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by

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"See the things that you want as already ours.

Know that they will come to you at need. Then let them come. Don't fret and worry about them. Don't think about your lack of them.

Think of them as yours, as belonging to you, as already in your possession."

Robert Collier (1885–1950)

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ABSTRACT

Environmental degradation is a global crisis. Products, services, technologies, buildings, cities and education are moving forward with ecological considerations. With Malaysia's manufacturing industry one of its top gross domestic product (GDP) contributors, this industry is under the spotlight with demands to accelerate its green movement. Many scholars have observed green supply chain management (GSCM), its drivers, barriers, practices and outcomes. However, what has been overlooked is the assessment of negative environmental consequences from the use of information technology (IT) and information systems (IS) within supply chains. This study, therefore, introduces two new variables: 'technological drivers' and 'technological performance'. Technological drivers consist of Green IT and Green IS variables, with the organizational and environmental drivers consist of internal commitment and regulatory pressure (the third and fourth are adopted from the work of previous scholars). Technological performance and environmental performance are used to measure the impacts of GSCM implementation. In this study, the research model is developed based on the input-process-output (IPO) theory and the technological-organizational-environmental (TOE) framework. This study is one of the first attempts to use both IPO and TOE theories to link these three areas of research, Green IT and Green IS, with GSCM, particularly in the context of Malaysia. The study is carried out with ISO 14001-certified manufacturing firms located in Malaysia with a survey questionnaire and participation of 165 firms. Using partial least squares-based structural equation modelling (PLS-SEM) analysis, the study found that all four drivers are positively significant in encouraging improvements in both environmental and technological performance. This study discovered that Green IT is the most significant driver influencing the implementation of GSCM, followed by regulatory pressure, internal commitment and, lastly, Green IS. This research provides additional findings beyond those of previously conducted research. The study has highlighted the importance of Green IT and Green IS which have often been ignored among

industrial practitioners, particularly those from non-IT sectors. The ISO 14001-certified manufacturing firms are realizing the importance of using environmentally-friendly IT and IS which consume less energy, emit less carbon, are safer for disposal and are cleaner for the environment. These findings provide many new perspectives for the managerial level of firms, industrial practitioners and policy makers on strategic areas that require further attention and improvement. As revealed in this study, the green practices that are actively being implemented within the supply chain are eco-labelling of products, green supplier selection and green logistics. This will open an avenue of research and development (R&D) among industrial practitioners as well as for policy makers, the formulation of future policies, programmes, incentives and international partnerships.

ABSTRAK

Kemerosotan alam sekitar merupakan krisis global. Negara maju dan negara membangun masing-masing berusaha bersunguh-sungguh untuk mengurangkan risiko kerosakan kepada alam sekitar. Produk, perkhidmatan, teknologi, bangunan, bandar-bandar dan pendidikan sedang bergerak maju ke hadapan dengan menitikberatkan aspek alam sekitar ini. Industri perkilangan Malaysia merupakan penyumbang tertinggi Keluaran Dalam Negara Kasar (KDNK), dan kini mulai fokus dalam mempercepatkan pembangunan berteraskan teknologi hijau. Ramai cendekiawan telah mengkaji Pengurusan Rantaian Bekalan Berasaskan Teknologi Hijau (*green supply chain management*), berkaitan dengan orientasi, kekangan dan hasil penemuan dalam kajian mereka. Walau bagaimanapun, cendekiawan ini terlepas pandang dalam menilai impak penggunaan Teknologi Maklumat Berteknologi Hijau (*Green IT*) dan Sistem Maklumat Berteknologi Hijau (*Green IS*) dalam pengekalan keadaan alam sekitar. Dalam kajian ini, tiga pembolehubah baru telah diperkenalkan, iaitu Teknologi Maklumat Berteknologi Hijau (*Green IT*), Sistem Maklumat Berteknologi Hijau (*Green IS*) dan prestasi teknologi *(technological performance).* Pembolehubah ini adalah untuk menilai peranan dan kesan penggunaan Teknologi Maklumat Berteknologi Hijau (*Green IT*) dan Sistem Maklumat Berteknologi Hijau (*Green IS*) dalam Pengurusan Rantaian Bekalan Berasaskan Teknologi Hijau (*green supply chain management*). Tambahan daripada ini, terdapat tiga lagi pembolehubah yang diambil daripada kajian-kajian sebelum ini, iaitu Komitmen Dalaman (*internal commitment*), Tekanan Pelaksanaan Undang-Undang *(regulatory pressure)* dan Prestasi Alam Sekitar *(environmental performanc*e). Teknologi Maklumat Berteknologi Hijau (*Green IT*), Sistem Maklumat Berteknologi Hijau (*Green IS*), Komitmen Dalaman dan Tekanan Perlaksanaan Undang-Undang adalah pemacu yang mempengaruhi perlaksanaan *GSCM,* manakala Prestasi Alam Sekitar dan Prestasi Teknologi mengukur hasil prestasinya. Dalam kajian ini, satu model berasaskan teori input-proses-output (*IPO*) dan kerangka technological-organizational-environmental (*TOE*) telah dibangunkan. Kajian skala penuh telah dijalankan ke atas firma-firma perkilangan yang mempunyai sijil ISO 14001 di seluruh Malaysia dengan menggunakan kaedah soalan kaji selidik, dan sejumlah 165 firma telah mengambil penglibatan. Dengan menggunakan analisis *partial least squares-based structural equation modelling (PLS-SEM)*, didapati kesemua hubungan hipotesis adalah benar. Pemacu paling ketara adalah Teknologi Maklumat Berteknologi Hijau (*Green IT*), yang mana telah diabaikan dalam banyak kajian sebelum ini oleh cendekiawan dan penggiat industri, terutamanya firma perkilangan dari sektor bukan-IT. Walaupun Teknologi Maklumat Berteknologi Hijau (*Green IT*) telah mendapat perhatian yang memberangsangkan terutamanya dalam teknologi pencahayaan tenaga efisyen, teknologi visual dan sistem pintar untuk perkilangan, tetapi firma perkilangan ini masih menghadapi kesukaran dalam menentukan prestasi teknologi dari segi tahap dan pemilihan metrik Teknologi Maklumat Berteknologi Hijau (*Green IT*) dan juga dalam menghasilkan laporan yang mapan. Hasil daripada kajian ini memberikan dapatan yang tidak ternilai kepada firma perkilangan, penggubal undang-undang, badan-badan pelaksana undang-undang dan pelabur-pelabur dalam menyusun semula strategi polisi alam sekitar dan juga inisiatif teknologi hijau dengan mengambilkira teknologi dan sistem maklumat yang mesra alam sekitar ini. Oleh kerana itu, pemantapan isu alam sekitar dalam kontek yang lebih besar dengan menambah Teknologi Maklumat Berteknologi Hijau (*Green IT*) dan Sistem Maklumat Berteknologi Hijau (*Green IS*) akan menjanjikan pengekalan alam sekitar yang lebih baik.

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3R	Reuse, Reduce and Recycle (programme)
ACCA	Asia Cloud Computing Association
AEE	Asian emerging economies
APEC	Asia-Pacific Economic Cooperation
APT	Asia-Pacific Telecommunity
ASEAN	Association of Southeast Asian Nations
ASQ	American Society for Quality
ASTAP	Asia-Pacific Telecommunity (APT) Standardization Program
B40 household	bottom 40% household income group
BcN	backbone concentrator node
BS	British Standard
BSI	British Standards Institution
BYOD	bring your own device
CAPEX	capital expenses
CB-SEM	covariance-based structural equation modelling (covariance-based SEM)
CFL	compact fluorescent lamp
CG	corporate governance
CI	confidence interval
CIO	Chief Information Officer
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
CPU	central processing unit
CR	corporate responsibility
CRI	Cloud Readiness Index
CRM	customer relationship management
CSCMP	Council of Supply Chain Management Professionals

CSF	critical success factor
CSR	corporate social responsibility
CUE	carbon use effectiveness
DfE	Design for the Environment
DJSI	Dow Jones Sustainability Index
DOE	Department of Environment (Malaysia)
DOSM	Department of Statistics Malaysia
DSM	Department of Standards Malaysia
e	electronic
E&E	electrical and electronics
ECER	East Coast Economic Region
EDE	electronics disposal efficiency
EE	energy efficiency
EES	economic, environmental and social (effects)
EHS	environment, health and safety
EM	environmental management
EMAS	Eco-Management and Audit Scheme
EMIS	environmental management information system
EMM	environmental management maturity
EMS	environmental management system/s
EOL	end-of-life
EPA	Environmental Protection Agency
EPEAT	Electronic Product Environmental Assessment Tool
EPU	Economic Planning Unit
ERP	enterprise resource planning
ESC	Energy Savings Certificate
ETP	Economic Transformation Programme
EU	European Union
EuP	energy-using product
FiT	feed-in tariff
FMM	Federation of Malaysian Manufacturers
GATT	General Agreement on Tariffs and Trade

GCI	Green Computing Initiative
GDP	gross domestic product
GEN	Global Ecolabelling Network
GeSI	Global e-Sustainability Initiative
GhG	greenhouse gas
GITS	green information technology and systems
Green IS	green information systems
Green IT	green information technology
GreenTech	Malaysian Green Technology Corporation
GRI	Global Reporting Initiative
GRP	good regulatory practice
GSC	green supply chain
GSCM	green supply chain management
$GtCO_2e$	gigatonne of carbon dioxide equivalent
GTF 2030	Green Technology Foresight 2030
GTFS	Green Technology Financial Scheme
GTP	Government Transformation Programme
GWP	gross world product
H	hypothesis
HCFC	hydrochlorofluorocarbon
HR	human resources
HSE	Health, Safety and Environment (department)
ICC	International Chamber of Commerce
ICT	information communications and technology
IDC	insulation-displacement contact
IGEM	International Greentech and Eco-Products Exhibition and Conference
ILO	International Labour Organization
IMD	Institute for Management Development
IoT	Internet of Things
IP	intellectual property
IP	Internet Protocol

IPO	input-process-output (theory)
IRDA	Iskandar Regional Development Authority (in Southern Johor, Malaysia)
IS	information system/s
ISM	interpretive structural modelling
ISM	Institute for Supply Management
ISO	International Organization for Standardization
ISV	independent software vendor
IT	information technology
ITEE	IT energy efficiency
ITIL	Information Technology Infrastructure Library
KeTTHA	Kementerian Tenaga, Teknologi Hijau dan Air (Ministry of Energy, Green Technology and Water) (Malaysia)
KFA	key focus area
KPI	key performance indicator
KT	Korea Telecom
kWh	kilowatt hour
LCA	life-cycle assessment
LED	light-emitting diode
LEED	Leadership in Energy and Environmental Design
LPI	Logistics Performance Index
MAMPU	Malaysian Administrative Modernization and Management Planning Unit
MB	marginal benefit
MC	marginal cost
MD	Managing Director
MDEC	Malaysia Digital Economy Corporation
MEPS	Minimum Energy Performance Standard
MGCC	Malaysian-German Chamber of Commerce and Industry
MICCI	Malaysian International Chamber of Commerce and Industry
MIDA	Malaysian Investment Development Authority
MIGHT	Malaysian Industry–Government Group for High Technology

MIMOS	MIMOS Berhad
MJ	megajoule
$MMtCO_2$	million metric tonnes of carbon dioxide
MNC	multinational corporation
MOSTI	Ministry of Science, Technology and Innovation
MS	Malaysian Standard
MSC	Multimedia Super Corridor
MT	metric tonnes
$MtCO_2e$	metric tonnes of carbon dioxide equivalent
MTCS	Malaysian Timber Certification Scheme
Mtoe	million tonnes of oil equivalent
MW	megawatt
MWh	megawatts per hour
MyIPO	Intellectual Property Corporation of Malaysia
NCER	Northern Corridor Economic Region
NEAC	National Economic Advisory Council
NEM	New Economic Model (Malaysia)
NGO	non-governmental organization
NO_x	nitrogen oxides
NRE	Natural Resources and Environment (Malaysian Ministry of)
NS	not significant
OECD	Organisation for Economic Co-operation and Development
OLS	ordinary least squares
OM	Operation Manager
OPEX	operating expenses
PC	personal computer
PD	Production Director
PDCA	plan-do-check-act (cycle)
PIKOM	Persatuan Industri Komputer dan Multimedia Malaysia (National Information and Communications Technology Association of Malaysia)
PLC	public listed company

PLS	partial least squares
PLS-SEM	partial least squares-structural equation modelling
PMS	performance measurement system
PREE	Peer Review on Energy Efficiency Policy
PS	problem statement
PUE	power usage effectiveness
PV	photovoltaic
Q-Q	quantile-quantile (plot)
R&D	research and development
RE	renewable energy
REACH	Restriction, Evaluation and Authorization of Chemicals (regulation)
RFID	radio-frequency identification
RG	research gap
RM	Malaysian ringgit
RO	research objective
RoHS	Restriction of Hazardous Substances (directive)
RQ	research question
SAVE	Sustainability Achieved via Energy Efficiency (programme)
SC	supply chain
SCM	supply chain management
SCORE	Sarawak Corridor of Renewable Energy
SCT	social cognitive theory
SDC	Sabah Development Corridor
SEM	structural equation modelling
sig.	significance
SIM	single item measure
SIRIM	Standards and Industrial Research Institute of Malaysia
SME	small and medium-sized enterprise
SO^2	sulphur dioxide
SPAN	Suruhanjaya Perkhidmatan Air Negara
SPSS	Statistical Package for the Social Sciences (now known as

	IBM's SPSS Statistics)
SRI	socially responsible investment
SRM	supplier relationship management
SSM	Suruhanjaya Syarikat Malaysia
ST	Suruhanjaya Tenaga (Energy Commission)
TBL	triple bottom line
tCO_2eq	tonnes of carbon dioxide equivalent
TOE	technological-organizational-environmental (framework)
TQEM	total quality environmental management
TQM	total quality management
TVET	technical and vocational education and training
UK	United Kingdom
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNWCED	United Nations World Commission on Environment and Development
UPS	uninterruptible power supply
US/USA	United States/United States of America
UTP	Universiti Teknologi PETRONAS
VIF	variance inflation factor
VSS	Voluntary Sustainability Standard
WEEE	Waste Electrical and Electronic Equipment (directive)
WSSD	World Summit on Sustainable Development
WTO	World Trade Organization
WWF	World Wide Fund for Nature (was called World Wildlife Fund)

LIST OF SYMBOLS

f^2	effect size
N	sample size
n	number of predictors/indicators
p	path
p-value	significance level
Q^2	predictive relevance
q^2	predictive relevance effect size
R^2	coefficient of determination
t	path coefficient

Chapter 1

INTRODUCTION

1.1 Background of Study

This chapter begins with a detailed explanation of the background of the study which focuses on the manufacturing and information technology (IT) sectors in Malaysia, as well as on environmental issues currently faced by Malaysia. The three domains correlated to this research, green supply chain management (GSCM), green information technology (Green IT) and green information systems (Green IS), are reviewed. The problem statement is next identified and discussed. Based on the discussion of the problem statement, three research questions (RQs) with three research objectives (ROs) are derived. In the final two sections, the scope and significance of the research to the body of knowledge and to practitioners are presented.

1.2 Malaysia

Strategically located in the heart of South-East Asia, Malaysia is a country with an emerging multi-sector economy spurred on by high-technology, knowledge-based and capital-intensive industries. Malaysia offers a cost-competitive location for investors intending to set up offshore operations and for manufacturing advanced technological products for both regional and international markets. As a result, industrialization and urbanization trends are rapidly intensifying in Malaysia.

Despite the challenging external economic environment, the Malaysian economy has maintained its growth from 2012 until the present time (Economic Planning Unit

Prime Minister's Department, 2015). The real gross domestic product (real GDP) grew 5.6% in 2012 with the main contributors to overall growth being the services, manufacturing, mining and quarrying sectors (Malaysian Investment Development Authority (MIDA), 2012). The manufacturing sector remained resilient in contributing 24.9% to GDP in 2012 (Malaysian Investment Development Authority (MIDA), 2012).

The latest statistics from 2017 reported that the Malaysian economy expanded 5.6% year-on-year in the first quarter of 2017 as compared to a 4.5% growth in the previous three months, with this above the market expectations of 4.8% (Bank Negara, 2017). In summary, Malaysia's GDP annual growth rate averaged 4.75% between 2000 and 2017.

The manufacturing sector's output accelerated to 5.9% in March 2017 (Department of Statistics Malaysia (DOSM), 2017a). The major sub-sectors which recorded an expansion in March 2017 were: (1) electrical and electronics products (8.5%); (2) petroleum, chemical, rubber and plastic products (3.6%); and (3) wood products, furniture, paper products and printing (10.3%).

Manufacturing sales were registered at Malaysian ringgits (RM)65.9 billion in March 2017, with a steady growth of 13.6% (RM7.9 billion), rising to RM65.9 billion, compared to RM58.0 billion in 2016 (Department of Statistics Malaysia (DOSM), 2017b). The significant increase in sales value was from the following three sub-sectors which contributed 80.0%: (1) electrical and electronics products; (2) petroleum, chemical, rubber and plastic products; and (3) non-metallic mineral products, basic metal and fabricated metal.

The manufacturing sector is one of the most important sectors in Malaysia, with a total number of employees in March 2017 of 1,046,040 persons, an increase of 2.1% from the figure of 1,024,175 persons in March 2016. Salaries and wages paid in March 2017 increased 7.8% by RM248.4 million to RM3,452.5 million. Thus, the sales value per employee increased to RM63,008, 11.2% higher than in March 2016.

The performance of the manufacturing sector is shown by the expansion of the sector's industrial output (measured by the Industrial Production Index), sales value and productivity. The manufacturing sector remains a significant contributor to the growth of the country's economy. The Department of Statistics Malaysia (DOSM) defines manufacturing as "the physical or chemical transformation of materials or components into new products, whether the work is performed by power-driven machines or by hand, whether it is done in a factory or in the worker's home, and whether the products are sold at wholesale or retail".

1.2.1 Malaysia's Environmental Management

Despite a relatively encouraging economic record, Malaysia continues to face several environmental issues, such as pollution from industrial activities and vehicular emissions; inland and marine water pollution; hazardous and communal waste and disposal; land reclamation; and deforestation (Zainal Abidin & Jelani, 2011). Among these issues, the prominent problems of ever-growing energy consumption, air pollution from industrial emissions and poor waste management leading to greenhouse gas (GhG) emissions are having a significant impact on Malaysia's ecology (Malaysian-German Chamber of Commerce and Industry (MGCC), 2011; Zainal Abidin & Jelani, 2011) (Zainal Abidin & Jelani, 2011).

The phenomena of globalization, industrialization, modernization and environmental issues have associated impacts on the performance of organizations. Organizations today are obliged to respond to an increasing rate of change as product and technology life cycles become shorter; competitive pressures force rapid changes in the design of products and services; and consumer demand requires greater differentiation of products and services, with these being primary causes of environmental degradation (Azevedo, Carvalho, & Cruz Machado, 2011).

The total amount of energy consumed in Malaysia has steeply increased to 51.584 million tonnes of oil equivalent (Mtoe) or 599,921,920 megawatts per hour (MWh) in 2014. Of the 51.584 Mtoe, 43.3% (22,357 MWh) was consumed by the transport sector and 26.2% (13.496 Mtoe or 156,958,480 MWh) by the industrial sector

(Suruhanjaya Tenaga (Energy Commission), 2015). In terms of carbon emissions, Malaysia emitted 257.69 metric tonnes of carbon dioxide equivalent ($MtCO_2e$) in 2014 (Knoema, 2016).

The poor management of waste is also contributing to climate change as decomposing waste produces methane and emits greenhouse gases (GhG) (Zainal Abidin & Jelani, 2011). Malaysia produced a total of 2,965,611.65 metric tonnes (MT) of scheduled wastes in 2013 compared to 2,854,516.78 MT that was reported in 2012 (Hassan, 2014).

In 2012, the industrial sector produced 78,278.05 metric tonnes of e-waste (Ibrahim, 2013), with this expected to grow to a million tonnes per year (Kaos Jr, 2016). It is estimated that Malaysia will generate 53 million pieces of e-waste in 2020 (Jayaraman & Raman, 2016).

Therefore, a proper programme and system are required to control the release of hazardous substances to the environment, with some substances consisting of valuable material that can be recovered as secondary resources to conserve energy and reduce GhG emissions (Ibrahim, 2013; (Hassan, 2014). The Malaysian Government aims to increase the recycling quota from the current stated target of 22% up to 40% in 2020 (Malaysian-German Chamber of Commerce and Industry (MGCC), 2011), and to move forward with the concept of ‘cradle to cradle’ instead of that of ‘cradle to grave’ (Hassan, 2014).

Malaysia has realized that investing in environmental management and protection is becoming vital for survival and success. Malaysia’s New Economic Model (NEM) consists of four pillars of national transformation which are: (1) 1Malaysia: People First, Performance Now; (2) Government Transformation Programme (GTP); (3) Economic Transformation Programme (ETP); and (4) Tenth Malaysia Plan 2011–2015 (National Economic Advisory Council (NEAC), 2010). The sustainability component of the NEM focuses on energy, environment, economy and social. These components ensure that all proposed measures must be sustainable in both economic and environmental terms with the aspiration of placing Malaysia as a green hub in the eyes of the world (Chua & Oh, 2011).

With the rollout of the Tenth Malaysia Plan (2011–2015) and Eleventh Malaysia Plan (2016–2020), the focus of the environmental agenda is “protecting the environmental quality of life and caring for the planet, while harnessing economic value from the process” (Economic Planning Unit Prime Minister’s Department, 2010). The aim of the Eleventh Malaysia Plan with the theme of “anchoring growth on people” is to become an advanced and sustainable nation (Economic Planning Unit Prime Minister’s Department, 2015). The NEM will assist in boosting Malaysia’s development towards becoming an advanced nation with inclusiveness and sustainability that are in line with Vision 2020.

The manufacturing sector continues to accelerate the country towards high value-added, high-technology, knowledge-intensive and innovation-based industries (Malaysian Investment Development Authority (MIDA), 2012). The advancements in products, computerization, miniaturization and value-added services are achieved through highly interconnected supply chains that are moving towards seamless and borderless global business.

1.2.2 Supply Chain Management (SCM), Information Technology (IT) and Information Systems (IS)

Traditional supply chain management (SCM) refers to the management of all activities associated with the flow and transformation of materials from the raw extraction phase through to the consumption of goods and services by an end-user (Rao & Holt, 2005). The integration of environmental concerns into SCM has become increasingly important for manufacturers in maintaining a competitive edge, yet continues to be a challenge for many business enterprises today (Srivastava, 2007).

Both environmental management and SCM have their own roots, complementing each other, and must not be disregarded if seeking the successful implementation of industrial ecosystems which are ecologically-friendly (Q. Zhu, Sarkis, Cordeiro, & Lai, 2008). Therefore, adding the ‘green’ component to SCM involves addressing the influence and relationships between SCM and the natural environment.

The extension into green supply chain management (GSCM) comprises supply chain activities that aim to minimize the ecological impacts of a product throughout its entire life cycle from product design, materials sourcing and selection, manufacturing processes, delivery of the final product through to consumers, as well as end-of-life (EOL) management of the product after its useful life (Srivastava, 2007). With the implementation of GSCM, environmental sustainability can be achieved through pollution prevention, product stewardship, internal process efficiency, sustainable products and sustainable development (Löser, 2015; Srivastava, 2007).

As the country continues to grow rapidly towards a knowledge-based economy, the need for IT is constantly growing. Advancements in technology development with a high degree of automation in business processes are offering more opportunities than has been the case in the past. In addition, the Malaysian Government recognizes the importance of IT in enabling economic growth. The pervasive adoption of IT across all sectors of the economy has not only supported the growth of these sectors but has also increased efficiency and productivity and raised the country's overall competitiveness (Persatuan Industri Komputer dan Multimedia Malaysia (PIKOM), 2012).

The Malaysian Government is taking proactive initiatives to promote and develop IT as a sector and as an enabler through successive economic development plans as well as various strategic policies and programmes. In continuing to be a critical foundation, IT enables the delivery and creation of cutting-edge solutions for businesses and communities in Malaysia.

The Malaysian Government introduced the Information and Communications Technology (ICT) Strategic Roadmap in 2008. Since then, the Roadmap has been reviewed and revised to realign with Economic Transformation Programme (ETP) initiatives, whereby nine IT-related megatrends have been introduced. These megatrends have pervasive impacts in reaching out to various industries that are using IT and also in the various ways in which IT solutions are used (Persatuan Industri Komputer dan Multimedia Malaysia (PIKOM), 2012).

Considered as the key enabler in achieving a low-carbon economy, IT creates spin-off effects in other sectors such as manufacturing, engineering, services, logistics and many others. Both private and public sectors are increasingly adopting IT as an enabling tool to improve operational efficiency, production effectiveness, innovation, and research and development (R&D) methodologies (Persatuan Industri Komputer dan Multimedia Malaysia (PIKOM), 2012).

Many competitive organizations today are seeking to create a dynamic infrastructure that converges business and IT infrastructure which co-jointly operates to achieve high levels of productivity and business value (Bose & Luo, 2011). The development of IT in the supply chain has rapidly changed the conditions for doing business around the world. As an infrastructure and a solution, IT plays a critical role in the improvement of SCM activities both downstream and upstream (G. Li, Yang, Sun, & Sohal, 2009). With its power to provide timely, accurate and reliable information, IT leads to better performance in the supply chain, enabling the real-time integration of SCM activities.

In addition, IT facilitates SCM by improving the integration and coordination of the physical flow as well as the various information flows in the supply chain (Omar, Ramayah, May-Chuin, Sang, & Siron, 2010). The points above highlight the importance of IT in supply chain functioning. The use of IT is considered a prerequisite for effective control of today's complex supply chain (Fasanghari, Roudsari, & Chaharsooghi, 2008). The conclusion is that "IT is not an actual source of competitiveness but a source of competitive necessity", and IT implementation has become a necessity, not a choice (G. Li et al., 2009).

On the other hand, IT is a significant contributor and a growing part of the environmental problems faced around the globe. During its production, usage and disposal, IT poses severe environmental problems. The embedded energy from the use of IT, lighting and office equipment can be 10 times higher than manufacturers' own operational consumption (Murugesan, 2008). Thus, the widespread use of IT in supporting technologies throughout supply chains can significantly add to energy costs and electricity bills and contribute largely to carbon and GhG emissions.

Global carbon emissions resulting from IT activities alone have been estimated at 2–2.5% worldwide and are forecast to triple by 2020 (The Climate Group & Global e-Sustainability Initiative (GeSI), 2008). The use of IT is growing twice as fast as gross world product (GWP) and is contributing to a large proportion of business energy costs (Jenkin, Webster, & McShane, 2011). Furthermore, fast-paced innovations in technologies and the high rate of technological obsolescence have created rapid growth in electronic waste (e-waste) not only in Malaysia but also globally (Persatuan Industri Komputer dan Multimedia Malaysia (PIKOM), 2012).

Supply chain activities are multipliers of energy costs and carbon emissions (Smith-Gillespie & Chang, 2016) and, with the escalating rate of IT usage, are leading to higher energy use with more detrimental effects on the environment (Löser, 2015). With the projection of a 10% rise in energy and fuel bills within the supply chain, this will reduce annual company operating profit by over 10% (Smith-Gillespie & Chang, 2016). As result, organizations are facing increasing pressure to look at every aspect of their operations and business with a green lens or else face the consequences (Brooks, Wang, & Sarker, 2012).

1.2.3 Green Information Technology (Green IT) and Green Information Systems (Green IS)

By going green, IT and IS are capable of reversing their harmful effects on the environment (Faucheux & Nicolaï, 2011; Jenkin et al., 2011). The overall potential of IT and IS in fighting climate change is significant. The SMART 2020 report stated that emissions from the IT sector is estimated 2.8% of total global emissions by 2020. However, with greening of IT and IS in other sectors, industries and consumers, a significant reductions of an estimated 7.8 gigatonnes of CO_2e ($GtCO_2e$) emissions by 2020 (Global e-Sustainability Initiative (GeSI), 2012). The IT sector has the largest influence in enabling energy efficiencies in other sectors through carbon savings that are five times more than total emissions from the IT sector (Global e-Sustainability Initiative (GeSI), 2012). Based on the latest report by the Global e-Sustainability Initiative (GeSI), 12 $GtCO_2e$ emissions can be minimized with the use of environmentally-friendly IT and IS within the non-IT sectors as well as a reduction of 20% in global CO_2e emissions by 2030 (Global e-Sustainability Initiative (GeSI), 2015).

Increasing energy costs have driven the rising demand for solutions that can reduce the need for IT-driven energy and make more efficient use of existing IS resources for organizations (Dedrick, 2010). Every user of IT, either in the IT sector or in other user sectors, is obliged to green IT infrastructures and IS resources, as well as using them in the most environmentally-friendly manner (Murugesan, 2008). This trend has led to the emergence of Green information technology (Green IT) and Green information systems (Green IS) which have been gaining attention and relevance among the practitioner and academic communities for the past few years.

Green IT and Green IS are being accepted as the technological solution to support environmentally-friendly business practices. The greening of IT and IS will assist in minimizing impacts on the environment through reduced power or energy consumption; lower carbon and GhG emissions, and lesser electronic waste (e-wastes); and improved systems performance and use; as well as increased business process optimization. Green IT is mainly focused on energy efficiency, the carbon footprint and equipment utilization, while the design and implementation of information systems that contribute to sustainable business processes is regarded as Green IS (R. T. Watson, Boudreau, Chen, Huber, & Dick, 2008).

The concept on Green IT, Green Computing and Green of IT as well as Green IS, IT for Green and Green by IT have been conceptualized in a number of ways, with wider or narrower scope, and with a variety of terminologies and concepts depending on the context of the study. The most common terms which prevalent and repeatedly used in the literature are Green IT and Green IS (Löser, 2015). Although Green IT and Green IS are interrelated, but each has a different focus and purpose (Molla, 2013).

Green IT refers [to] environmentally sound IT. The focus is on the study and practice of designing, manufacturing, using, and disposing of computers, servers, and associated subsystems – such as monitors, printers, storage devices, and networking and communications systems – efficiently and effectively with minimal or no impact on the environment (Murugesan, 2008). Green IT spans many focus areas and activities, including:

- design for environmental sustainability
- energy-efficient computing
- power management
- data centre design, layout and location
- server virtualization
- disposal and recycling
- regulatory compliance
- green metrics, assessment tools and methodology
- environment-related risk mitigation
- use of renewable energy sources eco-labelling of IT

Green IS refers [to] the design and implementation of information systems that contribute to sustainable business processes (R. T. Watson et al., 2008).

- Green IS spans many focus areas and activities, including:
- Fleet management systems and dynamic routing of vehicles
- Telecommuting systems and collaboration systems
- Group document management, and cooperative knowledge management systems
- Environmental information tracking systems

The researchers, Faucheux & Nicolaï (2011), Molla and Abareshi (2012), Cai, Chen, & Bose (2013) defined Green IT and IT for Green as follows:

- The first-order effect refers to the negative environmental impact of IT production, use, and disposal. This perspective considers IT as negatively impacting eco-sustainability. Thus, making IT production, use and disposal greener refers to Green IT.
- ‘‘The second-order effect refers to the positive impact of using IT on business and economic processes. This perspective considers IT as part of

the solutions to eco-sustainability. Thus, using IT to make enterprises greener refers to IT for Green.''

Whilst, Löser (2015) explained that Green IT practices focused on three specific aspects:

- Consideration of environmental criteria when purchasing IT equipment and services.
- Energy-efficient IT operations in data centres and in office environments
- Environmentally-friendly practices referring to the disposal of IT equipment.

On the other hand, Green IS focusses on:

- Reengineering of business and production processes.
- Implementation of IS-based environmental management systems (EMS).
- Innovations for environmental technologies in end user products and services.
- Tracking of resource demands and emissions of products and services (lifecycle analyses)

In sum, Löser (2015) defined the terms Green IT and Green IS as:

- Green IT refers to measures and initiatives which decrease the negative environmental impact of manufacturing, operations, and disposal of Information Technology (IT) equipment and infrastructure.
- Green IS refers to practices which determine the investment in, deployment, use and management of information systems (IS) in order to minimize the negative environmental impacts of IS, business operations, and IS-enabled products and services.

The local and global players are relying heavily on computing devices to support their industrial activities. When the computing industry becomes incapable in sustaining the industrial needs in computers and other computing devices, this has led to the new movement called Green Computing (Harris, 2008). The concept of Green Computing is focussed towards the right practice in using the computing resource in an efficient manner by utilizing green computing systems and eco-friendly technologies which will significantly contribute to environment protection and preservation.

Whilst, Harmon and Auseklis (2009) defined Green Computing as green computing as the “practice of maximizing the efficient use of computing resources to minimize environmental impact”. Similarly, Tushi, Sedera & Recker (2014) described Green Computing as the study and practice of using computing resources efficiently and that the main objective is to minimize the pollutions of environment.

However, in some studies, Green IT is also known as Green Computing although the focus of Green Computing is to minimize computing resources used and maximize the energy-efficiency. On the other hand, some studies use term Green IT and Green Computing interchangeably.

As mentioned in ICT Strategic Review 2012/13: Innovation for Digital Opportunities by Persatuan Industri Komputer dan Multimedia Malaysia (PIKOM), the concepts of Green of IT and Green by IT are coined based Sustainable Computing Framework by GCI, 2011 (Persatuan Industri Komputer dan Multimedia Malaysia (PIKOM), 2012). The Green of IT, also referred to as Green Computing, consists of five drivers that strive to make the ICT industry more cost effective and eco-friendly which focusses on:

- Green Computing Lifecycle
- Green Computing Processes
- Green Computing Functions
- Equipment Lifecycle Management
- Renewable and Efficient Energy Source

The Green by IT Dimension, also referred to as “IT as a Low Carbon Enabler”, consists of eight drivers that strive to utilize Information Technology to make other industries more cost effective and eco-friendly which focusses on:

- Sustainable Business Process Management Process
- Carbon Accounting
- Internet of Things (IoT)
- Smart & Sustainable Built Environment

- Telecommuting
- Green Supply Chain & Manufacturing
- Resource Intelligence
- Biomimetics

As IT and IS have permeated business processes and supply chains, they offer important means to tackle environmental issues and, simultaneously, the climate change problem (Molla, 2008). Throughout supply chain activities, IT and IS are the foundation and driver for new proficiencies and cost cutting; therefore, it is crucial to deduce Green IT and Green IS as the essential components of compliance with measures for reducing carbon and GhG emissions. Moreover, Green IT and Green IS are influential change agents in improving performance on sustainability indicators and in routines to combat negative environmental effects, particularly in rapidly developing economies (Bengtsson & Ågerfalk, 2011).

1.3 Motivation and Problem Statement

In Malaysia, green supply chain management (GSCM) implementation within manufacturing firms is still lacking. Based on the previous working experience in the manufacturing firms located in Malaysia, the researcher witnessed inadequate initiatives being implemented in greening the supply chains. Over the years, the manufacturing firms have geared up towards ISO 14001 certification with Environmental Management Systems (EMS). This embarked the official journey of green supply chain management (GSCM) implementation within the ISO 14001-certified manufacturing firms.

Although, many previous studies have discussed the interest of ISO 14001-certified manufacturing firms to implement GSCM, however, it is still lacking among the Asian countries, including Malaysia. Furthermore, the greening initiatives mainly focussed on supply chain activities such as product design, materials sourcing and selection, manufacturing processes, transportation/logistics and waste management. How about greening of the information technology (IT) and information systems (IS) infrastructure, hardware, software and application that support the execution of

GSCM activities? What are the environmental effects from greening the practices, information technology and information systems within the supply chain?

The theoretical underpinning theories for this study are input-process-output (IPO) and technological-organizational-environmental (TOE) which are applied to categorize the stages of the life cycle of a system that has a beginning, a middle and an end. The IPO theory describe the inputs required, the process of transforming inputs into outputs and the applications used to produce the result (the goal to be achieved) (MacCuspie et al., 2014).

In this study, the primary goal of the system is to increase environmental sustainability with the implementation of green practices as well as green information technologies and systems within the supply chain. Thus, the input is represented with the factors that influence the GSCM implementation. The GSCM practices involve activities from upstream, middle stream and downstream (process).

Based on TOE theory, the input is categorized into technological, organizational and environmental drivers. The TOE framework provides a useful analytical framework in which specific factors identified within the three contexts may vary across different studies. The existing studies on GSCM implementation focusses on organizational and environmental factors, and in many of these studies are still lacking in examining the role of Green IT and Green IS in influencing GSCM implementation.

The literatures also revealed that the effects of GSCM implementation is usually measured in terms of organizational, operational, economic and environmental performance. Since primary goal is to increase environmental sustainability, thus, ecological improvement is chosen as the primary outcome to be measured. However, the prior studies focus on the environmental performance from GSCM practices alone. Thus, a new performance measurement known as Technological performance is introduced in this study. The environmental performance measure environmental improvements from implementing green practices within supply chains. In contrast, technological performance measure environmental improvements from implementing environmentally-friendly information technologies and systems practices within supply chains.

The both theories are adapted to build the model which is used as frame of reference to show the dynamic relationships between the key drivers that influence GSCM implementation, and its effects on organization's environmental and technological performance. Thus, different combination of drivers (input) that influence GSCM practices (process) can yield to different outcomes (output).

Rao and Holt (2005) explained that implementation of GSCM is gaining increasing interest among researchers and manufacturers, including those in the Asian region. However, studies on environmental management and GSCM by researchers who are geographically located in the Asian region, with a specific focus on the Asian region itself, are very limited (Seuring, Sarkis, Müller, & Rao, 2008). Thus, research on GSCM is timely and necessary, as it has not yet been fully investigated (Q. Zhu et al., 2008a, 2008b). In their pursuit of improved environmental performance, manufacturing firms in Malaysia are slowly accepting GSCM (Tan, Zailani, Tan, & Shaharudin, 2016). Recently, GSCM literature is growing exponentially, but literature focusing on the assessment of GSCM performance in developing countries is still inadequate (Mishra, Gunasekaran, Papadopoulos, & Hazen, 2017).

Apart from that, the studies on Green IT and Green IS adoption and impact in other sectors are lacking in both research and practice (Global e-Sustainability Initiative (GeSI), 2015; Jenkin et al., 2011; Melville, 2010). Only a few studies have investigated issues related to Green IT and Green IS, and the outcomes after their implementation (Zaman & Sedera, 2015). Despite the benefits that Green IT and Green IS can bring to GSCM, these topics have been discussed intermittently in the literature (Fiorini & Jabbour, 2017). Therefore, further exploration is required on these three domains, GSCM, Green IT and Green IS within non-IT sectors such as manufacturing with specific focus on developing countries like Malaysia.

The key factors that drive the implementation of GSCM among ISO 14001-certified manufacturing firms in Malaysia are categorized into internal and external factors. The internal factors are top management support and internal commitment, while the external factors are regulations, customer pressures, expected business benefits and social responsibility (Eltayeb & Zailani, 2009; Eltayeb, Zailani, & Filho, 2010).

Another study conducted in Malaysia indicated that commitment and support from top management are the significant internal factors, while external factors are laws, legislation and regulations from the authorities (Rusli, Abd Rahman, & Ho, 2012). These findings are consistent with results from the literature review and other studies within and outside of Malaysia (Chien & Shih, 2007; Diabat & Govindan, 2011; Holt & Ghobadian, 2009; Hu & Hsu, 2006; Ishak & Ahmad, 2010; G.-C. Wu, Ding, & Chen, 2012; Q. Zhu, Geng, Fujita, & Hashimoto, 2010; Q. Zhu & Sarkis, 2004, 2006).

The relationship between IT, SCM and SCM performance have demonstrated the positive relationship between IT and SCM, while mixed results have been reported between IT and SCM performance (Bharadwaj, Bharadwaj, & Bendoly, 2007; Dehning, Richardson, & Zmud, 2007; Fasanghari et al., 2008; G. Li et al., 2009; Omar et al., 2010; Zhang, van Donk, & van der Vaart, 2011). Despite the mixed results for SCM performance, IT is considered as an important enabler in the supply chain.

Often, IT and IS are not correctly acknowledged and are ignored by organizations when assessing their environmental footprints (A. H. Huang, 2008). Carbon emissions from IT and IS adoption remain secondary concerns; thus, the sense of urgency to quickly cut emissions is absent and relevant policies and standards are lacking. Organizations perceive that mitigating environmental impacts from the utilization of IT and IS are not part of their environmental policies and activities (Jenkin et al., 2011). Hence, they do not feel obligated to invest in energy-saving devices, solutions and practices (Global e-Sustainability Initiative (GeSI), 2012). Thus, many researchers have disregarded the role of IT and IS in relation to environmental sustainability in their research.

The broader literature has suggested that internal and external forces have much stronger influences on organizations' behaviour in relation to sustainability.

Technological force also plays a critical role in mitigating environmental impacts (Cai et al., 2013; A. J. W. Chen, Boudreau, & Watson, 2008; Dedrick, 2010; Faucheux & Nicolaï, 2011; Global e-Sustainability Initiative (GeSI), 2012, 2015; Jenkin et al., 2011; Melville, 2010; Molla & Abareshi, 2012; Climate Group (The) & Global e-Sustainability Initiative (GeSI), 2008). Green IT is becoming the most important strategic technology movement on the organization's energy-efficient agenda, whereas an inseparable strategic weapon boosting the organization's sustainable practices in business processes is Green IS (Bose & Luo, 2011).

The IT sector has been implementing Green IT and Green IS for the past few years; however, insufficient research has been conducted on actual practices in other sectors, such as manufacturing and logistics (Faucheux & Nicolaï, 2011; Jenkin et al., 2011; Melville, 2010; Sarkis, Koo, & Watson, 2013). Most previous research has concentrated on the direct, first-order impacts of IT (in other words, Green IT), and only recently have researchers begun to study the second-order effects of IT (otherwise known as Green IS) (A. J. W Chen, Boudreau, & Watson., 2008; Dedrick, 2010; Melville, 2010; Sarkis et al., 2013). In addition, previous studies lack in reporting on the environmental impacts from the use of IT and IS solutions (Erek, Löser, Schmidt, Zarnekow, & Kolbe, 2011; Löser, Grimm, Erek, & Zarnekow, 2012).

The relationship between GSCM and performance outcomes has been investigated in numerous studies. However, the results are inconclusive and questionable in terms of determining the actual outcomes that can be realized from implementing GSCM (Eltayeb et al., 2010; Eltayeb, Zailani, & Ramayah, 2011). Based on the past literature, the typical performance outcomes that result from GSCM are categorized into environmental, economic, operational and tangible (Eltayeb et al., 2011; Q. Zhu et al., 2008a, 2008b). Accordingly, manufacturing firms in Malaysia attained the following outcomes from implementing GSCM: reduction of emissions (environmental), cost reduction (operational), market expansion and sales growth (economic) as well as corporate social responsibility and corporate image (tangible) (Eltayeb et al., 2010).

The impacts of Green IT and Green IS on environmental activities and subsequent environmental performance remain conceptual with some continuing to be ambiguous

(Jenkin et al., 2011; Melville, 2010). The assimilation of Green IT and Green IS as part of organizations' environmental initiatives is still poorly monitored and measured (Erek, 2011; Löser, Erek, Schmidt, Zarnekow, & Kolbe, 2011). The literature shows a lack of consensus in regard to metrics and indicators for measuring GSCM (Pimenta & Ball, 2015), as well as in Green IT and Green IS performance assessments (Löser et al., 2011; Löser, 2015).

Manufacturing firms are able to reap effective gains in performance from the adoption of GSCM practices with the integration of both internal and external factors which include financial and non-financial dimensions (Geffen & Rothenberg, 2000; S. Y. Lee & Klassen, 2008; Sarkis, 2003; Seuring & Müller, 2008; Vachon, 2007; G.-C. Wu et al., 2012; Q. Zhu, Sarkis, & Lai, 2012). The capability to monitor and measure performance and to tie it to certain GSCM practices is a challenging but necessary task for further execution of these practices by organizations seeking to survive and compete in the market (Q. Zhu, Sarkis, & Lai, 2007a). With the right coordination of internal, external and technology factors, as well as the implementation of green practices, multiple performance benefits can be achieved (Ai, Hon, & Sulaiman, 2015). Thus, Green IT and Green IS hold greater promise for addressing broader environmental issues across industries and business processes towards achieving environmental sustainability.

In sum, the gaps identified in addressing the problem statement "In Malaysia, green supply chain management (GSCM) implementation within manufacturing firms is still lacking" are:

1. Research on GSCM in developing country, particularly on Asian regions by Asian researchers themselves are limited.
2. IT and IS have been contributing to environmental problems for the past few decades which many have not realized until recently. By going green, IT and IS can reverse their negative impacts on the environment. However, the implementation of Green IT and Green IS in non-IT sectors such as manufacturing, logistics, services are lacking in both research and practice.

3. The drivers that influence GSCM implementation are commonly categorized into internal and external or organizational and environmental factors. However, technological factors that influence GSCM implementation are being overlooked in most research and practice particularly in non-IT sectors.
4. Despite the benefits that Green IT and Green IS can bring to GSCM, but these topics are discussed intermittently in the literature.
5. The relationship between GSCM and performance outcomes have been investigated in numerous studies, but improvements on environmental performance remain inconclusive depending on the factors that influence GSCM implementation.
6. The effects of Green IT and Green IS on GSCM and subsequent ecological improvements are remained conceptual and not being investigated in non-IT sectors. Thus, the actual realization of Green IT and Green IS benefits are unknown to manufacturing firms, other organizations, policy makers as well as researchers.

Grounded from the gaps identified, the both theories, IPO and TOE are chosen to categorize the stages of the life cycle into input, process and output. The input is classified into technological, organizational and environmental context based on TOE theory. The process is explained based on upstream, middle stream and downstream of GSCM activities. The output is assessed based on the ecological improvements in achieving environmental sustainability with the implementation of green practices as well as green information technologies and systems within the supply chain.

1.4 Research Questions

Based on the above problems, this study aims to investigate the influential factors that drive ISO 14001-certified manufacturing firms in Malaysia to implement green supply chain management (GSCM). Thus, the factors are categorized into three contexts, namely, technological, organizational and environmental, as suggested by the technological, organizational and environmental (TOE) framework. The drivers for the technological context are Green IT and Green IS, followed by internal commitment for the organizational context and, lastly, regulatory pressure to represent the environmental context.

In addition, this study aspires to assess the effects on environmental improvements from implementing green practices within supply chains as well as environmental improvements from implementing environmentally-friendly information technologies and systems practices within supply chains. Thus, the performance measures are categorized into environmental performance and technological performance.

The research questions (RQs) to be explored in realizing this study are:

RQ1: To what extent do Green information technology (Green IT) and Green information systems (Green IS) drive the implementation of GSCM within ISO 14001-certified manufacturing firms in Malaysia?

RQ2: To what extent do internal commitment and regulatory pressure drive the implementation of GSCM within ISO 14001-certified manufacturing firms in Malaysia?

RQ3: To what extent does the implementation of GSCM effect the organization's environmental performance and technological performance within ISO 14001-certified manufacturing firms in Malaysia?

1.5 Research Objectives

This study aims to find empirical evidence on the association between technological, organizational and environmental factors in driving GSCM implementation and the resultant outcomes in environmental and technological performance within a single framework. Based on the above research questions, this study is designed to accomplish the following research objectives (ROs):

RO1: To investigate Green information technology (Green IT) and Green information systems (Green IS) as the drivers that influence GSCM implementation within ISO 14001-certified manufacturing firms in Malaysia

RO2: To investigate internal commitment and regulatory pressure as the drivers that influence GSCM implementation within ISO 14001-certified manufacturing firms in Malaysia.

RO3: To assess the effects of GSCM implementation on environmental performance and technological performance within ISO 14001-certified manufacturing firms in Malaysia.

1.6 Scope of Study

Numerous existing studies have discussed the role of IT and IS in environmental sustainability. These existing studies are directed towards the IT sector, and only a few have investigated the manufacturing sector. In addition, studies on the manufacturing sector are much more focused on GSCM practices than on Green IT and Green IS practices. Usually, these studies are conducted outside of Malaysia or among organizations located in developed countries or Western countries. The studies are mostly carried out at the organizational level of analysis, and only some are at the individual level.

At present, the implementation of GSCM within the manufacturing sector in Malaysia is limited. Although, there are many internal and external factors influencing the implementation, yet the GSCM implementation is not widely prevalent. This study will investigate the drivers, practices and performance of GSCM. The study is carried out at an organizational level of analysis, and cross-sectional in nature.

As previously mentioned, the drivers are categorized into three contexts, namely, technological, organizational and environmental. For the technological context, the two variables, Green IT and Green IS, are investigated, with their indicators adapted from validated instruments of previous studies. The organizational and environmental contexts represent the internal and external factors. The variables are internal commitment and regulatory pressure, and the indicators are adapted from previous studies. The GSCM practices cover the entire product life cycle which involve activities from upstream, middle stream and downstream.

In terms of performance outcomes, various measures can be used, such as economic, financial, operational, tangible, organizational and environmental performance. This study assesses two performance outcomes, namely, environmental performance and technological performance. The prior studies focus on the environmental performance from GSCM practices alone. Thus, a new performance measurement known as Technological performance is introduced in this study. The environmental performance measure environmental improvements from implementing green practices within supply chains. In contrast, technological performance measure environmental improvements from implementing environmentally-friendly information technologies and systems practices within supply chains.

The participants of this study are from manufacturing firms located in Malaysia. The firms consist of multinational corporations (MNCs) as well as small and medium-sized enterprises (SMEs). In Malaysia, SME is defined as follows (SME Corporation Malaysia, 2013):

Category	**Small**	**Medium**
Manufacturing	Sales turnover from **RM300,000 to less than RM15 million** OR full-time employees from **5 to less than 75**	Sales turnover from **RM15 million to not exceeding RM50 million** OR full-time employees from **75** to **not exceeding 200**
Services & Other Sectors	Sales turnover from **RM300,000 to less than RM3 million** OR full-time employees from **5 to less than 30**	Sales turnover from **RM3 million to not exceeding RM20 million** OR full-time employees from **30** to **not exceeding 75**

The following businesses will not be deemed as SMEs and do not qualify for Government assistance (SME Corporation Malaysia, 2013):

- Public-listed companies in the main board such as Bursa Malaysia or main bourses in other countries.
- Subsidiaries of the following entities:
- Public-listed companies in the main board
- Large firms, multinational corporations (MNCs), Government-linked companies (GLCs), Syarikat Menteri Kewangan Diperbadankan (MKDs) and State-owned enterprises.

In this case, if the parent company falls under (i) and (ii), then its subsidiaries (A and B) and their next level of subsidiaries (A1 and B1) are not eligible for assistance.

Multinational Corporation or MNC is defined as an enterprise operating in several countries but managed from one (home) country. In other words, MNC is any company or group that derives a quarter of its revenue from operations outside of its home country corporation. These MNC companies have offices and/or factories in different countries and usually have a centralized head office where they coordinate global management.

In Malaysia, any companies including manufacturing firms that registered with FMM and certified with ISO 14001: Environmental Management Systems (EMS) must comply with legal requirements set by ISO 14001, Environment Quality Act 1974 (Act 127) and other relevant regulations. The DSM described ISO 14001 as the building block for GSCM implementation in Malaysia that complies with EMS criteria (Department of Standards Malaysia (DSM), 2015).

Thus, ISO 14001: EMS certification is applicable to any organisation, regardless of size, type and nature, and applies to the environmental aspects of its activities, products and services that the organisation determines it can either control or influence considering a life cycle perspective. The benefits of being certified with ISO 14001 are:

- to comply with legal requirements as specified in the *Environment Quality Act 1974* and other relevant legislation

- to address business and social responsibilities for environmental management through GSCM activities

In the latest FMM directory of year 2017, most of the registered companies are Small and Medium Enterprises (SME) which is 46% (Total Employee < 75) and 28% (Total Employee 75 – 200). The rest are larger and Multinational Corporations (MNCs) which is 26% (Total of employee > 200). Most of the companies are in Selangor (49%), followed with Johor (14%), Penang (11%) and Perak (9%). For the other states in Malaysia are Negeri Sembilan (4%), Melaka (4%), Kedah & Perlis (3%), Sabah & Sarawak (3%) and Pahang, Terengganu & Kelantan (1%). The numbers of companies that are certified with ISO 14001 is 459 in 2017 and 523 in 2012 (Federation of Malaysia Manufacturers (FMM), 2012, 2017).

Being certified with ISO 14001: Environmental Management System (EMS) standard, these manufacturing firms are expected to implement green practices and activities within their business processes and supply chains. The information on the manufacturing firms was captured from the Federation of Malaysian Manufacturers (FMM) 2012 Directory. The ISO 14001 certification details were also cross-checked with the Standards and Industrial Research Institute of Malaysia (SIRIM) QAS website and with companies' websites to ensure that they are certified and embarking on green practices and activities. The manufacturing firms were chosen based on purposive or judgmental sampling, and data were collected via a survey questionnaire.

1.7 Significance of the Research

This research aims to contribute to the body of knowledge in the fields of GSCM, Green IT, Green IS and performance outcomes in relation to environmental sustainability. Previous research findings derived from Western data from developed countries cannot be generalized to developing countries, such as those in the Asian region. Thus, a study should be carried out within the context of Malaysia with the focus on ISO 14001-certified manufacturing firms.

Most scholarly research has discussed the organizational and environmental factors that drive GSCM implementation in sectors such as manufacturing and logistics. However, questions arise regarding the technological factors that assist in mitigating environmental issues within the supply chains or in the firm itself.

In regard to organizational and environmental factors, internal commitment and regulatory pressure are chosen in this study to represent the organizational and environmental contexts. In contrast, the technological factors particularly relevant to Green IT and Green IS are generally ignored in most GSCM-related research. Thus, little is known about the effects of Green IT and Green IS in influencing GSCM implementation towards environmental sustainability.

This research contributes by supplementing the current literature on GSCM with the inclusion of Green IT and Green IS as the technological factors for GSCM implementation, with this having been largely neglected in prior literature. This research is one of the few studies that attempts to link, explore and assess the role of Green IT and Green IS within the GSCM field.

In terms of performance outcomes, many previous studies have assessed the extent of environmental performance from business processes and supply chain activities in an endeavor to mitigate the environmental risks. But then, what are the environmental effects from implementing Green IT and Green IS within supply chains? Therefore, this study introduces a new performance measure that differentiates environmental outcomes from supply chain practices and from Green IT and Green IS practices.

The combination of the input-process-output (IPO) and TOE theories have given this research a deeper understanding of the factors that drive the implementation of an initiative which, in return, improves the outcomes achieved. Taken together, this research provides a new avenue of scholarly research on GSCM, Green IT, Green IS and performance outcomes.

Furthermore, the findings from this research provide new insights for managerial-level staff and top management on strategic areas within Green IT and Green IS that require the most attention in being (or becoming) an environmentally-sustainable organization, in which a brief guideline is provided.

In addition, this research is aligned to the Tenth Malaysia Plan (2011–2015) and Eleventh Malaysia Plan (2016–2020). In the Tenth Malaysia Plan (2011–2015), the significance of environmental sustainability was perceived as a major aspect of social and economic development in Malaysia. With the accomplishments achieved in the Tenth Malaysia Plan, a new voyage with the Eleventh Malaysia Plan (2016–2020) is now launched for realization of Vision 2020. Malaysia is aiming to become an advanced and sustainable nation with the theme “anchoring growth on people”. In achieving the theme, the plan consists of six strategic thrusts and six game changers. Within the Eleventh Malaysia Plan, the thrust most relevant to this study is “pursuing green growth for sustainability and resilience”, while the most relevant game changer is “embarking on green growth”, with these both complementing the direction and outcome of this research.

This research is also support the mission of Green Technology Foresight 2030 (GTF 2030) to minimize the degradation of the environment; achieve zero or low GhG emissions; promote a healthy and improved environmental situation for all types of life; conserve the use of energy and natural resources; and utilize renewable assets. At the same time, Malaysia’s National ICT guidelines concentrate on the implementation of Green IT and Green IS in both these contexts: (1) reduce the burden of IT through power-saving technologies and efficient consolidation of data centres, networks and email; and (2) improve efficiency by using IT to reduce the use of materials/parts or use environmentally-friendly materials/parts.

The green growth strategies within the Malaysia’s national ICT guidelines include four key focus areas (KFAs) which are: (1) e-Services; (2) the Green Data Centre; (3) unified communication; and (4) Green IT practices, with these planned in the following three stages: Wave 1 (2011–2015); Wave 2 (2016–2020); and Wave 3 (2021–2025). Green IT and Green IS are being considered as the key enablers of the Green Growth Strategies towards environmental sustainability in Malaysia for the next 10 years.

