank is a commitment of senior managers to GSCM ($X1_5$). Green manufacturing practice has been shown to be significant in many previous research papers. It is also the most important practice for the electronics industry in Thailand. It strongly affects environmental performance. ISO 14001 certification is the evidence of going green so most factories are keen to obtain it. It can increase environmental performance considerably. Senior managers can show their intentions to

their workers by giving commitment to GSCM. This is clear direction for the organisation to apply green procedures. It strongly relates to competitive performance.

Table 8 Practical results of GSCM practices for effective business performance

Factor	*Economic performance (Y1)*	*Environmental performance (Y2)*	*Operational performance (Y3)*	*Competitive performance (Y4)*
Internal environmental management (X1)				
Canonical correlation	*0.619*	*0.912*	*0.665*	*0.845*
Commitment of senior managers to GSCM ($X1_1$)	0.957[a]	0.591[a]	–0.916[a]	–0.982[a]
Support for GSCM by mid-level managers ($X1_2$)	0.946[a]	0.663[a]	–0.915[a]	–0.884[a]
Cross-functional cooperation for environmental improvements ($X1_3$)	0.641[a]	0.299	–0.654[a]	–0.458[a]
Environmental compliance and auditing programs ($X1_4$)	0.715[a]	0.648[a]	–0.773[a]	–0.756[a]
ISO 14001 certification ($X1_5$)	0.826[a]	0.963[a]	–0.896[a]	–0.727[a]
Green purchasing (X2)				
Canonical correlation	*0.723*	*0.716*	*0.780*	*0.690*
Providing design specifications to suppliers that include environmental requirements for purchased item ($X2_1$)	–0.236	0.623[a]	–0.379[a]	–0.326[a]
Cooperation with suppliers to meet environmental objectives ($X2_2$)	–0.090	0.569[a]	–0.363[a]	–0.303[a]
Environmental audit for suppliers' internal management ($X2_3$)	–0.708[a]	0.897[a]	–0.831[a]	–0.798[a]
Suppliers ISO 14001 certification ($X2_4$)	–0.937[a]	0.753[a]	–0.887[a]	–0.912[a]
Eco–design (X3)				
Canonical correlation	*0.755*	*0.790*	*0.737*	*0.747*
Design of products for reduced consumption of material/ energy ($X3_1$)	–0.562[a]	0.871[a]	–0.760[a]	–0.770[a]
Design of products for reuse, recycle, recovery of materials and components part ($X3_2$)	–0.900[a]	0.811[a]	–0.894[a]	–0.910[a]
Design of products to avoid or reduce use of hazardous products and/or their manufacturing process ($X3_3$)	–0.846[a]	0.847[a]	–0.841[a]	–0.811[a]

Note: [a]The absolute value of canonical loading greater than 0.30 were used in this study.

Table 8 Practical results of GSCM practices for effective business performance (continued)

Factor	*Economic performance (Y1)*	*Environmental performance (Y2)*	*Operational performance (Y3)*	*Competitive performance (Y4)*
		Green manufacturing (X4)		
Canonical correlation	*0.801*	*0.944*	*0.710*	*0.656*
Clean manufacturing technologies are applied ($X4_1$)	0.825[a]	0.989[a]	0.811[a]	0.836[a]
Substitute for hazardous materials ($X4_2$)	0.830[a]	0.617[a]	0.855[a]	0.790[a]
Use eco-friendly energy production, reduce water usage and keep control of pollution source ($X4_3$)	0.747[a]	0.504[a]	0.729[a]	0.775[a]
		Cooperation with customers (X5)		
Canonical correlation	*0.807*	*0.818*	*0.704*	*0.690*
Cooperation with customer for eco design ($X5_1$)	–0.716[a]	0.723[a]	0.648[a]	–0.722[a]
Cooperation with customer for cleaner production ($X5_2$)	–0.763[a]	0.742[a]	0.715[a]	–0.803[a]
Cooperation with customer for green packaging ($X5_3$)	–0.980[a]	0.984[a]	0.989[a]	–0.963[a]
		Green distribution (X6)		
Canonical correlation	*0.805*	*0.753*	*0.741*	*0.769*
The return or take-back of a product or packaging ($X6_1$)	0.781[a]	–0.847[a]	0.644[a]	–0.778[a]
The company received the environmental certification ($X6_2$)	0.417[a]	–0.881[a]	0.682[a]	–0.606[a]
Environmentally friendly transportation ($X6_3$)	0.892[a]	–0.569[a]	0.873[a]	–0.870[a]

Note: [a]The absolute value of canonical loading greater than 0.30 were used in this study.

In the group of green manufacturing practice (X4), clean manufacturing technologies applied ($X4_1$) is the most important factor for economic and environmental performances (Y1, Y2). Moreover, substitution of hazardous material ($X4_2$) is also an important practice for economic performance.

For internal environmental management practice group (X1), ISO 14001 certification ($X1_5$) is the most effective practice for environmental performance (Y2). Commitment of senior managers to GSCM ($X1_1$), and support for GSCM by mid-level managers ($X1_2$) are important practices for competitive performance (Y4).