In alignment with the Malaysian Government initiatives, Persatuan Industri Komputer dan Multimedia Malaysia (National Information and Communications Technology Association of Malaysia) (PIKOM) published the ICT Strategic Review 2012/2013 with megatrends that are relevant to this research. One megatrend is Green innovating through the implementation of low-power servers, the Green Data Centre, telepresence and virtualization, with a recent development being cloud computing. The theme for the ICT Strategic Review 2014/2015 is “breaching the technology frontiers in the digital era”. Furthermore, the partnering with an international non-governmental organization (NGO), namely, Green Computing Initiative (GCI) provides the direction and possible certification for Green IT implementation in Malaysia.

Thus, Green IT and Green IS are apparent as significant catalysts to achieve carbon compliance and energy efficiency in Malaysia. The Malaysian Government has been proactive in promoting and developing IT as a sector and as an enabler in various other sectors through green strategic policies, programmes and plans. Thus, it is crucial for researchers to assess the extent to which manufacturing firms in Malaysia have implemented GSCM, Green IT and Green IS for ecological improvements in achieving environmental sustainability. In conclusion, Green IT and Green IS are integral parts of green growth in Malaysia to ensure that synergy prevails between technology and sustainability roadmaps with the national transformation strategies, policies and plans.

1.8 Organization of Thesis

The current chapter, Chapter 1 introduces the context of the research which covers the background, problem statement, research questions and research objectives as well as the scope and significance of the study. This chapter aims to provide an overview of the research. In the next five chapters, further insights of this research are revealed.

Chapter 2 covers the review of the main literature on global and national green directives, policies and standards, as well as GSCM, Green IT, Green IS, drivers and performance outcomes. This chapter provides a review of the previous literature on the constructs to be incorporated in this research.

Chapter 3 describes the research paradigm, followed by a description of the research process that discusses the exploration, research design and research execution stages. In the exploration stage, the research questions, theoretical framework and research framework are presented. The operational definitions of the terms and variables, hypotheses development and instrument development are discussed in the research design stage. Lastly, in the research execution stage, the pre-test, pilot test and main study activities are explained.

Chapter 4 presents the findings from the pre-test study using cognitive interviewing and semi-structured interview methods. Subsequently, the chapter describes the pilot study that was carried out with a representative sample of the population, with the results presented in this chapter.

Chapter 5 reveals the detailed analysis and results of the full-scale main study. The analysis is divided into data screening and descriptive analysis using the Statistical Package for the Social Sciences (now known as IBM's SPSS Statistics) version 19.0. Next, Partial Least Squares-Structural Equation Modelling (PLS-SEM) analysis was carried out using SmartPLS 3.0 software to determine the extent that the empirical data support the theory or concept; to evaluate the extent that the theory or concept had been empirically and statistically confirmed; and to measure the model's predictive capabilities and the relationships between the constructs.

Chapter 6 concludes the thesis with recapitulations of the findings and presentation of the contributions in terms of the theoretical, methodological and practical aspects. This is followed by the limitations or shortcomings of the research, after which future research work is suggested.

1.9 Chapter Summary

This research aims to contribute to the body of knowledge in the areas of GSCM, Green IT, Green IS and performance outcomes towards environmental sustainability. This research contributes by supplementing the current literature on GSCM with the inclusion of Green IT and Green IS as the technological antecedents for GSCM implementation, something which has largely been neglected in prior literature. This research is one of the few studies that attempt to link, explore and assess the role of Green IT and Green IS within the GSCM field. Furthermore, this study introduces a new performance measure that differentiates the environmental improvements GSCM as well as Green IT and Green IS implementation.

The findings from this research provide new insights for managerial-level on strategic areas within GSCM, Green IT and Green IS that require further attention with the rising urgency for organizations to be environmentally sustainable. A guideline is developed for manufacturing firms and policy makers with the hope to increase the implementation of GSCM in Malaysia. This research is strategically aligned with the Tenth Malaysia Plan (2011–2015), Eleventh Malaysia Plan (2016–2020) and Green Technology Foresight 2030 (GTF 2030), as well as with the Green Growth Strategies within Malaysia's national ICT guidelines. The association with these policies portrays the importance and significance of this research in Malaysia at present and for many years to come.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

This chapter begins with the description of environmental sustainability which is followed by detailed reviews of the international and national environmental directives, standards and policies. Next, the chronology of manufacturing and the supply chain is revealed. The last few sections highlight the four major fields under study which are GSCM, Green IT, Green IS and performance outcomes. From these fields, the influential drivers, green practices and performance measures are reviewed. From the analysis of the literature, the research variables are selected which underpin the development of the research framework and the research hypotheses. A summary concludes this chapter.

2.2 Environmental Sustainability

In 1987, the United Nations World Commission on Environment and Development (UNWCED) published the Brundtland Report titled “Our Common Future”, introducing the concept of sustainable development and suggesting the adoption of the concept as a solution to attain both economic and environmental goals (UNWCED, 1987). As mentioned in Welford (1998), the report emphasized that economic development and environmental protection must be rolled out, along with radical changes in economic practices, throughout the world (Melville, 2010). Even though the Brundtland Report concluded that the three conditions, namely Environment, Equity and Futurity had not been met, but the possibility to achieved them are feasible (Welford, 1998; Hiew, 2010).

Thus, it called for environmental and social sustainability, challenging industries to deliver higher yields with lower inputs while creating less wastage. The second Earth Summit in Rio de Janeiro in 1992 invited leaders from nations around the world to sign and join the agenda to address the environmental, economic and social challenges in achieving sustainable development. Governments, organizations and society at large are expected to work towards pollution prevention, climate change protection and overall ecological improvements. The new concepts of sustainable business and a sustainable global economy are emerging (Brundtland, 1987). Organizations and governments must begin to take strategic perspectives with respect to environmental policy, ecological strategy and administration issues while delivering a competitive edge.

The Earth Summit is conducted as a result from the climate change and biological diversity convention which known as Agenda 21. Rio 92 focussed upon agreements and arrangements on environmental preservation. In 2002, Rio+10 was held in Johannesburg to follow-up on the implementation of the Rio-92 promises. The Rio+20 conference was held on June 13-22, 2012 in Rio de Janeiro.

The aim of Rio+20 is to strengthen the balance between the environmental, economic and social pillars of sustainable development, as well as perfecting international environmental governance and green economy concept (United Nations General Assembly, 2012). The green economy focusses on economic growth with prioritization on social inclusion and environmental protection, while encouraging poverty eradication policies. The aim of Rio+20 is to renew political commitment towards sustainable development, aside from proposing and discussing new themes on sustainable development agenda for the next 20 years under “The Future We Want”.

The 10 priority themes on the international agenda related to sustainable development are (United Nations General Assembly, 2012; World Health Organization (WHO), 2012):

- Unemployment, Decent Work and Migrations
- Sustainable Development as an Answer to the Economic and Financial Crises

- Sustainable Development for Fighting Poverty
- The Economics of Sustainable Development, including Sustainable Patterns of Production and Consumption
- Forests
- Food and Nutrition Security
- Sustainable Energy for all
- Water
- Sustainable Cities and Innovation
- Oceans

In aligned to Rio+20, United Nations published a new agenda, Transforming our World: The 2030 Agenda for Sustainable Development in September 2015. The Sustainable Development Goals (SDGs), also known as Global Goals are built on the success of the Millennium Development Goals (MDGs). The 17 Sustainable Development Goals with 169 targets are to be achieved over the next 15 years are critical for the betterment of humanity and the planet. The five areas of focus are (United Nations, 2015a; United Nations, 2015b):

i. People
    - To end poverty and hunger
    - To ensure dignity and equality in a healthy environment

ii. Planet
    - To protect the planet from degradation and climate change
    - To sustainably consume, produce as well as manage natural resources
    - To support the needs of the present and future generations

iii. Prosperity
    - To enjoy prosperous and fulfilling lives
    - To support economic, social and technological progress that occurs in harmony with nature

iv. Peace
    - To foster peaceful and inclusive societies that are free from fear and violence towards sustainable development

v. Partnership

- To implement this Agenda through a revitalized Global Partnership for Sustainable Development with the participation of all countries, all stakeholders and all people

On 1 January 2016, the 17 Sustainable Development Goals (SDGs) of the 2030 Agenda for Sustainable Development came into forced which covers (United Nations, 2015):

- Goal 1. End poverty in all its forms everywhere
- Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture
- Goal 3. Ensure healthy lives and promote well-being for all at all ages
- Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
- Goal 5. Achieve gender equality and empower all women and girls
- Goal 6. Ensure availability and sustainable management of water and sanitation for all
- Goal 7 Ensure access to affordable, reliable, sustainable and modern energy for all
- Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
- Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
- Goal 10. Reduce inequality within and among countries
- Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable
- Goal 12. Ensure sustainable consumption and production patterns
- Goal 13. Take urgent action to combat climate change and its impacts
- Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development

- Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
- Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
- Goal 17. Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development

The interlinkages and integrated nature of the Sustainable Development Goals are importance in ensuring for realization of new Agenda to ensure the lives of all will be profoundly improved and the world will be transformed for the better (United Nations, 2015).

From a business perspective, corporate environmental management relates to how the organization's activities interact with and impact on the environment (Welford, 1998). Thus, handling environmental issues soon prompts growing enthusiasm for the range of corporate environmental management. Business segments are essential components in addressing environmental issues by adequately creating cleaner and greener procedures, administration, processes, products and services (Hiew, 2010).

Previously, the business sector considered the expanding and stricter regulations as a threat. Corporations may perceive the importance of creating environmental policies; however, they are subjected to the development and enactment of environmental legislation. As markets become more unpredictable, the pace of technological change and advancement is accelerating. Investors and consumers have greater expectations that businesses will perform their activities in more environmentally-friendly ways (Faulkner, Carlisle, & Viney, 2005).

The overall direction and strategies of firms must shift in response to environmental challenges and concerns through environmental innovations (Smith & Perks, 2010). Most businesses are adapting fast to the changing environment, with some of the more proactive ones transforming the perceived threats of stricter regulations into opportunities by implementing innovative practices, services and products through environmental innovations (Hiew, 2010).

Corporate management systems and corporate strategies are aligned to meet sustainable development through the following four basic voluntary initiatives (Anbumozhi & Kanda, 2005):

i. The environmental management system (EMS) concentrates principally on natural environment issues.
ii. Corporate governance (CG) focuses on economic and accountability factors. The Organisation for Economic Co-operation and Development (OECD) publishes guidelines to assist organizations with corporate governance.
iii. The corporate social responsibility (CSR) concept differs from one country to another, with the focus on non-financial areas such as human rights, employment, safe working conditions, environmental protection, etc.
iv. Corporate responsibility (CR) differs slightly from CSR as it focuses on the consumer movement and consumer protection.

From these four initiatives, the most popular self-regulating measure is the ISO 14001: Environmental management system (EMS) standard that is largely being adopted by firms around the world with the aim of minimizing environmental impacts and maximizing environmental performance (Hiew, 2010). As mentioned in the Asia-Pacific Telecommunity (APT) Standardization Program (ASTAP) Working Group on ICT and Climate Change (2011), the British Standards Institution (BSI) defined an EMS as “the organizational structure, responsibilities, practices, procedures, processes and resources for determining and implementing environmental policy” (BSI, 1994, p. 6). Most large firms have an EMS in place; however, the implementation and management of an EMS may differ from one firm to another, as they depend on the firm’s environmental policy and targets (Sarkis & Sroufe, 2004).

Hence, the EMS has been utilized by firms as a generic framework to carry out their business in more environmentally-friendly ways; thus, the common characteristics of an EMS are (M. Watson, 2006):

i. Declaration of environmental goals and targets
ii. Identification of the organization’s environmental impacts
iii. Recognition of relevant legislation/regulatory structures
iv. Establishment of control, measurement and monitoring procedures
v. Introduction of appropriate training programmes for employees
vi. Establishment of structured documentation systems

2.3 ISO 14001: Environmental Management Systems

The 1992 Rio de Janeiro Summit played a critical role in framing ISO 14001 with more than 100 nations participating in the United Nations Conference on Environment and Development (UNCED). As mentioned in Hiew (2010), the Geneva-based International Organization for Standardization (ISO) defined the EMS within ISO 14001 as “a tool that enables an organization of any size or type to control the impact of its activities, products or services on the natural environment” (Delmas, 2000, p. 5).

Before ISO 14001, the developments in EMS standards in various nations were the British Standard (BS) 7750 in 1992 and the Eco-Management and Audit Scheme (EMAS) in 1993. When the EMAS was launched, BS 7750 was withdrawn and replaced by ISO 14001. In its depth and demands on commitment, transparency and environmental performance, the EMAS seemed to contrast with ISO 14001; however, the structure of the EMS under the EMAS is similar to that described in ISO 14001 (Hiew, 2010).

As ISO 14001 is a voluntary standard, the option to adopt it or not is up to each individual firm. The firms that choose to adopt it must show their conformance to the ISO 14001 standard in two ways: (1) self-declaration; and (2) third-party independent certification. As the ISO 14001 standard is voluntary, a firm’s affirmation in seeking to be certified demonstrates its efforts to be environmentally and socially responsible.

Through ISO 14001, guidelines are provided for firms to plan, implement and execute an EMS through: (1) environmental policy; (2) environmentally-based activities; and (3) environmental management programmes with a clear structure of responsibility towards ecological improvements (Petrosillo, De Marco, Botta, & Comoglio, 2012). The key component of ISO 14001 is continual improvements (International Organization for Standardization (ISO), 2015). Based on the Deming Cycle (or PDCA cycle), ISO 14001 has four steps (Petrosillo et al., 2012):

i. Plan (P): planning of activities to accomplish management objectives and goals
ii. Do (D): execution of the changes decided during the plan phase
iii. Check (C): confirmation whether the objectives and goals have been accomplished
iv. Act (A): if objectives and goals are not achieved, the planning is investigated during the act stage and the cycle begins again.

The level of EMS adoption continues to rise, with the ISO 14001 standard revised in 2004. The new standard focuses more on environmental performance, evaluating measurable results of an organization’s management of its environmental aspects.

The motivations of firms to be certified through ISO 14001 as improving their environmental performance are outlined as follows (Nawrocka, Brorson, & Lindhqvist, 2009; Puvanasvaran, Muhamad, & Kerk, 2010):

- strong top management participation, support and commitment in EMS exercises and continuous improvements
- compliance with legal requirements with a systematic administration framework and management systems
- gain greater financial benefits with reductions in resource use, waste and energy use, and increases in SCM effectiveness and overall operational efficiency
- increase technological development and advancement, and transfer to other sectors or organizations
- portray good values and beliefs among managers on environmental management
- increase awareness and positive behavior among employees

- meet and comply with clients' environmental requirements and needs with this improving customer relationships and market competitiveness
- increase market share among customers who are environmentally conscious, especially in developed and advanced industrialized countries
- portray credibility, and increase customers' trust and confidence in firms
- achieve potential gains through business opportunities and recapture new and old customers with an enhanced corporate image, meeting customer requirements, penetration in new markets and gaining a competitive edge.
- greater public pressure that is influencing the general ecological management strategies of firms
- boosting both economic and environmental performance

Numerous authorities and government bodies perceive ISO 14001 as a possible remedy for mitigating Asia's environmental issues. Although ISO 14001 is a voluntary standard, it provides clear guidance and flexibility in addressing environmental and business issues while adhering to existing environmental legislation (Hiew, 2010; Puvanasvaran et al., 2010). The interest shown across Asia is very promising in implementing environmental management, mitigating environmental issues and enhancing environmental performance as well as attaining market competitiveness through ISO 14001 certification (Hiew, 2010).

The ISO standards are reviewed and revised regularly to ensure that they remain relevant. Through the ISO 14001 standard, organizations are guided to develop an EMS that identifies, manages, monitors and controls their environmental issues in a holistic manner. Recently, ISO 14001:2004 has been revised to ISO 14001:2015 which looks more rigorously at internal and external factors that influence the environmental impacts that will provide value to the environment, the organization itself and interested parties (International Organization for Standardization (ISO), 2015). The recent changes to the standard also increase its compatibility with other management system standards.

With the implementation of ISO 14001: 2015, the following few amendments are to be observed (International Organization for Standardization (ISO), 2015):

- Environmental management to be an essential element within the organization's strategic direction
- A greater commitment from leaders and top management
- Proactive initiatives to protect the environment from harm and degradation.
- Use of life-cycle thinking with consideration for environmental aspects from development to end of life (EOL)
- Incorporation of a stakeholder-focused communication strategy

The unit that acts as an accreditation body to administer national standards, policies and guidelines in Malaysia is the Department of Standards Malaysia (DSM). The main functions of the DSM are as follows (Department of Standards Malaysia (DSM), 2005):

- promote standards, standardization and accreditation as a means of advancing the national economy
- advocate industrial efficiency and development
- advancement of the health and safety of the public
- protect consumers
- facilitate domestic and international trade
- aid in international cooperation on standards and standardization

The DSM has appointed SIRIM Berhad (formerly known as the Scientific and Industrial Research Institute of Malaysia) to create and manage the Malaysian Standards. The DSM has also designated SIRIM Berhad as the operators for the circulation and sale of each Malaysian Standard (MS). These standards are aligned to international standards and developed through consensus by committees which comprise a balanced representation of producers, users, consumers and others with relevant interests. The *Standards of Malaysia Act 1996* governs the approval of a standard as a Malaysian Standard (MS). The use of a standard is voluntary unless it is being mandated by regulatory authorities as part of regulations, legislation or local by-laws.

The Malaysian Standard (MS) for environmental management is known as MS ISO 14001: 1997, Environmental management systems (EMS) which is identical to MS ISO 14001: 2004, Environmental administration frameworks – Requirements with direction for use, distributed by the ISO (Department of Standards Malaysia (DSM), 2005). In 2015, MS ISO 14001:2004 was revised to MS ISO 14001: 2015 Environmental management systems – Requirements with guidance for use (Department of Standards Malaysia (DSM), 2015.; Malaysian Standard (MS), 2015).

The ISO 14001: 2015 and MS ISO 14001: 2015 assist the organization to manage its environmental responsibilities in a systematic manner which contributes to the environmental pillar of sustainability. The expected outcomes of the environmental management system (EMS) standard are consistent with the internal environmental policy of an organization which are as follows (International Organization for Standardization (ISO), 2015; Department of Standards Malaysia (DSM), 2015; Malaysian Standard (MS), 2015).

- Enhance environmental performance
- Adhere to compliance requirements and obligations
- Accomplish environmental objectives

The EMS standard is applicable to any organisation, regardless of size, type and nature, and applies to the environmental aspects of its activities, products and services with consideration from a life-cycle perspective. However, ISO 14001: 2015 and MS ISO 14001: 2015 exclude specific environmental performance criteria; therefore, these standards can be used as a whole or in parts to systematically improve environmental management (International Organization for Standardization (ISO), 2015; Department of Standards Malaysia (DSM), 2015; Malaysian Standard (MS), 2015).

The DSM described MS ISO 14001 as the building block for GSCM implementation in Malaysia that complies with EMS criteria (Department of Standards Malaysia (DSM), 2015). The benefits of being certified with MS ISO 14001 are:

- to comply with legal requirements as specified in the *Environment Quality Act 1974* and other relevant legislation
- to address business and social responsibilities for environmental management through GSCM activities
- the EMS enables GSCM implementation which boosts the organization's capability to carry out activities in an environmentally-friendly manner.

Implementation of GSCM which complements EMS criteria will address the following areas:

- product materials with better product input processing, and substitution as well as recycling of by-products and waste
- energy consumption, and costs for emissions, discharges, waste handling, transport and disposal
- continual improvements to give the business a competitive edge so it can compete and be resilient in the marketplace
- availability of human resources that will increase employees' morale, commitment and competencies towards environmental management
- compliance with standards that give a competitive edge and increase business profitability.

2.4 Worldwide Green Directives and Policies

Local government, international countries and other private agencies are pushing for compliance with environmental laws, standards, directives and initiatives, as listed below, which will address up to 80% of environmental issues (Raza, Patle, & Arya, 2012; Saha, 2014):

- European Waste Electrical and Electronic Equipment (WEEE) directive: makers must take back old equipment to decrease electronic waste.
- European directive on the Restriction of Hazardous Substances (RoHS): minimization of lead, mercury, cadmium and different substances utilized in production, use and disposal. Other areas of focus are carbon-free computing, solar computing, lead-free computing and energy-efficient computing.
- Restriction, Evaluation, and Authorization of Chemicals (REACH) regulation: standardization of chemical production and use for health and environmental purposes.
- Eco-Design directive on Energy-using Products (EuPs): manages the life-cycle energy efficiency of products.
- Electronic Product Environmental Assessment Tool (EPEAT): promotes compliance and environmental rating for greener products, green technology, and green computers and other electronic equipment.
- Energy Star 5.0 standard: controls energy efficiency for desktop computers, workstations, notebooks and other electrical/electronic products.
- Leadership in Energy and Environmental Design (LEED) standard: certifies the Green Data Centre.
- OHSAS 18000: assists organizations to control occupational health and safety risks.
- ISO 14004: provides guidance on the establishment, implementation, maintenance and improvement of an EMS and its coordination with other management systems.
- ISO 14006: integrates eco-design into other management systems for organizations that have implemented EMS in accordance with ISO 14001.
- ISO 14064-1: specifies principles and requirements for the quantification, reporting and removal of GhG emissions at the organizational level.
- ISO 50001: empowers organizations to undertake a systematic approach towards continual improvements in energy performance in terms of energy efficiency, energy use and energy consumption.

- Green Information Technology Infrastructure Library (ITIL): includes sets of standards for IT services that align with business performance, with a specific focus on Green IT efficiency and carbon emissions reduction.
- Climate Savers Computing Initiative, Global eSustainability Initiative (GeSI) and the Climate Group: working towards eco-sustainability awareness for organizations.
- Green Grid (The): a voluntary international non-profit organization that develops standards to measure the efficiency of office equipment, facilities and data centres.
- Greenpeace, World Wide Fund for Nature (WWF) and Friends of the Earth: NGOs promoting the practice of greener business activities to organizations.
- Climate Savers Computing Initiative: non-profit agency of eco-conscious consumers, and business and conservation organizations that promotes the development and adoption of smart technologies that reduce global CO_2 emissions.
- Energy Savings Certificates (ESCs): achieve energy-efficiency targets through the measurement and verification of the actual reduction in energy usage by third parties such as commercial and industrial companies.

2.5 Malaysia's National Green Technology Foresight 2030 (Green Technology Policy)

The Green Technology Foresight 2030 (GTF 2030) is a joint activity between the Malaysian Ministry of Energy, Green Technology and Water (or Kementerian Tenaga, Teknologi Hijau dan Air [KeTTHA]) with the Malaysian Industry–Government Group for High Technology (MIGHT) to strategize the future of green technology in Malaysia by 2030. This comprehensive policy is developed upon four core pillars: (1) energy; (2) the environment; (3) the economy; and (4) society. These pillars were set as the new economic and financial drivers of development for the nation as they offer tremendous opportunities and huge potential in monetary recovery, technology advancement, innovation and wealth creation (Malaysian Industry–Government Group for High Technology (MIGHT), 2013).

KeTTHA defined green technology as the development and application of products, equipment and systems used to conserve the natural environment and resources, minimizing and reducing the negative impacts of human activities, with the following criteria (Mohd Nudri, 2014):

- minimize the degradation of the environment
- achieve zero or low GhG emissions
- promote a healthy and improved environmental situation for all types of life
- conserve the use of energy and natural resources
- utilize renewable assets

The policy on green technology is for various sectors, nine of which are: energy, waste, transport, manufacturing, water, building, agriculture, ICT and forestry.

The Sectoral Strategic Targets 2030 relevant to this study are as follows (Malaysian Industry–Government Group for High Technology (MIGHT), 2013):

- Manufacturing sector: The elements of green manufacturing that focus on the 'cradle to grave' life-cycle concept are product design, raw materials and manufacturing from Stages 1, 2 and 3. Stages 4, 5 and 6 are covered by other sectors which comprise transport, product usage and final disposal.
- IT sector: The emphasis on the greening of IT (or Green IT) is on the energy efficiency of IT equipment and data centres, while the greening of IS (or Green IS) focuses on the resources, applications and practices that contribute to environmental sustainability.

2.6 Malaysia's National Energy Efficiency Action Plan

KeTTHA published and distributed Malaysia's National Energy Efficiency Action Plan in 2014. The aim of the plan is to address the challenges in and barriers to the efforts to promote energy-efficient practices and developments. As recommended by the Asia-Pacific Economic Cooperation (APEC) Peer Review on the Energy Efficiency Policy (PREE), the plan consists of six monitoring steps (Kementerian Tenaga Teknologi Hijau dan Air (KeTTHA), 2014).

The steps are established to monitor the indicators set as highlighted in the PREE report. The effectiveness of energy efficiency strategies, actions and improvements in Malaysia is highly dependent on sound and continuous monitoring. Thus, the goals of the energy efficiency policy need to be measurable with clearly defined data sets for evaluation. The measure of achievements against the plan is evaluated to identify the limitations and deficiencies in performance which will provide feedback for rectification and correction. In summary, Malaysia's National Energy Efficiency Action Plan remains the main monitoring tool to be communicated to stakeholders as well as being used for reporting in the form of annual reports (Kementerian Tenaga Teknologi Hijau dan Air (KeTTHA), 2014).

2.7 Malaysia's Green ICT Guideline

The national IT activity initiated by the Malaysian Government to create and advance the ICT industry is known as the Multimedia Super Corridor (MSC) Malaysia. The pioneer to the transformation of Malaysia's digital economy is the holistic government-owned agency known as the Malaysia Digital Economy Corporation Sdn. Bhd. (MDEC). MDEC aim to unlocks significant economic, environmental, and social value towards a digital future in Malaysia. The four guiding principles of MDEC in supporting the digital economy in Malaysia are:

- Attracting Investors, Globalizing Local Tech Champions
- Catalyzing Industry-Driven Digital Ecosystem
- Building Critical Enablers of the Digital Economy
- Driving Inclusive Adoption of Technology

Green IT advancement forms the centre of Malaysia's national ICT development policy, in which the Green ICT guideline was introduced by the Malaysian Green Technology Corporation (or GreenTech Malaysia) (Md Salleh, 2010; Mohd Saleh, 2013). In the guideline, Green IT is defined as

> the study and practice of designing, manufacturing, using and disposing of computers, servers and associated subsystems such as monitors, printers, storage devices and networking & communications systems in an efficient and effective manner with minimal or no impact on the environment (Murugesan, 2008).

The Malaysian Government has encouraged the implementation of Green IT initiatives with the following strategies (Malaysian Administrative Modernisation and Management Planning Unit (MAMPU), 2007):

- increase in awareness through the greening of government IT programmes
- selection of Green IT Champion to be the role model for the implementation of Green IT initiatives within the organization in both public and private sectors
- development and execution of Green IT best practices in procurement initiatives
- establishment of the Green Data Centre as the first initiative of the Malaysian Government
- government agencies and KeTTHA working with international bodies and the Global Computing Initiative (GCI) to establish a Green Data Centre rating system known as DAHLIA.

The Green ICT guideline covers the following aspects of greening (Malaysian Administrative Modernisation and Management Planning Unit (MAMPU), 2007):

i. Reduce the burden of IT through power-saving technologies and efficient consolidation of data centres, networks and email. For example:
    - Remove active screensavers
    - Switch monitors to standby after five minutes of inactivity
    - Shut down personal computers (PCs) after office hours

- Reuse equipment
- Use central processing units (CPUs) that have low energy consumption
- Utilize thin client technology

ii. Improve efficiency by using IT materials/parts, or by using environmentally-friendly materials/parts, with the implementation of “zero visits” or “no wrong door” concepts. For example:
    - Sharing of network printers
    - “Zero visits” or “no wrong door” concepts through which the Malaysian Government aspires to build one government with many agencies to enable services to be delivered with ease and speed, and with closer relationships with customers/clients.

As mentioned in the guideline, the Green Growth Strategies are focused on four key focus areas (KFAs), as shown in Table 2.1 (GreenTech Malaysia, 2009).

Table 2.1: Key Focus Areas (KFAs) of Green Growth Strategies in Malaysia

e-Services	• Empowering SMEs and national organizations with e-Services • e-Government • Legalized e-Docs
Green Data Centre	• Creation of the Green Data Centre • Consolidation of government hosting • Increased awareness among businesses
Unified Communication	• Empowering participation of local players and businesses • Teleworking
Green IT Practices	• Empowering government offices and agencies with Green IT practices • Empowering businesses and firms with Green IT practices • Measures and standards for IT equipment and labelling

Green growth in Malaysia will undergo three waves covering the period from 2011 to 2025. As shown in Table 2.2, the focus of the first wave (2011–2015) is on guidelines and standards development; promotion of e-government activities; and

Green IT awareness and services from local companies. From 2016 to 2020 in the second wave, the government is empowering and enabling SMEs and other types of organization to implement Green IT practices. In the third wave, green growth implementation is focusing on enabling the government and local players with the consolidation of the data centre and Green IT practices.

Table 2.2: Green Growth Stages in Malaysia

Wave 1 (2011–2015)	Wave 2 (2016–2020)	Wave 3 (2021–2025)
1. Creating green data standards and guidelines 2. Telecommunicating and teleworking 3. Encouraging local companies to provide business and services related to Green IT 4. Improvement of e-Government activities	1. Empowering SMEs/consumers with e-Services 2. Empowering organizations with Green IT practices 3. Legalizing e-Documents	1. Consolidation of data centre for governments 2. Empowering the participation of local players

2.8 Malaysia's ICT Strategic Review 2014/2015

The National Information and Communications Technology (ICT) Association of Malaysia (Persatuan Industri Komputer dan Multimedia Malaysia [PIKOM]) comprises organizations that offer the entire range of IT products and services covering 80% of the aggregate IT trade in Malaysia. The latest reports by PIKOM are the ICT Strategic Review 2013/14: "The Digital Opportunity" and the ICT Strategic Review 2014/2015: "Breaching the New Frontiers in the Digital Age" (Persatuan Industri Komputer dan Multimedia Malaysia (PIKOM), 2013, 2014).

Malaysia's IT focus is on the enablement and convergence of technology, people and processes. This is achieved through the deployment of cloud computing, big data analytics, the Internet of Things (IoT), miniaturization of wearable devices, bring your own device (BYOD), social media applications for businesses, and teleworking and telecommunicating practices with flexi-hours and high mobility (Persatuan Industri Komputer dan Multimedia Malaysia (PIKOM), 2014).

Today, the business world and the public are exposed to numerous innovative technologies and applications. As a result, IT capabilities are vital for an organization to grow competitively in the marketplace, and to support the internal organizational processes and functions. In summary, IT plays an essential part in effectively taking hold of every part of today's business that enables innovativeness and advancement.

Thus, IT is an enabler and a motivator for companies that produce IT products and services, as well as for IT users within fields such as banking, insurance, medical, education, manufacturing, logistics, etc. Another prevalent movement within IT is to create a sustainable environment through the utilization of innovative environmentally-friendly IT products and services (Mohd Saleh, 2013).

The idea of Green IT has been presented in Malaysia since year 2008/2009; but, the implementation and usage of Green IT are still at mid of Wave 1, and slowly progressing towards Wave 2. The implementation of Green IT is highly dependent on many factors: size; financial capabilities; internal supports; core competencies; R&D and innovation capabilities; technology adoption; human resources; work culture; and organizational values. This list of factors is not exhaustive.

Typically, larger and multinational corporations (MNCs) are the earliest to implement the latest technologies and innovations with their infusion of the environmentally-friendly concept. By doing so, larger and multinational corporations (MNCs) will continue to remain relevant and competitive in the market. Thus, partnering with an international NGO, such as the Green Computing Initiative (GCI), provides the directions for and possible certifications in Green IT for organizations in Malaysia. These initiatives enable the alignment of IT processes and practices towards achieving environmental sustainability (GreenTech Malaysia, 2009; Malaysian Administrative Modernisation and Management Planning Unit (MAMPU), 2007).

In addition, the Frost & Sullivan Institute has derived the following nine technological areas which organizations around the globe must take into consideration as part of the green growth movement (Mohd Saleh, 2013):

- pervasive computing
- green innovation to zero [carbon emissions]
- smart infrastructure
- pay as you use
- preventive health care
- rise of the machine
- real time and all time
- flexible manufacturing
- cyber warfare

2.9 Tenth Malaysia Plan (2010–2015)

In the Tenth Malaysia Plan (2011–2015), the significance of environmental sustainability was perceived as a major aspect of social and economic development (Economic Planning Unit, Prime Minister’s Department, 2010). The environmental sustainability focus was particularly on climate change, environmental degradation and the sustainable utilization of natural resources. A target was set by the Malaysian Government to voluntarily reduce GhG emissions by 40% by 2020 (Kementerian Tenaga Teknologi Hijau dan Air (KeTTHA), 2013). By the end of 2013, Malaysia had accomplished a 33% reduction in GhG emissions.

The energy sector is the major contributor of GhG emissions; thus, the *Renewable Energy Act 2011* was enacted to promote the increased use of clean, environmentally-friendly and renewable sources of energy using solar photovoltaic (PV) cells, biomass, biogas and mini hydro for the power generation mix in Malaysia. Furthermore, another initiative was introduced known as the feed-in tariff (FiT) for renewable energy (RE) which has reduced GhG emissions by 432,000 tonnes of carbon dioxide equivalent (tCO_2e).

The Minimum Energy Performance Standard (MEPS) for electrical appliances, the Sustainability Achieved via Energy Efficiency (SAVE) programme and the phasing out of hydrochlorofluorocarbon (HCFC) substances in devices have been introduced to reduce electricity consumption. The retrofitting of four government buildings has also reduced monthly electricity usage by between 4% and 19%.

Apart from the energy sector, initiatives have been carried out for the transportation/logistics sector to control emissions from motor vehicles; thus, the use of energy-efficient vehicles and biofuels is encouraged. Emissions of GhGs can be reduced with proper waste management, for example: (1) oil palm fruit conversion to energy; (2) paper recycling; and (3) the Reuse, Reduce and Recycle (3R) programme.

In supporting the waste-to-health initiatives, a guideline known as the National Biomass Strategy 2020 was launched to assist businesses in Malaysia to utilize agricultural biomass waste to produce high-value products for local and export use. Furthermore, the forest areas in Pahang, Perak and Selangor states are gazetted as Permanent Reserved Forest which has contributed to a GhG emission reduction of 11.8 million tCO_2e.

In addition, the Malaysian Government introduced a Green Technology Financial Scheme (GTFS) that has contributed to a GhG emission reduction of 93,000 tCO_2e. The development of green products in Malaysia is further encouraged with the introduction of eco-label licenses to recognize products that have minimum or no impact on the environment. Moreover, in 2013, the MyCarbon Reporting programme was introduced to encourage and guide businesses to measure and report GhG emissions, and to identify possible actions to take for rectification. This reporting programme is voluntary in nature.

The initiatives on green growth and environmental sustainability are part of the Economic Transformation Programme (ETP). The most relevant sectors to the current study are the manufacturing sector and the IT sector. With the inclusion of innovative programmes, strategies and standards, it is expected that the manufacturing sector will grow 4.8% per annum and will contribute 23% of GDP by 2015.

The sub-sector in the manufacturing sector that makes the largest contribution is electrical and electronics (E&E) with the development of new applications and technologies in digitalization, mobility, connectivity, energy efficiency and miniaturization. The second largest is the chemicals sub-sector which is experiencing increasing demands for chemical products in areas such as automotive E&E, medical, pharmaceuticals and construction. The IT sector is the primary area of growth in the services sector in Malaysia at 6.3% per annum and, in terms of GDP, making a 53% contribution.

The Tenth Malaysia Plan (2010-2015) focused on the aspirations of both the Government Transformation Programme and the New Economic Model towards a progressive high-income and sustainable nation, as envisioned in Vision 2020. The Eleventh Malaysia Plan (2016-2020) is the final leg in the journey towards realizing Vision 2020. The Eleventh Plan is based on the theme “anchoring growth on people” and has six strategic thrusts and six game changers that will transform Malaysia towards the end state of being an advanced economy, inclusive and sustainable nation. The Tenth Malaysia Plan and Eleventh upholds the principles of 1Malaysia: People First, Performance Now.

2.10 Eleventh Malaysia Plan (2016–2020)

With acknowledgement of the accomplishments at that point, the Eleventh Malaysia Plan (2016–2020) was launched to achieve the realization of Vision 2020. The aim of Vision 2020 is to create a completely developed nation with stability in the economy and politics, as well as spiritually, psychologically and culturally. The Eleventh Malaysia Plan sets out the momentous journey for Malaysia towards becoming an advanced and sustainable nation with the theme of “anchoring growth on people”. To achieve the theme, the plan consists of six strategic thrusts and six game changers as described below (Economic Planning Unit, Prime Minister’s Department, 2015).

i. Thrusts:

- Enhancing inclusiveness towards an equitable society
- Improving well-being for all
- Accelerating human capital development for an advanced nation
- Pursuing green growth for sustainability and resilience
- Strengthening infrastructure to support economic expansion
- Re-engineering economic growth for greater prosperity

ii. Game changers:

- Unlocking the potential of productivity
- Uplifting the bottom 40% household income group (B40 household) from poverty and socio-economic imbalances to move towards a middle-class society
- Enabling industry-led technical and vocational education and training (TVET)
- Embarking on green growth
- Translating innovation to wealth
- Investing in competitive cities

For this study, the most relevant thrust is “pursuing green growth for sustainability and resilience”, while the game changer of most relevance is “embarking on green growth”.

In the Eleventh Malaysia Plan, green growth is defined as resource-efficient, clean and resilient. The focus is on acting in a sustainable manner from the very first step instead of utilizing the conventional and costly model of ‘grow first, clean up later’. This reveals Malaysia’s commitment to protecting the environment and its natural endowment for present and future generations, despite the intense challenge of balancing the growth of modernization, population and ecological concerns.

Thus, implementing green growth is an imperative action for Malaysia which requires a major reshuffle and changes to policies, legislation, human capital, green technology investment and financial strength, as well as values and belief systems. Furthermore, the shift towards sustainable consumption and production increases the utilization of energy-efficient technologies as well as that of low-carbon buildings, transport products and services.

In addition, a measurement framework on climate change, disaster risk management and conservation of natural resources will be introduced to reduce GhG emissions and increase the protection of terrestrial and inland waters as well as coastal and marine ecosystems.

The Malaysian Government has introduced a transformative green growth strategy framework with four focus areas that will lead to sustainable and resilient development which are listed as follows (Economic Planning Unit, Prime Minister's Department, 2015):

- Focus area A: Strengthening the enabling environment for green growth
- Focus area B: Adopting the sustainable consumption and production concept
- Focus area C: Conserving natural resources for present and future generations
- Focus area D: Strengthening resilience against climate change and natural disasters.

Therefore, green growth is not only a strategic thrust, but it is also a game changer as it focuses on the three pillars of sustainable development, namely, economic, social and environment.

With the establishment of the Eleventh Malaysia Plan, the manufacturing sector is moving towards high-value, diverse and complex products with support and interlinkages of various manufacturing sub-sectors. The manufacturing sector will grow at 5.1% per annum and will contribute up to 22.1% GDP and 18.2% of total employment by 2020. The evolution of the manufacturing sector is significantly dependent on sustainable manufacturing practices, improved R&D activities and compliance with global standards and legislation, as well as on close collaboration between stakeholders.

The IT sector will be the niche area on which to focus as a producer/exporter of IT products and services as well as being an enabler that supports users in other sectors. The nine identified areas of IT are: digital content; the Internet of Things (IoT); data centres and cloud services; cyber security; software development and testing; and big data analytics (Economic Planning Unit, Prime Minister's Department, 2015). These areas will attract and convert companies to anchor the building of local capacity and capability that will increase access to global markets through adopting a new business model by applying the greener concept.

2.11 Manufacturing Chronology

The advent of supply chain support for manufacturing occurred long ago at the time known as the Agrarian Period, well before the term was coined in the 1980s. Artisans represented some of the first innovators of products required by customers with their businesses consisting of relatively small, family-oriented (organic) firms with flat hierarchies (Nelson, Marsillac, & Rao, 2012).

In the Industrial Revolution era, the establishment of high-volume production with capital-intensive use of machinery and assembly lines took place through utilizing command-and-control logic technology. Manufacturers typically produced standardized products in mass volumes with limited product lines and lengthy production runs which increased the time required for changeover to new products (Nelson et al., 2012). At that time, minimization of waste was based on economics (less expenses/higher income) with little or no attempt to reduce environmental pollution resulting from manufacturing (Sarkis, Zhu, & Lai, 2011).

The Post-Industrial Revolution then emerged to address the rapidly changing market conditions from both customer and supplier perspectives. Manufacturing firms faced a paradigm change from industrial systems (mass production and reduced cost) to post-industrial systems (quick response with a variety of high-quality products and varying customer demands) (Nelson et al., 2012).

During the era of the Post-Industrial Revolution, societies became more affluent and modernized, thus creating customers who were more demanding and selective (Nelson et al., 2012). The complexity of supply chains increased in which competition no longer occurred between large individual firms, but between supply chain partners themselves (Suhong, Ragu-Nathan, Ragu-Nathan, & Subba Rao, 2006). Leading companies began to focus on broadening their business through a greater range of products, shorter production time and shorter time required for product shifts.

2.12 Supply Chain Chronology

With the evolution of industrialization, supply chains are differentiated based on the type of products manufactured, customers' influences, market demands and changes in technology. The types of product manufactured were divided into standard, innovative, hybrid and green (Lambert & Cooper, 2000; Nelson et al., 2012), while the levels of change in customer markets, demands and technology were categorized as standard, lean, agile, hybrid and green. In addition, the product life cycle was defined as the complete lifespan of a product, from cradle to grave, including all the product's costs (burdens) and benefits.

The product life cycle consists of six phases which are as follows (Nelson et al., 2012):

1. Cradle: inception, design, acquisition of raw materials and general factory set-up for manufacturing.
2. Introduction: accommodate either a new requirement (innovative product) or existing need (revision of standard product).
3. Growth: evolution of the product, demand and consumer acceptance that leads to improved market share.
4. Maturity: progress to product maturity, and possibility of competitors imitating the innovator's products at a lower cost.
5. Decline: reduced consumer demands that result in lower sales and decreased margins.
6. Grave: focused on product and component reuse/recycle, waste stream types and legal liabilities, as well as potential penalties for poor management of waste disposal.

Thus, products manufactured with different design and demand schemes are highly dependent on their relative phase in the product life cycle (Nelson et al., 2012):

1. Standard products: stable demand with slower change in both design and production, thus purchases tend to be periodic, rather than continuous.
2. Innovative products: unstable designs, frequent changes in customer needs, reflecting new or derivative products that require continuous customer involvement at any stage of the product life cycle.
3. Hybrid products: higher complexity with increase in the number and range of components required.
4. Green products: highest complexity as based on the hybrid concept and certified as environmentally-conscious products.

The different types of supply chains that emerged progressively are categorized into standard, lean, agile, hybrid and green (Nelson et al., 2012):

1. Standard supply chain: produces the products wanted by the customer, with little regard to flexibility or conservation of resources.
2. Lean supply chain: concern is on continuous improvement, elimination of waste and non-value steps along the supply chain. At the same time, simplicity, cost reduction, quality and limited flexibility are taken into consideration.
3. Agile supply chain: takes advantage of unpredictable market shifts while capitalizing through fast delivery, lead-time flexibility and utilization of new tools/technologies to resolve unanticipated issues.
4. Hybrid supply chain: this combination of agile and lean supply chains acts as an intermediary that exhibits the concept of ‘assemble to order’, with higher accuracy and shorter time in transporting products.
5. Green supply chain: has evolved with additional requirements encompassing environmental compliance throughout the entire lifespan of the product from inception/design (cradle) to disposal/reuse (grave) (Srivastava, 2007).

2.13 Green Supply Chain Management (GSCM)

Green supply chain management (GSCM) evolved from the hybrid category, as previously discussed. The goal of GSCM is continuous compliance with all relevant environmental regulations and continuous improvement at every stage: development, manufacturing, use, recycling, reuse and re-introduction of products (Nelson et al., 2012; Sarkis, 1999). Included in GSCM are inbound logistics and procurement, materials management, outbound logistics, packaging and reverse logistics.

The roots of GSCM are derived from both environmental management and SCM literature; thus, adding the 'green' component to SCM involves addressing its influence and relationships with the natural environment (Hervani, Helms, & Sarkis, 2005). Furthermore, GSCM is defined as the integration of environmental thinking into SCM that is focused on product design, materials sourcing and selection, manufacturing processes and delivery of the final product to consumers as well as end-of-life (EOL) management of the product after its useful life (Srivastava, 2007). Even though the concept of GSCM is to address an organization's internal supply chain, many of these operational elements involve linking to the external processes of other organizations (Q. Zhu et al., 2008a, 2008b).

Thus, the scope of GSCM ranges from reactive monitoring of general environmental management programmes to more proactive practices implemented for green design (marketing and engineering); green procurement (e.g. certifying suppliers, purchasing environmentally-sound materials/products); environmental management (internal performance measurement, pollution prevention); green packaging; green logistics as well as end-of-life (EOL) practices based on the Rs concept (Reduce; Reuse; Rework; Refurbish; Reclaim; Recycle; Remanufacture; Reverse logistics).

In summary, the concept of GSCM has been envisaged from the perspective of the product life cycle, taking into consideration the entire process from raw materials, product design and manufacturing, product sales and transportation, product use and recycling of products. With the help of green philosophy and conventional SCM principles, environmental issues could be reduced by many organizations as illustrated in Figure 2.1 below (Ekane & Nshimirimana, 2012).

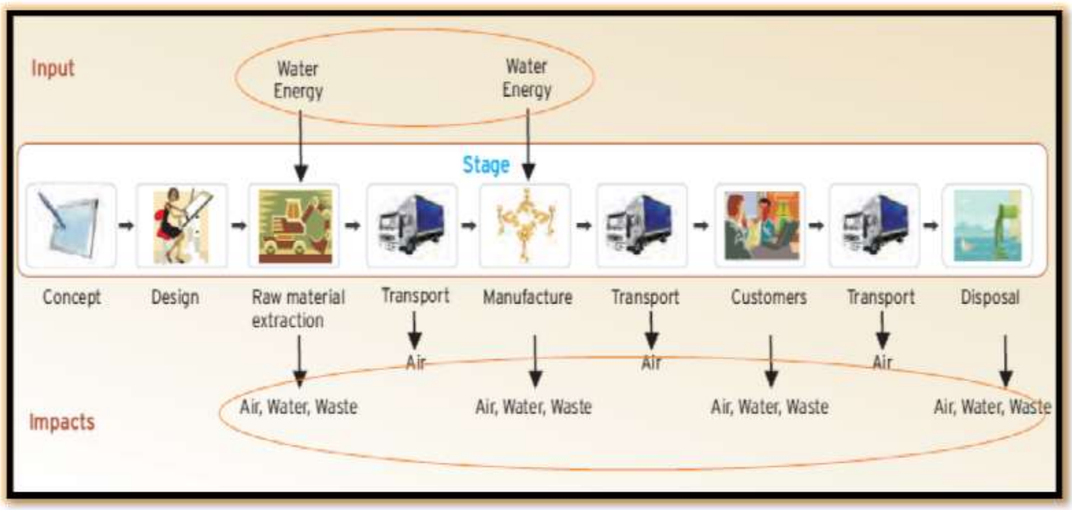


Figure 2.1: Environmental Impact at Each Stage of Supply Chain

Figure 2.1 illustrates the activities involved in a conventional supply chain from the concept to the disposal stage, and how these activities negatively impact on the environment. From the input stage, constant usage of energy and water occurs, particularly at the raw material extraction stage as well as at the manufacturing stage in which the product is being developed. The environmental impacts (and types of impact) can be seen at the various stages of the supply chain. Common impacts are air, water and waste pollution that come from raw material extraction, manufacturing, customer use and disposal stages of the supply chain as well as air pollution from the transport stage. These activities are responsible for environmental degradation; thus, the application of the GSCM principle is deemed necessary to curb these negative effects on the environment.

The three GSCM approaches, namely, reactive, proactive and value-seeking are described below (Srivastava, 2007):

1. Reactive approach: Companies commit minimal resources to environmental management, start labelling products that are recyclable and use ‘end-of-pipeline’ initiatives to lower the environmental impact of production.

2. Proactive approach: Companies start to comply with new environmental laws initiating the recycling of products and designing green products.
3. Value-seeking approach: Companies integrate environmental activities, such as green purchasing and ISO implementation, as strategic initiatives in their business strategy.

The boundaries of GSCM research are dependent on the researchers' goals and the problems at hand (Lai, Ngai, & Cheng, 2004). Based on the previous literature as presented in Appendix A, GSCM practices are inclusive of:

- Agi & Nishant (2017): 'GSCM Practices'
- Islam, Karia, Fauzi, & Soliman (2017): 'Green design', 'Green procurement', 'Green manufacturing', 'Green packaging', 'Green logistics', 'Green outsourcing', 'Green warehousing', 'Reverse logistics'
- Luthra et al. (2014): 'Green design', 'Green purchasing', 'Green production', 'Green management', 'Green marketing', 'Green logistics'
- X. Huang, Tan, & Ding (2015): 'Design and materials selection', 'Manufacturing', 'Use', 'Distribution', 'End-of-life (EOL) management'
- Kuei, Madu, Chow, & Chen (2015): 'Upstream (green purchasing, collaboration with suppliers and green design)', 'Focal (green-related programmes)', 'Downstream firms (collaboration with customers, green packaging, green product portfolio and reverse logistics)'
- Jabbour, Jabbour, Govindan, Kannan, & Arantes (2014): 'Internal environmental management', 'Green purchasing', 'Cooperation with customers', 'Eco-design', 'Investment recovery'
- Ab Talib & Muniandy (2013): 'Green purchasing', 'Green materials management', 'Green distribution', 'Green reverse logistics'
- Zailani et al. (2012) and Eltayeb et al. (2010): 'Eco-design', 'Green purchasing', 'Suppliers' environmental collaboration', 'Customers' environmental collaboration', 'Reverse logistics'
- Rusli et al. (2012): 'Green business strategy', 'Green purchasing', 'Internal green practices of supply chain', 'Eco-design', 'Reverse logistics', 'Cooperate with supply chain partners'

- Nelson et al. (2012): 'Green design', 'Green operation', 'Green manufacturing and remanufacturing', 'Reverse logistics and network design', 'Waste management'
- Green, Zelbst, Meacham, & Bhadauria (2012): 'Green purchasing', 'Eco-design', 'Investment recovery'
- Ekane & Nshimirimana (2012): 'Green procurement', 'Green manufacturing', 'Green distribution', 'Reverse logistics'

2.14 Drivers for Green Supply Chain Management (GSCM) Implementation

The review on drivers and enablers that influence GSCM implementation for organizations are presented in the works of several researchers (Luthra, Garg, & Haleem, 2014; Abu Seman, Zakuan, Jusoh, & Md Arif, 2012). These research papers consist of previous studies on GSCM from 2005 to 2011 from various industries and countries. The latest 23 research papers from 2012 to 2017 on drivers that influence GSCM implementation are presented Appendix A. The research papers have assisted in the formulation of the research framework and research hypotheses for this study. The list of factors that influence an adoption, acceptance or implementation of an innovation may vary between research domains.

For GSCM implementation, prior research categorized the factors, drivers or enablers into internal and external. The internal represent the organizational context and external represent the environmental context. Based on analysis from previous studies, the most influential internal factor is internal management which comprises of:

- Agi & Nishant (2017): 'Top management commitment', 'Employees' education and training', 'Employees' empowerment, involvement and incentives'
- Islam et al. (2017): 'Internal management support'
- Luthra et al. (2014): 'Internal management'
- Hwang, Huang, & Wu (2016): 'Organizational resources', 'Internal stakeholders'

- Stremlau & Tao (2016): ‘People’, ‘Organizational’, ‘Resources’, ‘Strategic’, ‘Adminstrative’
- X. Huang, Tan, & Ding (2015): ‘Personal and individual employees’ commitment’, ‘Involvement and support from top to bottom’, ‘Internal recognition and support’, ‘Internal environmentally-friendly image’, ‘Desire to reduce costs and save energy’
- Kohli & Hawkins (2015): ‘Internal readiness’
- Mohd Rozar, Wan Mahmood, Ibrahim, & Razik (2015): ‘Top management commitment’, ‘Involvement/training of employees’, ‘Ensure employee commitment’, ‘Ensure training needs and attendance by topic’
- Kuei et al. (2015): ‘organizational support’, ‘quality of human resources’
- Jabbour et al. (2014): ‘Top management support’, ‘Organizational structure for environmental management’, ‘Interaction with other functional areas’
- Schrettle, Hinz, Scherrer-Rathje, & Friedli (2014): ‘Strategy’, ‘Resource base’
- Dubey, Gunasekaran, & Samar (2014): ‘Leadership’
- Ab Talib & Muniandy (2013): ‘Human resource’
- Conding, Habidin, Mohd Zubir, Hashim & Sri Lanang (2013): ‘Internal environmental management’
- G.-C. Wu et al. (2012): ‘Organizational support’
- More & Mitra (2012): ‘Human resources related’
- Rusli et al. (2012): ‘Commitment and support from top management’
- Green et al. (2012): ‘Internal environmental management’
- Guang, Lenny, Baldwin, & Cucchiella (2012): ‘Intra-organizational environmental practices (internal resources and strategy)’
- Ekane & Nshimirimana (2012): ‘Understanding and support of top management’, ‘Cross-functional integration’
- Moorthy, Yacob, Chelliah, & Lawrence (2012): ‘Resources, motivation and knowledge’

The most influential external factor is regulatory pressure which includes the following:

- Luthra et al. (2014): ‘Regulatory’
- Hwang, Huang, & Wu (2016): ‘Government regulation’
- Stremlau & Tao (2016): ‘Government policies and incentives’
- X. Huang, Tan, & Ding (2015): ‘Pressure from regulations’
- Kohli & Hawkins (2015): ‘Government regulation’
- Kuei et al. (2015): ‘Regulatory pressure’, ‘government support’
- Schrettle, Hinz, Scherrer-Rathje, & Friedli (2014): ‘Environmental regulations’
- Dubey, Gunasekaran, & Samar (2014): ‘Regulatory pressure’
- Ab Talib & Muniandy (2013): ‘Government support’
- Zailani et al. (2012): ‘Regulations and incentives’, ‘Threat of legislation with non-compliance’, ‘Parent company’s environmental standards’, ‘Government environmental inspections’, ‘Government environmental regulations’
- Eltayeb et al. (2010): ‘Regulations’
- G.-C. Wu et al. (2012): ‘Government involvement’, ‘Regulatory pressure’
- More & Mitra (2012): ‘Stronger governmental regulations (ILO, GATT, WTO, EU, national laws)’, ‘National green regulatory compliance’, ‘Investors’ demands for socially responsible investment (SRI); Dow Jones Sustainability Index (DJSI)’, ‘Global environmental legislation’ , ‘Government subsidies for green initiatives’
- Rusli et al. (2012): ‘Compliance with the law and regulations’
- Nelson et al. (2012): ‘Compliance with environmental regulations (from mandatory and voluntary perspectives)’, ‘Compliance with appropriate standards, such as governmental standards, and voluntary industry standards, such as ISO 14001’
- Moorthy, Yacob, Chelliah, & Lawrence (2012): ‘Legislation’

IT and IS are considered as factors that drive and support the implementation of an innovation, however, only few studies take IT/IS or Green IT/Green IS into consideration. From the analysis of the 23 research, only eight studies included technological factors, which are in:

- Agi & Nishant (2017): 'Technological capabilities', 'Use of information technology (IT)'
- Islam et al. (2017): 'Green information technology and systems (GITS)'
- Mohd Rozar, Wan Mahmood, Ibrahim, & Razik (2015): 'Ascertain identity of provider of choice and use information systems (IS) to inform'
- Conding, Habidin, Mohd Zubir, Hashim & Sri Lanang (2013): 'Technology integration'
- Ab Talib & Muniandy (2013): 'Information technology (IT) and information systems (IS)';
- Green et al. (2012): 'Green information systems (IS)'
- More & Mitra (2012): 'Use of latest technology, such as IT, automation'
- Nelson et al. (2012): 'Information systems (IS)/software'

The use of IT and technological capabilities is gaining more attention as a factor and a practice within supply chains. Supply chain activities are multipliers of energy costs and carbon emissions (Smith-Gillespie & Chang, 2016), and with the escalating rate of IT usage, these activities are responsible for higher energy usage with more detrimental effects to the environment (Löser, 2015). Both IT and IS are often not allocated the right ownership and are ignored by organizations in their assessment of their environmental footprints (A. H. Huang, 2008). The carbon emissions from technology adoption remain a secondary concern; thus, cutting emissions quickly lacks a sense of urgency which is also lacking in relevant policies and standards (Jenkin et al., 2011). From the review of the literature summarised in Appendix A, little research has been undertaken on the role of Green IT and Green IS as a factor or a practice within the supply chain.