In eco-design practice group (X3), design of products for reduced consumption of material/energy ($X3_1$) and design of products to avoid or reduce the use of hazardous products and/or their manufacturing process ($X3_3$) directly relate to environmental performance. Design of products for reuse, recycle, recovery of materials and components ($X3_2$) is highly related to all of the business performances.

For cooperation with customers group (X5), cooperation with customers for green packaging ($X5_3$) is the most critical practice to increase all performances.

In the group of green distribution (X6), the company has received environmental certification ($X6_2$) influences environmental performance (Y2). The most critical practice is environmentally friendly transportation ($X6_3$), which affects economic, operational, and competitive performances (Y1, Y3, Y4).

In green purchasing practice group (X2), environmental audit for suppliers' internal management ($X2_3$) has a high canonical correlation to environmental and operational performances (Y2, Y3). Suppliers ISO 14001 certification ($X2_4$) has great influence on economic, and operational performances (Y1, Y3).

5.2.4 Correlations between sub-criteria of each business performance and each GSCM practices group

From the viewpoint of business performance, the results of canonical correlations of business performance variables and GSCM practices in Table 9 show that canonical loadings of GSCM practices and business performances are correlated in almost all variables. However, product price ($Y1_2$) is not affected by any GSCM practices, which means that all practices in Thai electronics industry do not statistically affect product price increase. The research of Rao and Holt (2005) showed that GSCM has strong relationships with economic performance, which includes new market opportunities, produce price increase, profit margin sales, and market share. However, they did not show the value of each sub-criteria of economic performance.

In Subsection 5.2.2, effective sub-criteria of GSCM practices were discussed. Then, sub-criteria of each business performance were determined based on the effective correlation greater than 0.65 in descending order. The first rank of all sub-criteria of business performance is an environmental certification ($Y2_4$), which is strongly influenced by internal environmental management (X1). Top management and senior managers have shown high interest in getting an environmental certificate, so the process of going green was started with a strong commitment, and the environmental certification was obtained. The second rank is the use of environmental friendly technology ($Y2_3$) that is highly affected by green manufacturing (X4). Clean technology, waste reduction processes and improvement of the current processes have been implemented in many electronics factories. Harmful substances were substituted for better life. The third rank is quality improvement ($Y4_1$), which is influenced by internal environmental management (X1), and can improve competitive performance. Wu and Dunn (1995) have also shown that GSCM practices can increase products' quality and reduce environmental accidents, fees, costs, wastes and materials purchasing.

For environmental performance, use of environmentally friendly technology ($Y2_3$) is impacted by eco-design, green manufacturing and cooperation with customers (X3, X4, X5). Environmental certification ($Y2_4$) is influenced by internal environmental management (X1). Partnership with green organisations and suppliers ($Y2_5$) results from green purchasing, green manufacturing, and cooperation with customers (X2, X3, X5).

Table 9 Effective business performances by GSCM practice

	X1	*X2*	*X3*	*X4*	*X5*	*X6*
Economic performance (Y1)						
Canonical correlation	*0.619*	*0.723*	*0.755*	*0.801*	*0.807*	*0.805*
New market opportunities ($Y1_1$)	0.135	–0.236	–0.326[a]	0.563[a]	–0.653[a]	0.654[a]
Product price increase ($Y1_2$)	–0.074	–0.090	0.018	0.250	–0.193	0.100
Profit margin ($Y1_3$)	0.607[a]	–0.708[a]	–0.786[a]	0.839[a]	–0.821[a]	0.715[a]
Sales ($Y1_4$)	0.614[a]	–0.937[a]	–0.828[a]	0.870[a]	–0.865[a]	0.730[a]
Market share ($Y1_5$)	0.704[a]	–0.236	–0.758[a]	0.855[a]	–0.848[a]	0.706[a]
Customer satisfaction ($Y1_6$)	0.753[a]	–0.090	–0.758[a]	0.691[a]	–0.765[a]	0.853[a]
Decrease of fees for waste discharge and waste treatment ($Y1_7$)	0.846[a]	–0.708[a]	–0.873[a]	0.914[a]	–0.815[a]	0.798[a]
Increase of operating cost and training cost ($Y1_8$)	0.449[a]	–0.937[a]	–0.774[a]	0.734[a]	–0.765[a]	0.664[a]
Environmental performance (Y2)						
Canonical correlation	*0.912*	*0.716*	*0.79*	*0.891*	*0.818*	*0.753*
Reduction of solid/liquid waste ($Y2_1$)	0.528[a]	0.741[a]	0.690[a]	0.326[a]	0.629[a]	–0.787[a]
Decrease of consumption for hazardous/harmful/toxic materials ($Y2_2$)	0.518[a]	0.659[a]	0.539[a]	0.403[a]	0.534[a]	–0.587[a]
Use of environmentally friendly technology ($Y2_3$)	0.266	0.759[a]	0.873[a]	0.991[a]	0.882[a]	–0.716[a]
Environmental certification ($Y2_4$)	0.989[a]	0.674[a]	0.371[a]	0.181	0.393[a]	–0.761[a]
Partnership with green organisations and suppliers ($Y2_5$)	0.584[a]	0.938[a]	0.896[a]	0.648[a]	0.915[a]	–0.824[a]
Operational performance (Y3)						
Canonical correlation	*0.665*	*0.78*	*0.737*	*0.71*	*0.704*	*0.741*
Increase amount of goods delivered on time ($Y3_1$)	–0.790[a]	–0.765[a]	–0.938[a]	0.886[a]	0.855[a]	0.823[a]
Improved utilisation ($Y3_2$)	–0.637[a]	–0.723[a]	–0.700[a]	0.599[a]	0.697[a]	0.740[a]
Decrease inventory levels ($Y3_3$)	–0.954[a]	–0.919[a]	–0.766[a]	0.795[a]	0.803[a]	0.797[a]
Increased production capacity ($Y3_4$)	–0.863[a]	–0.929[a]	–0.802[a]	0.838[a]	0.906[a]	0.926[a]
Competitive performance (Y4)						
Canonical correlation	*0.845*	*0.69*	*0.747*	*0.656*	*0.769*	*0.769*
Quality improvement ($Y4_1$)	–0.993[a]	–0.751[a]	–0.839[a]	0.718[a]	–0.738[a]	–0.775[a]
Cost saving ($Y4_2$)	–0.629[a]	–0.915[a]	–0.629[a]	0.642[a]	–0.805[a]	–0.925[a]
Corporate image improvement ($Y4_3$)	–0.364[a]	–0.710[a]	–0.871[a]	0.935[a]	–0.846[a]	–0.680[a]

Note: [a]The absolute value of canonical loading greater than 0.30 were used in this study.

For competitive performance, quality improvement ($Y4_1$) is mostly affected by internal environmental management (X1). Cost saving ($Y4_2$) is possible with green distribution (X6). Furthermore, corporate image ($Y4_3$) can be increased by green manufacturing and cooperation with customers (X3, X5).

For economic performance, profit and market share ($Y1_3$, $Y1_5$) are affected by green manufacturing and cooperation with customers (X4, X5), while sales ($Y1_4$) are influenced by green purchasing, as well as green manufacturing and cooperation with customers (X2, X4, X5). Decrease of fees for waste discharge and waste treatment ($Y1_7$) are affected by eco-design, green manufacturing, and cooperation with customers (X3, X4, X5), while the increase of operating cost and training cost ($Y1_8$) is mainly influenced by green manufacturing (X2).

For operational performance, in order to increase the amount of goods delivered on time ($Y3_1$), green manufacturing (X3) is the most practical activity. Decrease of inventory levels ($Y3_3$) and increase production capacity ($Y3_4$) can be done by adopting green purchasing (X2). Green distribution (X6) also supports increasing of production capacity ($Y3_4$).

6 Contribution and implication

The results from Tables 8 and 9 can be rearranged as shown in Table 10. This table concludes the main relationship between GSCM practices and their effective business performances from the above discussions. Practitioners can select the appropriate practice for the focused business performance from this table.

Table 10 Conclusion of GSCM practices and business performances

Business performance	*GSCM practices from Table 8*		*Effective business performances from Table 9*
Economic performance (Y1)	X2	($X2_4$)	($Y1_4$), ($Y1_8$)
	X3	($X3_2$)	($Y1_7$)
	X4	($X4_1$), ($X4_2$)	($Y1_3$), ($Y1_4$), ($Y1_5$), ($Y1_7$)
	X5	($X5_3$)	($Y1_3$), ($Y1_4$), ($Y1_5$), ($Y1_7$)
	X6	($X6_3$)	($Y1_6$)
Environmental performance (Y2)	X1	($X1_5$)	($Y2_4$)
	X2	($X2_3$)	($Y2_5$)
	X3	($X3_1$), ($X3_2$), ($X3_3$)	($Y2_3$), ($Y2_5$)
	X4	($X4_1$)	($Y2_3$)
	X5	($X5_3$)	($Y2_3$), ($Y2_5$)
	X6	($X6_2$)	($Y2_5$)
Operational performance (Y3)	X2	($X2_3$), ($X2_4$)	($Y3_3$), ($Y3_4$)
	X3	($X3_2$)	($Y3_1$)
	X5	($X5_3$)	($Y3_1$), ($Y3_4$)
	X6	($X6_3$)	($Y3_4$)
Competitive performance (Y4)	X1	($X1_1$), ($X1_2$)	($Y4_1$)
	X3	($X3_2$)	($Y4_3$)
	X5	($X5_3$)	($Y4_3$)
	X6	($X6_3$)	($Y4_2$)

Appropriate GSCM practices for economic performance (Y1) are ISO 14001 certification ($X2_4$), design of products for reuse, recycle, recovery of materials and components ($X3_2$), clean manufacturing technologies applied ($X4_1$), substitution for hazardous material ($X4_2$), cooperation with customers for green packaging ($X5_3$), and environmentally friendly transportation ($X6_3$). These GSCM practices affect profit margin ($Y1_3$), sales ($Y1_4$), market share ($Y1_5$), customer satisfaction ($Y1_6$), decrease the fees for waste discharge and waste treatment ($Y1_7$), and increase of operating cost and training cost ($Y1_8$).