2.15 Role of Green Information Technology (Green IT) and Green Information Systems (Green IS) in Environmental Sustainability

The electronics boom throughout the last few decades has witnessed the increased use of IT and IS which is growing faster than anticipated. Organizations are heavily dependent on IT and IS to leverage and excel in their productivity and market competitiveness. Figure 2.2 illustrates the use of IT and IS to support daily supply chain activities.

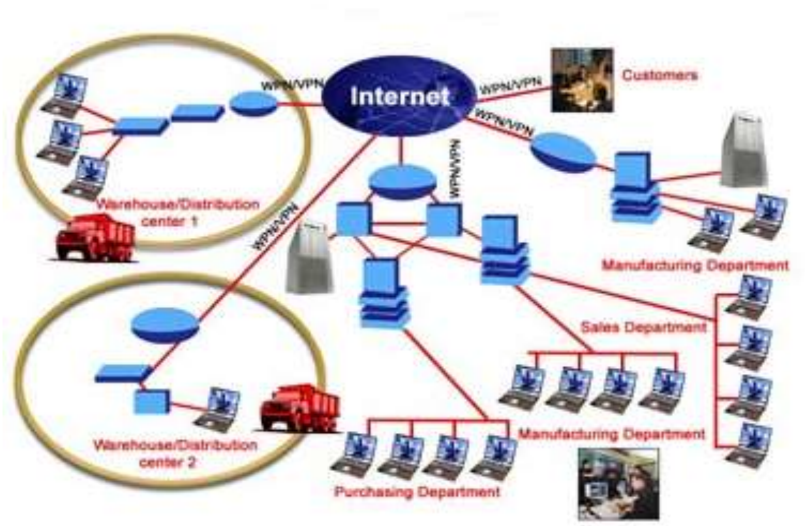


Figure 2.2: Use of Information Technologies and Information Systems to Support Daily Supply Chain Activities

Source: https://www.slideshare.net/anandjha123/role-of-information-technology-in-supply-chain-management

The literature suggests that environmental, organizational, regulatory–market and socio-cultural forces have a much stronger influence on the organization's behavior towards environment sustainability compared to technological force (Jenkin et al., 2011). An alarming request has now been made to minimize the direct and indirect effects from the exploding use of IT and IS (Global e-Sustainability Initiative (GeSI), 2012, 2015; Climate Group (The) & Global e-Sustainability Initiative (GeSI), 2008).

The daily use of IT and IS seems to have no environmental impact to the human eye because IT and IS do not produce direct harmful effects (Löser, 2015). However, the high utilization of IT and IS has a detrimental influence on the environmental footprint. Each stage of a computer's life from production and use through to disposal presents environmental challenges. Most IT products have short lifespans that lead to a huge quantity of unwanted electronic products referred to as e-waste. This e-waste contains heavy metals (lead, mercury, cadmium and beryllium) and other hazardous chemicals which end up in landfill and then contaminate water.

Furthermore, the high consumption of electricity to power up these technologies, systems and infrastructures has contributed to carbon emissions and pollution (Joumaa & Kadry, 2011; Murugesan, 2008; Jenkis et al., 2011). At a global level, the total electrical energy consumption by data centres, servers and computers is steadily increasing (Uddin & Rahman, 2012). The GhG emissions from the aviation, shipping, transportation, telecommunications and manufacturing industries are rising fast, but the emissions from IT are mounting even faster. The continuous increase in these emissions from IT is projected to increase from 3% of total global emissions in 2009 to a huge increase of 6% to 12% by 2020 (Climate Group (The) & Global e-Sustainability Initiative (GeSI), 2008).

Gartner Inc emphasizes that the IT industry is responsible for about 2% of global CO_2 emissions which is almost equivalent to that of the aviation industry (Gartner Inc, 2007a) while data centres contribute 23% of global IT CO_2 emissions (Gartner Inc, 2007b). The Environmental Protection Authority (EPA) report to the United States (US) Congress in 2007 emphasized that the current (at that time) energy consumption in data centres was leading to an annual increase in the emissions of CO_2 (greenhouse gases [GhGs]) from 42.8 million metric tonnes of carbon dioxide ($MMtCO_2$) in 2007 to 67.9 $MMtCO_2$ in 2011 (Uddin & Rahman, 2012).

Gartner Inc warns that today’s data centres are big energy consumers and are filled with high-density power-hungry IT equipment: if data centre managers remain unaware of these energy problems, they will most probably run the risk of doubling their energy costs between 2005 and 2011. If energy costs continue to double every five years, they will substantially increase to 1600% between 2005 and 2025 (Gartner Inc, 2008). Data centres’ energy use and environmental impact have recently become a significant issue for both operators and policy makers (Uddin & Rahman, 2012).

The energy use from office equipment and lighting can account for up to 2.5 watts and 1.5 watts per square foot of floor space, respectively (Syzdykbayeva, 2009). The electricity needed to power computers, office equipment, servers and related infrastructure worldwide reached 123 billion kilowatts per hour (KWh) which is equivalent to fourteen (14) 1,000 megawatt (MW) power plants (Syzdykbayeva, 2009). Moreover, the large consolidated data centres alone use more than 5% of all electricity consumed in the United States (US) (Bose & Luo, 2011).

Between 2002 and 2020, the number of personal computers (PCs) worldwide is expected to grow from 592 million to more than 4 billion; the emissions of PCs and monitors are predicted to increase from 200 $MMtCO_2e$ to 600 $MMtCO_2e$; the number of servers implemented will sharply increase from 18 million to 122 million; data centre emissions, approximately equal to 76 $MMtCO_2e$ in 2002, will continue to increase to more than triple to reach 259 $MMtCO_2e$ (Ardito & Morisio, 2014).

In addition, the amount of energy required to manufacture a PC amounts to 4250 megajoules (MJ), the energy spent in usage (considering an average usage time of three years) is 1500 MJ, and the overall energy cost (including transport and purchase) is about 7900 MJ. Furthermore, the total energy use strongly depends on the usage amount, timing and time spent. The rise in energy required during usage is due to the increase in consumption of other components of a PC (e.g. graphics cards and memories.) Thus, the overall PC energy consumption from manufacturing through to usage has increased over the last 10 years (Ardito & Morisio, 2014).

Organizations have the ability to reduce the harmful effects of IT and IS on the environment by going green (Jenkin et al., 2011) which means being environmentally- or ecologically-friendly. Thus, the adoption of Green IT and Green IS addresses two overarching and interrelated goals which, firstly, help a business to mitigate IT’s direct contribution to CO_2 emissions and, secondly, by using IS solutions, tackles and reduces the business’s overall environmental footprint (Faucheux & Nicolaï, 2011).

As innovative technologies continue to emerge, the potential of these technologies needs to be explored for improving supply chain performance and environmental sustainability. The organization's environmental policies and frameworks must include Green IT and Green IS which will contribute to benefits including the following (Uddin & Rahman, 2012):

- Reduction of organizations' overall energy costs and carbon emissions as well as easier and more appropriate disposal of waste and toxic hardware.
- Extension of the life of existing data centre equipment with the advantage of achieving energy efficiencies.
- Reduction of IT maintenance activities and costs which, overall, will improve the image of the organization.
- Entitlement to pricing incentives, tax breaks and rebates offered by utility companies, insurance companies and governments.
- Preparation for compliance with future regulations and certification.

Mr. Sam Soo Pyo, President of the Technology Strategy Office in Korea Telecom (KT) presented on the "ICT Role for Green Growth" during the 2009 International Symposium on ICTs and Climate Change. According to Mr Pyo, reductions in carbon emissions from ICT can be categorized as: green office, green energy and green infrastructure as outlined below (Pyo, 2009):

1. Green office
   - Light-emitting diode (LED) lighting
   - Video conferencing
   - Paperless
2. Green energy
   - Solar panel power plants
   - Geothermal air conditioning
3. Green infrastructure
   - All Internet Protocol (IP)-based backbone concentrator nodes (BcNs)
   - Green insulation-displacement contacts (IDCs)

Large reductions can be achieved through the use of Green IT and Green IS in key economic sectors, such as manufacturing, with five times greater savings compared to the IT sector (Uddin & Rahman, 2012). Thus, many opportunities exist for IT companies to enable the environmental sustainability of other industries by providing Green IT and Green IS solutions that reduce materials consumption, carbon emissions, and energy use in business and supply chain processes (Molla, 2013).

Green IT and Green IS serve as enablers for energy conservation, emission abatement, waste minimization, resource efficiency, cost cutting, and optimization of internal business processes and production processes as well as product innovation (Molla, Pittayachawan, Corbitt, & Deng, 2009; Elliot & Binney, 2008; James, Ghobadian, Viney, & Liu, 1999; Kuo & Dick, 2009; Löser, 2015; Sayeed & Gill, 2008). For example, cloud computing provides massively scalable computing power that offers software, infrastructure, platforms and payment arrangements for public, private or hybrid clouds. Cloud computing allows reduction of the carbon footprint while creating differentiation between activities to achieve a competitive edge and greater supply chain performance (Cao, Schniederjans, Triche, & Schniederjans, 2013). Figure 2.3 illustrates the use of Green IT and Green IS in supply chains.

Figure 2.3: Green IT and Green IS Use in Supply Chains

Source: http://smartamerica.org/teams/smart-manufacturing/

The carbon footprint from IT itself is expected to reach 1.25 $GtCO_2e$ in 2030, that is, 1.97% of global emissions. However, as much as 12 $GtCO_2e$ can be minimized with the use of Green IT and Green IS solutions within the IT-enabled sectors, thus unveiling the path to sustainable growth (Global e-Sustainability Initiative (GeSI), 2015). Carbon emissions from other sectors, namely, food, energy, health, education, manufacturing, mobility and logistics, work and business, and housing are 10 times higher than the IT sector's expected footprint in 2030. With green IT-enabled in various sectors, the SMARTer 2030 report predicted a reduction of 20% in global CO_2e emissions by 2030 (Global e-Sustainability Initiative (GeSI), 2015).

Compared to the previous reports, namely, SMART 2020 (Climate Group (The) & Global e-Sustainability Initiative (GeSI), 2008) and SMARTer 2020 (Global e-Sustainability Initiative (GeSI), 2012), in 2015, the latest report of SMARTer 2030 (Global e-Sustainability Initiative (GeSI), 2015) reported that emissions of 12 $GtCO_2e$ could be avoided by using Green IT and Green IS solutions in other sectors, with this being nearly 10 times higher than the carbon footprint of the ICT sector itself by 2030, as illustrated in Figure 2.4. The reduction of carbon emissions and expected improvements in other sectors are to be achieved through the use of Green IT and Green IS solutions and practices (Global e-Sustainability Initiative (GeSI), 2015).

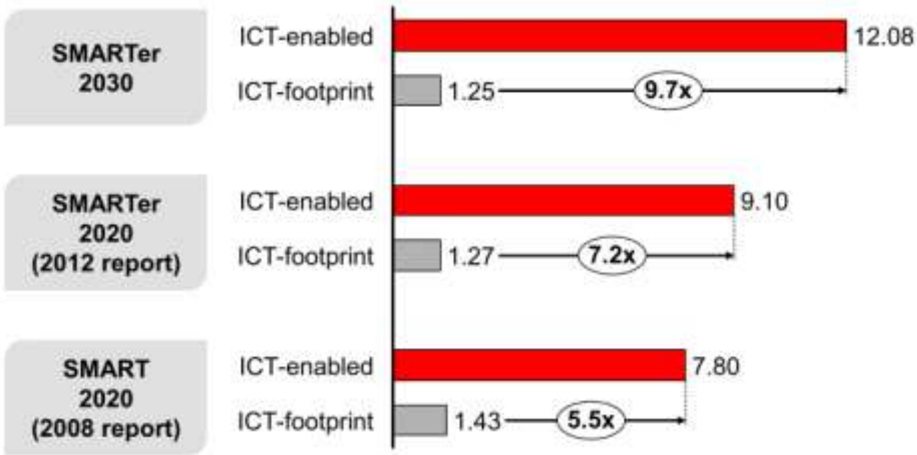


Figure 2.4: Comparison of Previous Reports, SMART 2020 and SMART er2020, with SMARTer 2030 Report

In the current business scenario, ICT-enabled emissions reductions are mostly not considered (Global e-Sustainability Initiative (GeSI), 2015). With the enablement of Green IT and Green IS solutions towards smart manufacturing, the potential savings in carbon emissions reduction in the manufacturing sector are approximately 2.7 $GtCO_2e$, as presented in Figure 2.5.

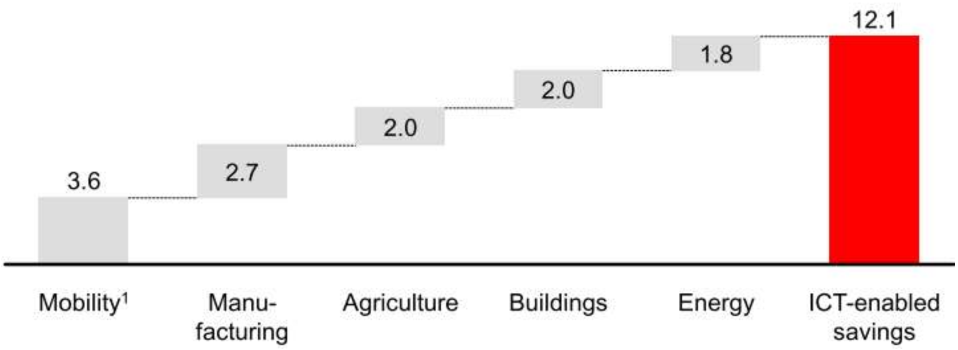


Figure 2.5: ICT-enabled Savings across Sectors

Therefore, a paradigm shift is needed for ecologically-sustainable development with Green IT and Green IS as the enablers to maximize environmental sustainability (Dedrick, 2010; Faucheux & Nicolaï, 2011; Jenkin et al., 2011; Löser, 2015; Melville, 2010; R. T. Watson et al., 2008). Green IT and Green IS solutions can offer disruptive and sustainable business models in various industry sectors (Global e-Sustainability Initiative (GeSI), 2015). With this shift, organizations would be able to reduce carbon emissions, energy consumption, e-waste production and overall environmental impacts.

Despite the benefits that Green IT and Green IS can bring to GSCM, these topics have only been discussed intermittently in the literature (Fiorini & Jabbour, 2017). Only a limited number of studies have investigated Green IT- and Green IS-related issues and outcomes after their implementation (Zaman & Sedera, 2015). Research on Green IT and Green IS adoption and their impacts in other sectors is lacking in research and practice (Global e-Sustainability Initiative (GeSI), 2015; Jenkin et al., 2011; Melville, 2010). Several publications from Asia demonstrate the interest of Asian researchers, yet the number of studies is still limited; therefore, further exploration is required (Fiorini & Jabbour, 2017).

2.16 Performance Outcomes from Green Supply Chain Management (GSCM) Implementation

In some developed countries, GSCM practices are already mature but GSCM is still a relatively new movement for most developing countries. In recent years, a significant increase has occurred in the number of studies on environmental issues in national and international journals (Luthra et al., 2014; Geng, Mansouri, Aktas, & Yen, 2017).

An increasing trend has been observed in the research literature on the implementation and performance measurement of GSCM practices. However, organizational awareness towards GSCM and of the effects of GSCM implementation in achieving environmental sustainability are still low (Luthra et al., 2014). The lack of measurement of sustainable performance has clearly become an obstacle in the success of the firm. The most prevalent dimensions that measure the effects of the firm's actions on environmental sustainability are still being overlooked in many organizations (Hourneaux, Hrdlicka, Gomes, & Kruglianskas, 2014).

Performance measurement is used to assess the degree to which an organization's objectives and desired goals are realized (Hervani et al., 2005). These measures provide a directive or an outcome by which to evaluate the effects of the implementation and to determine future actions or corrective plans (Ramayah, Khor, Ahmad, Abdul Halim & May-Chiun, 2013). Therefore, performance should be properly defined, measured and managed in order to lead the organization to improve its actions, achievement and position in relation to their stakeholders (Atkinson, Waterhouse, & Wells, 1997; Neely, Adams, & Kennerley, 2002). Some companies adopt existing measurement indicators and standards, while others create independent performance control mechanisms to evaluate performance outcomes (Hourneaux et al., 2014).

Despite many ways being available for measuring indicators, controversy still persists on the definition, standardization, usefulness and effectiveness of these indicators (Hourneaux et al., 2014). Many aspects must be taken into consideration for indicator selection, as different internal and external factors have different effects which may vary between organizations, industries and countries.

As mentioned in Johnston and Smith (2001), it is essential for measurement indicators to be relevant, simple, easy to understand, comparable and measurable (Hourneaux et al., 2014). To extend sustainability across the supply chain, it is therefore necessary to adopt the appropriate performance measurement system to identify bottlenecks, improvements in processes, opportunities and successes, with this system to enable tracking, monitoring and benchmarking towards proposed actions for rectification (Ahi & Searcy, 2015; Gunasekaran & Kobu, 2007).

Environmental indicators act as a point of reference for organizations to measure environmentally-friendly practices and solutions (Henri & Journeault, 2008; Hourneaux et al., 2014). To assess environmental performance, reports (e.g. Global Reporting Initiative [GRI]), studies (e.g. life-cycle assessment [LCA], carbon footprint) and/or the measurement of key performance indicators (KPIs) (e.g. eco-efficiency, ISO 14031) can be adopted. Therefore, a well-structured system with a minimum number of required indicators should be set up to achieve a better diffusion of monitoring and assessment (Pimenta & Ball, 2015). The common indicators used to measure environmental performance are: (1) reduction of air emissions; (2) reduction of waste water; (3) reduction of solid wastes; (4) decrease in consumption of hazardous/harmful/toxic materials; (5) decrease in frequency of environmental accidents; and (6) improvement in a company's environmental situation (Shaw, Grant, & Mangan, 2010; Q. Zhu et al., 2007a).

The company Carbon Trust has proposed a useful method for calculating end-to-end supply chain carbon emissions in raw materials production, distribution, manufacturing, product distribution, disposal and recycling. The Carbon Trust Standard measures the organization's impact on environmental sustainability in terms of energy use and GhG (CO_2e) emissions, water use and waste output (Carbon Trust, 2006). The ISO Standard, ISO 14031: 2013 Environmental management – Environmental performance evaluation, provides a set of tools to identify, measure and assess environmental performance using KPIs (International Organization for Standardization (ISO), 2013).

In addition, the Global Reporting Initiative (GRI) provides a flexible framework to enable organizations to report on their economic, environmental and social performance (also known as the triple bottom line [TBL]). In Malaysia, the GRI has organized a Supply Chain Disclosure Working Group to develop recommendations to improve supply chain disclosure in reporting guidelines, with this included in the GRI Guidelines G4 (Suruhanjaya Syarikat Malaysia (SSM), 2013). In addition, ISO 26000: 2010 Guidance on social responsibility serves as a guideline on social responsibility which enables companies to comply with predetermined standards in terms of organizing the communication and activities that will be presented in a report (Suruhanjaya Syarikat Malaysia (SSM), 2013). It will therefore promote the implementation of social responsibility among organizations and stakeholders in Malaysia.

The GSCM drivers, practices and performance outcomes constitute the main building blocks of GSCM implementation (Agi & Nishant, 2017). The literature has demonstrated the outcomes in environmental performance of GSCM implementation. Many studies have shown significant and positive improvements in environmental performance, but the effect of GSCM practices on firm performance has been inconsistent (Tan et al., 2016). Performance outcomes are affected by more than one driver and are subjected to internal and external factors when GSCM practices are implemented (Choi, Min, Joo, & Choi, 2016).

The IT industry and IT/IS researchers have acknowledged the importance of Green IT and Green IS in pursuing environmental sustainability. Perhaps as a consequence, only limited literature and findings have been reported for other industry sectors in comparison to the IT sector (Faucheux & Nicolaï, 2011; Jenkin et al., 2011; Löser et al., 2012; Melville, 2010). Nevertheless, the incorporation of Green IT and Green IS as part of environmentally-friendly practices within the organization’s environmental initiatives is still poorly managed and integrated (Erek, 2011; Löser et al., 2011).

The greening of IT assists in the minimization of environmental impacts through reducing the consumption of power or energy, carbon emissions and electronic waste (e-waste), thus considerably improving the power usage of office equipment, infrastructure, data centre and facilities (Faucheux & Nicolaï, 2011; Molla, Deng, & Corbitt, 2010). Greening of IS improves systems performance and usage and reporting capabilities; increases remote collaboration and interactions that reduce the impacts from logistics; and tracks environmental information (such as toxicity, energy and water usage, and waste production) as well as monitoring and reporting environment baseline inputs (energy, water and materials) and outputs (waste and GhG emissions) (Melville, 2010; R. T. Watson et al., 2008).

Green IT and Green IS comprise a vast number of methods, metrics and perspectives; however, the scope and underlying measures still remain vague and have not been well described (Erek, 2011; Holdener & Waldrip, 2009). Organizations continue to use uncoordinated and inappropriate environmental metrics to measure the environmental impacts of IT in data centres and the office environment as well as in industrial operations (Erek, 2011).

Only a limited number of studies have investigated Green IT- and Green IS-related issues and outcomes after their implementation (Zaman & Sedera, 2015). Studies on the adoption of Green IT and Green IS and their impact on other sectors are lacking in both research and practice (Global e-Sustainability Initiative (GeSI), 2015; Jenkin et al., 2011; Melville, 2010). Several publications from Asia have demonstrated the interest of Asian researchers, but the number of studies remain limited, with further exploration required (Fiorini & Jabbour, 2017).

Consequently, the extent of Green IT adoption and the actual realization of its benefits are unknown to organizations, the government and researchers (Jamaludin, Ahmad, & Ramayah, 2012). Further investigations with empirical evidence are essential in determining the effects and associated outcomes of Green IT and Green IS on GSCM, with this termed ‘technological performance’. Table 2.3 summarizes the previous literature that discusses the effects of GSCM implementation on ecological related performance.

Table 2.3: Environmental Performance from GSCM Implementation

No.	Summary of Findings	Source
1.	Determinants of green supply chain practices have a significant positive association with organizational performance. Organizational performance can be achieved when management successfully implements green practices in the supply chain. Green manufacturing, eco-design, cooperation with customers and green information systems are supported but not green purchasing. Green information systems have been shown to be a statistically significant predictor of organizational performance. A green information system integrates and coordinates across the internal and external supply chain to evaluate the environmental performance of firms.	(Khan & Qianli, 2017)
2.	The results of our meta-analysis indicate that the GSCM practices lead to better performance in three aspects: economic, environmental and operational. GSCM practices showed a positive and significant effect on environmental performance. The adoption of GSCM practices contributed to firm performance, but at various levels. Due to the era of globalization, the adoption of GSCM practices will play a larger role in manufacturing firms in the AEE [Asian emerging economies] not only in reducing environmental impact but also in contributing to firm performance.	(Geng, Mansouri, & Aktas, 2017)
3.	Korean firms' GSCM practices affected manufacturing performance in a positive way but did not necessarily improve their marketing performance. Korean manufacturing firms irrespective of their size are known to be more uniform in implementing environmentally-friendly practices and subsequently are more competitive in the era of green growth. GSCM has emerged as one of the increasingly critical areas of CSR and corporate bottom lines. The surveyed firms' practices were motivated by four distinctive factors: (1) customer; (2) internal management; (3) government regulations; and (4) industry peer (competitor) pressure. The surveyed firms were affected by more than one motivating factor (e.g. a combination of regulatory and competitive pressure) when adopting GSCM practices.	(Choi et al., 2016)

4.	The overall objective of a green supply chain is to reduce the negative environmental impacts (air, water and land pollution) and the waste of resources (energy, materials and products) starting from the extraction of raw materials through to the final usage and delivery of products. The findings can be used by practitioners to analyze their existing performance measurement system (PMS). Therefore, it is important for managers to attend to the diverse measures but also to the challenges related to their deployment.	(Mishra et al., 2017)
5.	Proper internal management and high commitment will help achieve economy in processes. Social factors will contribute to environmental protection and create the awareness level of customers, which will help in increasing the sales of an organization. Compliance with regulations and suppliers/vendors' management activities cost extra funds, that is, a reduction in economic performances. However, regulations that enforce the making of green products by organizations will improve social performances. Social factors will contribute to environmental protection and may help achieve social performance, and competitiveness factors will contribute to environmental protection and improved corporate image. Properly managed and motivated services of internal management towards GSCM will improve environmental performances. Social factors will help in achieving environmental performances through the reduction of air emissions, liquid and solid wastes, etc. Competitiveness factors will motivate organizations to implement GSCM practices which, in turn, will improve environmental performances. Customer management CSFs show a negative relationship. Internal management will optimize and improve operational performance. Organizational operational performances may be enhanced by the motivation of suppliers. Probably, some other areas of business performance (quality, technological advancements, adaptability, flexibility and delivery) could also be investigated.	(Luthra et al., 2014)
6.	GSCM is gaining popularity in the Asian region through external pressure from the European region.	(Tan et al., 2016)

	GSCM is gaining acceptance among manufacturing firms in Malaysia in their quest to improve their environmental performance in their operations. Despite the growth of GSCM practices among firms, there are still many issues pertaining to the implementation that may impede the overall initiatives of firms to improve competitiveness in their organizations. A similar scenario was found in the Malaysian context where industries are still slow in implementing GSCM practices even though they are aware of the importance of GSCM practices to improve firm performance. Greening any phase of the supply chain is claimed to establish a positive relationship with environmental and financial performance, which comes from cost reduction, increased market share and profit. Green production and green purchasing have a positive impact on firm competitiveness. However, the effect of the implementation of GSCM practices on the outcome of firm performance in the body of literature up to now has been inconsistent.	
7.	Much attention is crucial on the importance of GSCM development to effectively create a win-win relationship between environmental performance and economic efficiency throughout the supply chain. Academic research on GSCM for SMEs is still in the development stage and more studies, analyses and discussions are necessary for the development of the theoretical framework of GSCM.	(X. Huang et al., 2015)
8.	GSCM practice is positively linked with environmental management maturity (EMM) and green performance.	(Jabbour et al., 2014; Jabbour, Jabbour, Hengky, Teixeira & Oliveira, 2015).
9.	Purchasing, performance assessment and collaboration must be mutually supportive to achieve environmental sustainability practices across supply chains.	(Pimenta & Ball, 2015)
10.	The adoption of external GSCM practices (cooperation with customers and green purchases) have influence on the environmental performance of the firm. These external GSCM practices also mediate the relationship between environmental management maturity and environmental performance of the firm. In turn, GSCM practices mediate the relationship between the level of environmental management maturity and the green performance of firms.	(Jabbour et al., 2015)

	Thus, GSCM practices influence the green performance of firms.	
11.	The green practice with ISO 14001 certification has a higher impact on environmental sustainability. The green practice of cleaner production has a higher impact on social sustainability.	(Govindan, Azevedo, Carvalho, & Cruz-Machado, 2014)
12.	Internal GSCM practices have a greater relative adoption rate than external GSCM practices. The studied companies are subsidiaries to multinational companies which export their products to developed countries where positive environmental performance from their products is required.	(Jabbour et al., 2014)
13.	Supplier relationship management (SRM) and TQM integration under the influence of leadership and the moderation effect of institutional pressures (coercive pressure, normative pressure and mimetic pressure) help firms to achieve environmental performance. Despite that, the initial impact of regulatory and market pressures on the implementation of TQM is necessary to achieve superior environmental performance.	(Dubey et al., 2014)
14.	GSCM practices are already mature in some developed countries but GSCM is still a relatively new issue for most developing countries. An increasing trend in the implementation GSCM practices and their performance measurement has been observed in the research literature in recent years, yet further investigations are needed. Most performance models reported in the literature are theoretical. This suggests the need for the maturation of these topics and this field with great scope for future study.	(Luthra et al., 2014)
15.	Environmental proactivity (upstream and downstream environmental practices based on cleaner production technologies and environmentally-friendly products) is positively related to operational performance, organizational learning, environmental performance and stakeholder satisfaction.	(Sambasivan, Bah, & Jo-ann, 2013)
16.	The reduction of hazardous materials, as well as remanufacturing and operational assessments can benefit both manufacturers and partners along the supply chain in their implementation of green principles. With this implementation, productivity, improved economic conditions and profit as well as the facilitation of good environmental performance are possible. These are achievements towards sustainability and the triple bottom	(Nelson et al., 2012)

	line (TBL).	
17.	Improvement in environmental performance with GSCM is highly dependent on the successful implementation of internal environmental management practices first, and then external GSCM practices.	(Q. Zhu et al., 2012)
18.	Pressure from regulatory bodies, government bodies and policy makers and support from financial incentives have enabled firms to achieve higher environmental performance levels than is the case with those firms that implement GSCM based on voluntary efforts to protect the environment. However, customer pressure has a slight effect on environmental performance, in some cases, with this largely attributable to strategic decisions made to comply with government/regulatory bodies and incentives.	(Zailani et al., 2012)
19.	The relationship between GSCM practices and environmental performance is positive and significant as expected. The cost-saving nature of environmental performance will lead to improved economic performance. With positive environmental performance and economic performance, operational efficiency can be further enhanced. Therefore, environmental performance and economic performance enhance operational performance which enhances organizational performance.	(Green et al., 2012)
20.	Green purchasing has a positive effect on environmental performance among ISO 14001-certified manufacturing firms in Malaysia.	(Green et al., 2012; Zailani et al., 2012)
21.	GSCM practices influence the green performance of firms, based on the size of the firm.	(González-Benito & González-Benito, 2006; Murillo-Luna, Garcés-Ayerbe, & Rivera-Torres, 2011)
22.	Green product and process innovation are much more effective than green managerial innovation in improving a company's environmental performance.	(Chiou, Chan, Lettice, & Chung, 2011)
23.	GSCM significantly reduces environmental impacts yet it is still dependent on production/manufacturing processes and managerial decisions which are influenced by suppliers, customers and business partners.	(Testa & Iraldo, 2010)
24.	Green procurement, green manufacturing, green distribution and	(Ninlawan, Seksan,

	green logistics are important dimensions of GSCM practices that are needed by the manufacturing sector to achieve improvement in sustainability performance.	Tossapol, & Pilada, 2010)
25.	The regulation, incentive and customer pressure constructs have significant correlation in relation to protecting the environment; however, these initiatives are relatively well established in developed countries, while continuing to lag in developing countries.	(Gonzales, Sakundarini, Ariffin, & Taha, 2010; Shukla, Deshmukh, & Kanda, 2009)
26.	The implementation of GSCM practices has improved green performance and has recognized environmental performance as a source of competitive advantage.	(Wagner, 2005; Yang, Li, & Tan, 2013; Q. Zhu et al., 2007a)
27.	Positive environmental performance is achieved with pressure from environmental regulations and continuous internal efforts to produce green products. In return, improvements in a firm's environmental performance portray its positive image to the community and to other competitors showing that it is an exemplary entity with which to do business or compete.	(Q. Zhu, Sarkis, & Lai, 2007b)
28.	External GSCM practices have a direct and positive impact on environmental performance	(Q. Zhu & Sarkis, 2004)

After reviewing the literature on drivers and outcomes of GSCM implementation, three gaps were identified as illustrated in Figure 2.6.

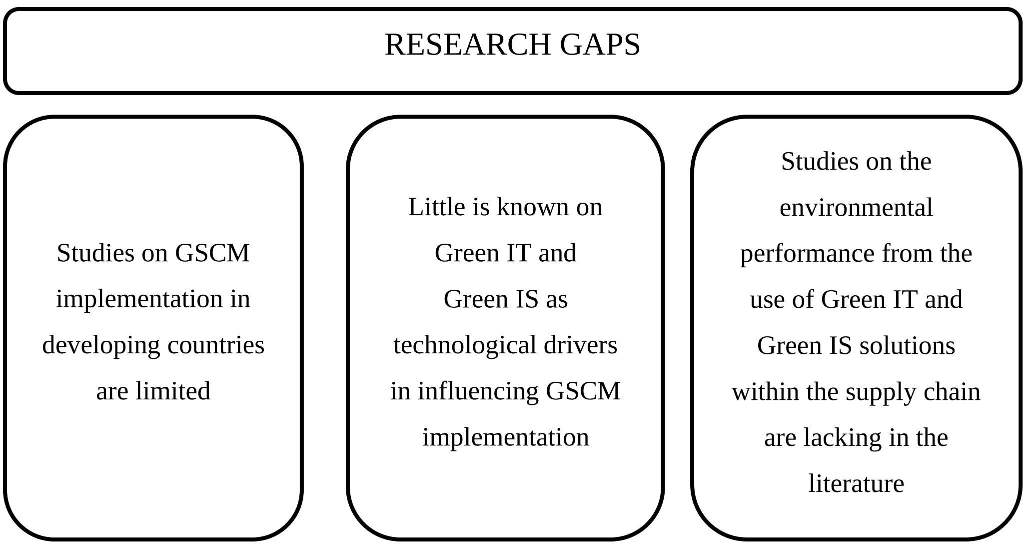


Figure 2.6: Identified Research Gaps

2.17 Chapter Summary

This chapter has discussed environmental sustainability as well as international standards, directives and policies pertaining to environmental management and environmental sustainability. Similarly, directives, policies and guidelines for Malaysia have been reviewed with greater attention given to ISO 14001: 2015; Malaysia's National Green Technology Foresight 2030; Malaysia's National Energy Efficiency Action Plan; Malaysia's Green ICT Guideline; Malaysia's ICT Strategic Review; the Tenth Malaysia Plan; and the Eleventh Malaysia Plan. Next, the chronology of manufacturing and the supply chain were presented. The type of supply chain that interests this study is green supply chain management (GSCM). As drivers, practices and performance outcomes are fundamental building blocks of GSCM, relevant previous studies have been reviewed and summarized.

The GSCM drivers are categorized into internal and external factors. From the review of the literature, another factor that may influence GSCM in achieving environmental sustainability is the utilization of environmentally-friendly information technologies and systems, also known as Green IT and Green IS. Thus, this study is interested in investigating the role of environmentally-friendly information technologies and systems as a driver, and the effect of their use in the supply chain in mitigating environmental issues. The effects from implementing GSCM are commonly measured in terms of environmental, economic and operational performance. This study focuses directly on the effect of GSCM practices in relation to environmental impacts; therefore, environmental performance and the newly introduced performance measurement known as technological performance are incorporated.

The chapter concluded with the identification of three research gaps, namely: (1) studies on GSCM implementation in developing countries is limited; (2) little is known about Green IT and Green IS as technological drivers in influencing GSCM implementation; and (3) studies on the performance outcomes of green supply chain activities and the use of Green IT and Green IS utilization in supply chains are lacking in the literature. The next chapter presents the detailed explanation of the research paradigm and research process.

Chapter 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents the research methodology of the current study. In the next few sections, the following topics are covered: science, scientific research, scientific method, the research paradigm and research process (exploration, design and execution). The exploration stage discusses the research questions and research framework, while the research design stage focuses on operational definitions of the constructs and variables, hypotheses development and survey research as well as survey questionnaire development and administration. Lastly, the execution stage focuses on pre-testing and pilot testing the survey questionnaire, followed by semi-structured interviews conducted with firms' representatives and, finally, the descriptive and multivariate steps taken to test the proposed hypotheses. This chapter concludes with a summary.

3.2 Science, Scientific Research and Scientific Method

Bhattacherjee (2012, p. 1) defines science as "[a] systematic and organized body of knowledge in any area of inquiry that is acquired using the scientific method". Science is categorized into natural sciences and the social sciences. The natural sciences are the sciences of naturally occurring objects or phenomena, while the social sciences are sciences that study people or collections of people, such as groups, firms, societies or economies, and their individual or collective behaviours (Bhattacherjee, 2012). Examples of social science disciplines are psychology (science of human behaviours), sociology (science of social groups) and economics (science of firms, markets and economies).

The aim of science is to create scientific knowledge. Bhattacherjee (2012, p. 2) explains scientific knowledge as “a generalized body of laws and theories to explain a phenomenon or behaviour of interest that are acquired using the scientific method”. Laws focus on observed patterns of phenomena or behaviours, while theories provide systematic explanations of the underlying phenomenon or behaviour. Bhattacherjee (2012, p. 5) describes the scientific method as “a standardized set of techniques for building scientific knowledge, such as how to make valid observations, how to interpret results, and how to generalize those results”.

Scientific research aims to discover laws and to postulate theories that can explain natural or social phenomena or that can build scientific knowledge (Bhattacherjee, 2012). Theories (logic) and evidence (observations) are the two pillars of science; scientific research thus operates at two levels known as the theoretical level and the empirical level. The theoretical level focuses on abstract concepts about a natural or social phenomenon and relationships between these concepts are developed. On the other hand, the empirical level tests theoretical concepts and relationships in terms of their reflection of observations of reality, with the goal of ultimately building improved theories.

In performing scientific research, scientific inquiry is undertaken either through inductive research or deductive research. In inductive research, patterns are sought from several observations of the specific variable of interest through which generalizations are made to formulate a general theory of the nature and behaviour of that variable. In contrast, deductive research narrows down from the general set of propositions to a specific set of testable hypotheses. The concepts and patterns deduced from the theory are tested using new empirical data which may generate novel ideas and new theories. Therefore, inductive research is also called theory-building research, and deductive research is known as theory-testing research. The three types of scientific research are exploratory, descriptive and explanatory.

3.3 Research Paradigm

The technique of thinking, designing and conducting research based on a set of shared assumptions, concepts, values and practices that represent the mental model or frame of reference is known as a paradigm (Bhattacherjee, 2012). The concept of the ‘paradigm’ was introduced by Thomas Kuhn in 1962 with its purpose being to identify patterns of activities which are viewed differently by different persons for the same observed event. The theoretical framework can be defined as a paradigm that comprises the way the study is conducted and interpreted as well as the questions proposed, and the methodology and analysis technique chosen (Mackenzie & Knipe, 2006).

The selection of the research methodology as a means by which to conduct research within the social sciences depends on the paradigm that guides the research activities. The three main philosophical dimensions used to distinguish existing research paradigms are epistemological, ontological and methodological (Tuli, 2010). Epistemology examines the science of knowledge between the one who knows and what is known to guide either the objective or the subjective stance (Fazlıoğulları, 2012). It is based on beliefs about the ways through which to generate, understand and use knowledge that are deemed to be acceptable and valid (Wahyuni, 2012). Ontology is explained as worldwide beliefs about reality and humanity that are unique to a certain theory or paradigm (Fazlıoğulları, 2012). The objectivist perceives the existence of reality as being external and independent of social actors and their interpretations of it, while the subjectivist believes that reality is dependent on social actors and individuals that contribute to social phenomena (Wahyuni, 2012).

Methodology describes the way in which the study is carried out to reveal information and new knowledge gained (Tuli, 2010). It introduces a frame for the research, so it can undertake a research process for each paradigm. This includes the research questions to be determined, the process steps to be applied and the methods to be used.

3.3.1 Positivist Paradigm

The positivist paradigm, representing the quantitative method, explains that social observations have the same intention and should be treated in the same way as in the natural sciences. This approach is used to find out the objective reality which is regulated by natural laws and theories that can be tested. Positivist researchers believe that there is one reality only; therefore, making predictions and exerting control are necessary to correctly understand how it works. Positivists believe that different researchers observing the same factual problem will generate a similar result by carefully using statistical tests and applying a similar research process in investigating a large sample (Creswell, 2014). Their common belief is the existence of a universal generalization that can be applied across contexts.

Positivism sees the social sciences as an organized and objective method for combining deductive logic with precise empirical observations to discover and confirm a set of probabilistic cause-and-effect patterns that can be used to predict general patterns of human activity and to get the closest approximation of reality (Tuli, 2010). Therefore, positivist researchers disregard themselves as important variables in their research, thus remaining detached from the research. The philosophical basis is that the world exists and is knowable, and that researchers can use quantitative methodology to discover it.

Through this orientation, knowledge is a given and must be studied using objective methods. This methodology is objective or detached, with the measuring of variables and testing of hypotheses explaining the general causality. Hence, the research is explained in quantitative terms, on how variables interact, shape events and cause outcomes that are expressed in the form of questions that lead to propositions that are tested in empirical and experimental studies (Tuli, 2010).

The data collection techniques focus on gathering hard data in the form of numbers to enable evidence of the research findings to be presented in quantitative form. With there being only one reality, positivist scholars believe in the power of replication research. Positivists use validity, reliability, objectivity, precision and generalizability to judge the rigour of quantitative studies as they are intended to describe, predict and verify empirical relationships in relatively controlled settings (Fazlıoğulları, 2012; Wahyuni, 2012). Thus, highly standardized tools, such as questionnaires and psychological tests with precisely worded questions, are employed, with statistical tests and multivariate analysis and techniques used for predictions (Tuli, 2010). Consequently, positivist research is most commonly associated with the quantitative research method (Creswell, 2014).

Positivist methods, such as laboratory experiments and survey research, are aimed at theory (or hypothesis) testing which employs a deductive approach to research, starting with a theory and testing theoretical relationships using empirical data (Bhattacherjee, 2012).

3.3.2 Interpretivist or Constructivist Paradigm

In contrast, the qualitative method exemplifies the interpretivist or constructivist paradigm in which the belief is that reality is subjective, multiple and socially constructed by individuals in their minds (Tuli, 2010; Wahyuni, 2012). Reality exists only in the mind of the participant; hence, subjective interaction is the only way to reach the experiences and subjective meanings that are attached to it by people. Therefore, multiple interpretations by different researchers are valid as multiple realities exist in which the one who knows and what is known are dependent on each other (Fazlıoğulları, 2012).

Interpretive researchers do not accept the idea of reality being ‘out there’, as this idea disregards the existence of people. They see reality as a human construct. Therefore, people are considered as participants of the research and not as objects, in comparison to positivist research; thus, the interpretivist paradigm sees the world as constructed, interpreted and experienced by people in their interactions with each other and with wider social systems (Tuli, 2010). The interpretivist or constructivist explains the research using qualitative methodology, immersing themselves in a culture or group by observing its people and their interactions, often participating in activities, interviewing key people, taking life histories, constructing case studies and analysing existing documents or other cultural artefacts (Tuli, 2010). The purpose is to understand a phenomenon, and not to generalize the findings to a population.

Thus, qualitative methodologies are inductive and more concerned with rich descriptions of social constructs in their unique context and a deeper understanding of the research problem. These research findings are usually reported descriptively using words. The interpretivist places emphasis on trustworthiness and credibility as the research aims to explore, investigate, discover, interpret and describe the social realities. Interpretive researchers place strong emphasis on a better understanding of the world through experience, subjective meaning, reporting and quotations of actual dialogue that contain rich, detailed and thick descriptions of real-world situations (Wahyuni, 2012).

The qualitative researcher's goal is to attain an insider's view of the group under study; thus, in-depth interviews, focus group discussions and naturalistic observation are the most widely used data-gathering methods (Tuli, 2010). In interpretivism, data are collected and theoretical insights are derived in developing a theory that is based on the pattern of the data, unlike positivism where the research begins with a theory (Kalof, Dan, & Dietz, 2008). Interpretivism or constructivism are typically seen as an approach to qualitative research (Creswell, 2014).

Interpretive methods, such as action research and ethnography, are aimed at theory building which employs an inductive approach starting with the observed data and attempting to derive a theory about the phenomenon of interest from that data (Bhattacherjee, 2012).

3.3.3 Other Paradigms – Pragmatist and Transformative

The pragmatist paradigm is not committed to any one system of philosophy or view of reality. In pragmatism, the world view arises from actions, situations and consequences rather than antecedent conditions. Pragmatists emphasize the research problem and use all available approaches to understand the problem, as well as using pluralistic approaches to derive knowledge about the problem (Creswell, 2014). Pragmatists do not see the world as an absolute unity.

In their philosophical underpinning for mixed-methods studies, pragmatist researchers look at many approaches for collecting and analysing data rather than subscribing to only one approach (e.g. quantitative or qualitative). Therefore, the pragmatist paradigm opens the door to multiple methods, different world views and different assumptions (Creswell, 2014). By integrating qualitative and quantitative data, pragmatists may help to generate unique insights into a complex social phenomenon, with this not available from either type of data on their own. Hence, mixed-methods design that combines both qualitative and quantitative data is often highly desirable (Bhattacherjee, 2012).

Another world view position, as cited in Creswell (2014), is known as the transformative world view. This world view holds that the research inquiry needs to be intertwined with politics and a political change agenda, an action agenda that may change the lives of participants, the institutions in which individuals work or live, and the researcher's life. The specific focus is on social issues such as empowerment, inequality, oppression, domination, suppression and alienation. Research in the transformative world view links political and social action to inequities that arise from asymmetric power relationships. Such research begins with one of the social issues as the focal point of the study. Transformative research provides a voice for social participants, raising their consciousness or advancing an agenda for change to improve their lives (Creswell, 2014).

Table 3.1 presents the research paradigms as well as corresponding research methods and designs (Creswell, 2014).

Table 3.1: Research Paradigms, Methods and Designs

Quantitative Method	Qualitative Method	Mixed Methods
Positivism/post-positivism	Constructivism (Interpretivism) Transformative	Pragmatism
Surveys and experiments	Phenomenology, grounded theory, ethnography, case study and narrative	Sequential, concurrent and transformative
Predetermined methods	Emerging methods	Both predetermined and emerging methods
Closed-ended questions Instrument-based questions	Open-ended questions	Both open-ended and closed-ended questions
Performance data, attitude data, observational data and census data	Interview data, observation data, document data and audiovisual data	Multiple forms of data drawing on all possibilities
Statistical analysis	Text and image analysis	Statistical and text analysis
Statistical interpretation	Themes and patterns' interpretation	Across databases' interpretation

3.3.4 Justification of Choice of Paradigm

This research applied a *positivist ontology*, *empirical epistemology* and *quantitative methodology*. The philosophical basis of positivism is that the world exists and is knowable with a stable reality; therefore, the researcher can utilize quantitative methodology to predict and discover findings using objective, specific and measurable data.

The first reason is the similarity of previous positivist studies conducted in these domains by renowned scholars. In these domains, with regard to GSCM, Green IT and Green IS studies, the quantitative approach has previously been widely applied. As most previous studies related to these domains have employed the quantitative approach, it is appropriate to assume that the potential audience/researchers will also have the tendency to approach this domain from a quantitative perspective. Moreover, the increased amount of research conducted in these domains indicates the existence of the extant literature, variables, theories and frameworks that assist in the formulation of a research model.

Next, the concepts, variables and hypotheses are chosen and developed before the research begins and remain fixed throughout the research. The research aim is to predict, challenge, explain and generalize findings to different domains. As this research was about the drivers and outcomes of GSCM, it took into consideration Green IT and Green IS that were previously ignored as well as other key internal and external factors. The researcher presumed that these factors could be identified and measured objectively; therefore, for this cross-sectional study, the survey research method was utilized to meet that purpose.

The second reason is that the positivist paradigm permits the researcher to apply the scientific method to support the findings. Deductive logic is utilized for testing or confirming the hypothesis and verifying the theory. Good reliability and validity of the data are achieved through objective data gathering, with the data mathematically as well as statistically analysed using highly standardized tools. For this research, antecedents of the research model are represented by technological (Green IT and Green IS), organizational and environmental drivers which influence GSCM implementation. The effects from implementing GSCM are measured through environmental and technological performance using validated variables and instruments adopted and adapted from previous studies.

The third reason is that positivist scholars believe in the power of replication research as there is only one reality. Thus, in terms of the object, similar research has been identified, studied and presented beforehand. Therefore, quantitative methodology and the deductive approach are adopted to replicate previous research in another context. The research findings arrived at are a reasoned conclusion through logical generalization of a known fact. Hence, a new opportunity exists to replicate the research in the Malaysian context in order to understand drivers and effects from implementing GSCM within ISO 14001-certified manufacturing firms in Malaysia. An avenue is also provided through which to address limitations from previous related studies.

Lastly, the main constructs and variables used in this research are adopted and adapted from accepted definitions and validated instruments of previous studies. The language used in the survey questionnaire and report is objective and formal.

3.4 Research Process

This study employed a research design which is common for positivist, deductive and descriptive-correlational research, as illustrated in Figure 3.1. The research process describes the activities carried out in three phases, namely, Phase 1: Exploration; Phase 2: Research Design; and Phase 3: Research Execution (Bhattacherjee, 2012).

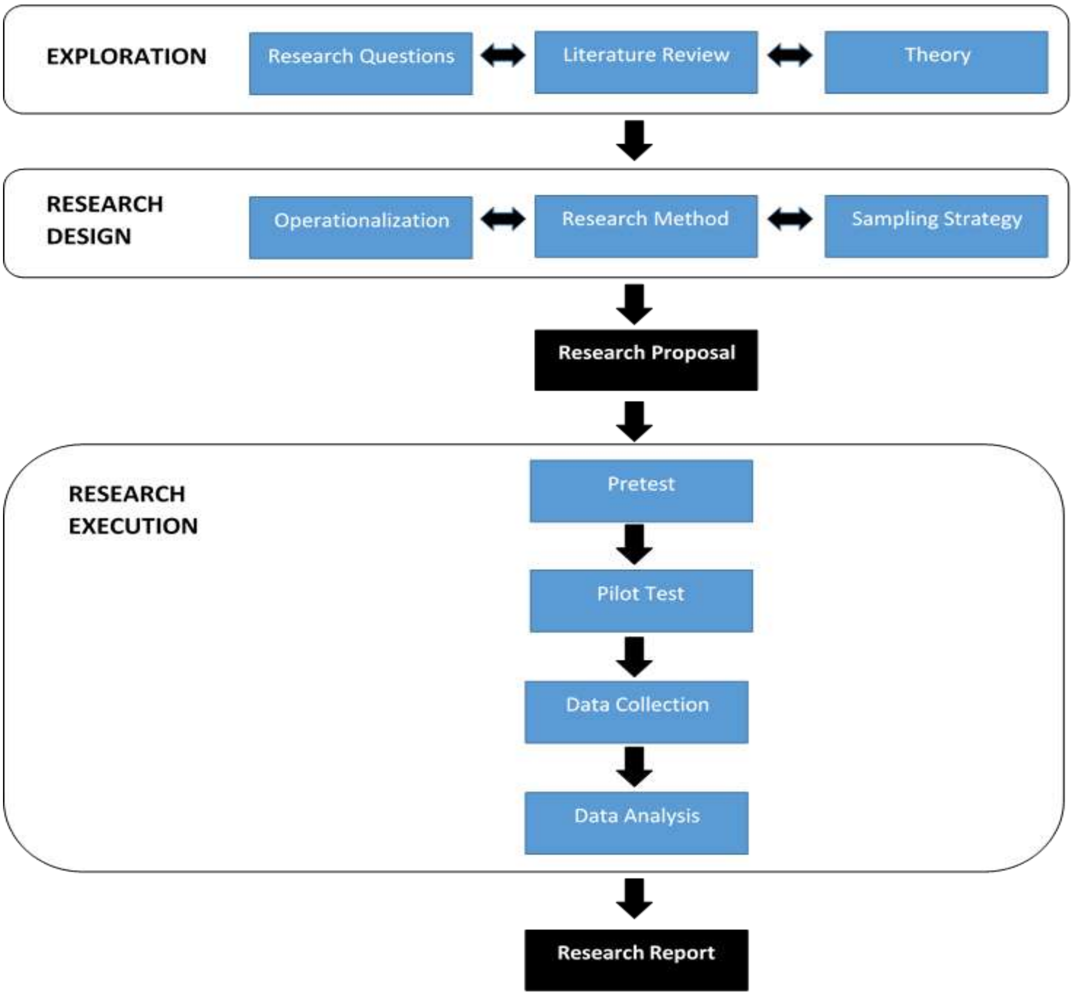


Figure 3.1: Research Design

3.4.1 Phase 1: Exploration

The first phase of research is exploration. This phase comprises exploring and selecting research questions for further investigation; examining the published literature in inquiries that seek to understand the current state of knowledge in the area; and identifying theories that may help to answer the research questions of interest.

The first step in the exploration phase is identifying one or more research questions dealing with a specific behaviour, event or phenomenon of interest. The research questions delve into issues of ‘what’, ‘why’, ‘how’, ‘when’, etc. The next step is to conduct a review of the literature on the domain of interest. The purpose of the literature review is threefold: (1) to survey the current state of knowledge; (2) to identify key authors, articles, theories and findings in that research area; and (3) to identify gaps in knowledge in that area.

The research focus in the current study is on green supply chain management (GSCM). The aims are to investigate the drivers and effects from GSCM implementation. The drivers are categorized into technological, organizational and environmental contexts based on the theory of the technological-organizational-environmental (TOE) framework. For each context, variables are chosen based on their significance in the literature as well as preliminary data gathered in this study. Based on the input-process-output (IPO) theory, the drivers represent the input, GSCM practices represent the process, and effects from GSCM implementation represent the output. The effects are measured through environmental and technological performance. The study is carried out within manufacturing firms in Malaysia that are registered with Federation of Malaysian Manufacturer (FMM) and certified with ISO 14001: Environmental Management Systems (EMS) certification.

3.4.1.1 Research Questions

Based on the systematic literature review carried out in the current study, the relevant research questions were formulated to address the problem statement discussed in Chapter 1. Thus, the research questions are:

RQ1: To what extent do Green information technology (Green IT) and Green information systems (Green IS) drive the implementation of GSCM within ISO 14001-certified manufacturing firms in Malaysia?

RQ2: To what extent do internal commitment and regulatory pressure drive the implementation of GSCM within ISO 14001-certified manufacturing firms in Malaysia?

RQ3: To what extent does the implementation of GSCM effect the organization's environmental performance and technological performance within ISO 14001-certified manufacturing firms in Malaysia?

3.4.1.2 Theoretical Framework and Research Framework

As positivist research involves theory testing, the third step is to identify one or more theories that address the desired research questions. The theory or theories help to identify which of the constructs is logically relevant to the target phenomenon and can be used as the logical basis for postulating hypotheses for empirical testing.

In this study, the input-process-output (IPO) theory is applied to categorize the stages of the life cycle involved in the research framework. A system is defined as a collection of people, products, technology and tools organized in such a way that it can be modelled as a life cycle, and a life cycle that can, in turn, be modelled as a process. A life cycle is a representational model of the stages in a process that has a beginning, a middle and an end, while a process is a collection of activities organized to produce a result. The IPO theory represents a system in three stages which describe the inputs required, the process of transforming inputs into outputs and the applications used to produce the result (the goal to be achieved) (MacCuspie et al., 2014).

The IPO theory is adopted, along with the TOE framework, to represent the three contexts of the input stage in the IPO model. The TOE framework was developed in 1990 by Tornatzky and Fleischer (1990). This framework identifies three aspects of an enterprise's context, that is, technological, organizational and environmental, that influence the process by which it adopts and implements a technological innovation. This framework then identifies three aspects of a firm's context that affect the process and performance of introducing, adopting or implementing new or advanced innovations or technologies (B. Li, 2015). The TOE framework provides a useful analytical framework founded on a solid theoretical basis with empirical support in which specific factors identified within the three contexts may vary across different studies (Oliveira & Martins, 2011). The TOE framework is commonly used to explain the adoption and implementation of new technologies or innovations as the TOE contexts are able to articulate the influential factors which are often regarded as the main drivers of technology diffusion in an inclusive manner (K. Zhu, Kraemer, & Xu, 2006).

The primary goal of the study is to increase environmental sustainability with the implementation of green practices as well as green information technologies and systems within the supply chain. Therefore, in referring to the input of IPO theory, the TOE framework is adopted to identify the factors that drive the implementation of the innovation known as GSCM in this study. The constructs of this study represent the three contexts epitomised in the TOE framework and the IPO model's input. Based on the IPO theory, the process is represented by constructs known as green practices. The variable to measure green practices is GSCM which is guided by input (antecedents from the TOE context) to produce output in terms of effects on performance measurement.

A theoretical framework refers to the application of a theory, or a set of concepts drawn from one and the same theory, to offer an explanation of an event, or to shed some light on a particular phenomenon or research problem (Imenda, 2014). Based on the theory and concept discussed earlier, the theoretical framework of this research is as illustrated in Figure 3.2.

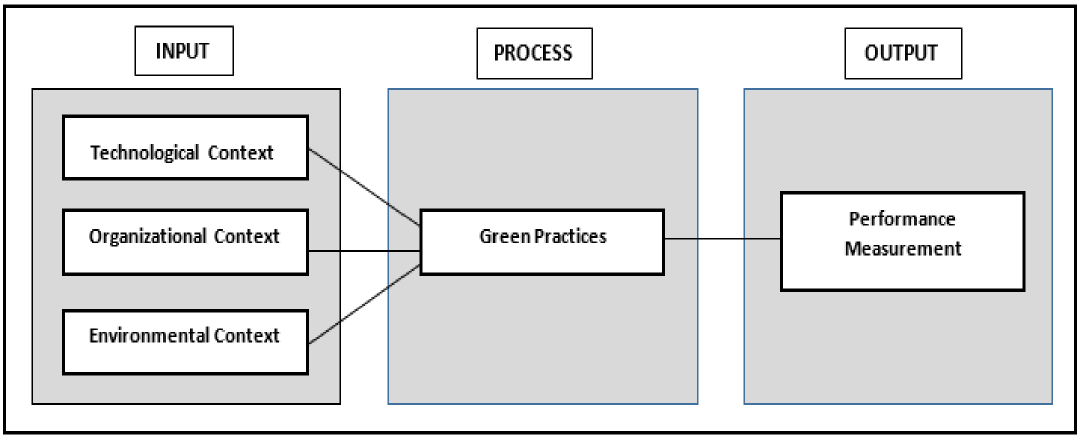


Figure 3.2: Theoretical Framework

The synthesis from the existing views in the literature from both the theoretical and empirical findings postulates an integrated manner for looking at the research problem. Hence, a research framework is defined as an end result of bringing together a number of related concepts to explain or predict a given event, or to provide a broader understanding of the research problem (Bhattacherjee, 2012). In the research framework, the measurable representations of abstract constructs are called variables. A variable explains the characteristic or attribute of an individual or an organization that can be measured or observed and that varies among the people or organization being studied (Creswell, 2014).

The independent variables, also known as exogenous latent variables, explain other variables in the model, while the dependent variables (or endogenous latent variables) are variables that are being explained in the model (Hair, Hult, Ringle, & Sarstedt, 2014). In other words, independent variables are those characteristics or attributes that probably cause, influence or affect outcomes, with these also known as treatment, manipulated, antecedent or predictor variables (Creswell, 2014). Dependent variables are those that depend on the independent variables that reflect the outcomes or results, with these also recognized as criterion, outcome, effect or response variables (Creswell, 2014).

Hair et al., (2014, 2017) explained the concept of exogenous and endogenous variables as follows:

- The sequence is displayed from left to right, with independent (predictor) constructs on the left, and dependent (outcome) variables to the right.
- The constructs to the left side are assumed to precede and predicts constructs to the right.
- Constructs that only act as independent variables is referred as exogenous latent variables and are on the extreme left side of the structural model.
- Constructs considered as dependent in structural model is called endogenous latent variables and are on the right side of the structural model.
- Constructs that operates as both independent and dependent variables in a model also are considered endogenous, and if they are part of a model appear in the middle of the diagram.

The moderator and mediator concepts are explained below (Hair et al, 2014, 2017):

- A moderator specifies the conditions under which a given effect occurs, as well as the conditions under which the direction (nature) or strength of an effect vary.
- Baron and Kenny (1986, pp. 1174, 1178) describe a moderator variable as the following:
    - *A qualitative (e.g., sex, race, class) or quantitative variable that affects the direction and/or strength of a relation between an independent or predictor variable and a dependent or criterion variable.*
    - *A basic moderator effect can be presented as an interaction between a focal independent variable and a factor (the moderator) that specifies the appropriate conditions for its operation.*
    - *Moderator variables are typically introduced when there is an unexpectedly weak or inconsistent relation between a predictor and a criterion variable.*

- The mediation conceptualization requires forethought about the relationships between the variables of interest and the theoretical meaning behind those relationships. (McKinnon et al., 2012)
- A mediator specifies how (or the mechanism by which) a given effect occurs (Baron & Kenny, 1986; James & Brett, 1984).
- Baron and Kenny (1986, pp. 1173, 1178) describe a mediator variable as the following:
  - *The generative mechanism through which the focal independent variable can influence the dependent variable of interest and Mediation is best done in the case of a strong relation between the predictor and criterion variable.*
  - *It is critical that the prerequisite that there be a significant association between the independent variable and the dependent variable before testing for a mediated effect.*

Despite the extensive use of complex statistical modelling in the behavioral sciences, the quality of a research project is largely determined by the design decisions that are made before any analysis is done and even before the study is conducted. Based on the findings from the literature review and pre-gathered data, the four independent (exogenous) variables were identified. The variables for the technological construct are Green IT and Green IS, followed by internal commitment for the organizational construct and regulatory pressure for the environmental construct. The three dependent (endogenous) variables are green supply chain management (GSCM) for the green practices construct, and environmental performance and technological performance for the performance measurement construct. As explained in Hair et al. (2014, 2017), GSCM variable operates as both independent and dependent variables, and it is considered as endogenous although it is appeared in the middle of the diagram which explains the sequence of the predictive relationships.

The control variable is a special type of independent variable that researchers measure as this variable potentially influences the dependent variable. Therefore, it needs to be controlled for in order for the true influence of the independent variable on the dependent variable to be determined (Creswell, 2014). As was suggested in the previous literature, this study included firm size as a control variable for statistical control and ISO 14001 certification as sampling control.

The nomological network of all independent and dependent variables is shown through the relationships between the seven variables, as represented by the directional arrows for hypothesis testing. Thus, the research framework of this study is presented in Figure 3.3.

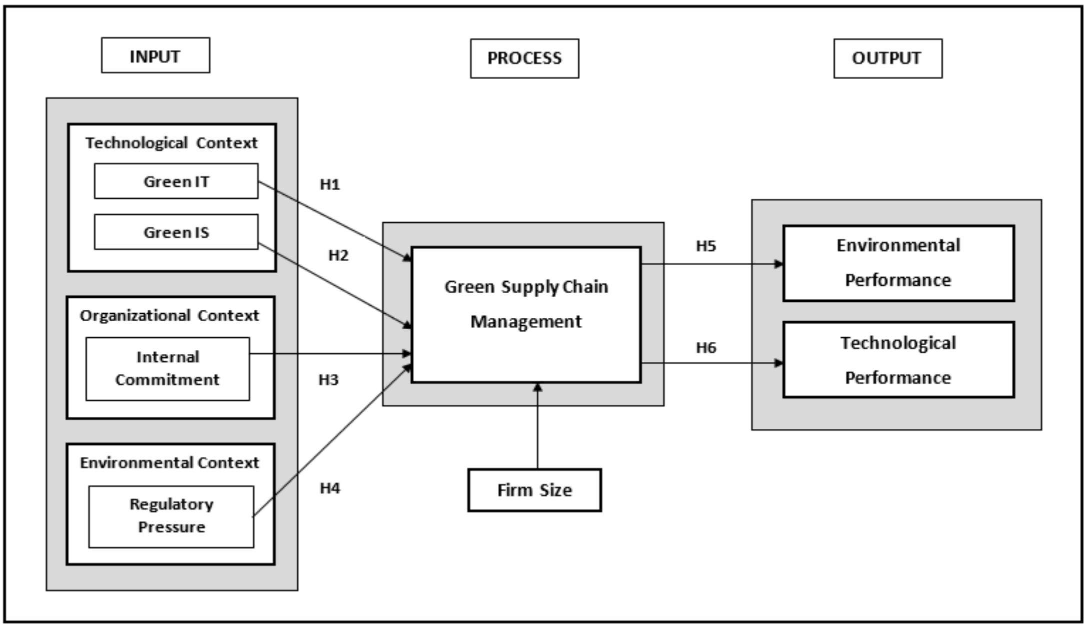


Figure 3.3: Research Framework

3.4.2 Phase 2: Research Design

The next phase in the research process is research design. This process crafts the overall strategy to integrate the activities that are to be carried out in the study in a coherent and logical way. Thus, research design creates a blueprint for the data collection, measurement and analysis to be used in addressing the research problem. In the current study, this phase focuses on the operational definition of the constructs and variables, the development of hypotheses and the data collection approaches. The measurement and analysis are discussed further in Section 3.4.3 (Phase 3: Research Execution).

3.4.2.1 Operational Definition of Constructs and Variables

The first step is to operationalise the theoretical constructs identified in Phase 1. The operational definition is adopted directly from the existing validated measure in the literature, although some are modified and adapted to suit the context of this study. The operational definition of the terms, constructs and variables in this study are presented respectively in Table 3.2 and Table 3.3.

Table 3.2: Operational Definition of the Terms and Constructs

Constructs	**Descriptions**	**Sources**
Sustainable development	"A development that meets the needs of the present without compromising the ability of future generations to meet their own needs."	(Brundtland, 1987; Elkington, 1994; Holden, Linnerud, & Banister, 2014)
Sustainability	"The balancing of economic profitability with social responsibility and environmental obligations, which [is] referred [to] as [the] "Triple Bottom Line."	(Brundtland, 1987; Elkington, 1994; Holden et al., 2014)
Environmental sustainability	The three strategies of environmental sustainability are: • pollution prevention – minimization of waste and emissions • product stewardship – optimization of product life cycles • sustainable development – reduction of the organization's environmental footprint and commitment to a long-term sustainability vision. Environmental sustainability focuses on [the] corporate environmental footprint, sustainable products and internal process efficiency (Löser, 2015).	(Hart, 1997)

Technological context	The influence of internal, external or innovative technologies that are relevant to the firm.	(Oliveira & Martins, 2011; Tornatzky & Fleischer, 1990)
Organizational context	The influence of internal factors of organizational attributes which facilitate or constrain the adoption of innovation such as managerial structure, readiness/commitment, availability of resources and internal communications methods.	(Oliveira & Martins, 2011; Tornatzky & Fleischer, 1990)
Environmental context	The influence of external factors in the arena in which a firm conducts its business, such as competitors, suppliers, customers, government and communities, on the decision to adopt innovation.	(Oliveira & Martins, 2011; Tornatzky & Fleischer, 1990)
Green practices	Green practices focus on environmentally-friendly activities that minimize negative ecological impacts. Green practices cover supply chain functions from upstream to downstream such as purchasing/procurement, design, manufacturing and operations; marketing and distribution/logistics; finance, human resources and information technology (IT).	(Azevedo et al., 2011)
Performance measurement	Performance measurement is a measure that assesses the degree of realization of an organization's objective and desired goals. The measure provides a directive or an outcome to evaluate the effects of the implementation and to determine future actions or corrective plans.	(Hervani et al., 2005; Ramayah, Khor, Ahmad, Abdul Halim, & May-Chiun, 2013)

Table 3.3: Operational Definition of the Variables

Constructs	Variables	Definition	Source
Technological context	Green information technology (IT)	"Green IT refers [to] environmentally sound IT. The focus is on the study and practice of designing, manufacturing, using, and disposing of computers, servers, and associated subsystems – such as monitors, printers, storage devices, and networking and communications systems – efficiently and effectively with minimal or no impact on the environment." Green IT spans many focus areas and activities, including: • design for environmental sustainability • energy-efficient computing • power management • data centre design, layout and location • server virtualization • disposal and recycling • regulatory compliance • green metrics, assessment tools and methodology • environment-related risk mitigation • use of renewable energy sources • eco-labelling of IT products	(Murugesan, 2008)
	Green information systems (IS)	"Green IS refers [to] the design and implementation of information systems that contribute to sustainable business processes."	(R. T. Watson et al., 2008)

		Green IS spans many focus areas and activities, including: • Fleet management systems and dynamic routing of vehicles • Telecommuting systems and collaboration systems • Group document management, and cooperative knowledge management systems • Environmental information tracking systems	
Green IT and Green IS are interrelated, but each has a different focus and purpose (Molla, 2013).			
Organizational context	Internal commitment	Internal commitment is a strategic imperative requirement in implementing an innovative technology or innovation, as it refers to key internal factors such as top management support and the availability of internal resources.	(Holt & Ghobadian, 2009; Sarkis et al., 2011; Q. Zhu et al., 2008a, 2008b)
Environmental context	Regulatory pressure	Regulatory pressure focuses on the legislative requirements from domestic environmental regulations, government environmental policies and international environmental agreements that influence an organization to implement an innovative technology or innovation.	(Chien & Shih, 2007; Sarkis et al., 2011; Q. Zhu et al., 2008a, 2008b)
Green practices	Green supply chain management (GSCM)	Green supply chain management (GSCM) integrates environmental concerns into supply chain management by forward-thinking organizations.	(Srivastava, 2007)

		The integration of environmental thinking includes product design, materials sourcing and selection, manufacturing processes and delivery of the final product to consumers as well as end-of-life (EOL) management of the product after its useful life.	
Performance measurement	Environmental performance	Environmental performance is the realization of environmental management performance from its direct impact on supply chain activities. Environmental performance relates to the ability of an organization to reduce air emissions, effluent waste and solid waste, and its ability to decrease the consumption of hazardous and toxic materials.	(Eltayeb et al., 2011; Hervani et al., 2005; Q. Zhu, Sarkis, & Geng, 2005; Q. Zhu et al., 2008a, 2008b)
	Technological performance	Technological performance is the realization of environmental management performance from the direct impact of the use of information technologies (IT) and information systems (IS) on supply chain activities. Technological performance relates to the ability of an organization to adopt eco-friendly technologies, systems and applications; safe practice of disposing of e-wastes; and compliance with IT resource efficiency and data centre environmental metrics, indices and standards as well as sustainability reporting.	(Erek, 2011; Löser et al., 2011)

3.4.2.2 Hypotheses Development

As shown in the research framework illustrated below in Figure 3.4, the research hypotheses for this study were developed with the intention of answering the identified research questions and proposed research objectives. The six hypotheses were developed to test the relationships between Green IT, Green IS, internal commitment, regulatory pressure, GSCM, environmental performance and technological performance.

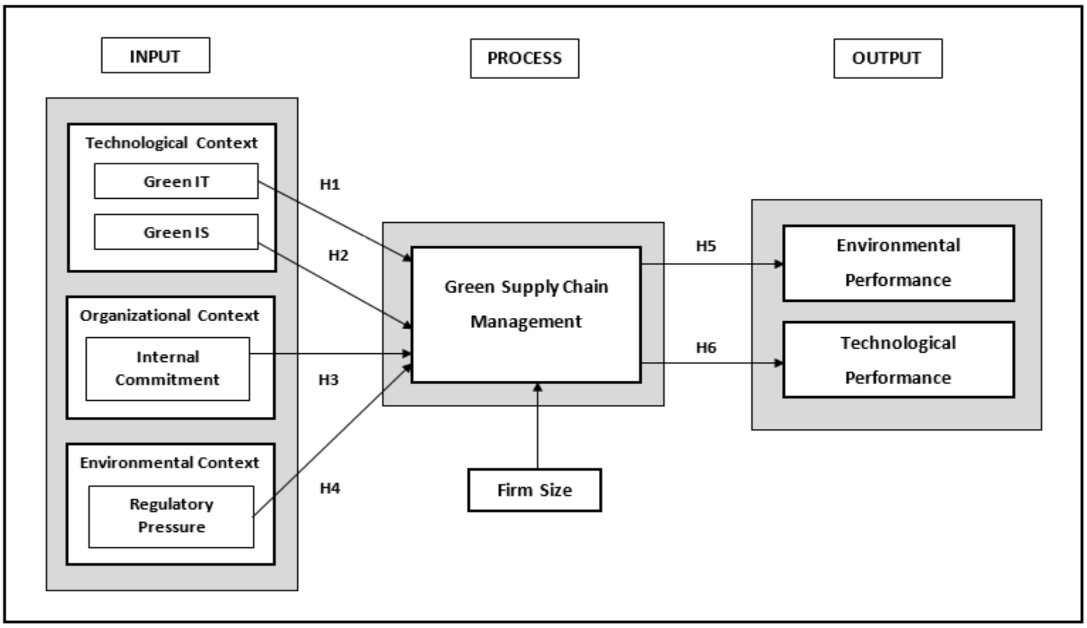


Figure 3.4: Research Framework

Hypothesis 1

The green elements of IT and IS are often ignored by organizations in the assessment of their green movement adoption and environmental footprints (Jenkin et al., 2011). Although technology components are critical, many organizations still lack a sense of urgency in measuring the IT and IS impacts on business processes and operations necessary for achieving environmental sustainability (Faucheux & Nicolaï, 2011). The IT sector has begun to deploy Green IT and Green IS; however, the studies on Green IT and Green IS in other sectors, such as manufacturing, logistics and services, are inadequate (Faucheux & Nicolaï, 2011; Jenkin et al., 2011; Melville, 2010).

Furthermore, most of the studies have concentrated on direct, first-order impacts of Green IT. Lately, researchers have initiated the investigation on the second-order effects of IT, or known as Green IS or IT for Green (Dedrick, 2010; Melville, 2010). Although Green IT and Green IS are interrelated, each has a different focus and purpose (Molla, 2013). Thus, Green IT and Green IS have been conceptualized in numerous ways depending on their context and scope.

In Malaysia, the concept of “Green” is actively emerging with the introduction of strategic policies, programmes and plans as part of government initiatives (Persatuan Industri Komputer dan Multimedia Malaysia (PIKOM), 2012). Nevertheless, the importance of the role of IT and IS for environmental sustainability in the manufacturing sector in Malaysia is still under-researched.

The traditional solutions and practices of IT and IS have been contributing to environmental problems for the past few decades which many have not realized until recently. The environmental issues are mainly caused by inefficient technologies, poorly designed systems and the short lifespans of IT products. These factors increase organizations’ electricity costs, carbon emissions and e-waste generation (Löser et al., 2012).

Organizations are facing increasing pressure to look at every aspect of their operations and business with the intention of adopting green practices to prevent environmental degradation and avoid incurring negative financial credentials (Brooks et al., 2012). Increased electricity costs have driven the rising demand for solutions that can reduce the need for technologies with a high level of consumption, while simultaneously using existing IS resources efficiently to operate processes in an integrated and sustainable manner (Dedrick, 2010).

By going green, IT and IS can reverse their negative impacts on the environment. The adoption of environmentally-friendly technologies, systems and practices increase the ability to address IT and IS environment-related issues. It is vital that these technologies, systems and practices are appropriately diffused and institutionalized (A. J. W. Chen et al., 2008). Hence, corporate greening can be construed as the first step towards the superior goal of environmental sustainability (Molla, 2009).

Through the incorporation of environmentally-friendly IT and IS solutions into supply chain daily activities, organizations can make sound and effective environmental decisions at each SCM stage. Hence, Green IT is considered to be one of the significant components that transform the SCM function towards an environmentally-conscious strategic movement (Cai et al., 2013; Gholami, Sulaiman, Ramayah, & Molla, 2013; Rao & Holt, 2005).

The current study therefore proposes to contribute to the body of knowledge by investigating the extent to which a technological factor termed as 'Green IT' influences GSCM implementation. With that, the first research question is:

> **RQ1:** To what extent do Green information technology (Green IT) and Green information systems (Green IS) drive the implementation of GSCM within ISO 14001-certified manufacturing firms in Malaysia?

The following hypothesis is proposed:

> **Hypothesis 1 (H1):** Green IT positively influences the implementation of GSCM within ISO 14001-certified manufacturing firms in Malaysia.

Hypothesis 2

In recent years, the IS literature has begun to realize the importance of sustainability and the potential relationship of IS to minimize ecological footprints. The concept of Green IS is proposed with the focus being to reduce the impact of IT but also to help firms to reduce their carbon footprints through automating systems and applications in order to transform products, processes and practices into an environmentally-friendly state (Melville, 2010; R. T. Watson et al., 2008).

As environmental sustainability is a supply chain commitment, Green IS is essential for the creation, maintenance and survival of environmentally-conscious practices in the supply chain (Green et al., 2012). Green IS has the ability to enable interconnectedness, and to realign and reinvent business processes in support of productivity and efficiency towards ecological improvements (Dwyer & Hasan, 2012). The design and development of IS represent the backbone of environmental management efforts that support the firm's environmental management system (EMS) (Cai et al., 2013).

Green IS encourages the application of IS thinking and skills to initiatives across all functions of the organization (A. J. W. Chen, Watson, Boudreau, & Karahanna, 2010). Green IS is a driver for inducing changes within and between business processes, decreasing the environmental impacts through appropriate integration and coordination throughout SCM (Boudreau et al., 2008; Green et al., 2012). Organizations are increasingly integrating their business processes without realizing that Green IS initiatives are not limited to use within companies, but can be extended to the externalities that require collaboration, such as suppliers, customers and shareholders (Brooks et al., 2012).

As emphasized in Melville (2010), much deeper research is required to determine the extent to which IS might improve sustainability in the realm of supply chains and logistics. Therefore, the second research question is:

> **RQ1:** To what extent do Green information technology (Green IT) and Green information systems (Green IS) drive the implementation of GSCM within ISO 14001-certified manufacturing firms in Malaysia?

Hence, the proposed hypothesis is:

> **Hypothesis 2 (H2):** Green IS positively influences the implementation of GSCM within ISO 14001-certified manufacturing firms in Malaysia.

Hypothesis 3

Many researchers have placed great importance on the firm's internal capabilities to overcome internal obstacles to achieving sustainable competitiveness (Hart, 1995; Vachon & Klassen, 2006; Q. Zhu & Sarkis, 2006).

Companies that focus on the development and deployment of the firm's internal resources more than on external factors are more likely to implement successful GSCM practices (Guang et al., 2012). Top management's environmental commitment, cross-departmental cooperation, employee dedication and an internal EMS with regular auditing as well as reliable financial resources are essential in the company's organizational capabilities to efficaciously implement environmentally-friendly practices in the supply chain (Guang et al., 2012; G.-C. Wu et al., 2012).

Many previous studies have concluded that regulation is the foremost external factor to drive an organization towards environmental management (Weng & Lin, 2011). Therefore, compliance with the laws, regulations, directives and standards will increase the organization's capability to go green and to become environmentally-friendly in its processes and business operations (A. J. W. Chen, Watson, Boudreau, & Karahanna, 2009). Hence, regulation pressure plays an important role in shaping a firm's sustainability efforts (Haanaes et al., 2011).

Internal commitment and legislation are the most influential factors for GSCM (Holt & Ghobadian, 2009). Internal environmental management and regulations were found to be the influential drivers in large Japanese organizations (Q. Zhu et al., 2010) as well as among manufacturers in the United Kingdom (UK) (Green et al., 2012). Using interpretive structural modelling (ISM), Diabat and Govindan (2011) revealed the most influential driver as being government regulation and legislation. Furthermore, the green movement is largely driven by stricter regulations as well as intense pressure from stakeholders and the community (Srivastava, 2007; Q. Zhu et al., 2008a, 2008b).

In the 30 research papers reviewed in another study, the factors that scored the highest in driving GSCM practices among ISO 14001-certified manufacturing firms in Malaysia were found to be regulations, expected business benefits, customer pressures and social responsibility (Eltayeb et al., 2010). Many of the previous studies in Malaysia concluded that support from top management, legislative requirements, customer/supplier pressure and the existence of an EMS are the most important factors influencing GSCM adoption within the manufacturing sector (Eltayeb & Zailani, 2009; Eltayeb et al., 2010; Rusli et al., 2012; Ishak & Ahmad, 2010). These findings are also very consistent with results from other studies conducted outside Malaysia.

The broader literature suggests that internal and external forces have a strong influence on the organization's behavior towards sustainability (Jenkin et al., 2011). Therefore, the first step towards GSCM implementation is for the organization to demonstrate continuous commitment towards its own internal management, before extending efforts to suppliers and customers (Q. Zhu et al., 2010). Hence, in conjunction with the second research question, that is:

> **RQ2:** To what extent do internal commitment and regulatory pressure drive the implementation of GSCM within ISO 14001-certified manufacturing firms in Malaysia?

The proposed hypothesis is:

> **Hypothesis 3 (H3):** Internal commitment positively influences the implementation of GSCM within ISO 14001-certified manufacturing firms in Malaysia.

Hypothesis 4

Many companies are adhering to environmental requirements and legislation imposed in Europe, Japan and the USA (Zailani et al., 2012) and to environmental standards such as REACH, WEEE or RoHS (Eltayeb et al., 2010). In Malaysia, however, obtaining ISO 14001 environmental protection certification is not compulsory.

Therefore, further investigation is required to identify the relationship between regulatory pressure and its influence on companies' commitment to integrating environmental thinking at each stage of the product life cycle. This is addressed in the question and hypothesis below:

> **RQ2:** To what extent do internal commitment and regulatory pressure drive the implementation of GSCM within ISO 14001-certified manufacturing firms in Malaysia?

The following hypothesis is proposed:

> **Hypothesis 4 (H4):** Regulatory pressure positively influences the implementation of GSCM within ISO 14001-certified manufacturing firms in Malaysia.

Hypothesis 5

Performance measurement defines the company's parameters for monitoring, controlling and achieving specific objectives and outcomes (Gunasekaran, Patel, & McGaughey, 2004). It provides a directive for the company to implement the desired practices, evaluate their execution, reveal the effects of the implementation and determine future actions or corrective plans (Ramayah et al., 2013). Improvement in environmental performance is highly correlated to the factors that drive the emergence of GSCM in an organization (Hsu & Hu, 2008). The implementation of GSCM practices in the manufacturing sector is shown to be significant in improving the environmental performance (Chien & Shih, 2007; Green et al., 2012; Rao & Holt, 2005; Testa & Iraldo, 2010; Y. Li, 2011; Q. Zhu et al., 2007b, 2010).

In reference to the Malaysian context, manufacturing firms that have implemented GSCM have attained significant positive outcomes in environmental performance in terms of enhancement of environmental compliance and reduction of emissions, harmful materials and waste (Eltayeb et al., 2010, 2011; Wan Mahmood et al., 2013). A proactive internal environmental strategy and external institutional drivers greatly influence a firm's environmental performance (Zailani et al., 2012). Despite these findings, GSCM's contribution still has an insignificant outcome in environmental improvements in waste reduction (Azevedo et al., 2011), reverse logistics and green purchasing (Eltayeb et al., 2011).

The relationship between GSCM and performance outcomes has been subject to numerous studies; however, the results are not conclusive as they vary depending on internal and external factors, firm characteristics and geographical locations. These inconclusive results raise the question of what actual environmental outcomes can be realized from the implementation of green practices in supply chains.

Consequently, this highlights the need for in-depth studies of the relationship between GSCM and performance (Q. Zhu et al., 2007a). In addition, more rigorous research on environmental management is needed from researchers who are geographically located in Asian regions, as well as research which has a specific focus on the Asian regions (Seuring et al., 2008). Hence, more empirical evidence on the environmental performance within the ISO 14001-certified manufacturing sector in Malaysia is required.

The next research question covers two aspects of performance measures on which GSCM implementation has effects on:

> **RQ3:** To what extent does the implementation of GSCM effect an organization's environmental performance and technological performance within ISO 14001-certified manufacturing firms in Malaysia?

From the performance measure on the direct effect from implementing green practices within supply chains, the proposed hypothesis is:

> **Hypothesis 5 (H5):** The implementation of GSCM has a positive influence on environmental performance within ISO 14001-certified manufacturing firms in Malaysia.

Hypothesis 6

The IT industry and IT/IS researchers have acknowledged the importance of Green IT and Green IS in pursuing environmental sustainability. Perhaps as a consequence, only limited literature and findings have been reported for other industry sectors in comparison to the IT sector (Faucheux & Nicolaï, 2011; Jenkin et al., 2011; Löser et al., 2012; Melville, 2010). In the operations and manufacturing functions, environmental benefits from incorporating Green IT and Green IS have recently begun to surface (A. J. W. Chen et al., 2008; R. T. Watson, Boudreau, & Chen, 2010). Nevertheless, the incorporation of Green IT and Green IS as part of environmentally-friendly practices within the organization's environmental initiatives is still poorly managed and integrated (Erek, 2011; Löser et al., 2011). So then, what is the situation in Asian countries like Malaysia?

The use of IT and IS are prerequisite for the effective control of complex and interconnected supply chains. To improve the performance of the supply chain, IT and IS are used as a decoupling point (Mason-Jones & Towill, 1999; Sundarakani, Tan, & Van Over, 2012). Regarded as an organization resource (F. Wu, Yeniyurt, Kim, & Cavusgil, 2006) and capability (Molla, Cooper, & Pittayachawan, 2011), IT and IS are required for an organization to succeed strategically in its green movement. As essential tools, IT and IS enable automation, simulation, coordination, integration and optimization of functions throughout the supply chain (Auramo et al., 2005; I. J. Chen & Paulraj, 2004).

The greening of IT and IS assists in the minimization of environmental impacts through reducing the consumption of power or energy, carbon emissions and electronic waste (e-waste), thus considerably improving the power usage of office equipment, infrastructure, data centre and facilities (Faucheux & Nicolaï, 2011; Molla, Deng, & Corbitt, 2010). Greening of IS improves systems performance and usage and reporting capabilities; increases remote collaboration and interactions that reduce the impacts from logistics; and tracks environmental information (such as toxicity, energy and water usage, and waste production) as well as monitoring and reporting environment baseline inputs (energy, water and materials) and outputs (waste and GhG emissions) (Melville, 2010; R. T. Watson et al., 2008).

Green IT and Green IS comprise a vast number of methods, metrics and perspectives; however, the scope and underlying measures still remain vague and have not been well described (Erek, 2011; Holdener & Waldrip, 2009). Organizations continue to use uncoordinated and inappropriate environmental metrics to measure the environmental impacts of IT in data centres and the office environment as well as in industrial operations (Erek, 2011).

Therefore, the consumption of energy by IT equipment and hardware is poorly or roughly estimated, with the measuring mechanism remaining unclear. The lack of standardized procedures has caused difficulties for organizations and the government in monitoring, evaluating and controlling IT and IS's environmental impacts. Recently, the Green Grid presented a set of metrics and indices that can be formally adopted by organizations to measure improvements in energy consumption and resource efficiency of IT usage in their organization and data centres (Green Grid (The), 2012).

Despite the benefits that Green IT and Green IS can bring to GSCM, these topics have only been intermittently discussed in the literature (Fiorini & Jabbour, 2017). Only a limited number of studies have investigated Green IT- and Green IS-related issues and outcomes after their implementation (Zaman & Sedera, 2015). Studies on the adoption of Green IT and Green IS and their impact on other sectors are lacking in both research and practice (Global e-Sustainability Initiative (GeSI), 2015; Jenkin et al., 2011; Melville, 2010). Several publications from Asia have demonstrated the interest of Asian researchers, but the number of studies remain limited, with further exploration required (Fiorini & Jabbour, 2017).

Consequently, the extent of Green IT and Green IS implementation as well as the actual realization of their benefits are unknown to organizations, the policy makers and researchers (Jamaludin, Ahmad, & Ramayah, 2012). Further investigations with empirical evidence are essential in determining the effects and associated outcomes of Green IT and Green IS on GSCM, with this termed 'technological performance'.

The next research question covers two aspects of performance measures on which GSCM implementation has an impact:

> **RQ3:** To what extent does the implementation of GSCM effect an organization's environmental performance and technological performance within ISO 14001-certified manufacturing firms in Malaysia?

Thus, from the performance measure on the direct effect from implementing environmentally-friendly information technologies and systems practices within supply chains, the proposed hypothesis is:

> **Hypothesis 6 (H6):** The implementation of GSCM has a positive influence on technological performance within ISO 14001-certified manufacturing firms in Malaysia.

Control Variable

As suggested in the literature, this study included firm size as a control variable (Dehning et al., 2007; Eltayeb et al., 2011; Ghobakhloo, Benitez-Amado, & Arias-Aranda, 2011; Liu, Ke, Wei, Gu, & Chen, 2010; Prajogo & Olhager, 2012; Teo, Lin, & Lai, 2009; G.-C. Wu et al., 2012; Q. Zhu & Sarkis, 2004; Q. Zhu et al., 2005, 2007b). The reason is that large firms are more likely to adopt innovation, such as green practices and technologies, in comparison to smaller firms. Large firms are expected to have a greater amount of resources available to keep abreast of technological advancements while, at the same time, remaining competitive in the market.

However, in a recent study, the control variable of firm size presented an insignificant impact on the adoption of green practices or green performance. In other words, regardless of firm size, all firms were found to be likely to adopt green practices (V. Lee, Ooi, Chong, & Seow, 2014). Therefore, as the participants of this study are from ISO 14001-certified manufacturing firms which comprise large firms as well as small and medium-sized enterprises (SMEs), firm size is included as a control variable. The context of this study is Malaysia, a developing country located in the Asian region. Malaysia is known as a production and manufacturing hub for international and national businesses.

3.4.2.3 Survey Research Strategy

Survey research continues to be the most used and most popular research strategy for business, management and applied social research (Kelley, Clark, Brown, & Sitzia, 2003). The term 'survey' can be defined as the selection of a comparatively large sample of individuals from a predetermined population based on certain parameters. Some parameter examples are characteristics, situations, events, attitudes, actions or opinions which the researcher is interested in studying. Thus, the research will collect a relatively small amount of data from those individuals, who form what is known as a sample, who represent the population in a systematic manner (Pinsonneault & Kraemer, 1991).

Survey research uses the questioning method as a strategy to elicit information from the sample in order to determine the parameters of selected populations (Yount, 2006). Survey research is categorized into two forms: a written survey called 'a questionnaire' and an oral survey known as 'an interview' (Bhattacherjee, 2012). Survey research provides a snapshot of associations that enable the discovery of relationships which are common or obvious within the sample being studied (Patock, 2012). The descriptive and inferential analysis of the collected data can be used to suggest possible reasons for relationships between variables as well as to produce models of these relationships. Thus, inferences are made with a higher possibility of generalizability to the wider population.

Survey research is often used to answer 'who', 'what', 'where', 'how much' and 'how' questions which represent the deductive approach. Therefore, survey research is usually utilized for exploratory and descriptive research (Saunders, Lewis, & Thornhill, 2009). Survey research has three properties: (1) it produces quantitative descriptions of the relationships between variables or descriptively predicts the findings of the predefined population; (2) it collects data through structured and predefined questions; and (3) it generalizes the findings from the sample to the population with the use of extensive statistical analyses (Pinsonneault & Kraemer, 1991).

As discussed in Dillman (1978) and Fowler (1984), the three vital components in survey research are: (1) research design; (2) sampling procedures; and (3) data collection methods as cited in (Pinsonneault & Kraemer, 1991). The term 'research design' refers to the strategy of answering the questions or testing the hypotheses of the research. In addition, survey designs can be distinguished as cross-sectional or longitudinal studies.

In the current study, survey research was conducted to answer the formulated research questions, as stated in Section 3.4.1.1, and to test the relationships between the variables through hypotheses testing, as discussed in Section 3.4.2.2. The time dimension of this study was of a cross-sectional design in nature, in which data were collected at one point in time from a sample selected to represent the population of interest at that time. The research design is further discussed in the next section. The sampling procedures and data collection methods are discussed in the next three sections, that is, Section 3.4.3.1 – Pre-Test; Section 3.4.3.2 – Pilot Test and Section 3.4.3.3 – Main Study.

3.4.2.4 Descriptive Research – Correlational Research

In this study, descriptive research was adopted to examine a phenomenon that occurred at a specific place and time. Therefore, descriptive research was utilized: (1) to examine the important factors associated with that situation, such as demographic, socio-economic and health characteristics, events, behaviours, attitudes, experiences and knowledge; (2) to estimate specific parameters in a population and to describe associations; and (3) to observe ongoing trends that exist with evidence on the conditions, practices, structures, differences or relationships (Bhattacherjee, 2012). In other words, descriptive survey research allows a higher level of understanding on the relevancy of a certain phenomenon and the distribution of the phenomenon in a population at a single point in time by using a cross-sectional survey strategy.

The type of descriptive research relevant to this study is correlational research which describes what exists at that moment by collecting data to determine whether, and to what extent, a relationship exists between two or more quantifiable variables. In correlational research, hypotheses or research questions are stated at the beginning of the study. Correlational research is aimed at determining the nature, degree and direction of relationships between variables or at using these relationships to make predictions (Bhattacherjee, 2012). Thus, correlational research uses numerical data to explore relationships between two or more variables. The exploration of the relationships between variables provides insights into the nature of the variables themselves as well as an understanding of their relationships. If the relationships are substantial and consistent, they enable researchers to make predictions about the variables.

The most critical element of sampling procedures is the choice of the sample frame which constitutes a representative subset of the population from which the sample is drawn. The sample frame must adequately represent the unit of analysis (Adams, Khan, Raeside, & White, 2007). Probability sampling is viewed as ideal because a probabilistic sample is one that is representative of the population from which it is drawn and, therefore, statistical generalizations about the population can be made on the basis of the analysis of the sample data (Rowley, 2014).

However, many social science researchers depend upon non-probability samples. The reasons are, firstly, that researchers often do not have a clear view of the population to which they are seeking to generalize, and boundaries regarding who might or might not be included in the population are vague. Secondly, it is often very difficult to compile a complete sampling frame, although a variety of partial lists of members of the population may be held by various organizations or government agencies. Finally, even in the unlikely instance that a researcher manages to gather a good sampling frame and apply probabilistic sampling, they are unlikely to achieve a 100% response rate: non-response is another source of potential bias. In practice, notwithstanding the importance of a systematic approach to sampling, many studies depend on non-probability samples, which are often purposive, convenience or snowball samples, as a result of the difficulties associated with creating sufficiently comprehensive sampling frames (Rowley, 2014).

This study has adopted a non-probability sampling method known as purposive or judgmental sampling. The qualifying criteria for the chosen sample were manufacturing firms in Malaysia that were registered under the Federation of Malaysian Manufacturers (FMM) and certified with ISO 14001: Environmental Management Systems based on the list provided in the 2012 FMM Directory. The list provided in the directory is neither a complete list nor is it the latest list of manufacturing firms that are certified with ISO 14001 in Malaysia. Although it is a partial list, due to its breadth, the FMM Directory is considered to be a valid representation of ISO 14001-certified manufacturing firms in Malaysia (V. Lee et al., 2014).

The certified manufacturing firms selected were anticipated to have implemented green practices within or throughout the organization. Consequently, these firms were the best representative of the population under study in investigating the drivers, practices and outcomes for achieving environmental sustainability. Respondents of the questionnaire survey and interview survey were executives or managers involved in operational and strategic environmental activities at the manufacturing firms and their facilities.

3.4.2.5 Survey Questionnaire Development

Invented by Sir Francis Galton, the questionnaire is defined as a research instrument for data collection that consists of a set of questions or items that capture responses from that same set of questions in a standardized or predetermined order (Bhattacherjee, 2012; Saunders et al., 2009). The design of the questionnaire affects the response rate and the reliability and validity of the collected data. The maximization of the response rate and of validity and reliability is possible through clarity in design of the individual questions, clear purpose of the questionnaire and clear layout of the questionnaire as well as effective execution of the pre-test/pilot test and survey administration. As stated in Foddy (1994, p. 17), “the question must be understood by the respondent in the way intended by the researcher and the answer given by the respondent must be understood by the researcher in the way intended by the respondent” as cited in (Saunders et al., 2009).

The instrument utilized for the current study is constructed based on the adoption of existing validated measurements from the extensive review of the literature. These selected items or questions were then adapted to fit the context of the study. The adoption and adaptation of items from other validated survey instruments bring two key benefits: (1) validity and reliability have already been assessed and (2) comparison between new findings and previous findings from other studies is possible (Kitchenham & Pfleeger, 2002). The survey items were confirmed during pre-test sessions comprising cognitive interviews with representatives from ISO 14001-certified manufacturing firms in Malaysia, as explained in Section 3.4.3.1 and Section 4.2.

The design of the research instrument consisted of a cover letter and 11 pages survey questionnaire. The cover letter included the title of the survey questionnaire, the purpose of the study, definition of key terms, confidentiality consent statement, an appreciative note and contact details. A cover letter is essential as it highlights the importance of the respondent’s participation in the research along with the assurance of anonymity that will increase the response rate (Dillman, Smyth, & Christian, 2014).

The questionnaire was divided into two sections. The first section focused on demographic details and was based on the nominal response format, with each response having a number beside each choice or the given list of choices. This numbering or listing had no meaning except as a placeholder for the response. The demographic variables of interest comprised six questions: job title (job position); department attached to (department classification); nature of business (types of manufacturing industry); category of firm (firm size); factory location (location of manufacturing plant); and ISO certification. The demographic information was used to identify the characteristics of the manufacturing firms involved as well as to identify any significant similarities or differences corresponding to the variables under study.

The second section consisted of three parts: Part 1: Drivers; Part 2: Practices; and Part 3: Outcomes, with these covering the empirical measurements of the variables in the proposed model. The response format for the second section was interval-level based, with rating questions used to obtain each respondent's opinions on a 5-point Likert scale. The most common Likert scales are 4-point, 5-point, 6-point or 7-point rating scales (Saunders et al., 2009). The 4-point and 6-point scales have no midpoint, in contrast to the 5-point and 7-point Likert scales.

Some research studies have recommended a larger Likert scale as it increases the reliability of the survey instrument, while others have found that the size of the Likert scale does not have much effect on its reliability (Asún, Rdz-Navarro, & Alvarado, 2015). However, it is crucial that the Likert scale has more than three points to ensure the validity of the scale and to provide a reasonable number of options from which respondents can choose. Furthermore, a Likert scale with more than seven points might cause difficulty for respondents in distinguishing and choosing the right option. The inclusion of the midpoint does not have a harmful effect on measurement reliability and validity, nor does it influence respondents towards a particular direction in choosing their option from the survey instrument (Tsang, 2012). In summary, the most common Likert scale used is between five and seven points, with the odd number of responses providing a midpoint of 'neutral' for each intended item that is being measured with clearly defined labels (Asún et al., 2015).

As presented in Appendix B, the first part on GSCM consisted of 13 questions on green practices implemented in the supply chain. The questions were measured using a 5-point Likert scale ranging from: (1): not considering; (2): considering it currently; (3): initiating implementation; (4): currently implementing; to (5): implementing successfully. Each item measuring GSCM practices was a formative measure indicator that captured a specific aspect (practice) of green supply chain management (GSCM).

The second part assessed the extent to which Green IT, Green IS, internal commitment and regulatory pressure influenced GSCM implementation. The questions were divided into three sub-sections, namely, technological context, organizational context and environmental context. All items were formative measure indicators. The technological context consisted of questions used to measure Green IT and Green IS: Green IT was measured with seven questions, and Green IS with six questions. The organizational context consisted of five questions used to measure internal commitment, while regulatory pressure from the environmental context was measured with five questions.

For the technological context, the items were measured using a 5-point Likert scale ranging from: (1): not considering; (2): considering it currently; (3): initiating implementation; (4): currently implementing; to (5): implementing successfully. The organizational and environmental contexts were measured on 5-point Likert scales ranging from: (1): not at all; (2): very little; (3): to some degree; (4): relatively significant; to (5): significant.

The last part of the survey questionnaire measured performance outcomes. Performance measurement was categorized into environmental performance and technological performance, with these measuring the direct effects from implementing green practices within supply chains as well as environmentally-friendly information technologies and systems practices within supply chains, respectively. Eight items were used to measure environmental performance, with seven items measuring technological performance. Both environmental and technological performance were measured on 5-point Likert scales ranging from: (1): not at all; (2): very little; (3): to some degree; (4): relatively significant; to (5): significant. The items for both performance outcomes were formative indicators in nature.

3.4.3 Phase 3: Research Execution

The instrument was pre-tested using cognitive interviews and semi-structured interviews, with the feedback gathered used to revise the survey questionnaire before the main data collection. Upon completion of the pre-test, the finalized survey questionnaire underwent a pilot test with 32 respondents from ISO 14001-certified manufacturing firms. The aim of the pilot test was to provide the researcher with a preliminary understanding of the context of the study. The researcher then proceeded with the main data collection. Once the data were gathered, they were cleaned and analysed using IBM's SPSS Statistics version 19.0 (IBM Corp., 2010) and SmartPLS 3.0 (Ringle, Wende, & Becker, 2015; Ringle, Wende, & Will, 2005).

3.4.3.1 Pre-Test: Cognitive Interviews

The terms 'pre-test' and 'pilot test' are sometimes used interchangeably. Some refer to the pilot test as the field pre-test (Rothgeb & Willis, 2007). The term 'pilot study' is used in two different ways in social science research as cited in (van Teijlingen, Rennie, Hundley, & Graham, 2001):

- Feasibility studies which are "small scale version[s], or trial run[s], done in preparation for the major study" (Polit et al., 2001, p. 467)

- Pre-testing or 'trying out' a research instrument (Baker, 1994, pp. 182-183).

Researchers usually focus on designing the questionnaire, standardizing the questionnaire procedures and pilot testing the questionnaire. However, these methods are insufficient for ensuring the quality and accuracy of the instrument as the respondents might have a poor understanding of the questions in the survey questionnaire (Collins, 2003; Haeger, Lambert, Kinzie, & Gieser, 2012).

The survey questions and instruments must be assessed in a more systematic way with the aid of cognitive psychology and information-processing theories (Collins, 2003; Willis, 1999; Willis, 2005). These theories focus on increasing the validity and reliability of measures and decreasing bias and measurement error. The cognitive interview procedure is one of the effective remedies in survey questionnaires for identifying, analysing and controlling the sources of response error that have arisen due to alternative interpretations of questions and items (Desimone & Le Floch, 2004).

The cognitive interview focuses on the cognitive process used by respondents to understand and answer the questions as intended by the researcher and demonstrates both explicit and implicit processes. Hence, the survey questions are the central focus of the cognitive interview rather than the person who answers the questions (Haeger et al., 2012).

During the cognitive process, the respondent performs four actions when answering a survey question: (1) comprehension of the question by focusing on the intention of the question and the meaning of the terms in the question being asked; (2) retrieval from the respondent's memory of relevant information by using a recall or estimation strategy; (3) using a decision process to make a thoughtful judgment based on its relevance and accurateness as an answer to the question; and (4) using a response process to match the response to the question and using internal judgment based on the explicit response options provided or a socially accepted or desirable answer (Collins, 2003; Haeger et al., 2012; Willis et al., 2005; Willis, 2005; Willis, 1999).

As the interviewer is not accurately assured of the thoughts, feelings, interpretations and ideas that occur in the interviewee's mind, the interviewer usually employs think-aloud and verbal probing techniques. These two techniques enable stimulation of the interviewee's mind so the processes of reaching and finalizing a response can be verbalized. The think-aloud method allows the interviewee to verbalize the thought process and interpretation of the question as the questionnaire is answered. The think-aloud and verbal probing techniques can occur concurrently or retrospectively (Willis, 1999; Willis, 2005). In the think-aloud concurrent process, the interviewer reads the questions to the interviewee, and the interviewer observes the think-aloud process of the interviewee as the questions are answered. In the retrospective process, the interviewee is asked to verbalize their thoughts on the questions at the end of the survey (Redline, Smiley, Lee, & DeMaio, 2001).

On the other hand, in concurrent verbal probing, further information is obtained after the interviewee has provided the response with the probes scripted or asked spontaneously (Daugherty, Harris-Kojetin, Squire, & Jael, 2001). In retrospective verbal probing, the interviewees are asked at the end of the interview to verbalize their thoughts on the questions answered earlier from the questionnaire. The interviewer is passive in the think-aloud process, except for providing encouragement when the interviewee hesitates or pauses in answering the survey questions, in contrast to the verbal probing method that focuses on the question-answering process.

The cognitive interviews were conducted with five managers from ISO 14001-certified manufacturing firms in Perak. Based on the purposive or judgmental sampling method, these firms were selected as it was expected that ISO 14001-certified firms would be in the best position to provide the required information as they were more likely to have adopted and implemented green practices. Each of the managers from the five selected firms participated in a one-on-one cognitive interview at their respective firm to test the survey questionnaire.

The selected managers were directly involved in the implementation of environmentally-friendly practices within the supply chain, in which they were attached to the Operations department. The managers willingly participated in the cognitive interview session which consumed between one to two hours. All the managers were informed about the nature of the study, with informed consent obtained to audio record and write notes for each session. The items in the survey questionnaire were adopted and adapted from the existing literature. The initial items included in the survey comprised 162 questions for 15 variables, and the questionnaire was 17 pages in length. The first version of the survey questionnaire was also reviewed by a local researcher who is an expert in the field of GSCM, Green IT and Green IS. The reviewing process was carried out at the researcher's office in a local university. The results from the cognitive interviews are discussed in Section 4.2 and presented in Appendix D.

3.4.3.2 Pre-Test: Interview Survey

The interview survey comprised face-to-face interviews and was structured in nature. The list of themes and questions to be covered during the session are adopted from the survey questionnaire. However, the order of the questions may vary from one interview to another, depending on the flow of interactions between the interviewer and interviewee; additional questions might also be added depending on the interviewee's responses (Saunders et al., 2009). The interview survey allows researchers to reveal and understand the 'what', 'how' and 'why'. As part of descriptive research, the interview survey provides the means to identify a general pattern and to understand the basic relationship between the variables.

Verbatim transcription of interview data is widely considered to be integral to the analysis and interpretation of verbal data. Verbatim transcription refers to the word-for-word reproduction of verbal data, where the written words are an exact replication of the audio recorded words (Poland, 1995) and concurrent note taking (Halcomb & Davidson, 2006). Thus, verbatim quotations from interviewees or research participants has become effectively standard practice in social research that include direct quotations in the reporting (Corden & Sainsbury, 2007). The verbatim quotations can be used as the matter of enquiry; as evidence; as explanation; as illustration; to deepen understanding; to give participants a voice, and to enhance readability (Corden & Sainsbury, 2007).

Thus, the objectives of the interviews were to identify the: (1) factors that influence ISO 14001-certified manufacturing firms to embark on green practices; (2) the role of IT and IS in the supply chain; (3) the role of IT and IS in improving environmental footprints; (4) green practices implemented in the supply chain, and (5) the effect of the implemented green practices on the organization's performance. With the consent of interviewees, the sessions were audio recorded and written notes were captured. Each session took about two hours, along with visits to the production lines, and the Health, Safety and Environment (HSE) and IT departments of the three companies.

3.4.3.3 Pilot Test: Survey Questionnaire Administration

The importance of pilot testing is highlighted in de Vaus (1993, p. 54) "[d]o not take the risk. Pilot test first", as stated in van Teijlingen et al. (2001). The sample size for the pilot test is explained by Sudman (1983, p. 181) who stated that "20 to

50 cases [are] usually sufficient to discover the major flaws in the questionnaire before it damages the main study" as cited in (Sekaran & Bougie, 2009).

The survey questionnaire was amended as suggested during the cognitive interview process, as discussed in Section 4.2. As the revised survey questionnaire achieved positive remarks, a pilot study was carried out with 60 ISO 14001-certified manufacturing firms located in Ipoh and Kulim.

These firms were approached using telephone calls and emails. Consent to participate in the study and in an agreed session for survey administration with the participating firms was obtained. A follow-up reminder via email and telephone call was carried out before the actual day. The administration of the survey questionnaire was assisted by two enumerators.

Of the 60 firms approached, only 37 participated in the pilot study. However, five of the questionnaires received were incomplete. Therefore, those five questionnaires were discarded in the total calculation. A total of 32 survey questionnaires were used as the data set to measure the reliability, measurement error and validity of the measurement items, as suggested in Dillman et al. (2014).

3.4.3.4 Main Study: Questionnaire Survey Administration

The main data collection process took a year starting in January 2014 through to January 2015. A total of 523 emails which included the link to the web-based survey were sent to ISO 14001-certified manufacturing firms listed in the Federation of Malaysian Manufacturers (FMM) 2012 Directory. After a month, no firms had participated; therefore, two reminders were sent via email to the firms every fortnight. After an allocated two-month period, only 21 responses had been received.

The poor response from the firms was for several reasons, such as the person in charge was on holiday, on a business trip or busy, while some refused to participate due to the confidentiality of the information that would need to be disclosed, and a few others required official approval from their Human Resources (HR) department. The researcher opted for self-administered delivery and collection of the survey questionnaire. Each of the ISO 14001-certified manufacturing firms was contacted via email and telephone multiple times. With persuasion and the support of the official letter from the university as well as assurance of the confidentiality of the information supplied, more firms agreed to participate. However, it took more than three months to obtain agreement on the appointment date to meet the firms' representatives.

Each firm's representative was provided with the questionnaire and an official letter. Prior to the data collection, the researcher and the two assisting enumerators provided a brief explanation about the aims of the study, the confidentiality of the information furnished, and the importance of their involvement in the research, as well as background to the concepts of Green IT, Green IS and green supply chain management (GSCM). The survey questionnaires were collected in the agreed time slot or on the same day before the end of office hours to ensure good participation.

The researcher and the two assisting enumerators took a period of six months for the data collection process among the firms that were in the various states of Malaysia. In total, 203 firms responded to the first and second rounds of data collection, but 38 of the survey questionnaires were disregarded for further evaluation since 28 survey questionnaires have more than 25% of items unanswered and another 10 have straight lining issues. Overall, only 165 effective responses were considered for further analyses in this study, as summarized in Table 3.4.

Table 3.4: Survey Response Rate

	Number of Questionnaires
Total of Questionnaires Distributed	523
Total of Questionnaires Received	203
Unusable Questionnaires	38
Usable Questionnaires	165 (31.5%)

A response rate in the range between 10% and 20% is common in the context of Malaysia, particularly for the survey method (Ramayah, Lim, & Mohamed, 2005). Furthermore, based on the 10 times rule, as stated in Barclay, Higgins and Thompson (1995), the most-cited sample size considerations as cited in (Hair et al., 2014):

- The sample size should be equal to the larger of 10 times the largest number of formative indicators used to measure a single construct, or
- The sample size should be equal to the larger of 10 times the largest number of structural paths directed at a particular construct in the structural model.

The minimum sample size should be 10 times the maximum number of arrowheads pointing to a latent variable in the partial least squares (PLS) path model (Hair et al., 2014). In this study, all the items are formative measures in nature. Therefore, the highest number of arrowheads pointing to a latent variable is 12 which was the number formatively directed at the GSCM variables. Hence, the minimum sample size is 120 (10 x 12). It is suggested that 100 cases are sufficient for achieving the acceptable statistical power in PLS-SEM (Reinartz, Haenlein, & Henseler, 2007).

G*Power software was used to calculate the minimum sample size required. As the model had a maximum of four predictors, the effect size was set at medium (0.15) and with confidence power at 0.95. The sample size required was 129. Hence, the data to be collected needed to be from a sample equal to or slightly larger than this required number.

Furthermore, sample size can be calculated using power analysis based on the largest number of predictors (Cohen, 1992) which, in this study, was 12. Therefore, the minimum sample size to give a medium effect size was in the range of 117 to 138 cases (Green, 1991).

The analysis of data for this study was based on 165 cases which is a sufficient sample size. It can therefore be concluded that the sample size for this study is adequate and sufficient based on the rules of thumb suggested.

3.4.3.5 Main Data Analysis: Part 1 Descriptions (SPSS)

This research employed IBM's SPSS Statistics version 19.0 to analyze the data for the first phase, as per the illustration in Figure 3.5. This software is widely used by researchers for data analysis (Zikmund, 2003). The issues that need to be addressed on the data collected are missing data, suspicious response patterns (straight lining or inconsistent answers), outliers and data distribution (Hair et al., 2014).

In this study, the SPSS software was used for data entry as well as for screening and editing the data in terms of coding, missing values, outliers and normality. The software was also used for computing univariate analysis, such as frequency distribution, central tendency and dispersion, in addition to bivariate analysis that was conducted on non-response bias and common method bias tests, and descriptive statistics, as illustrated in Figure 3.5.