Increased profit margin, market share, and customer satisfaction along with decrease of the fees for waste discharge and waste treatment can be achieved obtain by applying clean manufacturing, substitution for hazardous material and cooperation with customers for green packaging. Sales can also be improved by obtaining ISO 14001, and environmental audit for suppliers' internal management. Design of products for reuse, recycle, recovery of materials and components directly affects the decrease of fees for waste discharge and waste treatment. Customer satisfaction can be increased by environmentally friendly transportation, which can also decrease the fees for waste discharge and waste treatment. ISO 14001 certification is the key starting point to green manufacturing for many industries in Thailand.

Economic performance is the most important performance outcome for many industries. It has been shown that high performance has been achieved after implementing GSCM in China, Malaysia, and other countries (Kuei et al., 2015; Rahman et al., 2014; Rao and Holt, 2005). Some researchers investigated financial performance instead of economic performance, and concluded that GSCM practices can improve financial performance (Diab et al., 2015).

Active GSCM practices for good environmental performance (Y2) are the ISO 14001 certification ($X1_5$), environmental audit for suppliers' internal management ($X2_3$), suppliers ISO 14001 certification ($X2_4$), design of products for reduced consumption of material/energy ($X3_1$), design of products for reuse, recycle, recovery of materials and components ($X3_2$), design of products to avoid or reduce the use of hazardous products and/or their manufacturing process ($X3_3$), clean manufacturing technologies applied ($X4_1$), cooperation with customer for green packaging ($X5_3$) and the company received the environmental certification ($X6_2$). They affect use of environmentally friendly technology ($Y2_3$), environmental certification ($Y2_4$), and partnership with green organisations and suppliers ($Y2_5$).

Use of environmentally friendly technology and partnership with green organisations and suppliers are enhanced by design of products for reduced consumption of material/ energy, design of products for reuse, recycle, recovery of materials and components, design of products to avoid or reduce the use of hazardous products and/or their manufacturing process, clean manufacturing technologies, and cooperation with customers for green packaging. Moreover, partnership with green organisations and suppliers can also be improved by environmental audit of suppliers' internal management and suppliers ISO 14001 certification. Environmental certification is shown by obtaining ISO 14001 certification.

This result is supported by the work of Nawrocka et al. (2009) and Wiengarten et al. (2013). They focused on the role of ISO 14001 as a key part of the effort to reduce the supply chain's environmental impacts. Dubey et al. (2015) also found that supplier relationship positively impacts environmental performance. SC collaboration for

environmental sustainability can help companies improve their environmental objectives (Rammanathan et al., 2014).

Operative GSCM practices for operational performance (Y3) are environmental audit of suppliers' internal management ($X2_3$), supplier ISO 14001 ($X2_4$), design of products for reuse, recycle, recovery of materials and components ($X3_2$), cooperation with customers for green packaging ($X5_3$), and environmentally friendly transportation ($X6_3$). They influence an increase in the amount of goods delivered on time ($Y3_1$) improved utilisation ($Y3_3$), and increased production capacity ($Y3_4$).

Improving utilisation and increasing production capacity have significant relationships with environmental audit for suppliers' internal management and supplier ISO 14001. Increasing production capacity is also related with environmentally friendly transportation. Increasing the amount of goods delivered on time is impacted by design of products for reuse, recycle, recovery of materials and components.

According to prior research by Zhu et al. (2010) and Tippayawong et al. (2015) green supply chain includes activities associated with the transformation and flow of goods or services from sources of materials to the end customers including the integration of those internal and external activities to the firms. It was found that green sourcing strategy is an important initiative for a GSCM organisation to consider by focusing on raw material acquirement and packaging which can be recycled or reused. Collaboration both with suppliers and customers is a leading business strategy in today's competitive business world. Effective and environmentally friendly transportation can increase the amount of goods delivered on time and increase utilisation of transportation.

Finally, competitive performance (Y4) can be improved by commitment of senior managers to GSCM ($X1_1$), support for GSCM by mid-level managers ($X1_2$), design of products for reuse, recycle, recovery of materials and components ($X3_2$), cooperation with customers for green packaging ($X5_3$), and environmentally friendly transportation ($X6_3$). These practices influence all of the competitive performance variables (quality improvement, cost saving and corporate image improvement $Y4_1$, $Y4_2$, $Y4_3$).

Quality improvement starts from commitment of senior managers to GSCM and support for GSCM by mid-level managers. Corporate image improvement can be improved by design of products for reuse, recycle, recovery of materials and components and cooperation with customers for green packaging. Cost saving can be obtained from environmentally friendly transportation.