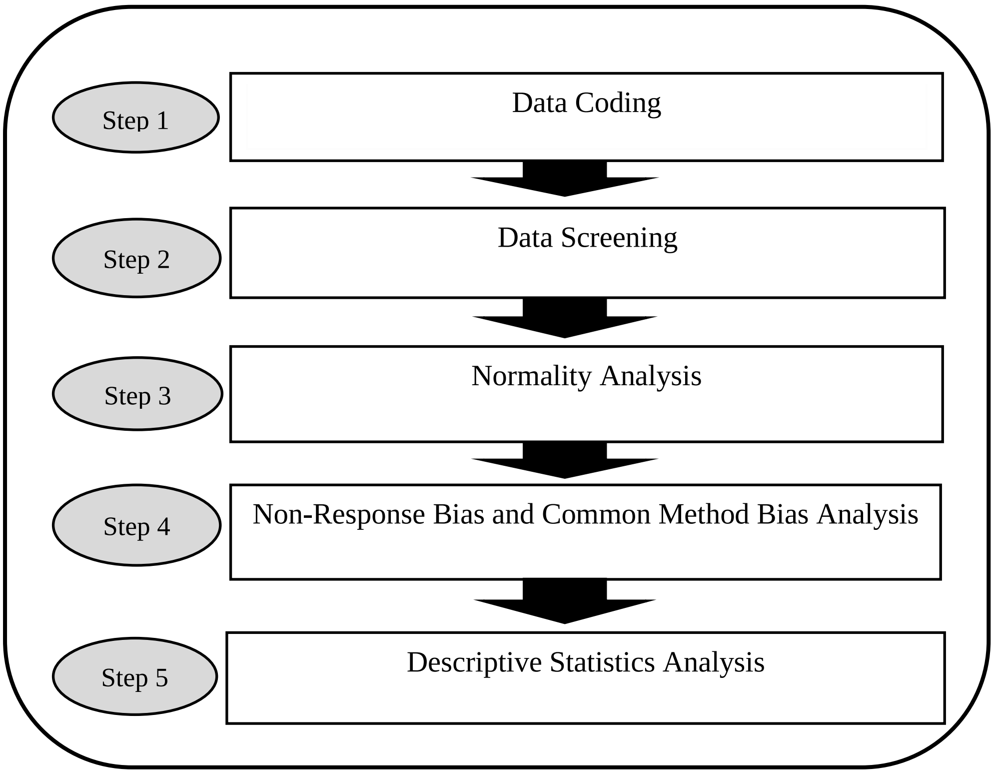


Figure 3.5: Preliminary Data Analysis

Upon completing the collection of survey responses, the raw data gathered underwent coding and the data entry process before being input for further analysis. The two methods of data coding are pre-coding or post-coding (de Vaus, 1993). In the current research, the pre-coding method was applied for all variables with all question items pre-coded with numerical values. The created code sheet contained a detailed description of each variable; the items measuring that variable; and the format of each item for both nominal and scales responses; as well as the explanation for each item, as suggested in Bhattacherjee (2012). The coded data were then entered directly into SPSS: in the data entry process, spot checks were carried out during as well as after data entry to help prevent human error.

Missing data tend to occur frequently in survey research as respondents either purposely or inadvertently fail to answer one or more questions. If the amount of missing data exceeds 15% for the entire questionnaire, or if poor responses exist for a single construct, then that particular questionnaire is removed from the collected samples (Hair et al., 2014).

Furthermore, extreme responses to a particular item or to all items in questionnaires are known as outliers. The existence of outliers may cause bias in the model fit, affecting the normality of the data and distorting the statistical results. The outliers can be identified by comparing each item value of the particular indicator to the mean of that indicator variable or by standardizing a data set’s scores in terms of distribution with a mean of 0 and a standard deviation of 1 (known as z-scores) (Field, 2013). In addition, box plots and stem-and-leaf plots are used to identify the outliers by respondent numbers (Mooi & Sarstedt, 2011).

As a non-parametric statistical method, PLS-SEM does not require the data to be normally distributed, unlike covariance-based structural equation modelling (CB-SEM). Despite this, it is crucial to identify the extent of normality as extremely non-normal data can be problematic in assessment of the significance of parameters, due to the high possibility of escalating standard errors acquired from bootstrapping and decreasing the probability of certain relationships being regarded as significant.

The Kolmogorov–Smirnov test and Shapiro–Wilks test are used to test normality in which the scores in the sample are compared to the same mean and standard deviation from a normally distributed set of scores (Field, 2013). Both tests indicate that only the null hypothesis of normally distributed data should be rejected or not based on the *p*-value (indicating significance [sig.]). These tests provide limited guidance for deciding on the extent to which the data are normally distributed. Therefore, the more suitable measures of normality distribution are skewness and kurtosis (Hair et al., 2014).

Skewness measures the extent to which the distribution of an item or a variable is symmetrical. The distribution of skewness is based on positive values indicating low scores (left tail), and negative values indicating high scores (right tail) in the distribution. Kurtosis assesses the peak of the distribution, with positive values representing a pointy and heavy-tailed distribution, whereas negative values indicate a flat and light-tailed distribution. Appendix E presents the study's results on z-scores, skewness and kurtosis.

3.4.3.6 Main Data Analysis: Part 2 Descriptions (PLS-SEM)

Multivariate analysis is the application of a statistical technique that simultaneously analyses multiple variables. First-generation techniques, such as cluster analysis, explanatory factor analysis, multidimensional scaling, analysis of variance, logistic regression and multiple regression, are often used among social scientists.

As a result of weaknesses in the above techniques, the second-generation technique was introduced: this enables the incorporation of unobservable variables measured indirectly by indicator variables and the facilitation of measurement error in the observed variables. Known as structural equation modelling (SEM), this technique is categorized into covariance-SEM (CB-SEM) and partial least squares-SEM (PLS-SEM). Hair et al. (2014) explained on the rules of thumbs to select PLS-SEM over CB-SEM as presented in Table 3.5:

Table 3.5: Rules of Thumb: PLS-SEM vs. CB-SEM

Use PLS-SEM when:	Use CB-SEM when:
The goal is predicting the key target constructs or identifying key driver constructs	The goal is theory testing, theory confirmation or the comparison of alternative theories
Constructs are formatively measured as part of the structural model	The constructs require specification modifications
The structural model is complex (many constructs and many indicators)	The structural model has non-recursive relationships
The sample size is small, and/or the data are non-normally distributed	Error terms require additional specification, such as covariation
The plan is to use scores of latent variables in subsequent analysis	The research requires a global goodness-of-it criterion

The PLS-SEM technique was chosen for this study because, (1) the measurement and structural models are based on formatively-measured constructs, (2) the goal of this study is to identify the key constructs and (3) the sample size is small.

When formative measurements are used in a study, PLS-SEM allows the identification of significant and insignificant items within a construct. For formative measurement, content validity must be assessed before collecting the data to ensure that the indicators represent at least the major aspects of the construct's content. As formative indicators are assumed to be error-free, internal consistency reliability concepts exercised in the reflective measurement model are inappropriate for the formative measurement model (Diamantopoulos & Siguaw, 2006; Edwards & Bagozzi, 2000). The criteria used in assessing convergent and discriminant validity in reflective measurement models are not appropriate when formative indicators and their weights are involved (Chin, 1998).

In formative measurement, the indicators are not interchangeable; hence, each indicator captures a specific facet of the construct. Collectively, the indicators explain the meaning of a particular construct; therefore, omitting an indicator alters the characteristics of the construct. Therefore, the breadth of coverage on the construct domain is extremely important to ensure that the domain of the construct is adequately captured. The assessment of the content validity of a formative measure construct is crucial in explaining the concept in such a way that it clearly specifies the domain of the constructs. This can be achieved with a comprehensive set of indicators (Hair et al., 2014) through a thorough literature review and a reasonable theoretical grounding that epitomises the measurements of the formative constructs' domain (Diamantopoulos, Riefler, & Roth, 2008; Diamantopoulos & Winklhofer, 2001; Jarvis, Mackenzie, & Podsakoff, 2003).

In the PLS-SEM technique, a latent variable is also recognized as a construct. Measurement theory thus presents how the latent variables (or constructs) are measured, either based on a formative measurement model, a reflective measurement model or both. Structural theory demonstrates how the latent variables are related to each other which includes the path relationship between the constructs in the structural model. In evaluating the measurement model, one must be able to distinguish between reflectively-measured and formatively-measured constructs. The formative and reflective indicators are based on different concepts; therefore, they require different evaluation measures.

The three important steps in assessment of the formative measurement model are illustrated in Figure 3.6. The first step focuses on assessing convergent validity through a technique known as redundancy analysis whereby a formatively-measured construct is correlated with the same construct which has been reflectively measured. In the second step, the collinearity issue between the indicators must be identified to determine any high correlations between two formative indicators. The existence of collinearity will have an impact on the estimation of weights and statistical significance. The third step examines the statistical significance and relevance of the formative indicators by measuring the relative contribution of the outer weight, the absolute contribution of the outer loadings and the estimation of outer weight significance or the *t*-value from the bootstrapping procedure.

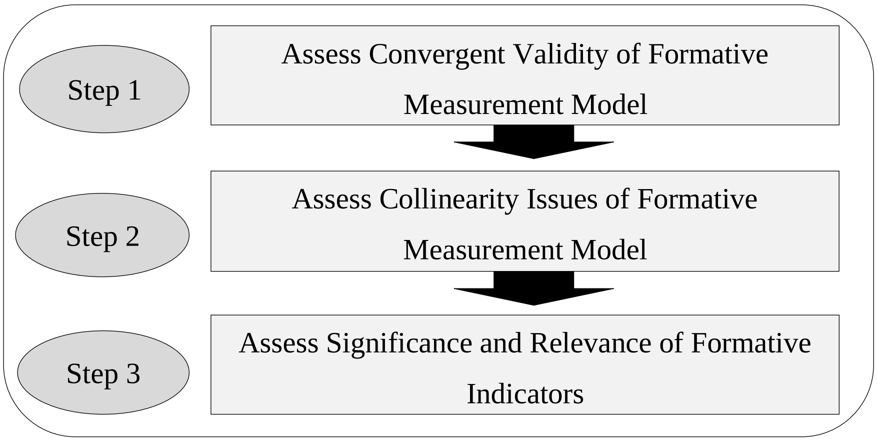


Figure 3.6: Formative Measurement Model Assessment Procedure

The assessment of the formative measurement model differs significantly from that of the reflective measurement model. In the formative measurement model, the first step is to measure convergent validity which involves assessing the measurement of the indicators of the same construct. The method known as redundancy analysis is engaged in measuring formative constructs. As previously mentioned, this method tests whether a formatively-measured construct is highly correlated with a reflective measure of the same construct (Hair et al., 2014).

In carrying out redundancy analysis, a global item is therefore used as a reflective indicator to summaries the essence of the formative construct (Sarstedt, 2008). The reflective latent variable for convergent validity must be included in the questionnaire. The strength of the path coefficient that links the two constructs is ideally of a magnitude of 0.80, or at least at a minimum of 0.70 or above, which translates into an R^2 value of 0.64, or at least 0.50 (Hair, Hult, Ringle, & Sarstedt, 2017). If the R^2 value is lower than 0.5, the formative indicators of that construct lack convergent validity to contribute sufficiently to its intended content. Thus, the formative construct needs to be theoretically or conceptually refined by exchanging and/or adding indicators (Hair et al., 2014, 2017).

In measurement models, formative indicators are not meant to be highly correlated, unlike reflective indicators. The collinearity issues between formative indicators will impact on the estimation of weights and statistical significance. The measurement technique exercised in finding collinearity is known as the variance inflation factor (VIF). The cut-off threshold value in assessing the VIF is a tolerance value of 0.20 or lower, or a VIF value of 5 or higher, which indicate potential collinearity issues (Hair et al., 2014, 2017).

In evaluating a formative indicator, the outer weight values are compared to each other to determine the relative contribution of each indicator in explaining the relative importance of the indicator to the construct. The outer weight is the result of a multiple regression (Hair et al., 2014, 2017), with the outer weights in formative measurement usually smaller than the outer loadings of reflective measurement. In formative measurement, the insignificant indicator weights must not be interpreted as an indication of poor measurement model quality as each indicator represents an independent effect to the construct (Hair et al., 2014, 2017).

Hence, the absolute contribution from the formative indicator's outer loading must be inferred in explaining the bivariate correlation (single regression) between each indicator and its corresponding construct. The absolute contribution of the formative indicator's outer loading is presented along with the indicator's outer weight. If the outer weight is non-significant but its outer loading is high (above 0.5), then the indicator is interpreted as absolutely important but not relatively important, and will be retained (Hair et al., 2014, 2017). However, if the indicator has a non-significant weight and an outer loading below 0.50, the indicator is to be retained or deleted based on its theoretical relevance, content validity or expert assessment. A non-significant formative indicator should never be discarded on the basis of statistical outcomes alone (Hair et al., 2014, 2017).

The PLS algorithm is run to obtain the structural model relationships which measure the path coefficients of the hypothesized relationships. The path coefficients have standard values between -1 and +1, in which the paths close to +1 coefficient values indicate strong positive relationships and are statistically significant. The paths with negative coefficient values that are closer to 0 have weaker relationships and usually are not significant (Hair et al., 2014, 2017). The bootstrapping procedure is run to assess the relevance and significance of the formative indicators' outer weights in the measurement model and the path coefficients' estimation that represents the hypothesized relationships between the constructs in the structural model. The path coefficient is significant when the empirical *t*-value is larger than the critical value.

Once the formative indicators of each construct achieve good validity, reliability, relevance and significance, the next step is to assess the measurement of the structural model, as shown in Figure 3.7.

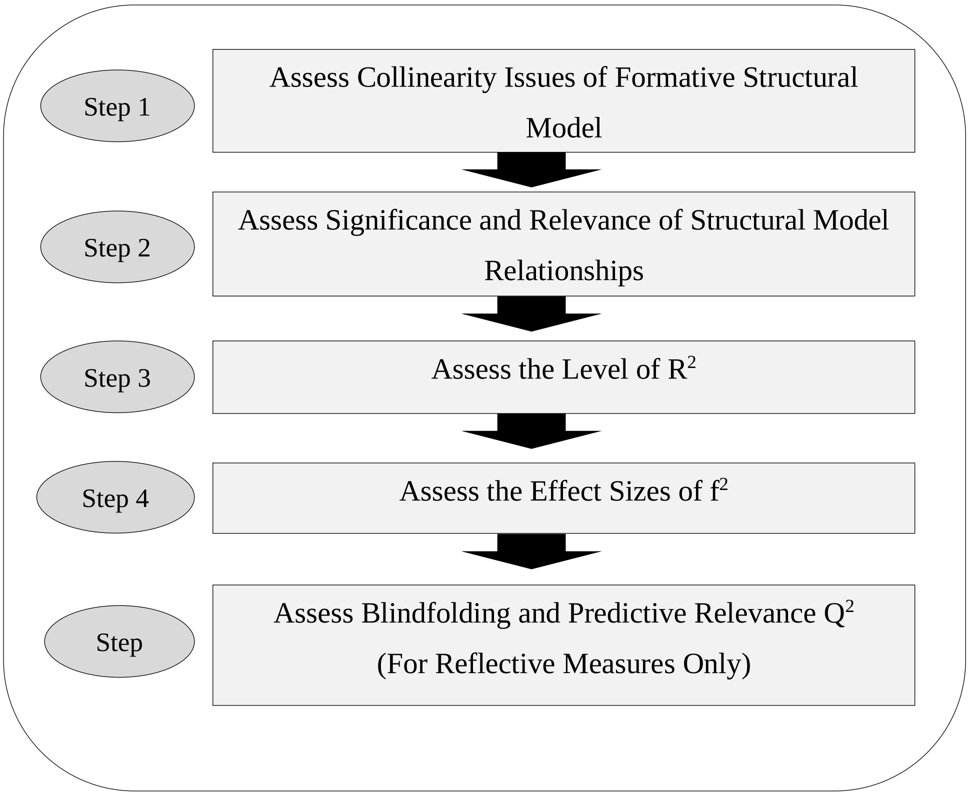


Figure 3.7: Structural Model Assessment Procedure

The objectives of structural model assessment are as follows (Hair et al., 2014):

- To determine the extent that empirical data support the theory or concept
- To evaluate the extent that the theory or concept has been empirically and statistically confirmed
- To measure the model's predictive capabilities and the relationships between the constructs.

The estimation of path coefficients for the structural model is based on ordinary least squares (OLS) regression of each endogenous latent variable on its corresponding predecessor constructs. During the estimation process, the path coefficients might be biased if the estimation involves significant levels of collinearity between the predictor constructs. The reason is that PLS-SEM fits the model to the sample data by maximizing the explained variance of the endogenous latent variable(s) (Hair et al., 2014).

Therefore, the first step in structural model assessment is to assess for collinearity separately for each set of predictor constructs. The measure for collinearity is the VIF, whereby a predictor construct's tolerance value of 0.20 or lower and a VIF value of 5 or higher indicate a potential collinearity problem (Hair et al., 2014, 2017).

The measurement of the structural model is based on heuristic criteria in determining the model's predictive capabilities for the endogenous variables or constructs (Rigdon, 2012). In the assessment procedure, the criteria used to measure the structural model in PLS-SEM are path coefficients, the coefficient of determination, effect size, blindfolding and predictive relevance.

In the second step, the bootstrapping procedure is run to obtain the empirical *t*-value as well as the bootstrapping confidence interval to assess the significance and relevance of the hypothesized relationships. The path coefficients represent the hypothesized relationships between the constructs. The significance of the path coefficient depends on its standard error, with this obtained from the bootstrapping procedure which computes the empirical *t*-value (Hair et al., 2014, 2017).

Once the empirical *t*-value is larger than the critical value, the path coefficient is significant at a certain error probability or significance level. The critical value is a cut-off value to determine the significance of a path coefficient or hypothesized relationship. For this study, the hypotheses are directional; therefore, one-tailed critical values are observed to determine the significance of the path coefficient and hypotheses. The critical *t*-values are presented in Table 3.6.

Table 3.6: Level of Confidence and Critical Value

Level of Confidence	Two-tailed Critical Value	One-tailed Critical Value
90% (*p < 0.10)	1.64	1.28
95% (**p < 0.05)	1.96	1.645
99% (***p < 0.01)	2.58	2.33

Next, the level of the coefficient of determination (or R^2 value), is calculated to determine the model's predictive accuracy. Thus, the coefficient of determination (or R^2 value) explains the amount of variance in endogenous constructs based on the number of exogenous constructs linked to the endogenous construct (Hair et al., 2014, 2017). The effect ranges from 0 to 1, in which the higher values represent better predictive accuracy. The common rule for R^2 is 0.75 for a substantial level of predictive accuracy; 0.50 for a moderate level; and 0.25 for a weak level (Hair et al., 2014, 2017; Hair, Ringle, & Sarstedt, 2011; Henseler, Ringle, & Sinkovics, 2009).

In the fourth step, the effect size (or f^2) is computed to explain the effect, that is, the change in R^2 of a specified exogenous construct when it is omitted from the model, and the subsequent impacts on the endogenous construct (Hair et al., 2014, 2017). The omission of the exogenous construct may cause substantive impact on the endogenous construct; therefore, the magnitude of the effect needs to be evaluated. The guidelines for assessing f^2 values are 0.02, 0.15 and 0.35 that represent small, medium and large effects, respectively, with effect size values of less than 0.02 indicating no effect (Cohen, 1988). If an exogenous construct strongly contributes in explaining an endogenous construct, the difference between R^2 included and R^2 excluded is high and, therefore, f^2 will be high.

In the fifth and final step, predictive relevance (Q^2) is evaluated to measure an indicator model's predictive relevance using the blindfolding procedure to obtain the cross-validated redundancy measures for each endogenous construct (Hair et al., 2014, 2017). However, the blindfolding procedure is used only in predicting the data points of the indicators of reflective measurement models comprising endogenous constructs and endogenous single-item constructs. The fifth step is not applicable for formative endogenous constructs; therefore, it is omitted for the structural model assessment in this study.

3.5 Chapter Summary

This chapter discussed a general understanding of scientific research, the scientific model and research paradigms. The steps undertaken for the three stages of the research process—exploration, design and execution—were then discussed. The chapter presented the study's three research questions and six hypotheses to be tested as illustrated in the research framework. This framework was developed based on the input-process-output (IPO) theory and the technological-organizational-environmental (TOE) framework, with the result being that the research model consisted of seven variables.

This study adopted a survey research strategy to obtain information from the sample of the selected population, namely, ISO 14001-certified manufacturing firms in Malaysia. The survey research strategy is usually adopted for exploratory and descriptive research. In the current study, the type of descriptive research chosen was correlation research, in which data were collected to determine whether, and to what extent, relationships existed between two or more quantifiable variables.

The sample was selected based on the purposive or judgmental sampling procedure. Manufacturing firms registered with the Federation of Malaysian Manufacturers (FMM) and ISO 14001-certified were the best representatives for investigating the drivers, practices and outcomes of the supply chain in moving towards achieving environmental sustainability. This study was cross-sectional in nature as the data were collected at one point in time from the selected sample to represent the population of interest at that particular time.

The instrument used in this study was constructed based on the adoption of existing validated measurements taken from the extensive review of the literature. The selected items were adapted to fit the context. The survey items were finalized during a pre-test study through cognitive interview sessions with five representatives from ISO 14001-certified manufacturing firms in Malaysia. In addition, interview surveys were carried out with three of the representatives. The interviews allowed the researcher to grasp a preliminary understanding of the 'what', 'how' and 'why' aspects of the study. As part of descriptive research, the interview survey provides the means to identify a general pattern and relationships between the variables under study; therefore, it provides valuable input for the main data collection and analysis.

The finalized version of the survey questionnaire underwent a pilot study with 60 ISO 14001-certified manufacturing firms in Ipoh and Kulim. However, only 32 questionnaires were received and used to test the validity and reliability of the questionnaire. As validity and reliability had been achieved, the researcher proceeded with the main study's data collection from 523 ISO 14001-certified manufacturing firms in Malaysia. At the end, only 165 effective responses were able to be considered in the statistical analysis and discussions.

This research employed IBM's SPSS version 19.0 for data coding, detecting missing data, suspicious response patterns (straight lining or inconsistent answers) and outliers, as well as computing data distribution, and descriptive analysis. The SPSS software was utilized for the first part of the analysis, while SmartPLS 3.0 was utilized for the second part.

Multivariate analysis is the application of statistical techniques that analyse multiple variables simultaneously, with PLS-SEM techniques preferred as the latent variables or constructs, and the indicators were formatively measured. The PLS path model consists of the structural model (inner model) that represents the constructs and the relationships between the construct, while the measurement model (outer model) displays the relationships between indicator variables. Thus, the PLS-SEM analysis was divided into two parts: (1) the measurement model with three stages of analysis and (2) the structural model with four stages of analysis.

Chapter 4 and Chapter 5 discuss the findings from the pre-test study, the pilot study and the main study. The descriptive and multivariate analyses with IBM's SPSS version 19.0 and SmartPLS 3.0 are presented along with detailed discussion.

Chapter 4

RESULTS AND DISCUSSION: PRE-TEST STUDY AND PILOT STUDY

4.1 Introduction

The results and discussion chapters are divided into two parts: Part 1: Pre-Test Study and Pilot Study Analyses, and Part 2: Main Study Descriptive and PLS-SEM Analyses. This chapter focuses on Part 1 in which the details of pre-test and pilot test procedures are discussed. The chapter is divided into three sections: cognitive interviews for the pre-test, interview survey and questionnaire survey for the pilot test.

The cognitive interview describes a systematic way of identifying, analysing and controlling sources of response error in the survey questionnaire due to alternative interpretations of the questions. Cognitive interviewing thus increases the validity and reliability of the measures of the indicators included in the survey questionnaire.

Interviews were carried out with representatives of three ISO 14001-certified manufacturing firms. The objectives of the interviews were to obtain a preliminary understanding as well as confirmation of the variables and indicators selected for the survey questionnaire from the systematic literature review.

In addition, this chapter discusses the preliminary findings obtained from representatives of 32 ISO 14001-certified manufacturing firms during the pilot study. Descriptive analysis, reliability analysis, normality test and bivariate correlation are discussed. This chapter concludes with a summary.

4.2 Pre-Test: Cognitive Interviews and Analysis

During the first wave of cognitive interviews, the interviewer adopted retrospective think-aloud probing to encourage interviewees to verbalize their thoughts on the questions they answered earlier while responding to the questionnaire. The advantage of this method is that, by being passive during the interviewing process, the interviewer is free from bias arising from frequent interruptions through use of the probes. Furthermore, retrospective think-aloud probing has minimal interviewer training requirements and uses open-ended design probes. However, a small possibility exists that interviewees might meander or be biased in the descriptions and decision processing used in answering the survey questionnaire. At the end of the first round, each interviewee was asked to provide verbal open-ended feedback on each item regarding the instructions, response category and scale, terminology, item interpretation, time frame, overall impression of content and coverage.

The results from the cognitive interviews demonstrated that the five interviewees interpreted and responded to the survey items as intended. Each interview took approximately one to two hours to express their opinions in answering the questionnaire. Interviewees were encouraged to use cognitive strategies such as thinking aloud and recalling the green practices currently being carried out in their companies. However, at times, an interviewee faced difficulty in grasping some terminology or a phrase; therefore, their interpretation of the questions may vary from that of another interviewee. The coverage of the content in the survey questionnaire was found to be too broad. Therefore, interviewees at executive level faced much more difficulty in comprehending, retrieving and responding to the items in the survey questionnaire. In addition, interviewees provided valuable feedback for improvements to the format of the questionnaire, the language, instructions, response options and the scale used.

In addition, the survey questionnaire was reviewed by a local researcher who is an expert in the field of GSCM, Green IT and Green IS. The reviewing process was done in the researcher’s office at a local university. Based on feedback provided by the firms and the experts, the survey questionnaire was revised and improved from 162 items of 15 variables to 51 items of seven variables and six socio-demographic items rated on 5-point Likert scales. The results from the cognitive interviews are discussed in Section 4.2 and presented in Appendix D.

4.3 Pre-Test: Interview Survey and Analysis

Of the five representatives who participated in the cognitive interview sessions, only three indicated their interest in participating in the interview survey. The interview sessions were carried out in their respective offices located in their own firm at the agreed date and time. The two of the firm representatives are unable to participate due to their busy schedule. But, they continue to give full support as they believe this research will benefits the manufacturing sector towards becoming environmentally and economically sustainable organization.

Verbatim transcription of interview data is widely considered to be integral to the analysis and interpretation of verbal data. Verbatim transcription refers to the word-for-word reproduction of verbal data, where the written words are an exact replication of the audio recorded words (Poland, 1995) and concurrent note taking (Halcomb & Davidson, 2006). Thus, verbatim quotations from interviewees or research participants has become effectively standard practice in social research that include direct quotations in the reporting (Anne Corden and Roy Sainsbury, 2006). The verbatim quotations can be used as the matter of enquiry; as evidence; as explanation; as illustration; to deepen understanding; to give participants a voice, and to enhance readability (Anne Corden and Roy Sainsbury, 2006).

Positivist research uses predominantly quantitative data, but can also use qualitative data (Bhattacherjee, 2012). Survey research is categorized into two forms: a written survey called ‘a questionnaire’ and an oral survey known as ‘an interview’ (Bhattacherjee, 2012). Survey research a research method involving the use of standardized questionnaires or interviews to collect data about people and their preferences, thoughts, and behaviors in a systematic manner.

The verbatim quotations offer researcher and readers a greater depth of understanding on the interviewee's views or feelings on the subject matters or themes (Anne Corden and Roy Sainsbury, 2006). In this study, the themes and list of questions to asked during the interview session are adopted from the survey questionnaire itself. Hence, this interview survey provides the means to identify a general pattern and to understand the basic relationship between the chosen variables which will deepen the understanding on the context under study.

Therefore, the objectives of the interviews were to identify the: (1) factors that influence ISO 14001-certified manufacturing firms to embark on green practices; (2) role of IT and IS in the supply chain; (3) role of IT and IS in improving environmental footprints; (4) green practices implemented in the supply chain, and (5) effect of implemented green practices on the organization's performance. With interviewees' consent, the sessions were audio recorded and written notes were captured. Each session took about two hours, along with visits to the production lines and the HSE and IT departments of the three companies.

4.3.1 Green Supply Chain Management (GSCM)

The first interview session was with the Managing Director (MD) of Company A, a European-based company that produces energy-efficient air filters for commercial and industrial use. The MD explained that the company is continuously researching and working towards producing green products. The company is environmentally-conscious in performing its activities throughout its supply chains.

Company B is an American-based company that produces household gloves, industrial rubber gloves and high-risk gloves. The Production Director (PD) indicated that its compliance with the green movement is directly influenced by the green policies of the parent company, along with having strong internal supports to reduce ecological impacts from factory activities.

The third interview session was with the Operation Manager (OM) of Company C, a company that produces foil and hot stamping for decorative and security industries. The OM highlighted that raw materials used in Company C's production are in accordance with international environmental standards, and that they also comply with directives and guidelines from sister companies and customers. The verbatim transcription transcripts are presented in Table 4.1.

Table 4.1: Green Supply Chain Management

Company A: "As stated in the sustainability report, our products are green because, firstly, we construct part of the products using environmentally-friendly and biodegradable materials. Secondly, economical use [is made] of resources to build the products. Thirdly, [we] stretch the lifetime of the products. These three steps have allowed us to minimize waste to reduce the impact on the environment. We design and produce products that reduce energy consumption for others. We work closely with our customers and suppliers in meeting the required green specifications as well as in complying with legislation and environmental directives. We launched a new generation of green low-energy filter which is much more compact with reduced use of raw materials and resources without affecting its performance. This has also resulted in lower transport volumes. Apart from this, our long-term commitment is to integrate environment sustainability and our corporate citizenship programme as we strive to show our care for our community, the environment and shareholders. Since 2009, we have organized community-oriented activities such as seminars on green tips for energy savings at home, resource efficiency and a waste reduction programme as well as activities that involve local charities".
Company B: "With assistance from in-house R&D, we are looking at ways to make our processes and products more environmentally-friendly. We closely collaborate with our customers whereby the products are produced according to the specifications given. We provide clear guidelines to our suppliers on the green requirements and compliance needed. However, only a few of our suppliers are certified.

We sell our reusable waste to other companies that build tyres and toy parts, which will reduce landfill waste. Our newly invented packages use less resources, are easier to produce and to dispose of, and some are biodegradable. This has increased the number of bags that can be transported at one time and reduces transportation costs. Our headquarters constantly evaluates our worldwide operations with the goal of zero waste. Not only that, but we constantly comply with the laws of the communities and energize our local community and employees to participate in sustainable projects."
Company C: "Our parent company's environmental policies provide the foundation for us to be environmentally conscious, with our focus being on economical use of resources in production processes and the development of products. We get most of our materials from our sister companies. The raw materials used must be according to the requirements, including chemical safety requirements, of the REACH standard. Those wastes that can be reused are fed into distillation machines to check their chemical composition before being reused in other processes. This has saved us the costs incurred for scheduled wastes. However, those that are not recyclable are disposed of safely using a third-party service."

The interviews revealed the anticipation of ISO 14001-certified manufacturing firms in implementing green practices throughout the supply chain. Looking at each stage of the supply chain, the three representatives emphasized:

- opting for materials or components that are less hazardous with minimal impacts on the environment
- design of products with reduced consumption of energy, extended product lifetime, use of biodegradable materials and minimization of the amount of resources used
- optimization in the packaging with minimal resources used, safe disposal and biodegradability of components in the packages/boxes
- end-of-life (EOL) products undergoing safe disposal as well as incineration of product remains and wastes via third-party services.

4.3.2 Organizational and Environmental Context – Internal and External Factors

The most significant drivers that motivate ISO 14001-certified manufacturing firms in Malaysia are regulations, expected business benefits, customer pressures and corporate social responsibility (CSR) (Eltayeb et al., 2010).

As reported by the MD of Company A, the influential factors that motivate the implementation of green practices in an organization are top management support, employee commitment and external stakeholders. As explained by the PD of Company B, the act of greening is voluntary in Malaysia, and is usually exercised to comply with international environmental standards and directives. Therefore, strong commitments from management and employees are vital factors for the adoption of innovation and invention. The OM of Company C highlighted that compliance with legislative requirements together with internal management commitment exert the greatest push for organizations to be proactive. The verbatim transcription is presented in Table 4.2.

Table 4.2: Internal and External Factors

Company A: "Firstly, continuous support from top management and the parent company. Continuous improvement is a must as long as you have the right people and right system in place. It must be done through targets, review meetings, audits, corrective actions with sufficient resources, R&D and money. The constant dialogues with our stakeholders and good relationships with our customers and suppliers have profiled us as a green enterprise."
Company B: "I very much believe that our green practice is voluntary as there is no push from local laws. Our management is very supportive, and our employees are committed. We do it systematically with proper records of internal and external audits. It is not a requirement for our suppliers to be certified, but we comply with our customers' requirements. We encourage our suppliers towards environmentally-friendly practice and to be certified."

Company C:

"We sell lots of our products to our sister companies and our subsidiaries. We comply with environmental law and some other international bodies' directives. It is not compulsory by Malaysian law to be ISO 14001 certified. We get good support from our parent company. However, the cost and budget are always management's biggest concern."

Green supply chain management (GSCM) is viewed as an initial strategy for firms in complying with environmental requirements and legislation imposed in most industrialized nations (Hu & Hsu, 2010). The critical factors are access and availability to organizational internal resources; management commitment; cross-departmental support; strong employee involvement; internal knowledge sharing; offering relevant environmental training; and assigning qualified personnel to handling environmental issues and green initiatives (S. Y. Lee, 2008; Sarkis, Gonzalez-Torre, & Adenso-Diaz, 2010; Q. Zhu et al., 2008a, 2008b) as well as having an eco-friendly proactive culture (Walker, Sisto, & McBain, 2008). Furthermore, GSCM implementation requires long-term investment which can be costly with an unclear return in the short term (Sarkis et al., 2010).

Regulations will induce organizations to review their supply chain in order to comply with laws and environmental directives (G.-C. Wu et al., 2012). Policy makers and government agencies must play a proactive role in formulating relevant environmental standards and legislation that have profound impacts on mitigating environmental risks (Zailani et al., 2012). This will influence organizations towards greening their processes, products and services. Thus, an organization can minimize risks and uncertainty by adhering to local and international regulations and standards.

4.3.3 Technological Context – Information Technology (IT), Information Systems (IS), Green IT and Green IS

The technological components, particularly environmentally-friendly IT and IS, are poorly adopted throughout the supply chain. However, the three representatives interviewed highlighted the importance of IT and IS in supporting supply chain activities. The verbatim transcription is presented in Table 4.3.

Table 4.3: Information Technology and Information Systems

Company A: "Technology and systems are part and parcel of our daily tools and are the catalyst to run processes efficiently, to communicate effectively, and to run the whole business smoothly. We are keeping abreast of technology and applications as long as it is justifiable and reasonable to the company, cost and environment."
Company B: "We need technology, we require technology, we depend on technology for everything, each day and every day in our business activities. Information technologies and systems are a necessity as different processes in supply chains need various technology components, hardware, software, applications and networks. But companies still question the tangible return versus the cost of implementing the technologies and systems. Nevertheless, companies will not be able to sustain their operations without the support of technologies and systems."
Company C: "In our company, technologies and systems are utilized in streamlining essential activities in our business, including supply chain processes. Much of the hardware and software and the applications used have resulted in higher productivity for the company, yet the trade-off between benefit and cost is still a concern in the company."

The above statements made by the companies' representatives clearly indicate the importance of IT and IS in supporting business processes and activities. The use of IT and IS enhances the companies' capabilities to facilitate seamless interaction with suppliers, to accommodate customer requirements and to react proficiently to the intensified race with competitors (Sundarakani et al., 2012).

The verbatim transcription by the companies' representatives on the extent of environmentally-friendly IT and IS implementation within their organizations is presented in Table 4.4.

Table 4.4: Green IT and Green IS

Company A: "Some of the software is purchased directly from the market, usually for the Purchasing and Logistics departments. We interact with employees, partners, suppliers and customers using video conferencing and other tools for collaboration. We developed in-house applications and purchase on-shelf to measure environmental indicators, such as the materials/components used, energy usage, and emissions and wastes produced in processes, as well as conducting final product simulation (e.g. to find the most energy-efficient solution). We procure energy-efficient IT hardware, for example, those with an Energy Star rating and suppliers that offer take-back options once the equipment reaches [its] end of life (EOL). Those [wastes] that are recyclable will be reused. For the rest, we opt for safe disposal of e-waste. We implemented server and storage virtualization technology recently to support the daily business operation, and yet the main data centre is based at the parent company. I believe that environmentally-friendly technologies and systems play important roles in today's complex supply chain management as a tool to get an organization moving towards becoming environmentally sustainable. Yet, it is difficult for us to quantify the benefits gained since we have not completely measured the efficiency of the energy consumed, or the waste or emissions produced from the IT infrastructure and equipment. Neither is routine for us to do, nor is using a KPI [key performance indicator]."

Company B: "We use applications to support interaction, collaboration, planning, buying, selling, transporting and many more. We use software and sensor technology in the production lines to track and monitor the physical item and many more. These include environmental markers such as water consumption, chemical composition, and generated waste and emissions. In terms of environmentally-friendly technology, we purchased energy-efficient computers and equipment. We have just adopted server virtualization technology. We prefer suppliers that collect the IT hardware and equipment once they are obsolete. We recycle some of the IT components. Others will be safely disposed of using a third-party service. We need to prioritize as the allocated funds, costs and intangible returns do not allow us to purchase technologies and systems that are right for the environment. Hopefully, we will be able to do much better in future. Moving towards sustainable IT and IS is a journey for us. Investment in systems and software is easily justifiable as compared to IT infrastructure and equipment. The cost of greening IT is high, and it is difficult for us to show the value that it will bring to the business. We are still new to it, and it is not as significant as it should be, compared to sustainable manufacturing practices."
Company C: "We encourage double-sided printing. We are working hard towards a paperless office. We use software for print optimization, PC management, teleconferencing and video conferencing. We prefer energy-efficient PCs, hardware and equipment but we are not strictly adhering to that policy. The obsolete equipment and electronic waste [e-waste] are safely disposed of by [a] third party. We have an in-house server room, but we are yet to adopt any [of the] latest technology. This is due to its cost and its relevancy to the business. However, the effects of IT and IS on the environment in terms of energy consumption, carbon emissions and e-waste are still insignificant to management, compared to other environmentally practices in the supply chain and logistics. The process of greening IT and IS are long, the products are costly and lead to unclear

business value, taking a longer time for a positive return. We do not have any specific metrics to measure the hardware, software and network performance."

Apart from human and financial resources, physical resources, such as IT and IS, are crucial for companies (S. Y. Lee, 2008). The incorporation of environmentally-friendly IT and IS solutions into everyday supply chain activities enables the organization's ability to make sound environmental decisions; however, this is still lacking in the three companies, as reported by their interviewed representatives. Most companies are still unable to explicitly recognize and integrate environmentally-friendly IT and IS solutions into their sustainability plans (Hodges & White, 2009; Löser et al., 2012). This situation is worsened by the lack of environmental awareness, lack of technological know-how and lack of a sense of urgency in minimizing ecological footprints from facilities, office equipment and data centres, as well as from system applications.

4.3.4 Performance Outcomes: Environmental Performance

Many organizations implement green practices to achieve improvements, ranging from good to significant, in their environmental performance. Many have successfully achieved reductions in: carbon emissions; and energy, water and hazardous materials consumption, as well as waste production.

Of the three companies interviewed, only Company A was participating in a CSR initiative. The performance outcomes attained varied between the organizations as they also depend on the nature of the business and the size of the firm. The interview transcripts are presented in Table 4.5.

Table 4.5: Environmental Performance

Company A:
"Our current green movement throughout the supply chain has resulted in: (1) a significant increase in energy efficiency and reduction of carbon emissions; (2) reduced consumption of hazardous materials and components; (3) reduced waste

production; and (4) increased process efficiency and product quality that has led to the introduction of a new green product line. Current water usage throughout production is very minimal. We are still working towards environmentally-conscious packaging, waste management and logistics. Every year we carry out activities that promote green practices and programmes to assist those in need within our local community.”
Company B: “We have: (1) minimized the production of landfill waste and packaging; (2) used environmentally-friendly materials according to international standards; (3) achieved a considerable amount of energy saving; and (4) introduced a new green product line. We use lots of water throughout production. The waste water undergoes treatment before its disposal. We are looking at ways to reuse the water. Our biggest achievement is on the packaging. The new packaging reduces the overall packaging material waste by as much as 81.9%.”
Company C: “The materials used are according to REACH guidelines, therefore they are environmentally acceptable. This also increases our product quality. We have managed to reduce to an extent the production of emissions and wastes. We have reasonably improved the environmental situation of our plant.”

The GSCM concept is widely diffused among companies seeking to improve their environmental performance (Testa & Iraldo, 2010). Most companies in developing countries are implementing green solutions within business operations with the intention of reducing negative environmental impacts rather than adopting a proactive approach to reduce the sources of environmental problems (Anbumozhi & Kanda, 2005). Manufacturing firms in different nations (e.g. Western vs. Asian countries) may face different pressures and barriers, resulting in variable performance outcomes. However, with strong internal support and by complying with regulations, firms can preemptively implement green practices in SCM for significant environmental improvements.

4.3.5 Performance Outcomes: Technological Performance

As concluded by the three interviewed representatives, the impacts from using environmentally-friendly IT and IS in mitigating environmental risks are still viewed by their firms as equivocal. The interview transcripts are presented in Table 4.6.

Table 4.6: Technological Performance

Company A: "Different parts of SCM processes have different requirements for hardware, software and applications. Some of these applications improve decision making, allow flexibility and enhance overall performance of SCM [supply chain management]. Greening of IT and IS are highly dependent on the trade-off between benefit gained and cost incurred. We need to identify the company's critical areas for ecological improvement. With paperless, energy-efficient hardware/components, energy-efficient lighting and facilities' equipment, and virtualization, we are able to capture and contribute to environmental gains. We comply with directives such as Energy Star, WEEE and safe e-waste disposal. Currently, we are still lacking in quantifying the efficiency of energy consumed, and the waste or emissions produced from the IT infrastructure, equipment and applications installed. It is also not part of our job routine. We are not aware of any specific metrics to measure this. The ones developed in-house are not comprehensive. It will be great if the parent company or internal management could see the importance of quantifying them as soon as they are implemented. It is possible as long as it is taken into consideration for the internal audit process and the firm's KPIs [key performance indicators]."
Company B: "IT and IS are required to streamline the processes in SCM: that will result in better productivity, quality and visibility. Moving towards sustainable IT and IS will be a journey for us. We are still new to it, and it is not as significant as compared to sustainable manufacturing practices. We are taking little steps to install environmentally-friendly infrastructures, equipment, hardware and system

applications. We are very much dependent on software and applications.

Those investments are more obvious for justification, compared to IT infrastructure and equipment. For us, virtualization technology is an obvious step for a company to implement green technologies. We often measure environmental indicators from supply chains, as compared to IT infrastructure, equipment and facilities. We observe certain standards such Energy Star and EPEAT. We dispose of e-waste in an environmentally-friendly manner, whereby some waste is recycled and reused, and other waste is managed by a third-party vendor.

Hopefully, with the budget and resources allocated, we will focus on systematically installing, monitoring, measuring and reporting our green initiatives."

Company C:

"The uses of IT and IS are critical and a prerequisite for seamless relationships throughout SCM processes, from downstream to upstream. Without them, we would be in mess. We are working towards a paperless office and use less electricity power and safe disposal of electronic waste [e-waste]. The entire greening processes are costly and difficult to rationalize to top management.

We need to balance between environmental and financial concerns. No specific metric is being used to measure eco-friendly activities related to IT and IS. But we are trying to comply with certain standards, like Energy Star."

From the preliminary data gathered, this study observed that IT and IS are the foundation for organizations to run business operations and processes smoothly. The use of technologies improved the availability, visibility and timely distribution of information to customers, and simultaneously increased production efficiency of the supply chain.

Based on the interviews, these three companies have successfully implemented procedures to safely dispose of electronic waste (e-waste). While consumable items are recycled, others are disposed of safely to landfill or incineration at disposal reserve areas by third-party companies. The firms also earn income from selling recyclable waste products. The implementation of environmentally-friendly IT and IS simultaneously lowers energy and utility costs, waste disposal costs and usage of consumable items, which leads to more tangible savings in costs and resources (Mithas, Jiban, & Roy, 2010; R. T. Watson et al., 2010).

The three representatives from the companies strongly believed that, with support from management and availability of financial resources, their companies could not only purchase energy-efficient computer systems, but also replace the current systems. However, only Company A had begun implementing technologies, such as virtualization and cloud computing, as part of its initiatives to reduce power consumption and electronic waste (e-waste). All three companies placed significant importance on the use of software and applications, such as collaboration tools, telecommuting, and telepresence and video conferencing tools that minimized travelling, as well as maximizing the efficiency of supply chain processes.

The three companies interviewed are still lacking in their adoption of metrics, standards or a framework to measure the IT and IS functions and their positive and negative impacts on the environment. Furthermore, performance outcomes from the greening of IT and IS are not included in current sustainability reporting.

The United Nations Conference on Trade and Development (UNCTAD) emphasizes the numerous internationally agreed standards, directives and guidelines that are used to measure IT and IS functions; however, it adds that these frameworks must be supported by clear internal environmental policies and strategies (United Nations Conference on Trade and Development (UNCTAD), 2011). With the systematic implementation of measurement frameworks and metrics, organizations can enjoy both financial and environmental gains.

The measurement of and reporting on the use of environmentally-friendly IT and IS in mitigating environmental issues are relatively new (United Nations Conference on Trade And Development (UNCTAD), 2011). The direct impacts can easily be demonstrated and measured using scientific knowledge, such as metrics with mathematical calculations. However, in some contexts, the impacts of the use of IT and IS are harder to capture and assess. Despite the importance of this field, empirical evidence is still lacking on the impacts of environmentally-friendly IT and IS in enhancing environmental performance.

4.4 Pilot Test: Questionnaire Survey Administration and Analysis

The aim of pilot testing a survey questionnaire is to determine its validity and reliability. The pilot test signals possible issues in instruments, methods or sampling that need to be resolved before proceeding to the main study (van Teijlingen et al., 2001). The invitation letter for survey participation and a sample of the survey questionnaire used in the current study are presented in Appendix C.

4.4.1 Demographic Profile

Table 4.7 presents the profile of respondents involved in the pilot study. Most respondents held an executive position (16 respondents/50.0%) with the remainder comprising 13 respondents (40.6%) in managerial positions and three respondents (9.4%) in director positions. These positions combined comprise the total 32 respondents who participated in this study. It can be concluded that most respondents in this study (20 respondents/62.5% of the total sample size) worked in the IT department. The remaining 12 respondents (37.5%) were employed in the Operations department.

In terms of industry sectors, the electrical and electronics industry, with seven respondents (21.9%), had an equal number of respondents to the rubber and plastic products industry. The distribution of respondents in the chemicals and chemical products industry was the same number (three respondents/9.4%) as in the machinery equipment industry. One respondent (3.1%) worked in the metal products industry and the remaining 11 respondents (34.4%) worked in other industries such as automotive parts, stationery, paper and packaging, and food and beverages. Most respondents, 23 of them (71.9%) came from multinational corporations (MNCs) with nine (28.1%) working in firms that were categorized as small and medium-sized enterprises (SMEs).

Table 4.7: Summary Results of Respondents' Profile (n=32)

Respondents' Profile	**n**	**%**
Position		
Director	3	9.4
Manager	13	40.6
Executive	16	50.0
Department Classification		
Operations	12	37.5
Information Technology	20	62.5
Industry		
Electrical and Electronics Products	7	21.9
Chemicals and Chemical Products	3	9.4
Rubber and Plastic Products	7	21.9
Metal Products	1	3.1
Machinery Equipment	3	9.4
Others	11	34.4
Firm Size		
SME	9	28.1
MNC	23	71.9

4.4.2 Reliability Analysis

The reliability of the measurement items was measured by performing an analysis of Cronbach's alpha values to ensure the quality of the research instrument. The widely accepted social science cut-off for Cronbach's alpha value is 0.70 or higher if a set of items is to be considered as a reliable scale; however, some researchers use 0.75 or 0.80, while others are as lenient as 0.60 (Nunnally & Bernstein, 1994).

Substantial variations were evident in Cronbach's Alpha values for all variables, ranging from 0.611 to 0.878. Alpha values greater than 0.60 are generally considered to indicate a reliable set of items, with regulatory pressure at 0.611 having the lowest value for reliability. However, with the value being above 0.60, this variable was still considered acceptable and reliable.

The variables for internal commitment and technological performance were also indicated as reliable grouped items (0.744 and 0.769, respectively). Furthermore, GSCM, Green IT, Green IS and environmental performance had a reliable set of grouped items to measure the variables accordingly (0.861, 0.850, 0.845 and 0.878, respectively). As all measurement items met the threshold value for reliability analysis (Cronbach's alpha > 0.60), it was thus concluded that all the measurement items were acceptable, valid and reliable for use in the main study, as presented in Table 4.8.

Table 4.8: Summary of Reliability Analysis

Variable	Cronbach's Alpha	Number of Items
Green IT	0.850	6
Green IS	0.845	5
Internal commitment	0.744	4
Regulatory pressure	0.611	4
Green supply chain management (GSCM)	0.861	12
Environmental performance	0.878	7
Technological performance	0.769	6

4.4.3 Normality Test

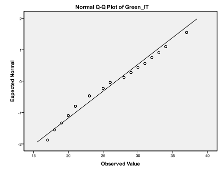
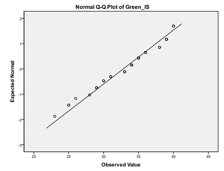
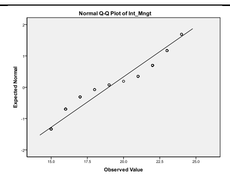
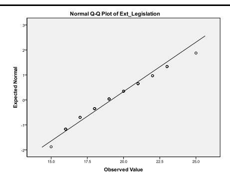
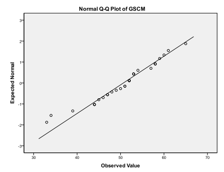
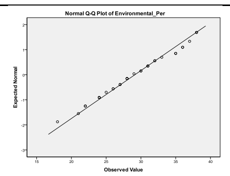
The normality test is performed to test the assumption about the distribution. Normal quantile-quantile (Q-Q) plots are also one method that is used to measure the normality of the variable. If the majority of the observed values (smaller dots) lie on a straight line in the plot, then that variable is considered as being approximately normally distributed (Pallant, 2010; Sheridan, Steed, & Ong, 2010).

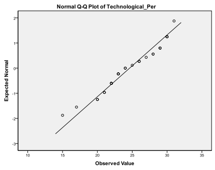
The data distribution pattern is considered normal when both skewness and kurtosis are close to zero (0), which is seldom encountered (Field, 2013). Hence, a general guideline for skewness is that a value greater than +1 or lower than -1 represents a substantial skewed distribution while, for kurtosis, if the value is greater than +1, the distribution is too peaked, and if less than -1, the distribution is too flat.

Therefore, distributions of data that exceed the guidelines of skewness and kurtosis are considered non-normal.

Most of the observed values lie on the straight line in the Q-Q plot which explains the nature of normally distributed items. Therefore, it was concluded that the items and data collected for the pilot study were within the normally distributed range, as presented in Table 4.9.

Table 4.9: Summary of Normal Distribution

Variables	Skewness Statistic	Kurtosis Statistic	Q-Q Plot	Decision
Green IT	0.151	-1.027		Normally Distributed
Green IS	-0.257	-0.727		Normally Distributed
Internal Commitment	0.162	-1.529		Normally Distributed
Regulatory Pressure	0.374	-0.567		Normally Distributed
Green Supply Chain Management (GSCM)	-0.529	0.485		Normally Distributed
Environmental Performance	-0.031	-0.646		Normally Distributed

Technological Performance	-0.259	-0.477		Normally Distributed

4.4.4 Pearson's Correlation

Pearson's correlation was used next to investigate the relationship between the variables of interest and the research hypotheses as the assumption of the normality of the variables had been met (Field, 2013). A coefficient correlation of 0.81 to 1.0 indicates excellent strength; a coefficient correlation between 0.61 to 0.80 indicates very good strength; a coefficient between 0.41 and 0.60 indicates good correlation strength; a coefficient between 0.21 and 0.40 measures fair strength; and a correlation coefficient of less than 0.20 shows poor correlation (Bluman, 2012).

The bivariate correlations between all independent variables, namely, Green IT (r (32) = 0.858, $p < .001$); Green IS (r (32) = 0.766, $p < .001$); internal commitment (r (32) = 0.720, $p < .001$); and regulatory pressure (r (32) = 0.607, $p < 0.001$), showed a significant positive bivariate correlation to green supply chain management (GSCM). Therefore, an increase in Green IT, Green IS, internal commitment or regulatory pressure will correspondingly increase GSCM implementation as they are bivariate correlated.

On the other hand, the analysis also indicated that Green IT (r (32) = 0.897, $p < 0.001$); Green IS (r (32) = 0.812, $p < 0.001$); internal commitment (r (32) = 0.847, $p < 0.001$); regulatory pressure (r (32) = 0.635, $p < 0.001$); and GSCM (r (32) = 0.856, $p < 0.001$) portray a significant positive bivariate correlation to environmental performance. This analysis indicated that, as they are bivariate correlated, the positive effects from Green IT, Green IS, internal commitment or regulatory pressure that increase with GSCM implementation will also positively increase the influence on environmental performance.

The same scenario was observed for technological performance. Hence, Green IT (r (32) = 0.842, *p* < 0.001); Green IS (r (32) = 0.712, *p* < 0.001); internal commitment (r (32) = 0.680, *p* < 0.001); regulatory pressure (r (32) = 0.699, *p* < 0.001); and GSCM (r (32) = 0.853, *p* < 0.001) were statistically positively bivariate correlated to technological performance. Thus, it is understood that if any of the independent variables listed above has a positive influence on GSCM implementation, then it will also increase the technological performance of the firm.

Moreover, environmental and technological performance were bivariate correlated as values of r (32) = 0.816 and *p* < 0.001 were achieved between these two variables. Therefore, if the level of environmental performance increases, then the level of technological performance will accordingly increase. In conclusion, the results obtained deduced that all variables had a positive bivariate correlation to each other (*p* < 0.001). The strength of the bivariate correlations was categorized from good to excellent (correlation range: 0.588 to 0.897), as presented in Table 4.10.

Table 4.10: Summary of Pearson's Correlation

Variables	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	1.000						
2	0.804**	1.000					
3	0.826**	0.882**	1.000				
4	0.650**	0.699**	0.588**	1.000			
5	0.858**	0.766**	0.720**	0.607**	1.000		
6	0.897**	0.812**	0.847**	0.635**	0.856**	1.000	
7	0.842**	0.712**	0.680**	0.699**	0.853**	0.816**	1.000

Notes: 1) Green IT; 2) Green IS; 3) Internal commitment; 4) Regulatory pressure; 5) Green supply chain management (GSCM); 6) Environmental performance; 7) Technological performance' **p < 0.001; n = 32

4.5 Chapter Summary

The chapter presents the initial findings gathered from the cognitive interviews, survey interviews and survey questionnaire. Firstly, for the pre-test study, cognitive interviews were conducted with five managers from ISO 14001-certified manufacturing firms located in Ipoh. The aim of the cognitive interviews was to assess the survey questions and instrument in a more systematic way. As a result, the survey questionnaire was revised and improved from 162 items of 15 variables to 51 items of seven variables with six socio-demographic items rated on 5-point Likert scales.

Of the five representatives from ISO 14001-certified manufacturing firms who participated in the cognitive interviews, three agreed to participate in the interview survey. From the interview sessions, a few important findings were captured, giving the researcher a preliminary understanding on the context of study as well as variables and hypothesized relationships.

For the pilot test of the survey questionnaire, 32 survey questions were used as the data set to check the reliability, measurement error, and the validity of each variable and of the measurement items. All the measurement items to be used in the main study were found to be valid and reliable, within the normal distribution range as well as have positive bivariate correlation to each other.

The next chapter presents and discusses the detailed analyses of the use of partial least squares-structural equation modelling (PLS-SEM) to conduct multivariate analysis. The aim was, firstly, to determine the extent to which the empirical data support the theory or concept. Secondly, the aim was to evaluate the extent which the theory or concept had been empirically and statistically confirmed. Thirdly, the aim was to measure the model’s predictive capabilities and the relationships between the constructs.

Chapter 5

RESULTS AND DISCUSSION: MAIN STUDY

5.1 Introduction

This chapter presents the second part of the results and discussion, with the focus being on the main study's findings from the survey questionnaire and the multivariate analysis with PLS-SEM approach using SmartPLS 3.0 software. The chapter is divided into four sections: data screening and descriptive analysis; assessment of the formative measurement model; assessment of the structural model; and discussion of the overall findings in relation to the research questions, research objectives and research hypotheses.