Ramanathan et al. (2014) suggested that the level of collaboration for achieving environmental sustainability can be separated to three levels namely preparatory level, progressive level and futuristic level. The finding of this research is intended to assist managers in improving the strategies for the involvement of supply chain players, in improving production to reduce CO_2 emissions, and in designing information sharing among different supply chain members. Top management is a key driver of GSCM initiatives for improving competitive performance. Internal environmental management has high effect on organisational performance (Diab et al., 2015). Thongplew et al. (2014) addressed corporate social responsibility as a principle and management framework for achieving sustainable consumption and production. Thai industrial sector has begun to see the benefit of corporate social responsibility, particularly in building good will and trust and in engaging with consumers. They communicate by eco-labels and strategies to increase range of eco-friendly products. Correspondingly this research shows that influences of green products can affect competitive advantage in the electronics industry in Thailand.

This study has clearly demonstrated that opportunities do exist to reduce pollution within supply chains by GSCM practices. However, these practices can be applied to the other industries too. Green Industry Project, which is supported by the Ministry of Industry of Thailand has stimulated firms to join and operate environmental-friendly businesses. This is the right direction for sustainable industry in the future. Government regulation and legislation are critical drivers for implementation of GSCM.

From the results of this research, electronics industry practitioners can select the effective GSCM practices to obtain better business performances or if they want to improve one of the performances, they can specify the effective GSCM practices that are suitable for it. These GSCM practices for electronics industry can be guidelines for other industries to enhance their performances. Electronics industry in Thailand has successfully implemented GSCM practices because of the many drivers from both internal and external organisation. The main practical activities that have been selected to be implemented in the factories are clean manufacturing technologies, ISO 14001 and commitment of senior managers to GSCM.

7 Conclusions

This research investigated the relationship of GSCM practices and business performance variables of the electronics industry in Thailand. First, Pearson's correlations were used to find the correlations between GSCM practices and business performances. The results showed that almost all GSCM practices have positive correlations with business performances except investment recovery. Next, canonical correlations between main factors of GSCM practices and business performances were analysed. It confirms that GSCM practices have very strong interdependencies with almost all of the business performance variables. The effective activities for GSCM are green manufacturing, green distribution, eco-design and internal environmental management. Product price is not affected by any GSCM practices. Then, all pairs of GSCM practices and business performances were investigated and correlation functions found. From these functions, GSCM practices, which strongly influence each business performance, have been highlighted. Next, practical results of GSCM practices, which have strong correlation for effective business performances have been summarised and concluded. The most effective practice is that clean manufacturing technologies be applied. Green manufacturing is the main strategy that electronics manufacturers in Thailand have applied and found successful. It strongly affects environmental performance. ISO 14001 certification is the second important practice, which mainly increases environmental performance. The next practice is the commitment of senior managers to GSCM that pushes all systems to be successful. The quality and corporate image can be improved and cost can be reduced, which are competitive performance. This study sought to generate evidence to understand how the adoption of each GSCM practice influences economic, environmental, operational, and competitive performances. The result of this study was also compared with other ASEAN countries and found that they are in the same direction.

Future research could be an investigation of the main successful practices (green manufacturing, green distribution, eco-design, and internal environment management) to obtain more specific actions for implementation. The study with the same GSCM

practices and business performances among ASEAN counties is also interesting to be investigated.

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References

Agyemang, M., Zhu Q., Adzanyo, M., Antarciuc, E. and Zhao, S. (2018) 'Evaluating barriers to green supply chain redesign and implementation of related practices in the West African cashew industry', *Resources, Conservation & Recycling*, Vol. 136, pp.209–222.

Bhateja, A.K., Babbar, R., Singh, S. and Sachdeva, A. (2011) 'Study of green supply chain management in the Indian manufacturing industries: a literature review cum an analytical approach for the measurement of performance', *International Journal of Computational Engineering & Management*, Vol. 13, pp.84–99.

Cote, R.P., Lopez, J., Marche, S., Perron, G.M. and Wright, R. (2008) 'Influences, practices and opportunities for environmental supply chain management in Nova Scotia SMEs', *Journal of Cleaner Production*, Vol. 16, pp.1561–1570.

Diab, S.M., Al-Bourini, F.A. and Abu-Rumman, A.H. (2015) 'The impact of green supply chain management practices on organizational performance: a study of Jordanian food industries', *Journal of Management and Sustainability*, Vol. 5, No. 1, pp.149–157.

Diabat, A. and Govindan, K. (2011) 'An analysis of the drivers affecting the implementation of green supply chain management', *Resources, Conservation and Recycling*, Vol. 55, pp.659–667.

Djunaidi, M., Sholeh, M.A.A. and Mufiid, N.M. (2018) 'Analysis of green supply chain management application in Indonesian wood furniture industry', in *Human-Dedicated Sustainable Product and Process Design: Materials, Resources, and Energy: AIP Conference Proceedings 1977*, API Publishing, No. 020050, pp.1–7.

Dubey, R., Gunasekaran, A. and Ali, S.S. (2015) 'Exploring the relationship between leadership, operational practices, institutional pressures and environmental performance: a framework for green supply chain', *International Journal of Production Economics*, Vol. 160, pp.120–132.

Electrical and Electronics Institute (2018) *Industry Economics Situation Report*, Bangkok, Thailand, pp.1–4.

Eltayeb, T.K., Zailani, S. and Ramayah, T. (2011) 'Green supply chain initiatives among certified companies in Malaysia and environmental sustainability: investigating the outcomes', *Resources, Conservation and Recycling*, Vol. 55, pp.495–560.

Goodman, P. (2008) 'Current and future hazardous substance legislation affecting electrical and electronic equipment', *Review of European Community & International Environmental Law*, Vol. 17, No. 3, pp.261–269.

Green Industry Project (2014) 'Green industry manual: the guideline for green industry promotion and development', *Green Industry*, Vol. ED-5, pp.1–58.

Hair, J.R, Joseph, F., Anderson, R.E., Tatham, R.L. and Black, W.C. (1995) *Multivariate Data Analysis with Reading*, 4th ed., Prentice-Hall International, Inc. New Jersey.

Holt, D. and Ghobadian, A. (2009) 'An empirical study of green supply chain management practices amongst UK manufacturers', *Journal of Manufacturing Technology Management*, Vol. 20, No. 7, pp.933–956.

Khiewnavawongsa, S. (2011) Barriers to green supply chain implementation in the electronics industry, PhD dissertation, Faculty of The Graduate College, Purdue University, West Lafayette, Indiana, USA.

Kim, S.T. (2010) *Implementation of Green Supply Chain Management: Impact on Performance Outcomes in Small and Medium-Sized Electrical and Electronic Firms*, PhD dissertation, The University of Nebraska-Lincoln, USA.

Kuei, C.H., Madu, C.N., Wing, S., Chow, W.S. and Chen, Y. (2015) 'Determinants and associated performance improvement of green supply chain management in China', *Journal of Cleaner Production*, Vol. 95, pp.163–173.

Lin, R-J., Tan, K-H. and Geng, Y. (2013) 'Market demand, green product innovation, and firm performance: evidence from Vietnam motorcycle industry', *Journal of Cleaner Production*, Vol. 40, pp.101–107.

Muma, B.O., Nyaoga, R.B., Matwere, R.B. and Nyambega, E. (2014) 'Green supply chain management and environmental performance among tea processing firms in Kericho Country-Kenya', *International Journal of Economics, Finance and Management Sciences*, Vol. 2, No. 5, pp.270–276.

Nawrocka, D., Brorson, T. and Lindhqvist, T. (2009) 'ISO 14001 in environmental supply chain practices', *Journal of Cleaner Production*, Vol. 17, pp.1435–1443.

Nguyen, X.H. and Le, T.A. (2020) 'The impact of global green supply chain management practices on performance: the case study of Vietnam', *Uncertain Supply Chain Management*, Vol. 8, pp.523–536.

Office of Industrial Economics, The Ministry of Industry (2018) *Industry Economics Situation Report*, p.13.

Pham, T.M.Y. and Pham, T.M.K. (2017) 'The factors affecting green supply chains: empirical study of agricultural chains in Vietnam', *Journal of Management and Sustainability*, Vol. 7, No. 2, pp.135–143.

Rahman, A.A., Ho, J.A. and Rusli, K.A. (2014) 'Pressures, green supply chain management practices and performance of ISO 14001 certified manufacturers in Malaysia', *International Journal of Economics and Management*, Vol. 8, No. S, pp.1–24.

Ramanathan, U., Bentley, Y. and Pang, G. (2014) 'The role of collaboration in the UK green supply chains: an exploratory study of the perspectives of suppliers, logistics and retailers', *Journal of Cleaner Production*, Vol. 70, pp.231–241.

Rao, P. and Holt, D. (2005) 'Do green supply chains lead to competitiveness and economic performance?', *International Journal of Operations & Production Management*, Vol. 25, No. 9, pp.898–916.

Robinson, C. (2012) *Exploring the Relationship between Environmental Operations and Supply Chain Practices, Complementary Assets, and Performance*, Doctoral dissertation, University of South Carolina, USA.

Sambasivan, M., Bah, S.M. and Jo-Ann, H. (2013) 'Making the case for operating 'green': impact of environmental proactivity on multiple performance outcomes of Malaysian firms', *Journal of Cleaner Production*, Vol. 42, pp.69–82.

Schneiderman, R. (2009) 'Regulatory compliance means going the extra green mile', *Electronic Design*, Vol. 57, No. 2, pp.26–30.

Sundram, V.P.K., Bahrin, A.S., Othman, A.A. and Munir, Z.A. (2017) 'Green supply chain management practices in Malaysia manufacturing industry', *International Journal of Supply Chain Management*, Vol. 6, No. 2, pp.89–95.

Thongplew, N., Koppen, C.S.A. and Spaargaren, G. (2014) 'Companies contributing to the greening of consumption: findings from the dairy and appliance industries in Thailand', *Journal of Cleaner Production*, Vol. 75, pp.96–105.

Tippayawong, K.Y., Tiwaratreewit, T. and Sopadang, A. (2015) 'Positive influence of green supply chain operations on Thai electronic firms' financial performance', *Procedia Engineering*, Vol. 118, pp.683–690.