For the main part of this study, a total of 165 responses were analyzed. Data screening was essential to ensure that the gathered data were correctly coded, entered and outlier-free, and to reveal the extent of the data normality measurement. The descriptive analysis was carried out to transform the data into meaningful information, particularly for demographic variables.

The two crucial steps of the main data analysis are presented in Section 5.3 and Section 5.4: these steps determine the extent to which the theory has been empirically and statistically supported. The data analyses comprise assessment of data validity, reliability, relevancy and path significance; hypothesized relationships; the model's predictive accuracy; and the effect size of the formative indicators of exogenous constructs (independent variables).

Section 5.5 discusses the findings in respect to the formative items for each variable and the hypothesized relationships in relation to the both theories, TOE and IPO. Finally, this chapter concludes with a summary in Section 5.6.

5.2 Data Screening and Descriptive Analysis (SPSS)

The descriptive statistics describe the respondents' profile, data distribution, non-responses and common method bias analysis. Upon completing the collection of survey responses, the data underwent coding and the data entry process before further analyses were carried out. For the missing values more than 25%, mean value replacement technique was used to replace the missing values of an indicator variable with the mean of the valid values of that indicator variable.

Next, any responses that marked the same response pattern, for example, in 5-point scales, all 1s, 3s or 5s, would create a suspicious response pattern, such as straight lining. After screening 165 questionnaires, 10 survey questionnaires with straight lining response pattern were removed. Extreme response to a particular item or to all items in the survey questionnaires is known as an outlier. The existence of outliers may cause bias in the model fit which would affect the normality of the data and distort the statistical results.

5.2.1 Data Distribution (Normality)

Partial least squares-structural equation modelling (PLS-SEM) is a non-parametric statistical method; therefore, unlike CB-SEM, it requires the data to be normally distributed (Field, 2013; Hair et al., 2014). However, despite this, it is crucial to identify the extent of normality as extremely non-normal data can be problematic for the following reasons: (1) assessment of the indicator variable's significance; (2) escalation of standard errors acquired from bootstrapping; and (3) decreased probability of certain relationships being regarded as significant.

Although the problem is much less severe with PLS-SEM, but researchers can examine the skewness and kurtosis by observing the values that are greater than 1 which indicate highly non-normal data (Hair et al., 2014). Thus, the more suitable measures of distribution are skewness and kurtosis (Hair et al., 2014). A general guideline for skewness is that a value greater than +1 or lower than -1 represents a substantial skewed distribution while, for kurtosis, if the value is greater than +1, the distribution is too peaked, and if the value is less than -1, its distribution is too flat. Therefore, if the distribution of data exceeds the guidelines for skewness and kurtosis, it is considered non-normal.

The values of skewness and kurtosis can be converted into z-scores. The outliers can be identified by comparing the value of each item of the particular indicator variable to the mean of that indicator variable or by standardizing a data set score in terms of distribution with a mean of 0 and standard deviation of 1 which are known as z-scores (Field, 2013). For z-scores, an absolute value greater than 1.96 is significant at $p < 0.05$; above 2.58 is significant at $p < 0.01$; and absolute values of about 3.29 are significant at $p < 0.001$ (Field, 2013). For this study, the z-score values for all the items of the seven constructs were smaller than 3.29. This result indicated that significant outliers were not present; therefore, 165 survey responses were retained in the data set. The results for z-scores, skewness and kurtosis are presented in Appendix E.

The bootstrapping procedure is a resampling technique that draws a large number of subsamples from the original data (with replacement) and estimates models for each subsample. It is used to determine standard errors of coefficients in order to assess the statistical significance without relying on distributed assumptions (Hair et al., 2014). The measurement model results on the outer weight, standard errors, *t*-values and the *p*-values for the formatively-measured indicators are presented in the Section of 5.3. The bootstrapping results for the formatively-measured constructs (Green IT, Green IS, Int Comm, Reg Pres, GSCM, Env Per and Tec Perf) on the *t*-values, standard errors, *p*-values and confidence interval for the structural model are presented in Section 5.4.

5.2.1.1 Green Information Technology (Green IT)

Green IT was measured with six items. The mean value of the Green IT variable was 3.289 (out of 5). This result indicated that, in the current study, the manufacturing firms responded at a level that was above the average and had started implementing

Green IT and infrastructures which would have less negative impacts on the environment.

The Green IT variable had a standard deviation of 0.880 which was relatively small compared to the mean. This clearly explained that manufacturing firms' responses on Green IT were consistently close to the mean rating. The values of skewness and kurtosis of the Green IT variable were 0.071 and -0.889 which were within the guided range of normality of between +1 and -1 for skewness and kurtosis. Skewness had a slight presence with more low scores at the left tail of the distribution, while kurtosis was indicated by minimal flat and light-tailed distribution. The z-score values for items under the Green IT variable were below 3.29 ($\alpha = 0.001$). Thus, no significant influence of outliers was found.

5.2.1.2 Green Information Systems (Green IS)

The Green IS variable was measured with five items. The mean value of the Green IS variable was 3.892 (out of 5) which is very close to 4. This indicates that the manufacturing firms were implementing software, applications and systems to support their firm's green movement to transform the supply chain towards sustainable business activities and processes.

The Green IS variable had a standard deviation of 0.732 which was relatively small compared to the mean. This clearly explained that manufacturing firms' responses on Green IS were consistently close to the mean rating. The values of skewness and kurtosis of the Green IS variable were at -0.175 and -1.033 which were within the guided range of normality of between +1 and -1 for skewness and kurtosis. Skewness had a slight presence with more high scores at the right tail of the distribution, and kurtosis was indicated by minimal flat and light-tailed distribution. The z-score values for the items under the Green IS variable were below 3.29 ($\alpha = 0.001$). Thus, no significant influence of outliers was found.

5.2.1.3 Internal Commitment

The internal commitment variable was measured with four items. The mean value of this variable was very close to 4 at 3.776 (out of 5). This explained that internal management commitment and employees' support were crucial and comparatively significant in driving the implementation of green practices within the supply chain.

The internal commitment variable had a standard deviation of 0.804 which was very small compared to the mean. This clearly showed that manufacturing firms' similar responses on the importance of internal commitment were consistently close to the mean rating. The values of skewness and kurtosis for the internal commitment variable were -0.026 and -1.190 which were within the guided range of normality of between +1 and -1 for skewness and kurtosis. Skewness had a slight presence with more high scores at the right tail of the distribution, while kurtosis was indicated by minimal flat and light-tailed distribution. The z-score values for the items under the internal commitment variable were below 3.29 (α = 0.001). Thus, no significant influence of outliers was found.

5.2.1.4 Regulatory Pressure

The regulatory pressure variable was measured through four items, with its mean value of 4.014 (out of 5) signifying that this variable was relatively significant. This indicated that regulatory pressure was crucial and significant in driving the implementation of green practices within the supply chain.

The regulatory pressure variable had a standard deviation of 0.519 which was very small compared to the mean. This clearly explained that manufacturing firms' similar responses on the importance of regulations and environmental directives were consistently close to the mean rating. The values of skewness and kurtosis for the regulatory pressure variable were 0.125 and -0.919 which were within the guided range of normality of between +1 and -1 for skewness and kurtosis. Skewness had a slight presence with more low scores at the left tail of the distribution, while kurtosis was indicated by minimal flat and light-tailed distribution. The z-score values for the items under the regulatory pressure variable were below 3.29 ($\alpha = 0.001$). Thus, no significant influence of outliers was found.

5.2.1.5 Green Supply Chain Management (GSCM)

The green supply chain management (GSCM) variable was measured with 12 items. The mean value of the GSCM variable was 3.356 (out of 5). The range indicates that a handful of ISO 14001-certified manufacturing firms in Malaysia have been implementing some green practices within the supply chain.

The GSCM variable had a standard deviation of 0.703 which was very small compared to the mean. This clearly explained that manufacturing firms' consistent responses on the nature of green practices implemented in the supply chain were steadily close to the mean rating. The values of skewness and kurtosis for the GSCM variable were -0.051 and -0.643 which were within the guided range of normality of between +1 and -1 for skewness and kurtosis. Skewness had a slight presence with more high scores at the right tail of the distribution, while kurtosis was indicated by minimal flat and light-tailed distribution. The z-score values for the items under the GSCM variable were below 3.29 ($\alpha = 0.001$). Thus, no significant influence of outliers was found.

5.2.1.6 Environmental Performance

The environmental performance variable was measured with seven items and had a mean value of 3.454 (out of 5). This explained to some degree the improvements achieved in mitigating environmental impacts through implementing green practices within the supply chain.

The environmental performance variable had a standard deviation of 0.660 which was very small compared to the mean. This clearly explained that manufacturing firms' consistent responses on improvements in environmental performance were steadily close to the mean rating. The values of skewness and kurtosis for the environmental performance variable were 0.051 and -0.734 which were within the guided range of normality of between +1 and -1 for skewness and kurtosis. Skewness had a slight presence with more low scores at the left tail of the distribution, while kurtosis was indicated by minimal flat and light-tailed distribution. The z-score values for the items under the environmental performance variable were below 3.29 ($\alpha = 0.001$). Thus, no significant influence of outliers was found.

5.2.1.7 Technological Performance

The technological performance variable was measured with six items, with the mean value of 3.019 (out of 5) indicating the scale to some degree. The ISO 14001-certified manufacturing firms of the respondents had started to measure outcomes from implementing environmentally-friendly IT and IS within their supply chains; however, this was still at the early stage of assessment and reporting.

The technological performance variable had a standard deviation of 0.719 which was very small compared to the mean. This clearly explained that manufacturing firms' consistent responses on the improvements of technological performance was steadily close to the mean rating. The values of skewness and kurtosis for the technological performance variable were 0.150 and -0.862 which were within the guided range of normality of between +1 and -1 for skewness and kurtosis. Skewness had a slight presence with more low scores at the left tail of the distribution, and kurtosis was indicated by minimal flat and light-tailed distribution. The z-score values for the items under the technological performance variable were below 3.29 ($\alpha = 0.001$). Thus, no significant influence of outliers was found.

5.2.2 Non-Response Bias and Common Method Bias

Survey research methodology, despite all its strengths and advantages, is prone to systematic biases such as non-response bias and common method bias (Armstrong & Overton, 1977). Even after two or three reminders, the response rate in survey research is usually low; however, non-response to the survey may raise questions about the validity of the results. Therefore, the independent *t*-test is used to test different groups of people, with the assumption being that variances in these populations are roughly equal (homogeneity of variances) and scores are independent as they come from different people (Bhattacherjee, 2012).

Based on Levene's test (Bhattacherjee, 2012), the assumption of homogeneity of variances was met, and the mean differences for the seven variables between the early and late response groups were small. Next, the *t*-test values at two-tailed probability for each variable were examined and the *p*-values were observed. The two-tailed values of the *p*-values for the seven variables were greater than 0.05; therefore, in conclusion, no significant difference was evident between the means of the early and late response groups. Therefore, the *t*-test values provided evidence that the responses of the surveyed participants from the manufacturing firms were a typical representation of the target population.

Common method bias is a form of bias or measurement error that may affect the relationship between the variables or may inflate or deflate the responses given which may impact on the validity of a conclusion that has been drawn based upon statistical results (MacKenzie, Podsakoff, & Podsakoff, 2011). To collect the data, the current study employed a single common method using a survey questionnaire and the perceptual judgment of individuals from the selected ISO 14001-certified manufacturing firms; therefore, common method bias could occur. Harman's single factor test was used to determine if the majority of the variance could be explained by a single factor by constraining the number of factors extracted to 1 using a non-rotation method (Bhattacherjee, 2012). The percentage of variance was 49.4%, that is, slightly below 50% as presented in Appendix F. Hence, the instrument and responses were considered to be free from the effects of common method bias.

5.2.3 Descriptive Statistics of Demographic Variables

This section presents the demographic profile of the respondents from ISO 14001-certified manufacturing firms in Malaysia.

Most responses were from executives (82/49.7%), followed by managers (79/47.9%). Four respondents (2.5%) held director positions. The combination of people in these positions made a total of 165 respondents who participated in this study. These ranks were chosen because respondents at the level of executive and above were in the best position to furnish information on operations and the green movement within the firms.

The respondents to the survey were mostly attached to the Operations department amounting to 111 personnel (67.3%), followed by those in the Information Technology (IT) department with 45 personnel (27.3%), while the remaining nine (9) (5.5%) personnel belonged to the Health, Safety and Environment (HSE) department. As the survey questionnaire focused on the operations aspect of supply chain management (SCM), the highest percentage of respondents was from the Operations department within the manufacturing firms. The IT department in most of the firms was undersized with few employees and, in some firms, it was absorbed as part of the Operations department. Low responses from the HSE department were due to the person-in-charge of the firms' green initiatives being based in the Operations department in comparison to only a few who were under the HSE department as the custodian of these initiatives. This study's respondents were equipped with the current information and the latest activities, as well as being subject matter experts within their field.

As presented in Table 5.1, respondents' firms were categorized into multinational corporations (MNCs) or small and medium-sized enterprises (SMEs). Among the 165 ISO 14001-certified manufacturing firms, 121 (73.3%) of respondents' firms were MNCs while SMEs comprised the remaining 44 (26.7%). Although large firms are more likely to adopt an innovation compared to smaller firms, the findings in all studies cannot be generalized. Therefore, this study took firm size as a control variable as the respondents' firms consisted of both large firms as well as small and medium-sized enterprises (SMEs).

Table 5.1: Firm Size

Firm Size	Frequency	Percentage
SME (5 - 200 employees)	44	26.7
MNC (201 employees and above)	121	73.3
Total	165	100.00

In terms of the industry sectors shown in Table 5.2, most survey respondents were from electrical and electronics products manufacturers, representing 55 manufacturing firms (33.3%). The distribution of respondents' firms in the rubber and plastic products industry had a number of responses close to those in the chemicals and chemical products manufacturers, that is 23 firms (13.9%) and 21 firms (12.7%), respectively. The next grouping of respondents' firms were machinery equipment manufacturers and metal products manufacturers comprising 18 firms (10.9%) and 15 firms (9.1%), respectively. The remaining 33 manufacturing firms (20.0%) belonged to: (1) automotive parts; (2) stationery, paper and packaging; and (3) food and beverages industries.

Table 5.2: Industry Type

Types of Industry	Frequency	Percentage
Electrical and Electronics Products	55	33.3
Chemicals and Chemical Products	21	12.7
Rubber and Plastic Products	23	13.9
Metal Products	15	9.1
Machinery Equipment	18	10.9
Others	33	20.0
Total	165	100.0

Most survey respondents were based in the industrial zones of the state in which they were located as shown in Table 5.3.

Table 5.3: Location of Firms

Location	**Frequency**	**Percentage**
Selangor	51	30.9
Kuala Lumpur	14	8.5
Johor	11	6.7
Penang	23	13.9
Perak	6	3.6
Kedah	12	7.3
Perlis	7	4.2
Pahang	10	6.1
Terengganu	8	4.8
Kelantan	7	4.2
Sabah	9	5.5
Sarawak	7	4.2
Total	165	100.0

Most manufacturing firms are situated in Selangor with the highest number of respondents who came from 51 firms (30.9%) and followed by the state of Penang with 23 firms (13.9%). Nineteen (19) of the respondents' firms were in the north of Malaysia (Kedah and Perlis states), while responses from the east of Malaysia came from Pahang, Terengganu and Kelantan states with 25 firms. In west Malaysia, 11 firms were from Johor state. Another 16 respondents' firms were from the states of Sabah and Sarawak.

The lowest number of respondents' firms in Peninsular Malaysia came from the state of Perak, with only six (6) firms (3.6%). The poor response from Perak state was due, firstly, to the limited numbers of ISO 14001-certified manufacturing firms in Perak and, secondly, to a few of these certified firms having participated in the pilot study. Firms that had contributed in the pilot study were excluded from the main study to reduce bias and increase the reliability of data gathered for the study.

Most SME respondents were from the electrical and electronics products industry (11 firms/6.7%) and, similarly for MNCs, with 44 firms (26.7%). The lowest participation was from respondents from the machinery equipment industry for SMEs, compared to MNCs where it was respondents from firms in the metal products industry. Most respondents who participated were from MNC-status manufacturing firms located in the regions of Kuala Lumpur and Selangor, with the same applying for SMEs.

5.3 Analysis and Results of Formative Measurement Model

In PLS-SEM, a latent variable is also recognized as a construct. Thus, measurement theory presents how the latent variables (or constructs) are measured, either based on a formative measurement model, a reflective measurement model or both. Structural theory demonstrates how the latent variables are related to each other which includes the path relationship between the constructs in the structural model. The formative and reflective indicators are based on different concepts; therefore, they require different evaluation measures.

The PLS-SEM technique was chosen for this study as the measurement and structural models were formatively-measured constructs. With formative measurements, PLS-SEM allows the identification of significant and insignificant items within a construct or latent variable. In formative measurement, the indicators are not interchangeable; hence, each indicator captures a specific facet of the construct. Collectively, the indicators explain the meaning of a particular construct; therefore, omitting an indicator alters the characteristics of the construct. As a result, the breadth of coverage of the construct domain is extremely important to ensure that it is adequately captured.

In PLS-SEM, three important steps are conducted in the formative measurement model assessment procedure: (1) assessment of convergent validity; (2) assessment of collinearity; and (3) assessment of the significance and relevance of formative indicators.

5.3.1 Assessment of Convergent Validity

In creating a redundancy analysis, a global item is used as a reflective indicator that summarises the essence of the formative construct (Sarstedt, 2008). The reflective latent variable for convergent validity is included in the questionnaire. Thus, a formatively-measured construct represents an exogenous latent variable that predicts an endogenous latent variable through the reflective indicator (Hair et al., 2014, 2017). In the current study, the global item, introduced in the survey questionnaire, summarised the essence of the constructs that the formative indicators were intended to measure.

The strength of the path coefficient that links two constructs is ideally of a magnitude of 0.80, or at least at a minimum of 0.70 or above, which translates into a R^2 value of 0.64 or at least 0.50 (Hair et al., 2017). For those with R^2 values below 0.5, the formative indicators of those constructs lack convergent validity in being able to contribute sufficiently to their intended content. Thus, the formative construct needs to be theoretically or conceptually refined by exchanging and/or adding indicators (Hair et al., 2014, 2017). The six diagrams in Figure 5.1 to Figure 5.7 demonstrate the results of redundancy analysis for the six formative exogenous constructs.

In Figure 5.1, the original formative construct for Green IT is labelled as Green IT_F, whereas the global assessment of Green IT that uses a single-item construct is labelled as Green IT_G. The analysis shows a path coefficient of 0.862 which is above the threshold of 0.80 as well as an R^2 value of 0.743 which is above the threshold of 0.64. This indicates good convergent validity for the Green IT formative construct.

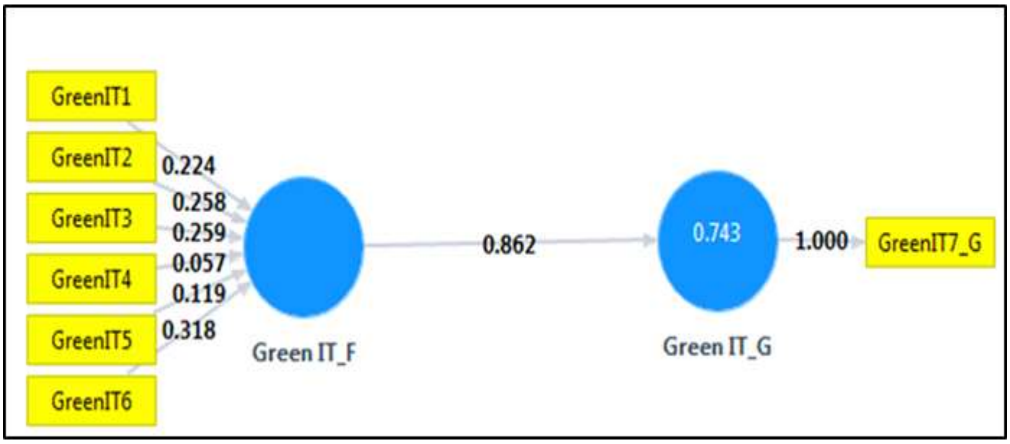


Figure 5.1: Convergent Validity Assessment of Green IT

The original formative construct for Green IS is labelled as Green IS_F, whereas the global assessment of Green IS that uses a single-item construct is labelled as Green IS_G, as shown in Figure 5.2. The analysis shows a path coefficient of 0.888 and an R^2 value of 0.788, both of which are above the suggested threshold values of 0.80 and 0.64, respectively. The results obtained indicate good convergent validity for the Green IS formative construct.

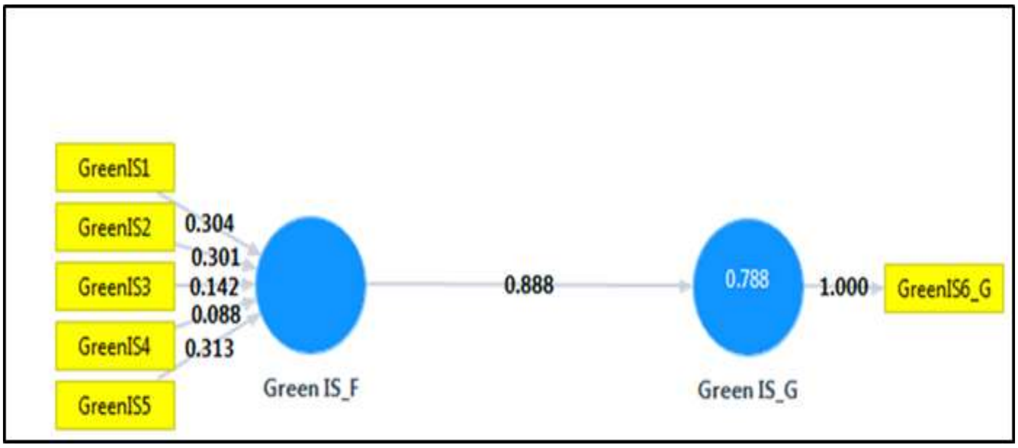


Figure 5.2: Convergent Validity Assessment of Green IS

As shown in Figure 5.3, the original formative construct for internal commitment is labelled as Int Comm_F, while the single-item construct employed for the global assessment of internal commitment, is labelled as Int Comm_G. The analysis shows a path coefficient of 0.885 and an R^2 value of 0.783, both of which are above the suggested threshold values of 0.80 and 0.64, respectively. The results obtained indicate good convergent validity for the internal commitment formative construct.

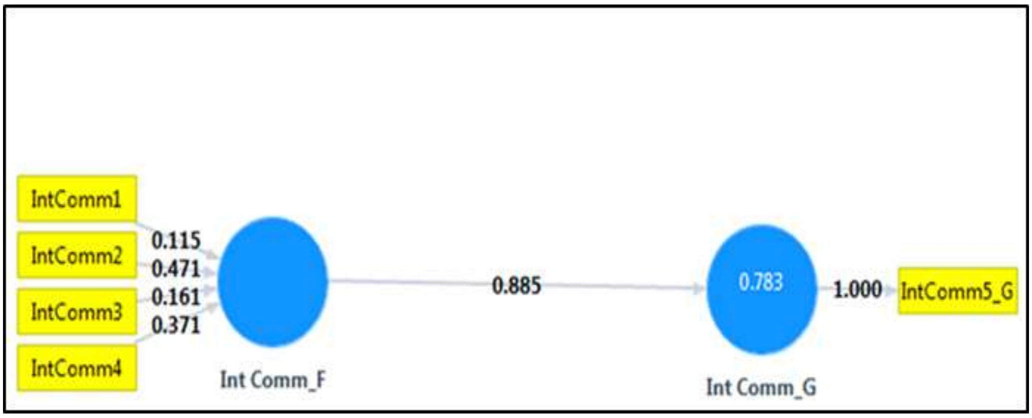


Figure 5.3: Convergent Validity Assessment of Internal Commitment

Reg Pres_F represents the original formative construct, while Reg Pres_G represents the single-item construct used for the global assessment of regulatory pressure, as illustrated in Figure 5.4. The analysis shows a path coefficient of 0.806 and an R^2 value of 0.649, both of which are above the suggested threshold values of 0.80 and 0.64, respectively. The results obtained indicate good convergent validity for the regulatory pressure formative construct.

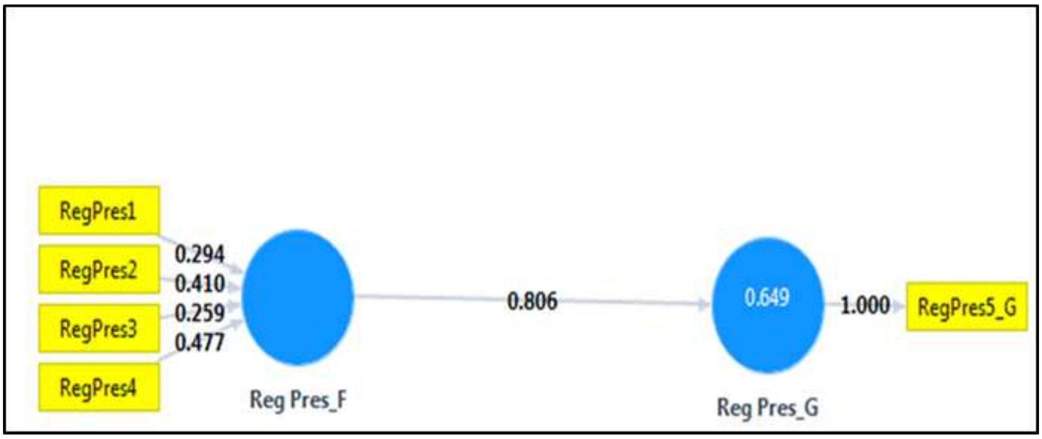


Figure 5.4: Convergent Validity Assessment of Regulatory Pressure

In Figure 5.5, the original formative construct is labelled as GSCM_F, whereas the global assessment of GSCM uses a single-item construct known as GSCM_G. The analysis shows a path coefficient of 0.856 which is above the threshold of 0.80 and an R^2 value of 0.732, both of which are above the suggested threshold values of 0.80 and 0.64, respectively. The path coefficient and R^2 value show good convergent validity for the GSCM formative construct.

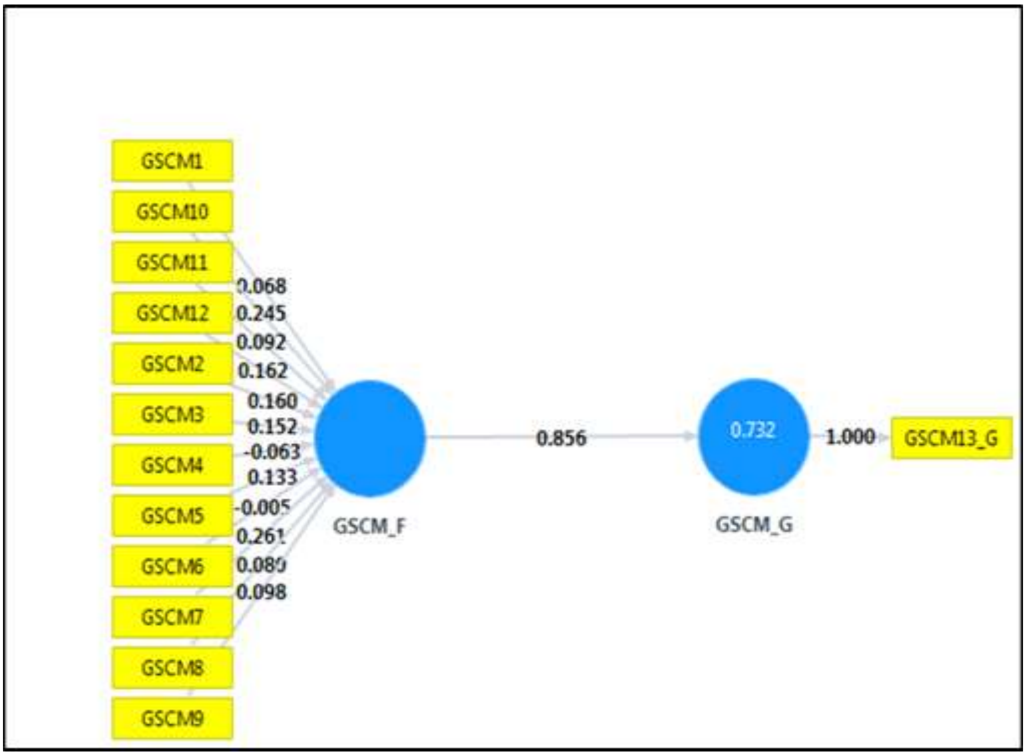


Figure 5.5: Convergent Validity Assessment of Green Supply Chain Management

Env Perf_F represents the original formative construct, while Env Perf_G represents the single-item construct used for the global assessment for environmental performance, as illustrated in Figure 5.6. The analysis shows a path coefficient of 0.885 and an R^2 value of 0.783, both of which are above the suggested threshold values of 0.80 and 0.64, respectively. The results obtained indicate good convergent validity for the environmental performance formative construct.

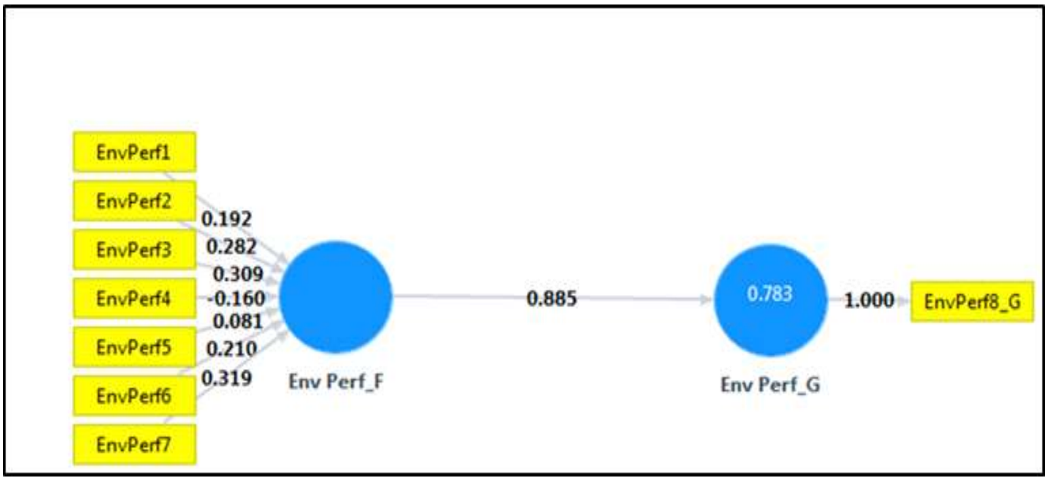


Figure 5.6: Convergent Validity Assessment of Environmental Performance

Tec Perf_F represents the original formative construct, while Tec Perf_G represents the single-item construct used for the global assessment of technological performance, as shown in Figure 5.7. The analysis shows a path coefficient of 0.811 and an R^2 value of 0.658, both of which are above the suggested threshold values of 0.80 and 0.64, respectively. The results obtained indicate good convergent validity for the technological performance formative construct.

Figure 5.7: Convergent Validity Assessment of Technological Performance

All measured constructs had path coefficients and R^2 values that were above the suggested threshold values. Hence, all formatively-measured constructs have sufficient degrees of convergent validity. In conclusion, the redundancy analysis of each construct is presented in Table 5.4.

Table 5.4: Convergent Validity – Redundancy Analysis

Construct	Path Coefficient Estimates	R^2 Values
Green IT	0.862	0.743
Green IS	0.888	0.788
Int Comm	0.885	0.783
Reg Pres	0.806	0.649
GSCM	0.856	0.732
Env Perf	0.885	0.783
Tec Perf	0.811	0.658

5.3.2 Assessment of Collinearity

In formatively-measured indicators, the existence of high correlations is a critical issue as it impacts on the estimation of weights and statistical significance. The measurement technique exercised to find collinearity is known as the variance inflation factor (VIF). The cut-off threshold values in assessing VIF is a tolerance value of 0.20 or lower or a VIF value of 5 or higher which indicate potential collinearity issues (Hair et al., 2014, 2017).

As shown in Table 5.5, all the formative indicators for Green IT are within the VIF values of 1.667 to 4.356, while the VIF values for Green IS formative indicators are from 1.954 to 4.272. All VIF values obtained are below the threshold value of 5. Therefore, no collinearity issue exists between the Green IT and Green IS formative indicators.

Table 5.5: Collinearity Assessment for Green IT and Green IS

Green IT		Green IS	
Indicators	**VIF**	**Indicators**	**VIF**
GreenIT1	3.479	**GreenIS1**	3.546
GreenIT2	1.667	**GreenIS2**	1.954
GreenIT3	1.774	**GreenIS3**	3.323
GreenIT4	4.356	**GreenIS4**	3.532
GreenIT5	3.515	**GreenIS5**	4.272
GreenIT6	2.766		

Table 5.6 shows the VIF values for the formative indicators of internal commitment and regulatory pressure. The VIF values obtained are between 1.264 and 4.211 for both constructs which are below the threshold value of 5. Therefore, no collinearity issue exists between the internal commitment and regulatory pressure formative indicators.

Table 5.6: Collinearity Assessment for Internal Commitment and Regulatory Pressure

Int Comm		Reg Pres	
Indicators	**VIF**	**Indicators**	**VIF**
IntComm1	2.292	**RegPres1**	1.539
IntComm2	4.211	**RegPres2**	1.327
IntComm3	3.596	**RegPres3**	1.264
IntComm4	2.105	**RegPres4**	1.423

Table 5.7 shows the VIF values for each of the formative indicators of green supply chain management (GSCM). The scored VIF values are between 1.851 and 3.546 which are below the threshold value of 5. Therefore, no collinearity issue exists between GSCM’s formative indicators.

Table 5.7: Collinearity Assessment for Green Supply Chain Management

GSCM			
Indicators	**VIF**	**Indicators**	**VIF**
GSCM1	2.949	**GSCM7**	3.546
GSCM2	3.009	**GSCM8**	3.057
GSCM3	2.405	**GSCM9**	1.972
GSCM4	2.419	**GSCM10**	2.284
GSCM5	2.641	**GSCM11**	1.851
GSCM6	2.152	**GSCM12**	2.564

The VIF values for the formative indicators of environmental performance and technological performance are shown in Table 5.8. The VIF values for both performance outcomes are between 1.563 and 2.796 which are below the threshold value of 5. Therefore, no collinearity issue exists between the formative indicators of environmental performance and technological performance.

Table 5.8: Collinearity Assessment for Environmental Performance and Technological Performance

Env Perf		Tec Perf	
Indicators	**VIF**	**Indicators**	**VIF**
EnvPerf1	1.779	**TecPerf1**	2.640
EnvPerf2	2.012	**TecPerf2**	2.154
EnvPerf3	1.832	**TecPerf3**	2.019
EnvPerf4	1.563	**TecPerf4**	3.372
EnvPerf5	1.776	**TecPerf5**	2.196
EnvPerf6	2.243	**TecPerf6**	2.303
EnvPerf7	2.796		

Among the constructs for the four drivers (latent variables), the indicator (item) with the highest VIF value is GreenIT4 with 4.356 while, among the practices of GSCM constructs, the highest VIF value is 3.546 for GSCM7. Looking at performance outcomes, TecPerf4 scored the highest VIF value at 3.372. All the formative indicators were uniformly below the threshold value of 5 and, therefore, below the critical level for all the formative constructs for the estimation of the PLS path model.

5.3.3 Assessment of Significance and Relevance of Formative Indicators

In evaluating formative indicators, the outer weight values are compared to each other in determining the relative contribution of each indicator to explain the relative importance of the indicator to the construct. The outer weight is the result of multiple regression (Hair et al., 2014, 2017). The outer weights in formative measurement are usually smaller than the outer loadings of reflective measurement. In formative measurement, the insignificant indicator weights must not be interpreted as an indication of poor measurement model quality as each indicator represents an independent cause to the construct (Hair et al., 2014, 2017).

Hence, the absolute contribution from the formative indicator's outer loading must be inferred in explaining the bivariate correlation (single regression) between each indicator on its corresponding construct. The absolute contribution of the formative indicator's outer loading is presented along with the indicator's outer weight. If the outer weight is non-significant but its outer loading is high (above 0.5), then the indicator is interpreted as absolutely important but not as relatively important, and will be retained (Hair et al., 2014, 2017). However, if the indicator has a non-significant weight and an outer loading below 0.50, the indicator is to be retained or deleted based on its theoretical relevance, content validity or expert assessment. The non-significant formative indicator should never be discarded only on the basis of statistical outcomes (Hair et al., 2014, 2017).

The significance of the outer weights in formative measurement is measured using the bootstrapping procedure. The number of bootstrap samples should be high and at least equal to the valid samples in the data sets; however, 5000 bootstrap samples are recommended (Hair et al., 2014, 2017). The bootstrap procedure provides the standard error of an estimated coefficient which allows the computation of the empirical *t*-value. When the empirical *t*-value is larger than the critical value, the path coefficient is significant at a certain error probability or significance level. The critical value is a cut-off value to determine the significance of a path coefficient or a hypothesized relationship, as demonstrated in Table 3.3 of Chapter 3.

The critical value (or theoretical *t*-value) is the cut-off value for significance testing in formative measurement, as presented in Table 5.9. The empirical *t*-value obtained from the bootstrapping procedure must be higher than the critical *t*-value in order to establish the significant outer weight at the given *p*-value. In addition, the bootstrap confidence interval can also be reported as it provides additional information on the stability of a coefficient estimate.

Table 5.9: Level of Confidence and Critical Value

Level of confidence	Two-tailed critical value	One-tailed critical value
90% (*p < 0.10)	1.64	1.28
95% (**p < 0.05)	1.96	1.64
99% (***p < 0.01)	2.58	2.33

The results of the outer weight estimates, *t*-values and corresponding significance levels as well as the *p*-values for the formatively-measured constructs are presented in the next section.

5.3.3.1 Green IT

The Green IT construct has six formative indicators through which it is conceptualized which are:

- **GreenIT1**: Enforce power management (office equipment, facilities and data centre)
- **GreenIT2**: Enforce paperless office
- **GreenIT3**: Use energy-efficient lights
- **GreenIT4**: Use virtualization technology
- **GreenIT5**: Purchase environmentally-friendly IT hardware and equipment

- **GreenIT6**: Dispose of electronic waste (e-waste) in an environmentally-friendly way

As shown in Table 5.10, the outer weights of the five indicators, GreenIT1 (0.180), GreenIT2 (0.121), GreenIT3 (0.378), GreenIT4 (0.351) and GreenIT6 (0.125) explain the relevance and relative contribution between each indicator in relation to the construct. In addition, the outer loadings of GreenIT1 (0.840), GreenIT2 (0.681), GreenIT3 (0.802), GreenIT4 (0.881) and GreenIT6 (0.830) are above the threshold value of 0.5 which indicates the absolute importance and contribution of the items in explaining the construct.

At 5000 bootstrap samples, the *t*-values obtained for GreenIT2 (1.551) and GreenIT6 (1.643) are higher than the one-tailed critical value of 1.28 at a 10% probability error. On the other hand, the *t*-value obtained for GreenIT1 (2.210) is higher than the one-tailed critical value of 1.645 at a 5% probability error. The *t*-values obtained for GreenIT3 (5.251) and GreenIT4 (3.4150) are higher than the one-tailed critical value of 2.33 at a 1% probability error. The GreenIT1, GreenIT2, GreenIT3, GreenIT4 and GreenIT6 indicators are relatively and absolutely important and significant in explaining the Green IT construct.

Although the outer weight of GreenIT5 (0.063) is not significant, the outer loading (0.794) is above the threshold value of 0.5. This explains that GreenIT5 is not relatively important when compared to the other indicators as it has an insignificant *t*-value (0.677). However, GreenIT5 has absolute importance in explaining the single relationship between GreenIT5 and the respective construct of Green IT (bivariate correlation) without considering other indicators. Although the outer weights and significance testing of outer weights (*t*-value) indicate insignificance, nevertheless, the outer loadings are significant. Therefore, the GreenIT5 indicator is retained as well as the other indicators of the Green IT construct for the structural model assessment and hypotheses testing.

Table 5.10: Green IT Formative Indicators' Significance Testing Results

Formative Constructs	Formative Indicators	Outer Weights (Outer Loadings)	Standard Error	*t*-value	Significance Level	*p*-value
Green IT	GreenIT1	0.180 (0.840)	0.082	2.210	Significant**	0.014
	GreenIT2	0.121 (0.681)	0.078	1.551	Significant*	0.060
	GreenIT3	0.378 (0.802)	0.072	5.251	Significant***	0.000
	GreenIT4	0.351 (0.881)	0.103	3.415	Significant***	0.000
	GreenIT5	0.063 (0.794)	0.092	0.677	Outer Weight: No relative importance Outer Loading: Show absolute importance *t*-value: Not significant *Indicator is retained	0.249
	GreenIT6	0.125 (0.830)	0.076	1.643	Significant*	0.050

Notes: SIM = single item measure; NS = not significant; *p < 0.1 (significance level of 10%); **p < 0.05 (significance level at 5%); ***p < 0.01 (significance level of 1%)

5.3.3.2 Green IS

The five formative indicators that conceptualize the Green IS construct are:

- **GreenIS1**: Use of software to monitor and record environmental indicators
- **GreenIS2**: Use of software for environmentally-friendly practices in development and design of product/materials procurement activities/ manufacturing activities
- **GreenIS3**: Use of software for environmentally-friendly practices in logistics activities
- **GreenIS4**: Use of video conferencing and/or telecommuting tools

- **GreenIS5**: Use of online groupware and collaboration tools

As shown in Table 5.11, GreenIS1 (0.358), GreenIS2 (0.313), GreenIS4 (0.181) and GreenIS5 (0.332) show relative importance when comparing each indicator's weight with that of the other indicators. On the other hand, the outer loadings for GreenIS1 (0.889), GreenIS2 (0.820), GreenIS3 (0.804), GreenIS4 (0.862) and GreenIS5 (0.919) are above the threshold value of 0.5 that indicates the absolute importance of each indicator in explaining the bivariate relationship with the Green IS construct.

At 5000 bootstrap samples, the *t*-values obtained for Green IS1 (3.147), GreenIS2 (3.902) and GreenIS5 (2.714) are higher than the one-tailed critical value of 2.33 at a 1% probability error, while the *t*-value for GreenIS4 (1.600) is higher than the one-tailed critical value which is 1.28 at a 10% probability error. The GreenIS1, GreenIS2, GreenIS4 and GreenIS6 indicators contribute as relatively and absolutely significant in explaining the content of the Green IS construct.

GreenIS3, with an outer weight of -0.045, is insignificant in comparison to the other indicators; however, the outer loading of 0.804 is above the threshold value of 0.5. Although the outer weights and significance testing of these outer weights (*t*-values) indicate insignificance, nevertheless the outer loadings are significant. Thus, GreenIS3 is not relatively important when compared to other indicators of the respective construct but GreenIS3 demonstrates absolute importance in explaining the bivariate correlation between GreenIS3 and the Green IS construct. All the indicators, together with GreenIS3, are retained as the Green IS construct items for the structural model assessment and hypotheses testing.

Table 5.11: Green IS Formative Indicators' Significance Testing Results

Formative Constructs	Formative Indicators	Outer Weights (Outer Loadings)	Standard Error	*t*-value	Significance Level	*p*-value
Green IS	GreenIS1	0.358 (0.889)	0.114	3.147	Significant***	0.001
	GreenIS2	0.313 (0.820)	0.080	3.902	Significant***	0.000
	GreenIS3	-0.045 (0.804)	0.099	0.454	Outer Weight: No relative importance Outer Loading: Show absolute importance *t* value: Not significant *Indicator is retained	0.325
	GreenIS4	0.181 (0.862)	0.113	1.600	Significant*	0.055
	GreenIS5	0.332 (0.919)	0.122	2.714	Significant***	0.003

Notes: SIM = single item measure; NS = not significant; *$p < 0.1$ (significance level of 10%); **$p < 0.05$ (Significance level of 5%); ***$p < 0.01$ (Significance level of 1%)

5.3.3.3 Internal Commitment

The four formative indicators that conceptualize the internal commitment construct are:

- **IntComm1**: Commitment from top management
- **IntComm2**: Cross-functional cooperation between departments for environmental improvements
- **IntComm3**: Inspection and audits by internal management
- **IntComm4**: Internal programs (training/seminars) on green and environmentally-friendly practices

As illustrated in Table 5.12, the four indicators scored values of outer weights and outer loadings, respectively, as follows: IntComm1 (0.259, 0.841), IntComm2 (0.276, 0.930), IntComm3 (0.403, 0.939) and IntComm4 (0.187, 0.785). The values of the indicators' outer loadings are above the threshold value of 0.5, while the *t*-values obtained from the bootstrapping procedure for IntComm1 (1.977), IntComm2 (1.974) and IntComm4 (2.155) are significant at 5%, along with IntComm3 (3.707) which, at the one-tailed critical value, is significant at a 1% probability error. The significant values achieved by the outer weights indicate the relative contributions between the indicators in representing the meaning of the internal commitment construct. The significant values of the outer loadings justified the absolute importance between the relationships of each indicator to the internal commitment construct through single regression that defines the bivariate correlation between them. All the indicators were retained as the indicators of the internal commitment construct for the structural model assessment and hypotheses testing.

Table 5.12: Internal Commitment Formative Indicators' Significance Testing Results

Formative Constructs	Formative Indicators	Outer Weights (Outer Loadings)	Standard Error	*t*-value	Significance Level	*p*-value
Internal Commitment	IntComm1	0.259 (0.841)	0.131	1.977	Significant**	0.024
	IntComm2	0.276 (0.930)	0.140	1.974	Significant**	0.024
	IntComm3	0.403 (0.939)	0.109	3.707	Significant***	0.000
	IntComm4	0.187 (0.785)	0.087	2.155	Significant**	0.016

Notes: SIM = single item measure; NS = not significant; *p < 0.1 (Significance level of 10%); **p < 0.05 (Significance level of 5%); ***p < 0.01 (Significance level of 1%)

5.3.3.4 Regulatory Pressure

The four formative indicators that conceptualize the regulatory pressure construct are:

- **RegPres1**: Compliance with environmental regulations set by company
- **RegPres2**: Compliance with environmental regulations set by the government
- **RegPres3**: Inspection and audits by government agencies or certification bodies
- **RegPres4**: Compliance with international environmental directives and standards (such as ISO/WEEE/ RoHs/REACH/EuPs)

As shown in Table 5.13, the RegPres1 (0.751, 0.918) and RegPres4 (0.331, 0.752) indicators show the importance with the outer weights and loadings, respectively, and the *t*-values of RegPres1 (11.337) and RegPres4 (4.465) are larger than the one-tailed critical value of 2.33 at a 1% probability error. Both indicators are relatively important based on the comparison of weights obtained between the indicators, and absolutely important based on the bivariate correlation between the indicators and the construct.

The outer weights and outer loading values, respectively, of RegPres2 (-0.218, 0.174) and RegPres3 (0.255, 0.389) are insignificant; therefore, the next step is to run the bootstrapping procedure at 5000 sub-samples to determine the *t*-values. The *t*-value of RegPres2 is 3.023 and of RegPres3 is 3.916, with these being larger than the one-tailed critical value of 2.33 at a 1% probability error. Despite the poor contribution from outer weights and outer loadings, RegPres2 and RegPres3 obtained significant *t*-values. Therefore, all the indicators, including RegPres2 and RegPress3, are retained as the indicators of regulatory pressure for the structural model assessment and hypotheses testing.

Table 5.13: Regulatory Pressure Formative Indicators' Significance Testing Results

Formative Constructs	**Formative Indicators**	**Outer Weights (Outer Loadings)**	**Standard Error**	***t*-value**	**Significance Level**	***p*-value**
Regulatory Pressure	RegPres1	0.751 (0.918)	0.066	11.337	Significant***	0.000
	RegPres2	-0.218 (0.174)	0.072	3.023	Outer Weight: No relative importance Outer Loading: No absolute importance *t*-value: Significant*** *Indicator is retained	0.001
	RegPres3	0.255 (0.389)	0.065	3.916	Outer Weight: No relative importance Outer Loading: No absolute importance *t*-value: Significant*** *Indicator is retained	0.000
	RegPres4	0.331 (0.752)	0.074	4.465	Significant***	0.000

Notes: SIM = single item measure; NS = not significant; *p < 0.1 (Significance level of 10%); **p < 0.05 (Significance level of 5%); ***p < 0.01 (Significance level of 1%)

5.3.3.5 Green Supply Chain Management (GSCM)

Table 5.14 presents the findings obtained from the significance tests of the formative indicators of the GSCM construct. The GSCM construct is conceptualized based on 12 formative indicators which focus on green practices within the supply chain:

- **GSCM1**: Provide specifications to suppliers that include environmental requirements
- **GSCM2**: Choose suppliers based on environmental criteria
- **GSCM3**: Use environmentally-friendly raw materials
- **GSCM4**: Design products based on environmental criteria
- **GSCM5**: Use cleaner technology to reduce environmental impacts
- **GSCM6**: Cooperate closely with customers to ensure product meets environmental criteria-conscious products
- **GSCM7**: Eco-labelling of products
- **GSCM8**: Use improved or environmentally-friendly packaging
- **GSCM9**: Reuse or recycle materials or components
- **GSCM10**: Recover company's end-of-life (EOL) products
- **GSCM11**: Use environmentally-friendly waste management
- **GSCM12**: Use environmentally-friendly transportation

The outer weights show the relative importance between the indicators in explaining the content of the construct, while the outer loadings that are larger than the threshold value of 0.5 highlight the absolute importance of the bivariate relationship between the indicators and the GSCM construct. The indicators that have both significant outer weight and outer loadings, respectively, are GSCM1 (0.145, 0.781), GSCM2 (0.275, 0.836), GSCM5 (0.144; 0.767), GSCM7 (0.271, 0.867) and GSCM12 (0.261, 0.809). Apart from measuring the importance (outer weights and outer loadings), the significance of each indicator needs to be assessed through the bootstrapping procedure. At 5000 bootstrap samples, the *t*-values obtained are significant for GSCM1 (1.797), GSCM2 (3.273), GSCM5 (1.899), GSCM7 (3.390) and GSCM12 (3.177). The *t*-values of GSCM1 and GSCM5 are larger than the one-tailed critical value of 1.645 at a 5% probability error, while the *t*-values of GSCM2, GSCM7 and GSCM12 are larger than the one-tailed critical value of 2.33 at a 1% probability error. These five formative indicators showed importance and significance; therefore, they are retained for the structural model assessment and hypotheses testing.

GSCM3 (0.015), GSCM4 (0.033), GSCM6 (0.096), GSCM8 (-0.11), GSCM9 (0.062), GSCM10 (0.009) and GSCM11 (0.078), on the other hand, demonstrate a smaller amount of relative contribution in defining the construct as the differences between the values of the outer weights of these indicators in comparison to others are large. Among these indicators, only GSCM3 (0.681), GSCM4 (0.729), GSCM6 (0.712), GSCM8 (0.698) and GSCM11 (0.602) have significant outer loading values as they are above the threshold value of 0.5. Despite showing a poor contribution on relative importance, each indicator displayed absolute importance through the significant bivariate correlation between itself and the GSCM construct. In regard to the significance testing of outer weights, the bootstrapping procedure was conducted to obtain the *t*-values, in which the *t*-values of GSCM6 (1.351) and GSCM8 (1.387) are larger than the one-tailed critical value which is 1.28 at a 10% probability error. However, indicators GSCM3 (0.208), GSCM4 (0.416) and GSCM11 (1.217) achieved non-significant *t*-values which explained the low significance of the outer weights and the coefficients between these formative indicators and the GSCM construct. Nevertheless, these formative indicators, GSCM3, GSCM4, GSCM6, GSCM8 and GSCM11, still meet the criteria based on the outer loading value achieved and, therefore, they are kept for the structural model assessment and hypotheses testing.

The indicators, GSCM9 (0.062, 0.387, 0.939) and GSCM10 (0.009, 0.451, 0.116) presented insignificant values for the outer weights, outer loadings and *t*-values, respectively. If the formative indicator attained a non-significant outer weight and outer loading, then the researcher must decide either to retain or delete the indicator based on the grounds of theoretical relevance or expert assessment in defining the construct content in order to prevent the unnecessary omission of this content (Cenfetelli & Bassellier, 2009; Hair et al., 2014). Moreover, the elimination of a formative indicator has little or no effect on the parameter estimates when re-estimating the model from the empirical perspective (Hair et al., 2014). The GSCM indicators are adopted from previous research. The chosen indicators conceptualized the content of GSCM which focuses on green practices within supply chains. As previously mentioned, the non-significant formative indicator should never be discarded only on the basis of statistical outcomes (Hair et al., 2014, 2017). Therefore, both indicators are retained for subsequent assessment of the structural model and hypotheses testing.

Table 5.14: Green Supply Chain Management Formative Indicators' Significance Testing Results

Formative Constructs	**Formative Indicators**	**Outer Weights (Outer Loadings)**	**Standard Error**	***t*-value**	**Significance Level**	***p*-value**
Green Supply Chain Management	GSCM1	0.145 (0.781)	0.081	1.797	Significant**	0.036
	GSCM2	0.275 (0.836)	0.084	3.273	Significant***	0.001
	GSCM3	0.015 (0.681)	0.072	0.208	Outer Weight: No relative importance Outer Loading: Show absolute importance *t*-value: Not significant *Indicator is retained	0.418
	GSCM4	0.033 (0.729)	0.080	0.416	Outer Weight: No relative importance Outer Loading: Show absolute importance *t*-value: Not significant *Indicator is retained	0.339
	GSCM5	0.144 (0.767)	0.076	1.899	Significant**	0.029
	GSCM6	0.096 (0.712)	0.071	1.351	Outer Weight: No relative importance Outer Loading: Show absolute importance *t*-value: Significant* *Indicator is retained	0.088

	GSCM7	0.271 (0.867)	0.080	3.390	Significant***	0.000
	GSCM8	-0.11 (0.698)	0.080	1.387	Outer Weight: No relative importance Outer Loading: Show absolute importance *t*-value: Significant* *Indicator is retained	0.083
	GSCM9	0.062 (0.387)	0.066	0.939	No relative and absolute importance *t*-value: Not significant *Indicator is retained	0.174
	GSCM10	0.009 (0.451)	0.076	0.116	No relative and absolute importance *t*-value: Not significant *Indicator is retained	0.454
	GSCM11	0.078 (0.602)	0.064	1.217	Outer Weight: No relative importance Outer Loading: Show absolute importance *t*-value: Not significant *Indicator is retained	0.112
	GSCM12	0.261 (0.809)	0.082	3.177	Significant***	0.001

Notes: SIM = single item measure; NS = not significant; *p < 0.1 (Significance level of 10%); **p < 0.05 (Significance level of 5%); ***p < 0.01 (Significance level of 1%)

5.3.3.6 Environmental Performance

The environmental performance construct is conceptualized based on seven formative indicators which are:

- **EnvPerf1**: Reduction in emissions generated
- **EnvPerf2**: Reduction in the amount of waste generated
- **EnvPerf3**: Decrease in consumption of hazardous/harmful/toxic materials or components
- **EnvPerf4**: Efficient use of water
- **EnvPerf5**: Increase in sustainable and CSR projects

- **EnvPerf6**: Improvement in firm's reporting capabilities on sustainable practices
- **EnvPerf7**: Improvement of corporate image

As shown in Table 5.15, the outer weights and outer loadings, respectively, of EnvPerf1, EnvPerf2, EnvPerf3, EnvPerf5 and EnvPerf6 are (0.234, 0.702), (0.242, 0.710), (0.280, 0.777), (0.397, 0.821) and (0.253, 0.732). In comparing their outer weights with each other, the differences in values between them are small, therefore, revealing the relative contribution of the indicators to the construct. The outer loadings are obtained from single regression, and the values attained are above the threshold value of 0.5. Therefore, EnvPerf1, EnvPerf2, EnvPerf3, EnvPerf5 and EnvPerf6 indicators achieved absolute importance through bivariate correlation of each indicator with the construct.

Apart from measuring the importance (outer weights and outer loadings), the significance of each indicator needs to be assessed through the bootstrapping procedure. At 5000 bootstrap samples, the *t*-values obtained were significant for EnvPerf1 (3.349), EnvPerf2 (2.854), EnvPerf3 (3.557), EnvPerf5 (4.526) and EnvPerf6 (2.879) which are larger than the one-tailed critical value which is 2.33 at a 1% probability error.