Tsoulfasr, G.T. and Pappis, C.P. (2006) 'Environmental principles applicable to supply chains design and operation', *Journal of Cleaner Production*, Vol. 14, pp.1593–1602.

Vijayvargy, L. and Agarwal, G. (2013) 'A comparative study of green supply chain management practices in Indian, Japanese and Chinese companies', *The IUP Journal of Supply Chain Management*, Vol. 10, No. 2, pp.1–13.

Wang, Z., Wang, Q., Zhang, S. and Zhao, Z. (2018) 'Effects of customer and cost drivers on green supply chain management practices and environmental performance', *Journal of Cleaner Production*, Vol. 189, pp.673–682.

Wiengarten, F., Pagell, M. and Fynes B. (2013) 'ISO 14000 certification and investments in environmental supply chain management practices: identifying differences in motivation and adoption levels between Western European and North American companies', *Journal of Cleaner Production*, Vol. 56, pp.18–28.

Wu, H.J. and Dunn, S.C. (1995) 'Environmentally responsible logistics systems', *International Journal of Physical Distribution & Logistics Management*, Vol. 25, No. 2, pp.20–38.

Youn, S., Yang, M., Hong, P. and Park, K. (2013) 'Strategic supply chain partnership, environmental supply chain management practices, and performance outcomes: an empirical study of Korean firms', *Journal of Cleaner Production*, Vol. 56, pp.121–130.

Zhu, Q., Geng, Y., Fujita, T. and Hashimoto, S. (2010) 'Green supply chain management in leading manufacturers: case studies in Japanese large companies', *Management Research Review*, Vol. 33, No. 4, pp.380–392.

Zhu, Q., Sarkis, J. and Geng, Y. (2007a) 'Green supply chain management in China: pressures, practices and performance', *International Journal of Operations & Production Management*, Vol. 25, No. 5, pp.449–468.

Zhu, Q., Sarkis, J. and Lai, K. (2007b) 'Initiatives and outcomes of green supply chain management implementation by Chinese manufacturers', *Journal of Environmental Management*, Vol. 85, No. 1, pp.179–189.

Zhu, Q., Sarkis, J. and Lai, K. (2007c) 'Green supply chain management: pressures, practices and performance within the Chinese automobile industry', *Journal of Cleaner Production*, Vol. 15, pp.1041–1052.

Appendix

The relationship of each GSCM practice was analysed with respect to each business performance, as shown in Tables A1–A7.

Table A1 Canonical redundancy indices of internal environmental management (X1) and business performances

Functions	*Average loading squared*	*Canonical R^2*	*Redundancy index*	*Cumulative proportion*
Independent variable: internal environmental management (X1)				
1	0.683	0.383	0.262	0.262
Dependent variable: economic performance (Y1)				
1	0.312	0.383	0.119	0.119
Independent variable: internal environmental management (X1)				
1	0.445	0.832	0.370	0.370
2	0.371	0.419	0.155	0.525
Dependent variable: environmental performance (Y2)				
1	0.322	0.832	0.268	0.268
2	0.115	0.419	0.048	0.316
Independent variable: internal environmental management (X1)				
1	0.701	0.442	0.310	0.310
2	0.098	0.170	0.017	0.327
Dependent variable: operational performance (Y3)				
1	0.297	0.442	0.131	0.131
2	0.026	0.170	0.004	0.135
Independent variable: internal environmental management (X1)				
1	0.612	0.714	0.437	0.437
2	0.158	0.255	0.040	0.477
Dependent variable: competitive performance (Y4)				
1	0.360	0.714	0.257	0.257
2	0.077	0.255	0.020	0.277

Table A2 Canonical redundancy indices of green purchasing (X2) and business performances

Functions	*Average loading squared*	*Canonical R^2*	*Redundancy index*	*Cumulative proportion*
Independent variable: green purchasing (X2)				
1	0.361	0.523	0.189	0.189
Dependent variable: economic performance (Y1)				
1	0.270	0.523	0.141	0.141
Independent variable: green purchasing (X2)				
1	0.521	0.513	0.267	0.267
2	0.111	0.212	0.024	0.291
Dependent variable: environmental performance (Y2)				
1	0.297	0.513	0.152	0.152
2	0.027	0.212	0.006	0.158
Independent variable: green purchasing (X2)				
1	0.438	0.608	0.266	0.266
2	0.137	0.210	0.029	0.295
Dependent variable: operational performance (Y3)				
1	0.429	0.608	0.261	0.261
2	0.016	0.210	0.003	0.264
Independent variable: green purchasing (X2)				
1	0.417	0.476	0.198	0.198
Dependent variable: competitive performance (Y4)				
1	0.303	0.476	0.144	0.144

Table A3 Canonical redundancy indices of eco-design (X3) and business performances

Function	*Average loading squared*	*Canonical R^2*	*Redundancy index*	*Cumulative proportion*
Independent variable: eco-design (X3)				
1	0.614	0.570	0.350	0.350
Dependent variable: economic performance (Y1)				
1	0.280	0.570	0.160	0.160
Independent variable: eco-design (X3)				
1	0.711	0.624	0.444	0.444
2	0.142	0.230	0.033	0.447
Dependent variable: environmental performance (Y2)				
1	0.309	0.624	0.193	0.193
2	0.017	0.230	0.004	0.197
Independent variable: eco-design (X3)				
1	0.695	0.543	0.377	0.377

Table A3 Canonical redundancy indices of eco-design (X3) and business performances (continued)

Function	*Average loading squared*	*Canonical R^2*	*Redundancy index*	*Cumulative proportion*
Dependent variable: operational performance (Y3)				
1	0.353	0.543	0.192	0.192
Independent variable: eco-design (X3)				
1	0.693	0.558	0.387	0.387
Dependent variable: competitive performance (Y4)				
1	0.346	0.558	0.193	0.193

Table A4 Canonical redundancy indices of green manufacturing (X4) and business performances

Function	*Average loading squared*	*Canonical R^2*	*Redundancy index*	*Cumulative proportion*
Independent variable: green manufacturing (X4)				
1	0.642	0.642	0.412	0.412
Dependent variable: economic performance (Y1)				
1	0.355	0.642	0.228	0.228
Independent variable: green manufacturing (X4)				
1	0.538	0.891	0.479	0.479
2	0.286	0.356	0.102	0.581
Dependent variable: environmental performance (Y2)				
1	0.286	0.891	0.255	0.255
2	0.108	0.356	0.038	0.293
Independent variable: green manufacturing (X4)				
1	0.641	0.504	0.323	0.323
2	0.192	0.163	0.031	0.354
Dependent variable: operational performance (Y3)				
1	0.313	0.504	0.158	0.158
2	0.022	0.163	0.004	0.162
Independent variable: green manufacturing (X4)				
1	0.641	0.430	0.276	0.276
Dependent variable: competitive performance (Y4)				
1	0.264	0.430	0.114	0.114

Redundancy indices measuring the proportion of GSCM practices shared with each business performance variable are shown in Tables A1–A7. All the functions which have redundancy index less than 0.1 was excluded because they have low interdependencies. So, investment recovery variables were omitted. The other variables are statistically related to business performance variables.

Table A5 Canonical redundancy indices of cooperation with customers (X5) and business performances

Function	*Average loading squared*	*Canonical R^2*	*Redundancy index*	*Cumulative proportion*
Independent variable: cooperation with customers (X5)				
1	0.686	0.651	0.447	0.447
2	0.192	0.356	0.068	0.515
Dependent variable: economic performance (Y1)				
1	0.362	0.651	0.236	0.236
2	0.004	0.356	0.001	0.237
Independent variable: cooperation with customers (X5)				
1	0.681	0.669	0.456	0.456
2	0.257	0.209	0.054	0.510
Dependent variable: environmental performance (Y2)				
1	0.328	0.669	0.219	0.219
2	0.027	0.209	0.006	0.225
Independent variable: cooperation with customers (X5)				
1	0.637	0.496	0.316	0.316
Dependent variable: operational performance (Y3)				
1	0.332	0.496	0.165	0.165
Independent variable: cooperation with customers (X5)				
1	0.698	0.476	0.332	0.332
2	0.489	0.215	0.105	0.437
Dependent variable: competitive performance (Y4)				
1	0.303	0.476	0.144	0.144
2	0.050	0.215	0.011	0.155

Table A6 Canonical redundancy indices of green distribution (X6) and business performances

Function	*Average loading squared*	*Canonical R^2*	*Redundancy index*	*Cumulative proportion*
Independent variable: green distribution (X6)				
1	0.527	0.648	0.341	0.341
Dependent variable: economic performance				
1	0.307	0.648	0.199	0.199
Independent variable: green distribution (X6)				
1	0.606	0.567	0.344	0.344
2	0.249	0.274	0.068	0.412
Dependent variable: environmental performance				
1	0.311	0.567	0.176	0.176
2	0.388	0.274	0.106	0.282

Table A6 Canonical redundancy indices of green distribution (X6) and business performances (continued)

Function	*Average loading squared*	*Canonical R^2*	*Redundancy index*	*Cumulative proportion*
Independent variable: green distribution (X6)				
1	0.547	0.549	0.300	0.300
Dependent variable: operation performance				
1	0.373	0.549	0.205	0.205
Independent variable: green distribution (X6)				
1	0.576	0.591	0.340	0.340
2	0.241	0.186	0.045	0.385
Dependent variable: competitive performance				
1	0.241	0.591	0.142	0.142
2	0.028	0.186	0.005	0.147

Table A7 Canonical redundancy indices of investment recovery (X7) and business performances

Function	*Average loading squared*	*Canonical R^2*	*Redundancy index*	*Cumulative proportion*
Independent variable: investment recovery (X7)				
1	0.834	0.271	0.226	0.226
Dependent variable: environmental performance (Y2)				
1	0.135	0.271	0.037	0.037
Independent variable: investment recovery (X7)				
1	0.700	0.202	0.141	0.141
Dependent variable: operation performance (Y3)				
1	0.137	0.202	0.028	0.028