On the other hand, EnvPerf4 and EnvPerf7 indicators had no relative contribution based on their corresponding outer weight values, -0.134 and -0.023. The outer loading of EnvPerf4 (0.363), that is, below the threshold value of 0.5, signified that there was no absolute contribution, but then the outer loading of EnvPerf7 (0.682) was above the 0.5 cut-off value which denoted the absolute importance of the EnvPer7 indicator. This insignificant outer weights' result described larger relative differences between EnvPerf4, EnvPerf7 and the other indicators in contributing to the content of the environmental performance construct. The insignificant outer loading suggested poor bivariate correlation between EnvPerf4 and the respective construct, environmental performance.

However, the *t*-value obtained from the bootstrapping procedure explained the significance of the coefficient value of EnvPerf4 (1.868) and the insignificance of the coefficient value of EnvPerf7 (0.247). The EnvPerf4 indicator is significant at 1.868 which is larger than the critical value of 1.645 at a 5% probability error. Despite this result, all the indicators of environmental performance, including EnvPerf4 and EnvPerf7, are kept for the structural model assessment and hypotheses testing.

Table 5.15: Environmental Performance Formative Indicators' Significance Testing Results

Formative Constructs	**Formative Indicators**	**Outer Weights (Outer Loadings)**	**Standard Error**	***t*-value**	**Significance Level**	***p*-value**
Environmental Performance	EnvPerf1	0.234 (0.702)	0.070	3.349	Significant***	0.000
	EnvPerf2	0.242 (0.710)	0.085	2.854	Significant***	0.002
	EnvPerf3	0.280 (0.777)	0.079	3.557	Significant***	0.000
	EnvPerf4	-0.134 (0.363)	0.072	1.868	Outer Weight: No relative importance Outer Loading: No absolute importance *t*-value: Significant** *Indicator is retained	0.031
	EnvPerf5	0.397 (0.821)	0.088	4.526	Significant***	0.000
	EnvPerf6	0.253 (0.732)	0.088	2.879	Significant***	0.002
	EnvPerf7	-0.023 (0.682)	0.092	0.247	Outer Weight: No relative importance Outer Loading: Show absolute importance *t*-value: Not significant *Indicator is retained	0.402

Notes: SIM = single item measure; NS = not significant; *p < 0.1 (Significance level of 10%); **p < 0.05 (Significance level of 5%); ***p < 0.01 (Significance level of 1%)

5.3.3.7 Technological Performance

The six formative indicators which conceptualized the technological performance construct are:

- **TecPerf1**: Increase in deployment of Green IT and Green IS solutions
- **TecPerf2**: Increase in digitalization, automation, integration and optimization within supply chain processes
- **TecPerf3**: Increase in safe disposal of electronic waste (e-waste)
- **TecPerf4**: Improvement in power usage of office IT equipment and the total facility (e.g. lighting, uninterruptible power supply [UPS], cooling system, network)
- **TecPerf5**: Improvement in firm's reporting capabilities on Green IT and Green IS practices
- **TecPerf6**: Increased compliance with IT and IS environmental indicators or standards (e.g. ISO, EPEAT, Energy Star 4.0, the Green Grid, power usage effectiveness [PUE], carbon use effectiveness [CUE], electronics disposal efficiency [EDE] and IT energy efficiency [ITEE])

As shown in Table 5.16, the indicators' outer weights, outer loadings and *t*-values, respectively, for TecPerf1 (0.415, 0.898, 3.712), TecPerf2 (0.241, 0.799, 2.778), TecPerf4 (0.264, 0.890, 2.258) and TecPerf6 (0.189, 0.784, 1.884) are significant. The relative contributions of the outer weights indicate the importance of the four indicators for explaining the content of the construct. The measure of outer loadings shows positive bivariate correlation between the indicators and technological performance, thus signifying the absolute importance between the indicators and the construct.

Using the bootstrapping procedure, the *t*-values are significant for TecPerf1 and TecPerf2 at the one-tailed critical value of a 1% probability error, in comparison to TecPerf4 and TecPerf6 that are significant at the one-tailed critical value of a 5% probability error. However, the outer weights (0.064, 0.008) and *t*-values (0.689, 0.091) of TecPerf3 and TecPerf5, respectively, demonstrate weak results for their relative contribution and significance testing. Despite that, TecPerf3 and TecPerf5 attained significant outer loadings above the threshold value of 0.5. This explained the significant positive bivariate correlation with the absolute importance of TecPerf3 and TecPerf5 with the construct.

Overall, the results, including for TecPerf3 and TecPerf5, indicate good relevancy, importance and significance. Therefore, the six formative indicators of the technological performance construct are retained for the structural model assessment and hypotheses testing.

Table 5.16: Technological Performance Formative Indicators' Significance Testing Results

Formative Constructs	**Formative Indicators**	**Outer Weights (Outer Loadings)**	**Standard Error**	***t*-value**	**Significance Level**	***p*-value**
Technological Performance	TecPerf1	0.415 (0.898)	0.112	3.712	Significant***	0.000
	TecPerf2	0.241 (0.799)	0.087	2.778	Significant***	0.003
	TecPerf3	0.064 (0.709)	0.093	0.689	Outer Weight: No relative importance Outer Loading: Show absolute importance *t*-value: Not significant *Indicator is to be retained	0.245
	TecPerf4	0.264 (0.890)	0.117	2.258	Significant**	0.012
	TecPerf5	0.008 (0.715)	0.092	0.091	Outer Weight: No relative importance Outer Loading: Show absolute importance *t*-value: Not significant *Indicator is to be retained	0.464
	TecPerf6	0.189 (0.784)	0.100	1.884	Significant*	0.030

Notes: SIM = single item measure; NS = not significant; *p < 0.1 (Significance level of 10%); **p < 0.05 (Significance level of 5%); ***p < 0.01 (Significance level of 1%)

The formative measurement models are based on the assumption that the indicators cause the construct. In formative measurement, the insignificant indicator weights must not be interpreted as an indication of poor measurement model quality as each indicator represents an independent cause to the construct (Hair et al., 2014, 2017). The non-significant formative indicator should never be discarded only on the basis of statistical outcomes (Hair et al., 2014, 2017).

Thus, the non-significant indicators were retained in this study as each indicator explained the specific aspect of the construct's domain. These indicators determine the meaning of the constructs, therefore, omitting any of these indicators may potentially alters the nature as well as the content validity of the constructs. Based on the expert assessment, the researcher was advised to retain the indicators as it explained an insight to what and why the indicators are significant and non-significant in this study. Also, it enlightens the researcher on the extent the manufacturing firms are implementing the green drivers, technology, solutions and practices within the supply chains as well as the extent these implementations have improved or worsen the environmental and technological performances of ISO 14001 manufacturing firms.

5.4 Analysis and Results of Structural Model

Once the formative indicators of each construct have achieved good validity, reliability, relevance and significance, the next step is to assess the structural model measurement. The four important steps in the formative structural model assessment procedure are: (1) assessment of collinearity issues; (2) assessment of significance and relevance of the structural model relationships; (3) assessment of the coefficient of determination (R^2 value); and (4) assessment of the effect size (f^2).

The objectives of structural model assessment are (Hair et al., 2014):

- To determine the extent that empirical data support the theory or concept
- To evaluate the extent the theory or concept has been empirically and statistically confirmed
- To measure the model's predictive capabilities and the relationships of the constructs.

5.4.1 Assessment of Collinearity

The measurement technique exercised in finding collinearity is known as the variance inflation factor (VIF). As previously mentioned, the cut-off threshold values in assessing VIF are the tolerance value of 0.20 or lower, or a VIF value of 5 or higher which indicate potential collinearity issues (Hair et al., 2014, 2017). In managing collinearity issues for the structural model, problematic constructs are eliminated, and the predictor's constructs are merged into a single construct or higher-order constructs are created.

Table 5.17 presents the results of the collinearity assessment of three sets of constructs (predictors). In the first set, Green IT, Green IS, Int Comm, Reg Pres and Firm Size are predictors of GSCM with corresponding VIF values of 4.164, 4.333, 4.262, 3.503 and 1.487, respectively. In the second set, GSCM is the predictor of Env Perf with a VIF value of 1, and in the third set, GSCM is the predictor of Tec Perf with a VIF value of 1. All VIF values are clearly below the threshold value of 5. Therefore, no collinearity issue exists between the predictor constructs in the structural model.

Table 5.17: Collinearity Assessment – Structural Model Measurement

First Set	
Constructs	**Variance Inflation Factor (VIF)**
Green IT → GSCM	4.164
Green IS → GSCM	4.333
Int Comm → GSCM	4.262

Reg Pres → GSCM	3.503
Firm Size → GSCM	1.487
Second Set	
Constructs	**Variance Inflation Factor (VIF)**
GSCM → Env Perf	1
Third Set	
Constructs	**Variance Inflation Factor (VIF)**
GSCM → Tec Perf	1

5.4.2 Assessment of Structural Model Path Coefficients

The bootstrapping procedure was run to obtain the empirical *t*-values as well as the bootstrapping confidence interval for assessing the significance and relevance of the hypothesized relationships. The path coefficients represent the hypothesized relationships between the constructs. The significance of the path coefficient depends on its standard error which is obtained from the bootstrapping procedure which computes the empirical *t*-value (Hair et al., 2014, 2017). When the empirical *t*-value is larger than the critical value, the path coefficient is significant at a certain error probability or significance level. The critical value is a cut-off value to determine the significance of a path coefficient or hypothesized relationship. For the current study, the hypotheses are directional; therefore, one-tailed critical values are observed to determine the path coefficient and hypotheses' significance, as shown in Figure 5.8, Figure 5.9 and Table 5.18.

The path coefficient of Hypothesis 1 (H1) from Green IT to GSCM has a value of 0.434. Using the bootstrapping procedure, at the 5000 bootstrap sample, the empirical *t*-value obtained for H1 is 5.663 which is larger than the theoretical *t*-value of the one-tailed critical value which is 2.33 at a 1% probability error. As a result, the H1 relationship from Green IT to GSCM is significant at a level of 1%. Looking at the confidence interval of H1, the lower bound is 0.307 and the upper bound is 0.561. The difference between the lower and upper bound confidence intervals (CIs) is 0.254. This concludes that the path coefficient of H1 with a value of 0.434 is significant as zero (0) does not fall within the lower and upper bounds of the confidence interval at a 1% probability error.

The path relationship from Green IS to GSCM, which represents Hypothesis 2 (H2), has a coefficient value of 0.129 and a *t*-value of 1.687. The *t*-value of H2 is larger than the one-tailed critical value of 1.645 at a 5% probability error. This explains that the H2 relationship from Green IS to GSCM is significant at a 5% probability error. The lower and upper confidence intervals of H2 are from 0.004 to 0.254 which indicates that the zero (0) value is outside the range. The difference between the lower and upper bound confidence intervals is 0.250. The confidence interval obtained supports the findings of the H2 path coefficients, explaining that the relationship from Green IS to GSCM is significant at a 5% probability error.

The coefficient value for Hypothesis 3 (H3) that represents the relationship between Int Comm and GSCM is 0.144. The *t*-value of H3 is 1.989; therefore, it is larger than the one-tailed critical value of 1.645 at a 5% probability error. The confidence interval for H3 does not contain the zero (0) value as lower and upper bounds are from 0.026 to 0.262. The difference between the lower and upper bound confidence intervals is 0.236. Hence, the H3 relationship from Int Comm to GSCM is significant at a 5% probability error for both the *t*-value and the confidence interval.

The Hypothesis 4 (H4) path coefficient is established for the relationship from Reg Pres to GSCM with a value of 0.231. At a 1% probability error, the *t*-value is 3.261 which is larger than the one-tailed critical value of 2.33; therefore, the path relationship is significant. At the same time, the confidence interval scored a lower bound value of 0.114 and an upper bound value of 0.348. The difference between the lower and upper bound confidence interval is 0.234. As the zero (0) value is not within the confidence interval range of H4, the relationship from Reg Pres to GSCM is significant at a 1% probability error.

The Hypothesis 5 (H5) path relationship from GSCM to Env Perf has a path coefficient value of 0.835 and, with the bootstrapping procedure at 5000 sub-samples, the *t*-value obtained is 39.673. The *t*-value is higher than the one-tailed critical value of 2.33 at a 1% probability error. The result concludes that H5 is significant at a level of 1% probability error. Moreover, the bootstrapping confidence interval indicates the absence of the zero (0) value within the lower and upper bound range that has values from 0.800 to 0.870. The difference between the lower and upper bound confidence interval is 0.070. In summary, the path relationship from GSCM to Env Perf that explains H5 is significant at a 1% probability error.

The coefficient value of 0.791 explains the path relationship from GSCM to Tec Perf that denotes Hypothesis 6 (H6). The *t*-value attained is 26.521 which is significant at a 1% probability error as the *t*-value is larger than the theoretical *t*-value of 2.33 for the one-tailed test. The additional information provided by the confidence interval shows the non-existence of the zero (0) value between the lower and upper bounds of the interval [0.742, 0.840]. The difference between the lower and upper bound confidence interval is 0.098. For that reason, the path relationship of H6 is significant at a 1% probability error.

As a control variable, firm size has a path relationship with GSCM at a coefficient value of 0.069. At 5000 bootstrap samples, the *t*-value obtained is 1.531 which is larger than 1.28 at a 10% probability error. However, the confidence level value acquired for the lower bound is -0.005 and for the upper bound is 0.143 which evidently includes the zero (0) value within the interval. Therefore, the path relationship is insignificant from firm size to GSCM.

In PLS-SEM software, the results are presented in the form of a detailed report. In the current study, the relevant results are captured, presented and discussed from Table 5.10 to Table 5.16 in Section 5.3.3.1 to Section 5.3.3.7. Figures 5.8 and 5.9 are extracts from the PLS-SEM report that shows the summary of the results in graphical view.

Figure 5.8 summarized the results for the formatively-measured indicators and constructs (Green IT, Green IS, Int Comm, Reg Pres, GSCM, Env Per and Tec Perf) by graphically displaying the standardized outer weights for the formative measurement models. The standardized path relationships between the constructs for the structural model are shown as well as the R^2 values for the endogenous latent variables (GSCM, Env Perf and Tec Perf).

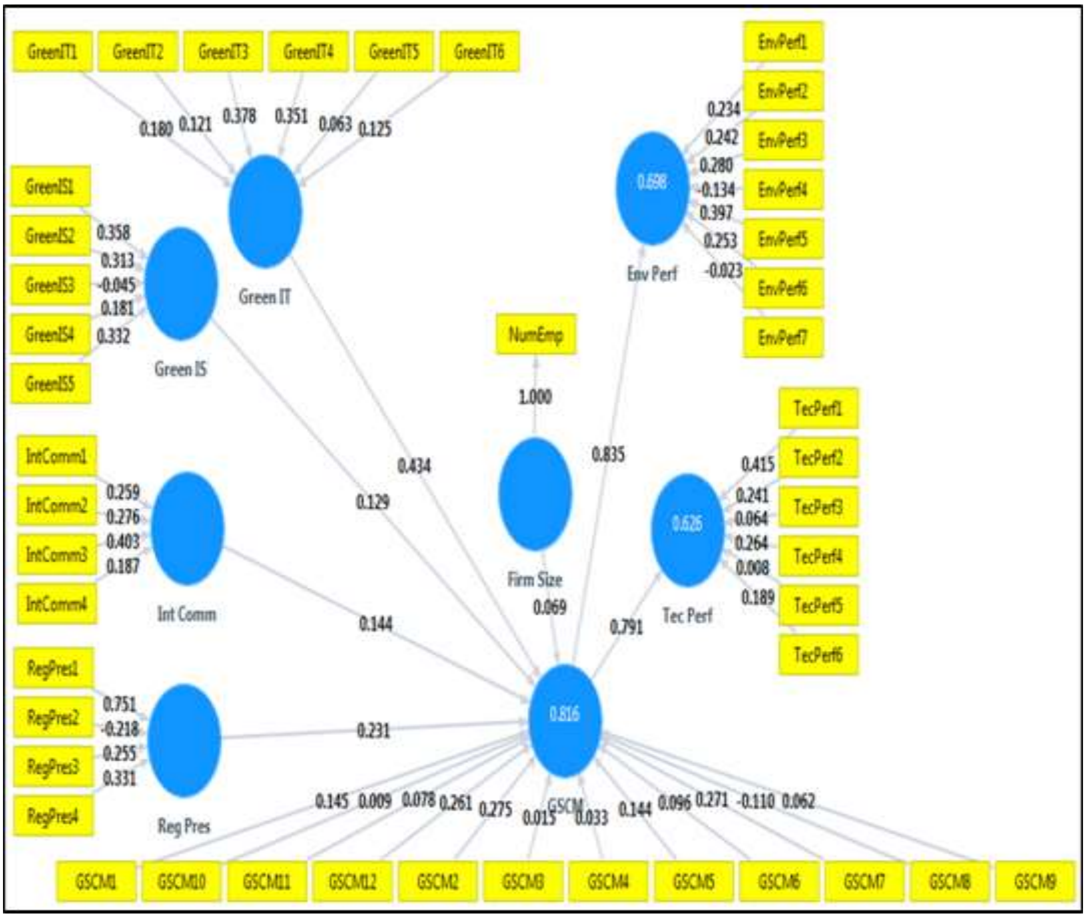


Figure 5.8: Measurement Model Results

The evaluation of the measurement and structural models in PLS-SEM uses the bootstrapping procedure to evaluate the reliability and validity of the constructs measured as well as the model's predictive capability. In the bootstrapping procedure, sub-samples are randomly drawn (with replacement) from the original set of data. The bootstrapping procedure produces *t*-values that are calculated to assess each indicator weight's significance in the measurement model, as well as estimating the path coefficients and statistical testing of the hypotheses in the structural model.

Figure 5.9 summarized the bootstrapping results for the formatively-measured indicators and constructs (Green IT, Green IS, Int Comm, Reg Pres, GSCM, Env Per and Tec Perf) by graphically displaying the indicator weight significance (*t*-values) for the measurement model as well as the path coefficients and the statistical testing of the hypotheses for the structural model.

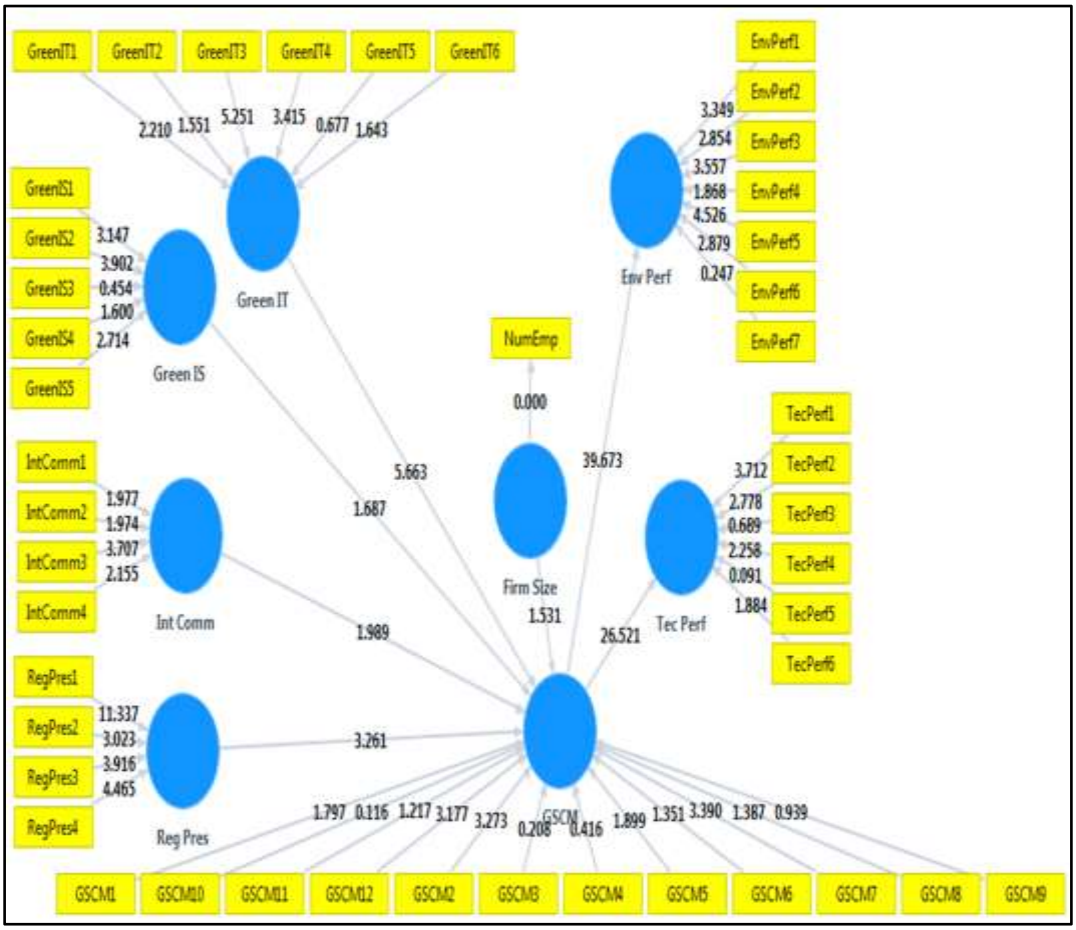


Figure 5.9: Bootstrapping Results for Measurement and Structural Models

In Table 5.18, the direct effects path relationships of the structural model are presented with this demonstrating the coefficient values, *t*-values, significance levels, *p*-values, lower and upper bound confidence intervals and path relationships between the variables.

Table 5.18: Significance Testing Results of the Structural Model Path Coefficients

Path	Path Coefficient	Standard Error	*t*-value	Significance Level	*p*-value	Confidence Intervals	Relationship
Green IT → GSCM (H1)	0.434	0.077	5.663	***	0.000	[0.307, 0.561]	Significant
Green IS → GSCM (H2)	0.129	0.076	1.687	**	0.046	[0.004, 0.254]	Significant
Int Comm → GSCM (H3)	0.144	0.072	1.989	**	0.023	[0.026, 0.262]	Significant
Reg Pres → GSCM (H4)	0.231	0.071	3.261	***	0.001	[0.114, 0.348]	Significant
GSCM → Env Perf (H5)	0.835	0.021	39.673	***	0.000	[0.800, 0.870]	Significant
GSCM → Tec Perf (H6)	0.791	0.030	26.521	***	0.000	[0.742, 0.840]	Significant
Firm Size → GSCM	0.069	0.045	1.531	*	0.063	[-0.005, 0.143]	Not Significant

Notes: NS = not significant; *p < 0.1 (Significance level of 10%); **p < 0.05 (Significance level of 5%); ***p < 0.01 (Significance level of 1%)

In addition, four indirect effects of path relationships are observed in order to understand the influences that Green IT and Green IS have on performance outcomes. The indirect effects of the structural model's path relationships are presented in Table 5.19 which shows the coefficient values, *t*-values, lower and upper bound confidence intervals, significance levels and path relationships between the variables.

Table 5.19: Significance Testing Results of the Indirect Effects

Path	Path Coefficient	*t*-value	Significance Level	Confidence Intervals	Relationship
Green IT → Env Perf	0.362	5.548	***	[0.266, 0.481]	Significant
Green IT → Tec Perf	0.343	5.093	***	[0.249, 0.469]	Significant
Green IS → Env Perf	0.107	1.715	**	[0.015, 0.223]	Significant
Green IS → Tec Perf	0.102	1.711	**	[0.014, 0.211]	Significant

Notes: NS = not significant; *p < 0.1 (Significance level of 10%); **p < 0.05 (Significance level of 5%); ***p < 0.01 (Significance level of 1%)

The path coefficient from Green IT to Env Perf has a value of 0.362, while the value from Green IT to Tec Perf is 0.343. The empirical *t*-values acquired between the drivers and performance outcomes are Green IT to Env Perf (5.548) and Green IT to Tec Perf (5.093) which are higher than 2.33, the critical *t*-value of the one-tailed test. Therefore, the path relationships from Green IT to Env Perf as well as from Green IT to Tec Perf are significant at a 1% probability error. The confidence interval measures the significance of the relationships through the differences between the lower and upper bounds, with these equal to 0.215 and 0.220 from Green IT to Env Perf and from Green IT to Tec Perf, respectively. The path relationships from Green IT to Env Perf as well as from Green IT to Tec Perf are significant as the zero (0) value does not fall within the lower and upper bound confidence intervals.

The indirect relationship from Green IS to Env Perf and from Green IS to Tec Perf, correspondingly, have the following path coefficients, 0.107 and 0.102. The *t*-values for the path from Green IS to Env Perf is at 1.715, while from Green IS to Tec Perf, it is 1.711. Both *t*-values are significant at a 5% confidence level as the empirical *t*-value obtained is larger than the critical value of 1.645. The disparity between the lower and upper bound confidence intervals for the path from Green IS to Env Perf is 0.208, while it is 0.197 for the path from Green IS to Tec Perf. Both paths are significant as the zero (0) value does not fall within the lower and upper bounds of the confidence interval.

The small value of the confidence interval difference indicates the stability of the path estimates, while the path coefficients show the significance and relevancy of the path in the structural model. The result demonstrates that Green IT has higher relative importance and relevancy compared to Green IS in the direct improvement of environmental and technological performances within the ISO 14001-certified manufacturing firms in Malaysia.

Being a positivist researcher, the concepts, variables and research hypotheses are developed before the research begins and remain fixed throughout the research. Therefore, the indirect paths analyses are beyond than the scope of this study. The paths and relationships of Green IT and Green IS in the technological context, and their impacts on environmental and technological performances are worth further interpretation in future studies.

5.4.3 Assessment of Level of Coefficient of Determination (R^2)

Next, the level of the coefficient of determination (or R^2 value) is calculated to determine the model's predictive accuracy. The coefficient of determination (or R^2 value) explains the amount of variance in the endogenous constructs based on the number of exogenous constructs linked to them (Hair et al., 2014, 2017). The effect ranges from 0 to 1, with the higher values representing better predictive accuracy. The common rule for R^2 is 0.75 for a substantial level of predictive accuracy, 0.50 for a moderate level and 0.25 for a weak level (Hair et al., 2011, 2014, 2017; Henseler et al., 2009).

As presented in Table 5.20, the R^2 value for the endogenous variable, GSCM, is 0.816. This indicates the substantial predictive accuracy of the model, explaining that the variance in implementing GSCM within ISO 14001-certified manufacturing firms is 82%, with this determined by the drivers of Green IT, Green IS, internal commitment and regulatory pressure. As for the endogenous variables of the outcomes, environmental performance scored 0.698 and technological performance recorded 0.626 for their R^2 values. Both performance outcomes explain the moderate predictive accuracy of the model. The practice of GSCM explains 70% of the variance in improving environmental performance and 63% of the variance in improving technological performance.

The models are good at explaining the gathered research data as high R^2 values are obtained with moderate to substantial predictive accuracy. Furthermore, the model has fewer exogenous constructs, thus allowing it to be parsimonious.

Table 5.20: Coefficient of Determination (R^2)

Endogenous Constructs	**R-Squared (R^2)**	**Predictive Accuracy**
GSCM	0.816	Substantial
Env Perf	0.698	Moderate
Tec Perf	0.626	Moderate

5.4.4 Assessment of Effect Size (f^2)

The effect size (or f^2) is computed to explain the effect of a specified exogenous construct when it is omitted from the model, and the subsequent impact on the endogenous construct (Hair et al., 2014, 2017). The effect size (f^2) explains the change in R^2 when a specified exogenous construct is omitted from the model. The omission of the exogenous construct may cause a substantive impact on the endogenous construct; therefore, the magnitude of the effect needs an evaluation. The guideline for assessing f^2 values are 0.02, 0.15 and 0.35 representing small, medium and large effect sizes, respectively (Cohen, 1988). Effect size values of less than 0.02 indicate no effect (Cohen, 1988). If an exogenous construct strongly contributes in explaining an endogenous construct, the difference between R^2 included and R^2 excluded is therefore high, then f^2 will also be high.

The results shown in Table 5.21 are for the exogenous constructs and their effect sizes on the endogenous constructs. The effect size for the exogenous constructs of Green IS, internal commitment and regulatory pressure in explaining the endogenous construct of GSCM are 0.021, 0.026 and 0.083, respectively, with this being a small effect size. The exogenous construct of Green IT has the f^2 value of 0.245 which explains the medium effect size on GSCM's endogenous construct. Furthermore, as an exogenous construct, GSCM has a medium effect size in explaining the outcomes on environmental performance and technological performance with f^2 values of 0.231 and 0.167, respectively.

Table 5.21: Effect Size (f^2)

Path	**f-Squared (f^2)**	**Effect Size**
Green IT → GSCM	0.245	Medium
Green IS → GSCM	0.021	Small
Int Comm → GSCM	0.026	Small
Reg Pres → GSCM	0.083	Small
GSCM →Env Perf	0.231	Medium
GSCM → Tech Perf	0.167	Medium

5.5 Discussions on the Findings

The analyses of the main data from the survey questionnaires were discussed earlier in this chapter. The analyses are divided into two parts with: (1) data screening and descriptive analysis using SPSS presented in Section 5.2; and (2) assessment of the measurement and structural models using PLS-SEM analysis as presented in

Sections 5.3 and 5.4. Further deliberation on the detailed discussion of the results is presented in the next few sections.

5.5.1 Research Framework and Hypotheses Testing

The path diagram, as illustrated in Figure 5.10, is derived from the proposed research framework to assess Research Questions 1 to 3 (RQ1 to RQ3) and to validate Hypotheses 1 to 6 (H1 to H6) through the PLS-SEM method.

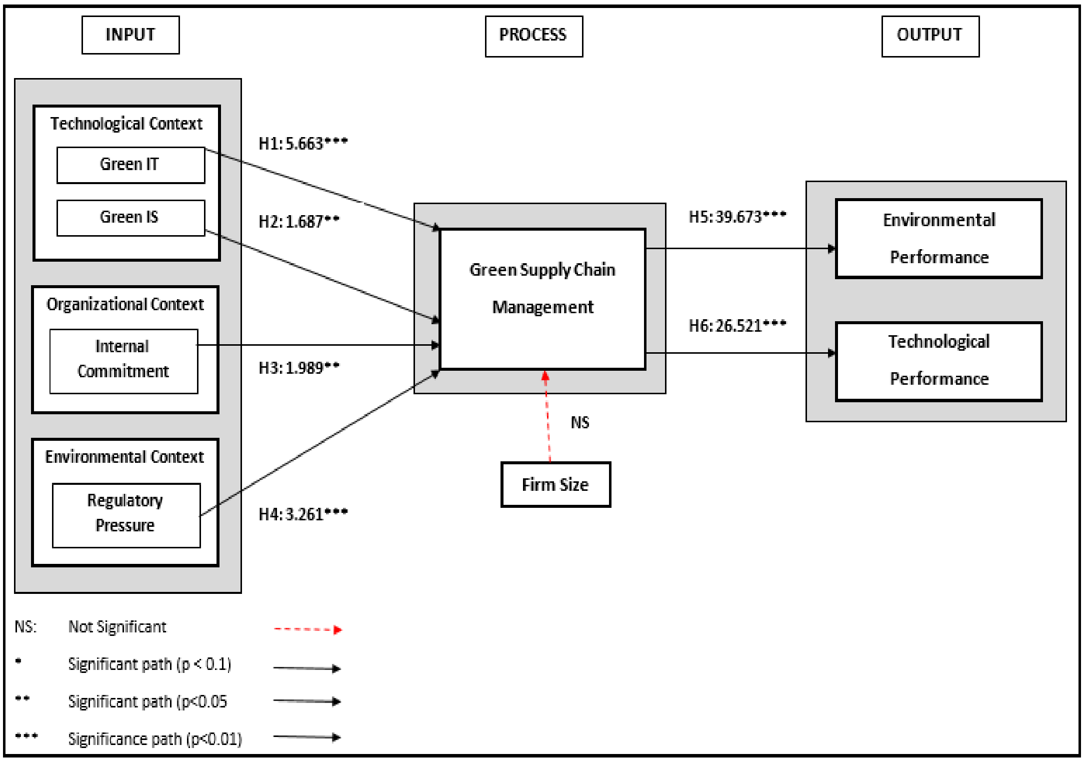


Figure 5.10: Path Diagram

To recap the findings from the measurement and structural model assessment, the summary of the results is presented in Table 5.22.

Table 5.22: Summary of PLS-SEM Results

Path	Path Coefficient	Standard Error	*t*-value	Significance Level	*p*-value	Confidence Intervals	Relationship
Green IT → GSCM (H1)	0.434	0.077	5.663	***	0.000	[0.307, 0.561]	Significant
Green IS → GSCM (H2)	0.129	0.076	1.687	**	0.046	[0.004, 0.254]	Significant
Int Comm → GSCM (H3)	0.144	0.072	1.989	**	0.023	[0.026, 0.262]	Significant
Reg Pres → GSCM (H4)	0.231	0.071	3.261	***	0.001	[0.114, 0.348]	Significant
GSCM → Env Perf (H5)	0.835	0.021	39.673	***	0.000	[0.800, 0.870]	Significant
GSCM → Tec Perf (H6)	0.791	0.030	26.521	***	0.000	[0.742, 0.840]	Significant
Firm Size → GSCM	0.069	0.045	1.531	*	0.063	[-0.005, 0.143]	Not Significant

The final results from the PLS-SEM analysis are shown in Table 5.22. In Table 5.23, the three research questions are presented along with six hypotheses which were validated using the PLS-SEM method as discussed in Section 5.3 and Section 5.4. The detailed discussion on the results is presented in the next few sections, from Section 5.5.2 to Section 5.5.8.

Table 5.23: Summary of Hypotheses Results

RQ1: To what extent do Green information technology (Green IT) and Green information systems (Green IS) drive the implementation of GSCM within ISO 14001-certified manufacturing firms in Malaysia?

Hypothesis	Description	Result
H1	*Green IT positively influences the implementation of GSCM within ISO 14001-certified manufacturing firms in Malaysia*	*Supported*
H2	*Green IS positively influences the implementation of GSCM within ISO 14001-certified manufacturing firms in Malaysia*	*Supported*

RQ2: To what extent do internal commitment and regulatory pressure drive the implementation of GSCM within ISO 14001-certified manufacturing firms in Malaysia?

Hypothesis	Description	Result
H3	*Internal commitment positively influences the implementation of GSCM within ISO 14001-certified manufacturing firms in Malaysia*	*Supported*
H4	*Regulatory pressure positively influences the implementation of GSCM within ISO 14001-certified manufacturing firms in Malaysia*	*Supported*

RQ3: To what extent does the implementation of GSCM effect the organization's environmental performance and technological performance within ISO 14001-certified manufacturing firms in Malaysia?

Hypothesis	Description	Result
H5	*The implementation of GSCM has a positive influence on environmental performance within ISO 14001-certified manufacturing firms in Malaysia*	*Supported*
H6	*The implementation of GSCM has a positive influence on technological performance within ISO 14001-certified manufacturing firms in Malaysia*	*Supported*

5.5.2 Discussion: Green IT

The preliminary data gathered during the pre-test and pilot test, as summarised in Sections 4.3 and 4.4, indicate that the ISO 14001-certified manufacturing firms expressed a lower level of interest in investing in visualization technologies, energy-efficient lighting and green technologies. The reason was their concern about the amount of investment needed up-front, the quality and performance of the technologies, as well as the payback period.

Referring to the findings in Section 5.3.3.1 and in Table 5.10, the indicators of Green IT that scored the higher outer weight values and *t*-values are 0.378 and 5.251 for GreenIT3: Use energy-efficient lights, as well as 0.351 and 3.415 for GreenIT4: Use virtualization technology.

Compared to other electrical appliances or IT equipment, lighting has one of the highest usages in the commercial sector. It is crucial to replace lighting products such as compact fluorescent lamp (CFL) tubes, halogen tubes and incandescent bulbs with energy-efficient lighting such as light-emitting diodes (LEDs). Switching to energy-efficient lighting technologies allows a considerable amount of energy saving, up to 27% in residential buildings and 30% in the commercial sector (Trifunovic, Mikulovic, Djurisic, Djuric, & Kostic, 2009). The process of replacing inefficient lighting systems with more advanced and higher efficiency systems is called a lighting retrofit (Ma, Cooper, Daly, & Ledo, 2012).

Energy-efficient lighting, such as LEDs, lasts up to 17 years while, within the same period, incandescent lamps must be replaced 25 times and CFLs six times (Khorasanizadeh, Parkkinen, Parthiban, & Moore, 2015). The lowest levels of emissions generated per year were scored by LEDs compared to CFLs and incandescent lamps: if 62% of incandescent lamps were replaced with LEDs, emissions would drop to 0.145 $MMtCO_2$ by 2020 for residential buildings. Being mercury-free, LEDs are environmentally-friendly and illuminate without emitting harmful infrared or ultraviolet radiation, as compared to fluorescent lamps and CFLs which require special disposal of their hazardous waste (Ganandran, Mahlia, Ong, Rismanchi, & Chong, 2014).

The marginal benefits (MBs) and marginal costs (MCs) of LEDs exceed those of CFLs in the MB/MC ratio with a cost of Malaysian ringgit (RM) 0.334 after six years and, after nine years, of RM 0.218. The reason is that the capital cost for LEDs is paid once only, whereas a new CFL must be purchased every 2.74 years (Khorasanizadeh et al., 2015). As a result of retrofitting, the overall amount of electricity consumption decreases; consequently, this would help the environment by decreasing the harmful effect of greenhouse gases (GhGs). Therefore, energy-efficient lighting has a shorter payback period with greater cost savings and is much cleaner for the environment.

Malaysia is currently partnering with Carbon Trust, a UK enterprise, along with Malaysian Green Technology Corporation (GreenTech Malaysia) and other local partners to accelerate the deployment of energy-efficient lighting with the mission being to reduce energy use and carbon emissions (McCarthy, 2015). This programme will phase out incandescent lamps through prohibition of their sale in the market and through running rigorous campaigns on energy-efficient lighting and the benefits of CFLs and LEDs to increase awareness. The Department of Standards Malaysia, an agency under the Ministry of Science, Technology and Innovation (MOSTI) has introduced the 12 Malaysian Standard (MS) as well as Minimum Energy Performance Standards (MEPS) for five domestic electrical products (air conditioner, refrigerator, television, domestic fan and lighting) in response to the impending policy change to promote energy-efficient technologies (Umar, 2014).

The implementation of energy-efficient lighting with light-emitting diodes (LEDs) has increased steadily from 2012 to 2016 in Malaysia. LEDs are expected to take a leading role in the lighting market with a greater customer market for both residential use and the commercial sector with the launch of the Eleventh Malaysia Plan (2016–2020) that focuses on a sustainable environment and development. In addition, Malaysia aims to be one of the top manufacturers and exporters of LEDs for the international market (Kementerian Tenaga Teknologi Hijau dan Air (KETTHA), 2014b).

Apart from energy-efficient lighting technologies, manufacturing firms, especially the multi-national corporations (MNCs), are gearing up to implement virtualization technologies. These firms have implemented virtualization technology to efficiently handle data and to reduce energy costs as well as the total cost of ownership. The consolidation of servers can increase the utilization ratio of various servers by 50% or more with additional reliability and security features. Virtualization technology is considered as part of server and cloud infrastructure, offering many technical, economic and environmental advantages to the manufacturing sector (Ezell, 2016; Hale, 2016; Uddin, Shah, Abubakar, & Adeleke, 2014; Walther & Regtmeier, 2016). Thus, it is expected that most traditional data centres will have to transform themselves to cloud data centres in the years to come.

The implementation of cloud technologies is steadily growing in most markets in Malaysia. A similar trend is observed in the manufacturing sector including many non-business critical applications that are running in a cloud environment with the focus on Green IT in order to obtain business differentiation. The data centre service industry in Malaysia is obtaining significant government commitment for driving the industry’s growth including among small and medium-sized businesses (Global e-Sustainability Initiative (GeSI), 2015). More firms are expected to adopt virtualization technologies and external data centres which would further assist in cost and resource savings.

The recent report by Asia Cloud Computing Association (ACCA) in March 2016 showed that the Cloud Readiness Index (CRI) for Malaysia is ranked at 7.6 which is higher than in Singapore (7.3) and Hong Kong (7.4) on two out of 10 key parameters thus indicating the preparedness of Malaysia to adopt cloud computing (Mah, 2015). Malaysia has emerged as the undisputed leader for cloud computing in South-East Asia when it comes to business sophistication with dedicated support from emerging industry clusters and a range of local suppliers. Furthermore, Malaysia has one of the best cybersecurity measures in place in the region, although it scored poorly on connectivity and data centre risk (Mah, 2015).

In early 2016, the emerging technology known as the Internet of Things (IoT) again changed the game among the manufacturing industry in Malaysia. The IoT and integrated industry are now introducing more software into manufacturing environments which allow for embedded virtualization (Wind River Systems, 2014). With the advent of the IoT, industrial control devices are now connected to the cloud which will optimize production efficiency, reduce downtime and minimize environmental impact.

In a recent post on CIO Asia, Helmi Halim from the MIMOS Berhad emphasized that the introduction of the IoT in supply chains would allow the digitalization of manufacturing and logistics data which would result in better forecasting of anticipated demand, facilitating zero-inventory manufacturing and increasing total efficiency in the management of the supply chain (See, 2016). Thus, the manufacturing industry is no longer all about creating products, but is now integrating different components to provide better end-products more quickly to meet customer requirements.

Furthermore, MIMOS foresees the trend of the “Uber-fication” of the logistics sharing culture that is driven by cost optimization and empowerment of consumers and which resembles the future supply chain (Persatuan Industri Komputer dan Multimedia Malaysia (PIKOM), 2014). As mentioned in the CIO Asia post by Dato Raj Arumugam from the Malaysian Trade and Industry Organisation Berhad as well as Kelvin Kumar from Monier Asia that many manufacturers will be paralyzed if they fail to adapt to customers’ demands to utilize the IoT in supply chains (See, 2016). Industrial practitioners feel that the IoT is another innovation for forward-thinking enterprises, which could significantly improve manufacturing and supply chain performance in terms of efficient procurement, lower raw materials inventory, and reduction in the variability of orders and shipments.

The ISO 14001-certified manufacturing firms in Malaysia are under pressure to tag along with the latest trends of computing technologies such as virtualization, cloud computing and the IoT as well as adopting energy-efficient technologies such as LED lighting for optimization and ecologically-friendly practices.

From the results presented in Section 5.3.3.1, ISO 14001-certified manufacturing firms in Malaysia are implementing environmentally-friendly IT infrastructures and technologies which enable integrated business functions and minimize negative impacts to the environment.

As shown in Figure 5.10, Hypothesis 1 (H1) is supported. Thus, Green IT has a positive influence as a technological driver for influencing GSCM implementation within ISO 14001-certified manufacturing firms in Malaysia, thus addressing Research Objective 1 (RO1).

5.5.3 Discussion: Green IS

The preliminary data gathered during the pre-test and pilot test, as summarized in Sections 4.3 and 4.4, indicate that many of the ISO 14001-certified manufacturing firms use video conferencing, telecommuting (teleworking), groupware and collaborative software as well as applications to support design, procurement and manufacturing activities. These are common applications to support routine activities in order to stay connected and perform business transactions with their internal teams and external collaborators/partners.

Referring to the findings in Section 5.3.3.2 and Table 5.11, the indicators of Green IS scoring the higher values for outer weight and *t*-value were 0.358 and 3.147, respectively, for GreenIS1: Use of software to monitor and record environmental indicators as well as 0.313 and 3.902, respectively, for GreenIS2: Use of software for development and design of product and materials procurement.

Information systems (IS) have been a faithful servant of the dominant logic in which IS bundle core competencies of skills and technologies to support the strategic direction and value proposition for the organization’s success as well as its survival (R. T. Watson, Lind, & Haraldson, 2012). Thus, the suitability and usage of IS in the context of GSCM as well as reverse logistics are being demonstrated much earlier in comparison to information technology (IT). In a recent study, a positive correlation was found between Green IS and environmental sustainability with GSCM as the mediator to strengthen the relationship (Al-Zu’bi, 2016). Information systems (IS) play a major role in facilitating sustainability transformations in various types of organization (Seidal, Recker, & vom Brocke, 2013).

Manufacturing firms today are focusing on implementing software and applications to monitor the environmental indicators that allow them to benchmark their progress in achieving sustainable practices, while complying with environmental laws. The concept of Environmental Management Information Systems (EMISs) represent “organizational-technical systems for systematically obtaining, processing and making environmentally relevant information available for companies” (Hilty & Rautenstrauch, 1997). The EMIS is implemented to detect, plan, manage and monitor environmental measures and to support decision making as well as providing information needed by external stakeholders and legal bodies on the environmental impacts of products and processes (Schweiger, 2016).

In addition, many organizations are implementing applications known as green software, such as energy monitoring software that utilizes visualization of power consumption whereby it calculates the estimated level of energy that can be saved from other features or hardware. Moreover, green software adopts inventive algorithms to reduce the total power consumption of Internet usage by optimizing all decision processes in software and power consumption of the hardware on which the Internet is built (Abenius, 2009).

Many companies that have migrated to virtualization technology and cloud computing infrastructure are using software as a platform of service. The software includes email, customer relationship management (CRM) and enterprise resource planning (ERP) as well as platforms for application development, decision support, the web and streaming. Thus, as a result of the convergence of technologies developed over the past few years and the recent advent of the Internet of Things (IoT), innovative business solutions and smarter computing solutions are being offered in various industries with more accurate predictive capabilities, higher efficiency and greater productivity. The example for viable solutions for the manufacturing industry are smart manufacturing solutions as a way to increase manufacturing yield, and smart environmental tracking solutions to monitor and benchmark the environmental indicators, output and overall impacts.

In Malaysia, Malaysia Digital Economy Corporation (MDEC)), Multimedia Super Corridor (MSC) and major IT players have been instrumental in the creation of more than 100 independent software vendors (ISVs) and the use of over 20 types of cloud by local IT players to offer smart solutions to various industries, including manufacturing, retail, energy efficiency, public security, health care services, traffic management and many more (Malaysian International Chamber of Commerce and Industry (MICCI), 2015).

Information systems (IS) tie together the various elements of IT to provide a complete solution. Information technology (IT) is needed to run the IS that will enable firms to move towards sustainable business practices (R. T. Watson et al., 2008). Many previous studies have placed less importance on, while some have completely overlooked, the inclusion of Green IT and Green IS components as an input, a driver or a factor that contribute to the adoption of organizational green practices and sustainable actions within an organization. In the current study, Green IT and Green IS are introduced as technological drivers.

From the results presented in Section 5.3.3.2, ISO 14001-certified manufacturing firms in Malaysia are showing the importance of implementing systems, software and applications that support green practices and sustainable business processes.

Based on Figure 5.10, Hypothesis 2 (H2) is supported. Thus, Green IS play a positive role as a technological driver in influencing GSCM implementation within ISO 14001-certified manufacturing firms in Malaysia, thus addressing Research Objective 1 (RO1).

5.5.4 Discussion: Internal Commitment

Based on the preliminary data gathered during the pre-test and pilot test, as summarized in Sections 4.3 and 4.4, ISO 14001-certified manufacturing firms emphasized that internal factors such as top management support and employee commitment are the main push factors for implementing environmentally-friendly practices and processes within organizations.

Referring to findings in Section 5.3.3.3 and Table 5.12, the indicators of internal commitment that scored the highest outer weight value and *t*-value are 0.403 and 3.707 for IntComm3: Inspection and audits by internal management, apart from support from top management and coworkers.

In these early days, companies in Malaysia are lacking continuous monitoring and improvements in environmental practices because many have the perception that an environmental audit will expose their companies to costly penalties (Department of Environment Malaysia, 2011). However, the result from this study showed that audits by internal management currently have a bigger influence. Still, an internal audit can be performed successfully only with support from top management and commitment from employees.

Internal audit, also known as first-party audit, is performed within an organization by internal staff members to measure the strengths and weaknesses against its own procedures or methods and/or against external standards adopted by (voluntary) or imposed on (mandatory) the organization (American Society for Quality (ASQ), 2012). The audit process involves internal employees from various areas within the organization, with the relevant information then furnished as input to the audit documents. The internal audit is usually carried out on a routine or periodic basis, depending on the accessibility of resources, company policies and regulatory requirements. The snapshot of the companies' practices and actions is then documented in the internal environment audit report. Furthermore, these internal audit reports assist in external audits by ensuring that the requirements of both local and international standards and laws are met.

In 1989, the International Chamber of Commerce (ICC) defined environmental auditing as

> [a] management tool comprising a systematic, documented, periodic and objective evaluation of how well environmental organization, management and equipment are performing with the aim of helping to safeguard the environment by facilitating management control of environmental practices and assessing compliance with company policies, which would include meeting regulatory requirements (Hillary, 1998).

The environmental audit is carried out internally by companies on the basis of investigating, identifying, understanding, measuring and verifying the effects of existing activities on the environment against set criteria or standards as well as whether companies are compliant with internal policies and legal requirements. Companies also perform environmental auditing for the following reasons (Chong, 2014; Hillary, 1998; Sheate & Diaz-Chavez, 2014):

- Highlight positive efforts made in environmental performance
- Ensure compliance with environmental legislation
- Manage environmental liabilities and insurance costs
- Perform detailed investigation of specific issues
- Enhance corporate image and marketing opportunities
- Concern about the environmental impact of the organization
- Identify potential or rectify past environmental accidents
- Initiate corrective and preventive action to avoid accidents and disasters
- Increase cost savings and efficiency
- Increase confidence of customers in the processes and products
- Educate and motivate the workforce
- Demonstrate management commitment to environmental control
- Improve the working environment towards safer and healthier conditions
- Encourage self-regulation to reduce the burden of external enforcements or penalties

In Malaysia, industrial-based organizations are highly encouraged by the Department of Environment (DOE) to be certified with the Environmental Management System (EMS) ISO 14001. This standard provides an assurance that the organization has a process and system in place to manage environmental issues (Department of Environment Malaysia, 2011). Although being certified with EMS ISO 14001 is a voluntary initiative, organizations will not be exempted from penalties for non-compliance or non-conformance discovered during the external audit. If found to be non-compliant or non-conforming, the organizations will be given an opportunity to rectify the identified environmental issues through the implementation of a Corrective Action Plan. The MNC-based manufacturing firms in Malaysia are subjected to environment, health and safety (EHS) audits, which are conducted by corporate auditors every two to three years.

Thus, the aims of environment auditing are to minimize the adverse effects of these activities on the environment; safeguarding the environment through systematic facilitation and management control; complying with company policies and regulatory requirements; and providing recommendations for corrective environmental strategies to meet the overall organizational environmental mission.

In this study, internal commitment represents the internal factor of the organizational context. From the results presented in Section 5.3.3.3, the implementation of GSCM is possible with support and commitment from top management and internal teams. In order to succeed, internal auditing is essential to ensure compliance with internal and external environmental directives as well as stakeholders' demands for green products.

Based on Figure 5.10, Hypothesis 3 (H3) is supported. Thus, internal commitment is an essential organizational driver for influencing GSCM implementation within ISO 14001-certified manufacturing firms in Malaysia, which addresses Research Objective 2 (RO2).

5.5.5 Discussion: Regulatory Pressure

Based on preliminary data gathered during the pre-test and pilot test, as summarized in Sections 4.3 and 4.4, ISO 14001-certified manufacturing firms highlighted that the external factor that influences their firms towards green practices and green products is the pressure to comply with international environmental laws and legislation.

Referring to findings in Section 5.3.3.4 and Table 5.13, the indicators of regulatory pressure that scored the higher outer weight value and *t*-value, respectively, are 0.751 and 11.337 for RegPres1: Compliance with environmental regulations set by company as well as 0.331 and 4.465 for RegPres4:Compliance with international environmental directives and standards (such as ISO/EEE/RoHs/REACH/EuPs).

Compliance with environmental regulations set by their own organization is crucial as it reflects the declaration of top management's commitment to protect the environment. It also represents the unified vision of environmental concern by the entire organization. Furthermore, compliance reflects the values that support improving the organization's environmental performance which, in return, portray the right image, belief, values and status of the organization to all stakeholders, including current and potential clients. The ISO 14001 standard is the best reference standard for the development of internal environmental policy and regulations because it provides guidance for the fulfilment of other related environmental laws and legal requirements (Burden, 2010).

Compliance with internal environmental regulations is the initial key step towards observing international environmental directives and standards. With successful internal compliance, these companies are much better equipped with higher assurance of meeting international regulatory requirements as well as trading products on the international market with minimal possibility of product rejection in foreign countries.

Some of the prominent environmental international standards, laws or policies that are to be observed by manufacturing firms in Malaysia are as follows:

- The Rio Declaration on Environment and Development
- International Chamber of Commerce (ICC) Business Charter for Sustainable Development
- European Waste and Electrical Equipment Directive (WEEE)
- Restriction of Hazardous Substances (RoHS)
- Restriction, Evaluation, and Authorization of Chemicals (REACH)
- Eco-Design of Energy-using Products (EuP)
- Electronic Product Environmental Assessment Tool (EPEAT)
- Energy Star 5.0 standard – controls energy proficiency for desktop computers, workstations and notepads
- Leadership in Energy and Environmental Design (LEED)

Many international companies choose Malaysia as their preferred base in South-East Asia owing to the attractive investment incentives, efficient administrative infrastructures, large pool of human capital and industry-friendly policies (Schoepp, 2015). Malaysia is one of the leading manufacturing production hubs among Association of Southeast Asian Nations (ASEAN) countries. The countries of Singapore, Malaysia, Thailand, Indonesia and the Philippines have developed their infrastructures to support international businesses which covers export-processing zones, training and education systems, and an investment-friendly regulatory climate (Wilson, 2015).

Malaysia is known among international companies for its strategic location as well as its youthful educated workforce. The migration of manufacturing plants into Malaysia has been strengthened with the commencement of the ASEAN Economic Community's multilateral trade system in 2015. Furthermore, foreign companies have begun to increase the trade fragmentation business with an extension to global supply chains. Malaysia has therefore been active in implementing trade facilitation initiatives (World Trade Organization (WTO), 2014). With Malaysia being a trading nation and manufacturing production hub, the implementation of the multilateral trade system has further increased business opportunities and eased business transactions between Malaysia and other foreign countries. The ISO 14001-certified manufacturing firms in Malaysia must closely observe and comply with internal as well as international environmental regulations. By practicing green activities and trading green products, these firms will be able to remain competitive and sustainable in global supply chains.

In this study, regulatory pressure represents the external factor of the environmental context. From the results presented in Section 5.3.3.4, the compliance to one's own organization's environmental regulations and international environmental laws are the biggest influence for ISO 14001-certified manufacturing firms in Malaysia in carrying out green activities and processes within the supply chain as well as in producing and trading green products in the international market.

Based on Figure 5.10, Hypothesis 4 (H4) is supported. Thus, regulatory pressure is the vital environmental driver for influencing GSCM implementation within ISO 14001-certified manufacturing firms in Malaysia, which addresses Research Objective 2 (RO2).

5.5.6 Discussion: Green Supply Chain Management (GSCM)

Based on preliminary data gathered during the pre-test and pilot test, as summarized in Sections 4.3 and 4.4, ISO 14001-certified manufacturing firms are practising the following environmentally-friendly activities in supply chains: (1) using environmentally-friendly raw materials; (2) designing products based on environmental criteria; (3) using improved or environmentally-friendly packaging; and (4) using environmentally-friendly waste management.

Referring to the findings in Section 5.3.3.5 and Table 5.14, the indicators of green supply chain management (GSCM) that scored the higher outer weight value and *t*-value, respectively, are 0.271 and 3.390 for GSCM7: Eco-labelling of the products; 0.275 and 3.273 for GSCM2: Choose suppliers based on environmental criteria as well as 0.261 and 0.809 for GSCM12: Use environmentally-friendly transportation.

Eco-labels are recognized as information tools that internalize the external effects on the environment of the production, consumption and disposal of products

(Taufique, Siwar, & Chamhuri, 2016). Malaysia launched its first Product Certification and Labelling Programme in 1996 which was led by the Standards and Industrial Research Institute of Malaysia (SIRIM). At that time, the eco-labelling scheme was looking at verification of the following environmental criteria: environmentally-degradable, non-toxic plastic packaging material, hazardous metal-free electrical and electronics equipment, biodegradable cleaning agents and recycled paper.

In line with the national policies, eco-labels that related to the efficient use of energy were launched in 2001. The goal was to regulate and promote energy efficiency (EE) and obtain the cooperation of interested stakeholders. The Malaysia Energy Commission kept extending its promotional efforts to encompass more energy-efficient appliances and equipment (Nik Abdul Rashid, 2009).

In line with the National Green Technology Policy, Malaysian Green Technology Corporation (or GreenTech) introduced a new eco-label known as the MyHIJAU Mark in 2012 (GreenTech Malaysia, 2017). MyHIJAU refers to a recognition programme for products adopting green technology, whereby the product that complies with the given criteria can register as a MyHIJAU Mark Product. This mark recognizes certified green products and services which also comply with both the local and international environmental standards.

The eco-labelling certification mark is granted to products that are able to meet the following environmental criteria:

- minimize degradation to the environment, or reduce greenhouse gas (GhG) emissions
- promote health and/or improvement of the environment
- conserve the use of energy, water and/or other forms of natural resources, or promote the use of renewable energy, or is a recyclable material.

Participation in eco-labelling schemes is voluntary, with these schemes being recognized as the environmental quality certification by industry, government and NGOs (Environmental Protection Agency (EPA), 1998; SIRIM QAS International

Sdn Bhd, 2014). As per 2015, a total of 18 different eco-labels were in use within Malaysia, covering appearances and specifications (Global Ecolabelling Network, 2016).

The implementation of eco-labelling has twofold advantages benefiting both the manufacturer and consumers. The manufacturer tends to volunteer to use the eco-labelling mark because it provides verification on environment-conscious products that are exported to international markets and consumed by consumers from various countries. These products need to comply with local eco-labelling standards, environmental guidelines provided by overseas head offices as well as international environmental standards and laws.

As mentioned by SIRIM QAS International Sdn. Bhd, the eco-labelling certification provides another platform for independent assurance that the manufactured products are supervised, tested and controlled properly, reflecting efficiency in production with lower rejection or wastage as well as being guaranteed to meet the required safety and reliability. Furthermore, the future purchasers or consumers of the products are no longer required to carry out further tests as the eco-label mark is compliant with international standards. In addition, these certified products are protected against competition from sub-standard products and misrepresentation. Thus, eco-labels act as a way in which to legitimize business practices as well as being a protection from public misinterpretation.

From the consumer perspective, eco-labelling furnishes the product's environmentally-related information assisting consumers to make sound purchase decisions. Therefore, uncertainty about the product's environmental performance is reduced, and this increases the consumer's power to choose and purchase products that cause less damage to the environment or that are much more ecologically friendly. Consumers tend to purchase products if they notice, read, understand, believe and use the eco-label information provided on those products; therefore, eco-label marks must be eye-catching, presentable and informative (Taufique et al., 2016).

The ISO 14001-certified manufacturing firms in Malaysia are highly motivated to ensure that their products entering local and international markets are equipped with proper recognition. With the right identification provided, purchasers or consumers will be very satisfied to purchase and consume environmentally-friendly products. Thus, products from Malaysia will be able to compete along with other lines of goods for local as well as international trading. The Eco-Labelling Certification mark is an excellent marketing tool in boosting consumers' perception of the products' brand and the company's name. As a result, eco-labelling creates a platform to enhance the reputation of ISO 14001-certified manufacturers in Malaysia in both local and international markets. However, research is still lacking on Malaysian consumers' perceptions and acceptance of eco-labelling and green products (Taufique et al., 2016).

The next important GSCM practice is supplier selection based on environmental criteria or green suppliers. In the past, criteria for supplier selection comprised quality, finance, customer service, production capacity, design and technical capacity, and information technology (IT) (Chung, Chao, & Lou, 2016). However, selection criteria have changed with time and are insufficient in today's market. In the current dynamic business environment, the selection of the right supplier has a critical effect on the success of the supply chain (Chung et al., 2016; Gurel, Acar, Onden, & Gumus, 2015; Tamosaitiene, Zavadskas, Liou, & Tzeng, 2014) which directly affects the quality of final products and competitiveness in the marketplace.

Many companies have begun to consider suppliers' environmental performance as an added criterion in the selection process and it is chosen as the most important decision criterion for supplier selection (Gurel et al., 2015). In addition, the four determinants for green supplier selection are green competencies, environmental efficiency, supplier's green image and net life cycle cost (Deshmukh & Vasudevan, 2014). Thus, a green supplier is expected to embark on green product design and the end-of-life (EOL) cycle process in order to achieve environmental compliance as required by their clients and regulatory bodies (Villanueva-Ponce, Avelar-Sosa, Alvarado-Iniesta, & Cruz-Sánchez, 2015).

As they are ISO 14001-certified manufacturing firms in Malaysia that are equipped with an appropriate Environmental Management System (EMS), these companies have greater environmental awareness and are able to encourage their suppliers to go green in order to achieve better environmental performance. Thus, these companies place enormous importance on selecting suppliers based on a given pre-established set of environmental criteria. By doing so, the raw materials that are procured must comply with the ecological standards provided either by the companies or their headquarters as well as the requirements of local and international customers. Not only that, but these companies are also under intense pressure to produce environmentally-friendly products that meet international environmental standards and laws. The differences in the criteria chosen by each manufacturing firm mostly depend upon the final products produced, the company image as well as customer and regulatory pressure.

Another important GSCM practice is recognition of the use of environmentally-friendly transportation or green logistics/transportation. Green logistics represent practices and strategies that reduce the environmental and energy footprint of freight distribution and transportation (Seroka-Stolka, 2014). As the world is moving strongly towards environment sustainability, products that are to be transported across borders via sea or air must comply with the given environmental criteria. Those companies that fail to adhere to these criteria face penalties and disruptions in trading that will result in significant losses. If products are transported by land, their method of transportation must use less fossil fuel options that emit lower carbon emissions. Apart from management support and regulatory pressure, technological advancements are the most important determinant for successful green logistics (Seroka-Stolka, 2014). Technological factors reflect on the technical capabilities of companies as well as their advancements in IT infrastructure and logistics-based applications to optimize the flow and movement of products through the most efficient route with less impact on the environment and a reasonable logistics cost. Companies are encouraged to adopt technologies such as radio-frequency identification (RFID) technology, sensor-based technology, an automatic vehicle monitoring system, energy-efficient systems and advanced applications to support the needs of green logistics.

The logistics companies in Malaysia have demonstrated interest in green logistics (Tengku Aziz, Jaafar & Mohd Tajuddin, 2016); however, greater support from top management and the establishment of green logistics policies by the Malaysian Government are much demanded (Abu Bakar & Jaafar, 2016). The manufacturing firms in Malaysia are opting for green logistics as one initiative to minimize end-to-end environmental impacts from supply chain activities. Thus, the push factors towards green logistics are based on types of sector/industry, geographical location, company's environmental standing, regulatory requirements and customer requirements. The future of green logistics is unstoppable, and it is coming fast with demands for green warehousing, green ships and green ports (Abdul Hamid, 2014).

As shown in the results presented in Section 5.3.3.5, the implementation of green suppliers, eco-labelling of green products and green logistics, ISO 14001-certified manufacturing firms in Malaysia will be able to boost green supply chain implementation and their sustainability mission in today's fiercely competitive world**.**

5.5.7 Discussion: Environmental Performance

Based on preliminary data gathered during the pre-test and pilot test, as summarized in Sections 4.3 and 4.4, many of the ISO 14001-certified manufacturing firms have successfully achieved one or more benefits in terms of reductions of air emissions produced, energy and/or water consumed, toxic materials consumed, or amount of materials used as well as the amount of waste disposal.

Referring to the findings in Section 5.3.3.6 and Table 5.15, the indicators of environmental performance that showed the most improvement, and scored the highest outer weight value and *t*-value, respectively, were 0.397 and 4.526 for EnvPerf5: Increase in sustainable and CSR projects, apart from the reduction in emissions and waste generated, decrease in consumption of hazardous/harmful/toxic materials or components as well as improvement in the firm's reporting capabilities on sustainable practices.

Environmental performance has always been associated with reductions in the generation of emissions and waste as well as minimal consumption of hazardous materials, with these concerns remaining substantial in this study. Although significant values were achieved in terms of improvements in most of the direct environmental indicators, the items that scored the highest values were increases in sustainability and corporate social responsibility (CSR).

Defined as a holistic approach to business management, CSR incorporates economic, environmental, social and governance considerations alongside those of a financial nature, serving as a sound business model that supports business continuity and long-term value creation for stakeholders and society at large (Bursa Malaysia Berhad, 2015b; Teh, 2016). The CSR disclosures are categorized into the following four areas: marketplace, workplace, community and environment (Suruhanjaya Syarikat Malaysia (SSM), 2013).

The CSR categorization for the environment content focuses on the company's efforts to protect and preserve natural resources and the environment, such as: using renewable energy; reducing air and water pollution; reducing use of hazardous chemicals; reducing effluent and waste generation; monitoring energy usage, monitoring and reducing greenhouse gas (GhG) and other emissions; and maintaining biodiversity (Suruhanjaya Syarikat Malaysia (SSM), 2013).

In 2011, KPMG's Survey of Corporate Responsibility (CR) Reporting reported that Asian regions were lagging behind in CSR reporting by 50% compared to other regions (KPMG, 2016). In Malaysia specifically, CSR is very much lacking despite the Malaysian Government's efforts to promote CSR practices, as reported in 2012 (Mustafa, Othman, & Perumal, 2012). The organizations that engage in CSR practices are mostly international or big corporations within Malaysia. These foreign and multinational companies (MNCs) are mandated by their headquarters to contribute to improving the economic, environmental and social (EES) effects in the local areas in which they are operating. The companies that have international trade or are partly owned by foreigners in developed or developing countries, have the tendency to be more active in the sustainability approach. Most of these companies that disclose via environmental or sustainability reports to the public are multinational companies (MNCs).

At the same time, the CSR initiatives by Malaysian owned-companies and SMEs still fall short in meeting international standards for the preservation and protection of the environment as well as the social welfare of the community (Mustafa et al., 2012). In 2007, the participation of public listed companies (PLCs) in CSR initiatives was slow yet it was catching up with the mandatory disclosure on CSR dimensions required by Bursa Malaysia in the annual report. More recently, in October 2015, Bursa Malaysia launched a new Sustainability Framework with amendments to the previous listing requirements. Along with the framework, Bursa Malaysia provided a Sustainable Reporting Guide and Toolkit.

The Sustainability Reporting Guide and Toolkit provide PLCs with an in-depth guide and practical methods to embed sustainable business strategies, to assess the impact of material economic, environmental and social risks and opportunities on their business and their stakeholders, and to undertake reporting (Bursa Malaysia Berhad, 2015a). The increase in sustainability reporting in most countries including Malaysia is due to the legislative driver, as was stated by Kasturi Nathan, Executive Director, Risk Consulting and Sustainability Partner of KPMG in Malaysia (KPMG, 2016). It is too soon to measure the impacts of the new Sustainability Framework, and the PLCs seem to be struggling to provide better quality and material content for their reports (Teh, 2016).

Companies can adopt one or more mediums through which to disclose their CSR initiatives, with this being an effective way to reach their respective stakeholders. Mediums used include a dedicated section in the annual report; a stand-alone report on sustainability (environmental or social); the corporate website; CD-ROMs; a newsletter either published or via the corporate intranet; a summary hard copy report with a full report on the corporate website; information packs; and/or product labels (Suruhanjaya Syarikat Malaysia (SSM), 2013). In addition to the mediums suggested by Suruhanjaya Syarikat Malaysia, many companies are actively using social media such as Facebook, Twitter and Instagram through which photographs, audio and video, and reports are shared (Ahmad, 2016). Consequently, in today’s world, companies are revealing their CSR initiatives using both traditional media and social media platforms.

At this time, sustainability disclosure remains a voluntary practice in Asian countries including Malaysia (Waworuntu, Wantah, & Rusmanto, 2014). Despite the voluntary nature of CSR reporting, all types of organization in Malaysia are showing increased implementation of CSR initiatives. In addition, higher awareness is apparent of the CSR disclosure frameworks, such as the Global Reporting Initiative (GRI), the United Nations Global Compact and ISO 26000 (Md Nor, Shaiful Bahari, Adnan, Sheh Kamal, & Mohd Ali, 2016). The CSR initiatives can influence the organization's environmental policy, environmental impacts and environmental performance, as well as its sustainability reporting (Wan Yusoff & Adamu, 2016).

At present in Malaysia, CSR activities are designed as part of the organization's overall strategy, and in line with the organization's movement to sustainability. By strengthening the internal company policy on CSR as well as the issuance of stronger directives by policy makers, the CSR implementation among ISO 14001-certified manufacturing firms in Malaysia can be greatly enhanced, especially among locally-owned companies and SMEs. The increased in involvement for CSR initiatives would allow the ISO 14001-certified manufacturing firms in Malaysia to gain a positive reputation for preserving the environment through their corporate involvement in environmentally-friendly business activities and in socially-responsible activities for social causes. Organizations that choose to disclose their contributions to sustainability-based activities will be able to attract more profitable investors, and to address their existing stakeholders' concerns. In return, these organizations will gain more business opportunities and financial benefits.

In the current study, performance outcomes are measured in terms of environmental performance and technological performance as the result of GSCM implementation. The results presented in Section 5.3.3.6 show an increase in sustainable and CSR projects by ISO 14001-certified manufacturing firms in Malaysia. Moreover, these firms have improved their environmental indicators.

Based on Figure 5.10, Hypothesis 5 (H5) is supported, as GSCM implementation has a significant effect on improvements in environmental performance within the

ISO 14001-certified manufacturing firms in Malaysia, thus address Research Objective 3 (RO3).

5.5.8 Discussion: Technological Performance

Based on preliminary data gathered during the pre-test and pilot test, as summarized in Sections 4.3 and 4.4, ISO 14001-certified manufacturing firms in Malaysia are actively using IT and IS to support their daily business operations and processes. Some companies have started implementing energy-efficient IT equipment as well as applications and software to assist in making business decisions. However, the firms have not been monitoring and reporting on improvements achieved by utilizing environmentally-friendly technologies and systems.

Referring to findings in Section 5.3.3.7 and Table 5.16, the indicators of technological performance that showed the most improvements and scored the higher outer weight value and *t*-value, respectively, are 0.415 and 3.712 for TecPerf1: Increase in deployment of Green IT and Green IS solutions as well as 0.241 and 2.778 for TecPerf2: Increase in digitalization, automation, integration and optimization within supply chain processes.

The use of IT and IS today is growing tremendously, with IT and IS the enablers that drive business processes smoothly and proficiently. Organizations, like ISO 14001-certified manufacturing firms, are obliged to reengineer the supply chain from time to time. Many of these firms are currently investing in Green IT and Green IS solutions to assist them more efficiently in their daily business activities, while mitigating the negative technology impacts on the environment.

The implementation of Green IT and Green IS solutions, along with digitalization and automation, to optimize supply chain activities has achieved positive improvements in technological performance; however, reporting on the use of Green IT and Green IS are still inadequate or unavailable. Although 80% of the firms were found to discuss carbon emissions, the content of these reports varies in terms of the type and quality of information published, with some companies neither providing an explanation for why their targets were selected nor why their targets were not met (Teh, 2016). The reason is that many organizations still lack a proper method for measuring the amount of energy consumed and saved as well as the amount of carbon emitted and abated through the implementation of Green IT and Green IS solutions (Erek, 2011; Löser et al., 2011).

In 2012, the Malaysian Ministry of Natural Resources and Environment (NRE), in partnership with the United Nations Development Programme (UNDP) introduced a programme known as MYCarbon: A National Corporate GHG Reporting Programme for Malaysia. The programme aims to measure progress towards achieving national emissions reduction as well as to assist in tracking greenhouse gas (GhG) emissions and their reduction from various sectors (Economic Planning Unit, Prime Minister's Department, 2015). Participation in the MYCarbon programme is on a voluntary basis. The contents of the report focus on three scopes, which are Scope 1: direct emissions (mandatory); Scope 2: purchase energy (mandatory); and Scope 3: all other indirect (optional). The firms reporting on accomplishments in the annual report or in environment/sustainability reporting are specifically from supply chain activities or product life cycle activities which cover Scope 1 and Scope 2 of the MyCarbon programme. Scope 3 that focuses on indirect emissions and remains optional. However, the MYCarbon programme does not include reporting on carbon emissions from IT and IS usage.

Manufacturing firms in Malaysia are not widely exposed to the metrics or indicators for measuring technological performance from IT and IS usage. The common one is Energy Star 5.0 and the Electronic Product Environmental Assessment Tool (EPEAT). These metrics and indicators are not included in Malaysia's guideline for sustainability reporting or carbon reporting. Other guidelines on data centre metrics can be obtained from the Green Grid, while general ones can be found in research papers (Bozzelli, Gu, & Lago, 2013; Holdener & Waldrip, 2009; Löser, 2015). Therefore, without proper measurement and reporting as well as integration into the wider business entity, Green IT and Green IS initiatives will be at risk of being considered as short-term projects, that are consequently ignored (Fujitsu, 2010). Hence, the first step forward is through inclusion of Green IT and Green IS strategies in the company’s environmental policy and corporate agenda.

From the results presented in Section 5.3.3.7, an increase was noted in the use of Green IT and Green IS solutions within supply chains, along with greater automation and digitalization that is being used to optimize supply chain activities.

Based on Figure 5.10, Hypothesis 6 (H6) is supported, as GSCM implementation has a positive effect on improvements in technological performance within ISO 14001-certified manufacturing firms in Malaysia, thus addressing Research Objective 3 (RO3).

5.5.9 Discussion: Summary of Findings

In this study, the input-process-output (IPO) theory was applied to categorize the stages of the life cycle involved in the research framework. The IPO theory represents a system in three stages, describing: (1) the inputs required; (2) the process of transforming inputs into outputs; and (3) the applications used to produce the result (the goal to be achieved) (MacCuspie et al., 2014). The IPO theory was adopted along with the technological-organizational-environmental (TOE) framework to represent the three contexts of the input stage in the IPO model. The TOE framework identifies three aspects of an enterprise’s context that influence the process by which it adopts and implements a technological innovation.

Based on the IPO theory, the input comprises the drivers from the three contexts in the TOE framework that influence GSCM implementation. The drivers are Green IT, Green IS, internal commitment and regulatory pressure. The earlier discussions from Section 5.5.2 to Section 5.5.8 explained the significant indicators within each construct (latent variable), namely, Green IT, Green IS, internal commitment, regulatory pressure, GSCM, environmental performance and technological performance. As was summarized in Table 5.21 and Table 5.22, these four drivers have a major influence towards successful implementation of GSCM within ISO 14001-certified manufacturing firms in Malaysia. Of the four drivers, Green IT has the highest *t*-value at 5.663 and medium effect size at 0.245 in comparison to other drivers that influence GSCM implementation, and is followed by regulatory pressure, internal commitment and, finally, Green IS.

With these four input (drivers), GSCM implementation have resulted in a greater output (outcome). Based on the results presented in Table 5.21 and Table 5.22, positive improvements in both performance measurements were observed. Environmental performance achieved greater improvements compared to technological performance with *t*-values of 39.673 and 26.521, respectively, and medium effect size for both as a result of GSCM implementation.

Therefore, the IPO and TOE theories adopted in this study are fully supported. In conclusion, the hypotheses from H1 to H6 are supported as presented in Table 5.23, indicating that the study has successfully addressed RQ1 to RQ3 as well as realizing the research objectives, RO1 to RO3.

5.5.10 Green Supply Chain Management Model

The findings from this research provide guidance for the managerial level of firms, industrial practitioners and policy makers on influential factors that drive the implementation of GSCM as well as the effects on environmental performance and technological performance. This study produced a basic guideline in the form of a model that is being copyrighted under Intellectual Property Corporations of Malaysia (myIPO), with the ID CRLY00001813. The official copyright letter is attached in Appendix G.

The model represents the guideline that is designed based on the concept of a tree as illustrated below. Each component illustrates each essential element of a tree. For each element, the position, color, shape and size carry their own meaning that represents the functions of the tree’s characteristics for an effective implementation of GSCM towards environmental sustainability.

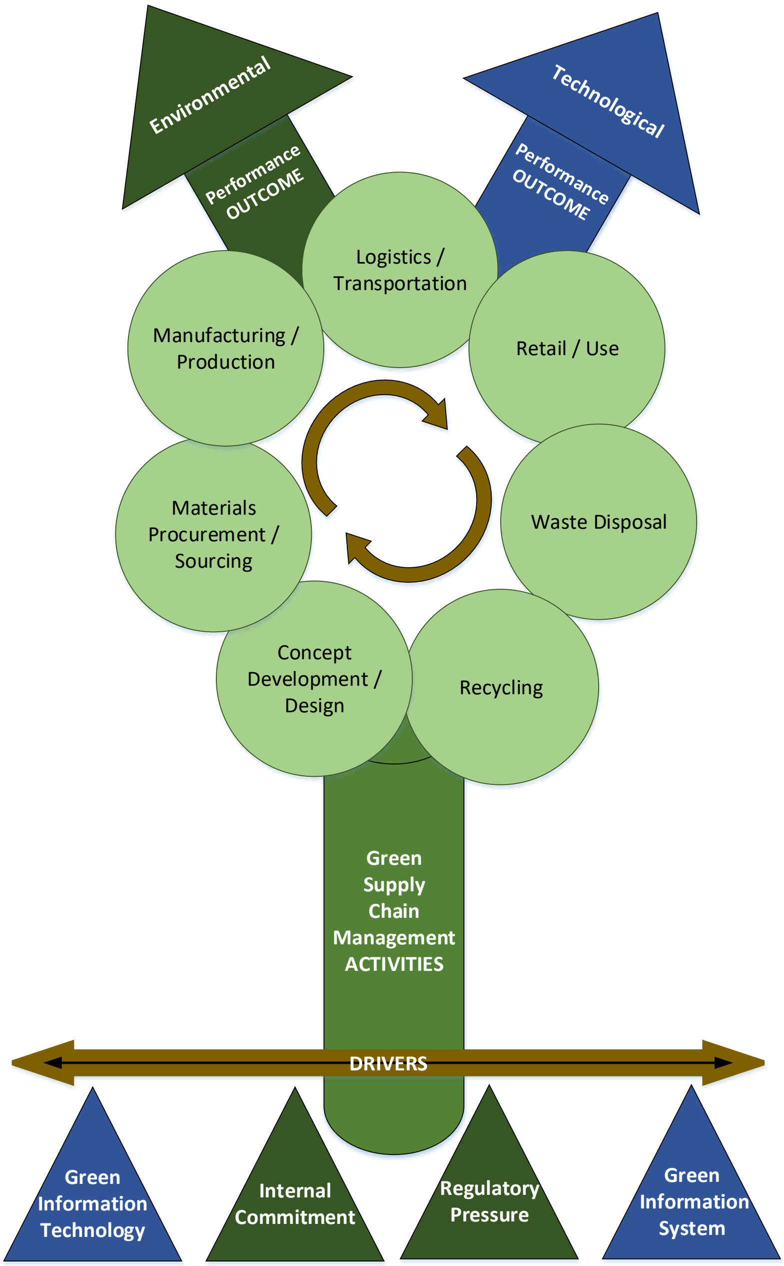


Figure 5.11: Model of Green Supply Chain Management

Each element represents the motivating drivers and performance outcomes from the implementation of Green Supply Chain Management (GSCM) activities. This model is designed for the manufacturing sector in developing countries such as Malaysia, with high possibilities also of generalization in other sectors. This model is designed to serve the following purposes:

- As a guideline for manufacturing firms that intend to adopt green practices in the supply chain
- As a benchmark measure for those firms who have already ventured into the adoption or implementation of green practices in the supply chain
- As a blueprint for governments in developing countries to assist, monitor and regulate manufacturers in reducing environmental impacts from their processes
- As an anchor in integrating eco-friendly information technologies and systems throughout the supply chain cycle, which in total will minimize the ecological footprints.

The model is designed based on the concept of a tree to show that green movement requires improvement of the environmental situation towards ecological sustainability. Each component illustrates each part of a tree. For each element, the position, color, shape and size carry its own meaning that represents the function of the tree's characteristics for effective implementation of GSCM. The details are described below:

- The four triangles in dark green (symbolize essential factors) and dark blue (symbolize newly suggested factors) signify the roots of the tree which rationalize the influential factors that drive the implementation of green practices in the supply chain.
- The brown arrow represents the soil that requires nourishment through continuous devotion to boost the implementation of green practices in supply chain.
- The green trunk indicates the concept of GSCM that will grow tremendously upwards to address environmental issues within the organization in moving towards ecological sustainability.
- The green flower with seven petals shows the activities carried out throughout the supply chain from downstream, within and upstream that require concentrated effort to make each one eco-friendly.
- The sprouts (young growing shoot/branch) are illustrated with cylinder and triangle shapes of green and blue in colors to represent the aftermath

effect of implementing GSCM. The green sprout indicates the essential and critical outcomes to be measured which is environmental performance. The blue sprout enlightens the new contributed outcome that focuses on technology-oriented performance. It is necessary that this outcome is introduced in measuring the impacts of deploying information technologies and systems throughout the supply chain. Moreover, it is timely for every organization to integrate, assimilate and evaluate eco-friendly technologies and systems to minimize environmental problems, such as carbon emissions, poor e-waste disposal and high energy consumption.

The shape and size of each part of the tree carry specific meaning and characteristics which are justified below:

- The triangle shape is chosen for its concentrated energy to push the seed to grow into a strong healthy tree. These explain the importance of impetus provided to the right factors in order to achieve the desired eco-friendly activities and to enable stronger performance outcomes.
- The arrow at both sides indicates the possibility of the introduction of new factors that will boost the momentous implementation of GSCM.
- The cylinder shape resembles the solid, upstanding and growing movement to perform continuous and enduring environmentally-conscious practices, as well as to enhance the aftermath impacts in minimizing environmental problems and enriching the organization's overall image.
- The circle shape explains the ongoing process of executing each green activity throughout the supply chain which is indicated by the circular arrow to illustrate the continuous progression.
- The size of each shape will change according to the significance of its role: the larger the shape, the more dominant and influential is the effect.
- Based on its own context in this model, the shape is of an equivalent size, indicating its identical impact, implication or significance in terms of the driving factors, the eco-friendly activities performed and the outcomes.

5.6 Chapter Summary

Firstly, this chapter has presented the study's findings derived by using IBM's SPSS Statistics version 19.0 for data entry, coding, and computing univariate analysis as well as bivariate analysis of the non-response bias, common method bias test and descriptive statistics.

Next, multivariate analysis was carried out to simultaneously analyse multiple variables using a second-generation technique known as structural equation modelling (SEM). The SEM approach adopted in this study is called PLS-SEM using SmartPLS 3.0 software. The PLS-SEM was chosen as all the constructs were formatively measured as well as the goal was to predict and identify the key drivers or constructs. The evaluation was divided into a two-stage analysis, namely, the measurement model and the structural model.

Based on the measurement model, the evaluation comprised three steps, namely, convergent validity, collinearity between indicators as well as significance, and relevance of outer weights. The indicators for all seven constructs in this study (Green IT, Green IS, Int Comm, Reg Pres, GSCM, Env Perf and Tech Perf) were kept for the structural model measurement.

From the structural model assessment, insights were provided into the model's predictive capabilities and relationships between constructs. The four important steps in the formative structural model assessment procedure are: the collinearity issue; the significance and relevance of the structural model relationships or the hypothesized relationships; the coefficient of determination (or R^2 value); and effect size (f^2).

The hypotheses of H1, H2, H3, H4, H5 and H6 are all positively supported. In the context of the drivers, H1: Green IT → GSCM demonstrates the highest path coefficient in influencing GSCM implementation, followed by H4: Reg Press → GSCM, H3: Int Comm → GSCM and lastly H2: Green IS → GSCM. The performance outcomes from implementing GSCM are measured through environmental performance (H5) and technological performance (H6). In assessing the path coefficients and significance of the relationships which are the effect from implementing GSCM, it is noted that both outcomes of H5: GSCM → Env Perf and H6: GSCM → Tec Perf are significant.

As a control variable, the firm size *t*-value obtained is significant, however, the confidence level value acquired evidently includes the zero (0) value within the interval. Therefore, the path relationship is insignificant from firm size to GSCM. This conclude that the size of the firm does not influence the implementation of green supply chain management among ISO 14001 manufacturing firms in Malaysia. This is because with the strong internal management commitment and government support, as well as comply to internal, national and international environmental standards and laws, these firms will able to successfully implement green practices, technology, systems in enhancing overall ecological performance in becoming environmentally sustainable organization.

Subsequently, the coefficient of determination (or R^2 value) was used to measure the model's predictive accuracy. The R^2 value for GSCM indicated the model's substantial predictive accuracy, in which the variance in implementing GSCM within ISO 14001-certified manufacturing firms was explained as being 82% influenced by Green IT, Green IS, internal commitment and regulatory pressure. As for the outcomes, the GSCM implementation explained 70% of variance in enhancing environmental performance and 63% of variance in improving technological performance.

The model was good at explaining the research data gathered, as R^2 values were obtained with from moderate to substantial predictive accuracy. The effect sizes for Green IS, internal commitment and regulatory pressure in explaining GSCM were small while, for Green IT, it explained the medium effect size of the GSCM implementation. Furthermore, GSCM had a medium effect size in explaining the outcomes on environmental performance and technological performance.

In conclusion, the hypotheses from H1 to H6 were supported, thus indicating that the study has successfully addressed RQ1 to RQ3 as well as realizing the research objectives, RO1 to RO3. The contributions and limitations of this study as well as suggestions for future work are discussed in the next chapter.

Chapter 6

CONCLUSION

6.1 Introduction

The preliminary findings on the pre-test and pilot study were described in Chapter 4, while the main findings from the full-scale study were discussed in

Chapter 5. This chapter summarises the overall findings on the drivers, practices and outcomes of GSCM implementation within ISO 14001-certified manufacturing firms in Malaysia. The research questions (RQs) and research objectives (ROs) of this study are revisited, the results from hypotheses testing are recalled, and empirically validated findings from Chapter 5 are recapitulated in Section 6.2. In Section 6.3, contributions that emerged from the findings are presented in three contexts, namely, theoretical, methodological and practical. Discussions on the shortcomings encountered in this research follow in Section 6.4. The way forward for future studies is suggested in Section 6.5, with this addressing existing limitations and unlocking a new avenue for further research in the areas of GSCM, Green IT and Green IS. This chapter ends with an overall conclusion of the study.

6.2 Recapitulation of Findings

Green supply chain management (GSCM) is viewed as an initial strategy for firms in complying with the environmental requirements and legislation that are imposed in most industrialized nations (Hu & Hsu, 2010). In the pursuit of improved environmental performance, GSCM is gaining acceptance among manufacturing firms in Malaysia (Tan et al., 2016). Supply chain activities are multipliers of energy costs and carbon emissions (Smith-Gillespie & Chang, 2016) and, with the escalating rate of IT usage, are causing higher energy usage with more detrimental effects to the environment (Löser, 2015). The broader literature has suggested that internal and external forces have much stronger influences on the organization's behaviour towards sustainability. However, technological forces can play a critical role in mitigating environmental impacts (Cai et al., 2013; A. J. W. Chen et al., 2008; Dedrick, 2010; Faucheux & Nicolaï, 2011; Global e-Sustainability Initiative (GeSI), 2012, 2015; Jenkin et al., 2011; Melville, 2010; Molla & Abareshi, 2012; The Climate Group (The), 2008).

Along with the influence from internal and external factors, Green IT and Green IS solutions can offer disruptive and sustainable business models in various industry sectors (Global e-Sustainability Initiative (GeSI), 2015). With this shift, organizations can reduce carbon emissions, energy consumption, e-waste production and overall environmental impacts. Despite the benefits that Green IT and Green IS can bring to GSCM, this topic has only been intermittently discussed in the literature (Fiorini & Jabbour, 2017). Green IT- and Green IS-related issues and outcomes after their implementation have only been investigated by a limited number of studies (Zaman & Sedera, 2015). Studies on the adoption of Green IT and Green IS and their impacts on other sectors are lacking in both research and practice (Global e-Sustainability Initiative (GeSI), 2015; Jenkin et al., 2011; Melville, 2010). Although the GSCM literature is growing exponentially, the literature focusing on the assessment of GSCM performance in developing countries is scant (Mishra et al., 2017). Several publications from Asia demonstrate the interest of Asian researchers: however, the number of studies is still limited and, therefore, further exploration is required (Fiorini & Jabbour, 2017).

In summary, the problem statement of this research is

> *In Malaysia, green supply chain management (GSCM) implementation within manufacturing firms is still lacking.*

Thus, the research motivation *is*

> *"to increase environmental sustainability with the implementation of green practices as well as green information technologies and systems within the supply chain"*

With that, the research objectives are:

- To investigate Green information technology (Green IT) and Green information systems (Green IS) as the drivers that influence GSCM implementation within ISO 14001-certified manufacturing firms in Malaysia
- To investigate internal commitment and regulatory pressure as the drivers that influence GSCM implementation within ISO 14001-certified manufacturing firms in Malaysia
- To assess the effects of GSCM implementation on environmental performance and technological performance within ISO 14001-certified manufacturing firms in Malaysia.

Table 6.1 recaps and presents the three research questions along with the six hypotheses that were validated using the PLS-SEM method, as discussed in Section 5.3 and Section 5.4.

Table 6.1: Recap - Research Questions, Hypotheses and Results

RQ1: To what extent do Green information technology (Green IT) and Green information systems (Green IS) drive the implementation of GSCM within ISO 14001-certified manufacturing firms in Malaysia?

Hypothesis	**Description**	**Result**
H1	*Green IT positively influences the implementation of GSCM within ISO 14001-certified manufacturing firms in Malaysia*	*Supported*
H2	*Green IS positively influences the implementation of GSCM within ISO 14001-certified manufacturing firms in Malaysia*	*Supported*

RQ2: To what extent do internal commitment and regulatory pressure drive the implementation of GSCM within ISO 14001-certified manufacturing firms in Malaysia?

Hypothesis	**Description**	**Result**
H3	*Internal commitment positively influences the implementation of GSCM within ISO 14001-certified manufacturing firms in Malaysia*	*Supported*
H4	*Regulatory pressure positively influences the implementation of GSCM within ISO 14001-certified manufacturing firms in Malaysia*	*Supported*

RQ3: To what extent does the implementation of GSCM effect the organization's environmental performance and technological performance within ISO 14001-certified manufacturing firms in Malaysia?

Hypothesis	**Description**	**Result**
H5	*The implementation of GSCM has a positive influence on environmental performance within ISO 14001-certified manufacturing firms in Malaysia*	*Supported*
H6	*The implementation of GSCM has a positive influence on*	*Supported*

technological performance within ISO 14001-certified manufacturing firms in Malaysia.

The hypotheses from H1 to H6 are positively supported, and the values obtained are good at explaining the gathered research data with the research model having good predictive accuracy.

6.2.1 Drivers: Green IT, Green IS, Internal Commitment and Regulatory Pressure

The daily use of IT and IS seems to have no environmental impacts in the eyes of humans because IT and IS do not produce directly harmful effects (Löser, 2015). However, the use of traditional IT and IS are causing detrimental effects to the environment of which many organizations are unaware or are choosing to ignore. The literature suggests that forces such as environmental, organizational, regulatory-market and socio-cultural have much stronger influence on the organization's behavior towards environment sustainability compared to technological force (Jenkin et al., 2011).

Many industrial practitioners have overlooked the implementation of environmentally-friendly IT and IS to support their daily business functions, processes or activities. This is common particularly among industrial practitioners from non-IT sectors, such as manufacturing, logistics, health care and more. Therefore, the alarming request has been made to minimize direct and indirect effects from the exploding use of IT and IS (Global e-Sustainability Initiative (GeSI), 2012, 2015; Climate Group (The) & Global e-Sustainability Initiative (GeSI), 2008). The environmentally-friendly IT and IS are known as Green information technology (Green IT) and Green information systems (Green IS). The implementation of Green IT and Green IS addresses two overarching and interrelated goals which, firstly, help businesses to mitigate IT's direct contribution of CO_2 emissions and, secondly, to tackle the overall business footprint by using IS solutions to reduce the environmental footprint of businesses (Faucheux & Nicolaï, 2011).

Hence, this study firstly aimed to investigate the role of Green IT and Green IS and their influence towards the implementation of GSCM within ISO 14001-certified manufacturing firms in Malaysia. This leads to the first research question:

> *"RQ1: To what extent do Green IT and Green IS drive the implementation of GSCM within ISO 14001-certified manufacturing firms in Malaysia?*

The preliminary findings, as explained in Section 4.3.3, conclude that the manufacturing firms highlighted the importance of IT and IS in supporting business processes and activities, as well as in the facilitation of seamless interactions and collaborations with stakeholders. The firms had started to implement green IT and IS practices such as:

- procurement of energy-efficient IT hardware with an Energy Star rating
- preliminary adoption of server virtualization technology
- choosing suppliers that offered take-back options once equipment had reached the end-of-life (EOL) stage
- using sensor technology in production lines to track and monitor physical items as well as environmental indicators markers/trackers
- using software for print optimization, PC management, teleconferencing and video conferencing
- development of in-house applications and on-shelf purchases to measure environmental indicators
- use of video conferencing, telecommuting (teleworking), groupware and collaborative software
- use of applications to support design, procurement and manufacturing activities

However, firms were very much concerned with the amount of investment needed up-front, the quality and performance of the technologies, and the payback period.

From the analysis of the survey questionnaire data from the main study, as presented in Sections 5.3.3.1 and 5.3.3.2, the ISO 14001-certified manufacturing firms in Malaysia are in the midst of implementing environmentally-friendly IT, IS and practices to support business activities within the supply chain. To recap the findings presented in Table 5.10, the ISO 14001-certified manufacturing firms in Malaysia are mainly implementing the Green IT practices of energy-efficient lighting, virtualization technology and energy-efficient IT equipment which will directly reduce the consumption of energy and, ultimately, will reduce carbon emissions to the environment. For Green IS, the summary of the findings is presented in Table 5.11. The ISO 14001-certified manufacturing firms in Malaysia are implementing Green IS practices which are largely on the use of software to monitor and record environmental indicators as well as the use of software for the development and design of products, materials procurement and manufacturing activities that are much smarter and greener. The results from the main study are consistent with those of the preliminary study.

As summarised from Sections 5.5.2 and 5.5.3, the ISO 14001-certified manufacturing firms are implementing software and applications to monitor environmental indicators and energy efficiency. This allows them to benchmark their progress in achieving sustainable practices, while complying with environmental laws. Furthermore, the local government is committed and supportive in providing necessary incentives and funds to firms, especially for small and medium-sized enterprises (SMEs) and locally-owned firms. In addition, partnering with international bodies such as GreenTech and Carbon Trust has accelerated the deployment of energy-efficient lighting with the mission being to reduce energy use and carbon emissions. Government agencies, such as the Ministry of Science, Technology and Innovation (MOSTI), have introduced the new Malaysian Standard (MS) for domestic electrical products, including lighting, in response to the impending policy change to promote energy-efficient technologies.

Furthermore, virtualization technology is considered as part of server and cloud infrastructure that offers many technical, economic and environmental advantages. More and more software which allows for embedded virtualization in the cloud is being introduced into manufacturing environments. Thus, applications that currently are receiving much attention are software that can record and monitor environmental indicators. A higher priority is today placed on smart solutions that go beyond current solutions that support design, procurement and manufacturing activities, and collaboration and communication tools. The emerging technologies of cloud computing and the Internet of Things (IoT) are again game-changers in Malaysia among manufacturing firms. The convergence of matured technologies and the recent advent of the IoT allow for more innovative business solutions and much smarter computing solutions and applications, as well as green software that is being offered in various industries with more accurate predictive capabilities, higher efficiency, greater productivity and minimal impacts on the environment.

Thus, Green IT and Green IS have a significant role as drivers for influencing the implementation of GSCM within ISO 14001-certified manufacturing firms in Malaysia. Consequently, RQ1 is addressed, with RO1 achieved, that is

> *"To investigate Green information technology (Green IT) and Green information systems (Green IS) as the drivers that influence GSCM implementation within ISO 14001-certified manufacturing firms in Malaysia".*

Luthra et al. (2014) and Zakuan et al. (2012) carried out reviews on drivers and enablers that influenced GSCM implementation from 2005 to 2011. This study further reviewed internal and external drivers from 2012 to 2017. The literature constantly discusses the importance of internal and external factors as factors of influence that push the implementation of green practices within supply chains. The most influential internal factor is internal management which comprises top management commitment, employee involvement, cross-functional cooperation and availability of resources. Regulatory pressure, standards compliance, suppliers' cooperation, customers' pressure and government support remain prevalent external factors that drive GSCM implementation.

Next, this study aimed to investigate the role of internal commitment and regulatory pressure in influencing the implementation of green practices within the supply chains of ISO 14001-certified manufacturing firms in Malaysia. This leads to the second research question:

"RQ2: To what extent do internal commitment and regulatory pressure drive the implementation of GSCM within ISO 14001-certified manufacturing firms in Malaysia?"

The preliminary findings, as reported in Section 4.3.2, conclude that the manufacturing firms highlighted the importance of internal commitment and compliance with regulatory pressure. Being certified with ISO 14001 is a voluntary initiative; therefore, top management support, commitment from co-workers and compliance with international regulatory bodies are the most vital factors for implementation of an innovation or practice such as green supply chain management (GSCM).

As revealed in the analysis of the survey questionnaire data, presented in Section 5.3.3.3, the ISO 14001-certified manufacturing firms in Malaysia emphasized that internal audit is crucial for monitoring the organization's green movement in order to mitigate environmental risks from business and supply chain activities. Therefore, internal programmes or training sessions are necessary to increase employees' awareness and to create a sense of urgency among them. In order to do so, top management support and co-workers' commitment are prerequisites to ensure the success of GSCM implementation. Based on the results from Table 5.12 and discussion in Section 5.5.4, all four indicators for internal commitment are significant. The main study results show that internal audit is a crucial factor as an internal commitment driver, which was not found to be prevalent in the preliminary study.

In relation to external drivers, the summary of the findings on regulatory pressure is presented in Section 5.3.3.4 and Table 5.13. In comparison to the preliminary study, the main study findings revealed that the ISO 14001-certified manufacturing firms in Malaysia emphasized the importance of first complying with regulations set by a firm's own company or its parent company, before adherence to international directives and legislation.

Although being certified with ISO 14001 is a voluntary act, the firms would not be exempted from penalties for non-compliance discovered during external audits.

Thus, it is crucial that firms adhere to the requirements disclosed by their own company or its parent company. The firms chose to be certified owing to support from top management; however, this also required cooperation and commitment from other departments in order to achieve complete compliance. To ensure compliance and conformance to the given requirements, close internal monitoring was required from time to time. The success of the internal environmental audit through internal compliance is the first step towards compliance with international environmental directives and standards. With this compliance, the ISO 14001-certified manufacturing firms are much better equipped and better assured to meet international regulatory requirements for global market trading, as discussed in Section 5.5.5.

Thus, internal commitment and regulatory pressure have a vital role as drivers for influencing the implementation of GSCM within ISO 14001-certified manufacturing firms in Malaysia. Consequently, RQ2 is addressed with RO2 achieved, that is:

> *"To investigate internal commitment and regulatory pressure as the drivers that influence GSCM implementation within ISO 14001-certified manufacturing firms in Malaysia".*

6.2.2 Practices: Green Supply Chain Management (GSCM)

Green supply chain management (GSCM) has its roots in both the environmental management and SCM literature; thus, adding the 'green' component to SCM involves addressing the influence and relationships between SCM and the natural environment (Hervani et al., 2005). A further definition of GSCM is integration of environmental thinking into SCM that focuses on product design, materials sourcing and selection, manufacturing processes, delivery of the final product to consumers, and end-of-life (EOL) management of the product after its useful life (Srivastava, 2007).

Based on preliminary data gathered as summarized in Section 4.3.1, the ISO 14001-certified manufacturing firms are practising the following environmentally-friendly activities in supply chains: (1) use of environmentally-friendly raw materials; (2) design of products based on environmental criteria; (3) use of improved or environmentally-friendly packaging; and (4) use of environmentally-friendly waste management.

The analysis of the survey questionnaire data, as presented in Section 5.3.3.5 and Table 5.14, found that the most significant green practices in the supply chains of the ISO 14001-certified manufacturing firms in Malaysia are eco-labelling of products, green supplier selection and green logistics. The results of the main study are different to those of the preliminary study in terms of the leading green practices implemented in the supply chain. This indicates a change of focus among the ISO 14001-certified manufacturing firms in Malaysia on the green practices to be implemented to achieve greater performance outcomes. This detailed discussion is presented in Section 5.5.6.

In line with the National Green Technology Policy, GreenTech Malaysia introduced a new eco-label known as the MyHIJAU Mark in 2012. This mark recognizes certified green products and services that can meet both local and international environmental standards. Furthermore, the selection of the right suppliers has a critical effect on the success of the supply chain as it will directly affect the quality of the final products and competitiveness in the marketplace. Many firms have begun to consider suppliers' environmental performance as an added criterion in the selection process. This is to ensure that the raw materials, components or products supplied meet the minimal environmental requirements of the companies themselves as well as their customers. The manufacturing firms are placing more importance on engagement with green suppliers. In addition, green logistics focus on the company's strategies and activities that reduce the environmental and energy footprint of freight distribution and product transportation. Advancements in IT infrastructure and logistics-based solutions have further optimized the flow and movement of products through the most efficient routes with lesser impact on the environment with a reasonable logistics cost.

6.2.3 Outcomes: Environmental Performance and Technological Performance

Studies on environmental management and GSCM by researchers who are geographically located in the Asian region, with a specific focus on the Asian region itself, are very limited (Seuring et al., 2008). In some developed countries, GSCM practices are already mature but GSCM is still a relatively new movement for most developing countries. Firms view GSCM as an initial strategy for compliance with the environmental requirements and legislation imposed in most industrialized nations (Hu & Hsu, 2010). The most prevalent dimension to measure the effects of firms' actions on environmental sustainability is still being overlooked in many organizations (Hourneaux et al., 2014). Although the GSCM literature is growing exponentially, the literature focusing on assessment of GSCM performance in developing countries is still lacking (Mishra et al., 2017).

Despite the benefits that Green IT and Green IS can bring to GSCM, this topic has only been intermittently discussed in the literature (Fiorini & Jabbour, 2017). Only a limited number of studies have been conducted that investigate Green IT- and Green IS-related issues and outcomes after their implementation (Zaman & Sedera, 2015). Studies on Green IT and Green IS adoption and their impacts in other sectors are lacking in both research and practice (Global e-Sustainability Initiative (GeSI), 2015; Jenkin et al., 2011; Melville, 2010). Although IT's own footprint is expected to reach 1.25 $GtCO_2e$, or 1.97% of global emissions, in 2030, up to 12 $GtCO_2e$ can be minimized with the use of Green IT solutions within the IT-enabled sectors which unveil the path to sustainable growth (Global e-Sustainability Initiative (GeSI), 2015).

Lastly, this study aimed to assess the effects of GSCM implementation on environmental and technological improvements with the aspiration of protecting the environment. This leads to the third research question,

> *"RQ3: To what extent does the implementation of GSCM effect the organization's environmental performance and technological performance within ISO 14001-certified manufacturing firms in Malaysia?*

The preliminary findings, as explained in Section 4.3.4, conclude that the ISO 14001-certified manufacturing firms have successfully achieved one or more benefits in terms of reductions of air emissions produced, energy and water consumed, toxic materials consumed, amount of materials used as well as the amount of waste disposal. The firms are working proactively to use recycled materials and reuse waste; however, more research and development (R&D) are required.

The analysis of survey questionnaire data from the main study, as presented in Section 5.3.3.6 and Table 5.15, found that ISO 14001-certified manufacturing firms in Malaysia have achieved improvements in the reduction of emissions and waste generated and the decrease in consumption of hazardous/harmful/toxic materials or components. In addition, the biggest improvement discovered was the increase in sustainable and CSR projects along with better reporting on sustainable practices.

The major influence of these drivers has motivated the ISO 14001-certified manufacturing firms in Malaysia to reduce negative impacts on the environment from supply chain activities. Among the ISO 14001-certified manufacturing firms in Malaysia, a rising trend towards CSR initiatives is apparent. The initiatives are very much environmental and community focused. With greater achievements, the firms are very motivated to report and publish either on an independent medium or in formal reports.

As discussed in Section 5.5.7, MNCs are mandated by their headquarters to contribute to improving the economic, environmental and social (EES) effects in the local areas in which they are operating. Most companies that disclose environmental or sustainability reports to the public are MNCs: on the other hand, the public listed companies (PLCs) in Malaysia participate in CSR initiatives in order to fulfil the mandatory disclosure on CSR dimensions in their annual reports as required by Bursa Malaysia. However, as expected, the rate of CSR initiatives from locally-owned companies and SMEs is much slower as these companies are still working towards mitigation of the environmental risks within the organization itself. Involvement in CSR activities and circulation of reports on sustainable practices have directly or indirectly increased the reputation of firms as environmentally-conscious organizations. As a result, these organizations receive greater attention from new investors and customers which, in return, increases organizations’ financial performance.

With regard to technological performance, preliminary findings from Section 4.3.5 conclude that firms are implementing Green IT and Green IS solutions, such as: paperless strategies; power management; energy-efficient IT equipment; energy-efficient lighting and facilities equipment; virtualization technology; safe disposal; and software and applications to support supply chain activities and collaborations with stakeholders. These firms also comply with some of the international standards and directives such as Energy Star, WEEE and EPEAT. These firms measure environmental indicators from their supply chain activities, and not from the use of IT infrastructure, equipment and facilities.

From the analysis of the main study data, as presented in Section 5.3.3.7 and Table 5.16, the ISO 14001-certified manufacturing firms in Malaysia were found to have increased the deployment of Green IT and Green IS solutions, as well as digitalization and automation, for the optimization of supply chain activities. In addition, improvement was found in power usage by office IT equipment and the total facility (e.g. lighting, uninterruptible power supply [UPS], cooling system, network). The results from the main study are consistent with those from the preliminary study.

As discussed in Section 5.5.8, the use of Green IT and Green IS will reduce the amounts of energy used and carbon emitted. The ISO 14001-certified manufacturing firms are moving towards virtualization and cloud technologies to support their business activities within the supply chains. As a result, a greater number of Green IT and Green IS solutions are being implemented by the manufacturing firms to monitor environmental indicators and their performance along with increases in the use of energy-efficient technologies, with these having digitized and optimized performance-related business activities.

Despite encouraging improvements in technological performance, the firms were still lacking in terms of measuring and reporting direct improvements from IT infrastructure, equipment or facilities as well as applications that could enable sustainable business processes. Also lacking were the metrics used to measure the impact from the use of Green IT and Green IS within supply chains. Furthermore, reporting on technological improvements directed towards the environment is not compulsory in Malaysia; therefore, firms are not obliged to measure and report. Apart from that, firms usually publish a general environmental policy.

The essential performance measurements in realizing environmental sustainability are environmental performance and technological performance which focus on supply chain activities and the use of technology. Positive improvements were observed with the implementation of GSCM, together with the right influence of technological, organizational and environmental factors. With that, RQ3 was addressed and RO3 was achieved,

> *"To assess the effects of GSCM implementation on environmental performance and technological performance within ISO 14001-certified manufacturing firms in Malaysia".*

6.3 Contributions of Research

In this section, the contributions of this research are discussed after being categorized into: (i) theoretical contributions; (ii) methodological contributions; and (iii) practical contributions.

6.3.1 Theoretical Contributions

Through this research, the Green IT and Green IS literatures are expanded. This research investigated Green IT and Green IS as the technological drivers that influence the implementation of GSCM within organizations located in Asian country, namely Malaysia. The research scope was among manufacturing firms in Malaysia that were certified with ISO 14001. Although studies on GSCM, Green IT and Green IS are emerging in the literature, but the findings are derived from developed countries which cannot be generalized to the developing Asian countries, particularly Malaysia.

The existing literature lacks investigations into Green IT and Green IS as drivers that influence the implementation of GSCM. Thus, little is known about the effects of Green IT and Green IS on GSCM. This research is one of few studies that have attempted to link these three areas of research, GSCM, Green IT and Green IS for Malaysia context.

The two theories adopted in this research are the input-process-output (IPO) (MacCuspie et al., 2014) and the technological-organizational-environmental (TOE) (Tornatzky & Fleischer, 1990). The IPO theory is applied to categorize the stages of the life cycle as the representation of a system into three stages: inputs required; the process of transforming inputs into outputs; and the results produced/output achieved. The input represents the three contexts of the TOE framework; green practices within the supply chain epitomize the process; and performance outcomes denote the output.

To date, only a few researchers have integrated both the IPO theory and the TOE framework. Therefore, this study is one of the first attempts to use both theories in investigating the drivers, practices and outcomes. The combination of the IPO theory and the TOE framework has given this research a new insight into understanding the drivers that influence the implementation of an initiative, that is, GSCM, which, in return, reveals the outcomes achieved.

The literature highlights the importance of internal and external factors for the successful implementation of an initiative, innovation or invention. The author has carried out an analysis of the literature from 2012 to 2017. Based on this analysis, internal commitment and regulatory pressure are introduced as the drivers for the organizational and environmental contexts, respectively. To the best of the author's knowledge, this is one of the first study to introduce Green IT and Green IS as the drivers for technological context. In moving towards environmental sustainability, it is crucial for companies from non-IT sectors to consider the use of environmentally-friendly IT and IS. The inclusion of drivers from the three contexts is vital in mitigating environmental risks on a larger scale and in achieving greater improvements in technology use that are smarter and safer to the environment as well as for an environmentally-sustainable supply chain.

In previous studies, the outcomes of implementing green initiatives are commonly categorized into: economic performance; financial performance; operational performance; intangible performance; organizational performance; and environmental performance. This study introduces a new performance measurement that differentiates environmental outcomes from supply chain activities, with environmental outcomes achieved by using Green IT and Green IS solutions. The new performance outcome is known as technological performance.

This research provides additional findings beyond those of previously conducted research. It furthers the understanding of the influence of Green IT and Green IS along with internal commitment and regulatory pressure on GSCM implementation, and of the effects on environmental performance and technological performance for ISO 14001-certified manufacturing firms in Malaysia. As part of the contribution to the body of knowledge, scholarly papers have been published in conference proceedings and journals which provide a new avenue of scholarly research in the area of GSCM, Green IT and Green IS towards realizing the goals of environmental sustainability.

6.3.2 Methodological Contributions

This research adopts the cognitive interviewing method to pre-test the survey questionnaire. The survey questions and items are adopted and adapted from the literature, with these mostly used in Western studies. With the cognitive interviewing method, the survey questions are evaluated in a more systematic way with the aid of cognitive psychology and information processing theories (Collins, 2003; Willis, 1999; Willis, 2005). The central focus of the cognitive interview is the survey question itself instead of the person who answers the question. This method is adopted as it allows researchers to identify, analyse and control sources of response error in survey questionnaires due to alternative interpretations of questions and items.

The cognitive interviews were conducted in the earlier part of the study during the design stage of the instruments, and before proceeding with the pilot test of the instrument. Thus, with a pre-tested survey questionnaire using cognitive interviewing, the validity and reliability of measures are increased, and bias and measurement error are decreased. As a result, the survey questions undergo some improvements based on feedback gathered during the cognitive interviewing process. The finalised version of the survey questionnaire is used to collect data for the pilot study and main study.

Another significant methodological contribution is the formative nature of the indicators and constructs in the survey questionnaire. With formative measures, content validity must be assessed before collecting the data to ensure that the indicators represent at least the major aspects of the construct's content. The indicators are not interchangeable; hence, each indicator captures specific facets of the construct's domain. Collectively, the indicators explain the meaning of a particular construct; therefore, omitting an indicator alters the characteristics of the construct. Consequently, the breadth of coverage of the construct domain is extremely important to ensure that the domain of the construct's content is adequately captured. Due to the formative nature of model, this research selected partial least squares-structural equation modelling (PLS-SEM) approach and using SmartPLS software for data analyses as well as testing the hypotheses. The PLS-SEM method enables the identification of key indicators within the constructs (or variables) that influence the implementation of GSCM in ISO 14001-certified manufacturing firms in Malaysia.

6.3.3 Practical Contributions

This study discovered that Green IT is the most significant driver influencing the implementation of GSCM, followed by regulatory pressure, internal commitment and, lastly, Green IS. The findings highlighted the importance of Green IT and Green IS which have often been ignored among industrial practitioners, particularly those from non-IT sectors. The ISO 14001-certified manufacturing firms are realizing the importance of using Green IT and Green IS solutions since they consume less energy, emit less carbon, safer for disposal and cleaner for the environment. These findings provide many new insights for the managerial level of firms, industrial practitioners and policy makers on strategic areas that require further attention and improvement.

This study observed that the periodic internal audit is receiving more attention than previously. For a successful audit procedure and internal programmes, firms need supportive top management and committed co-workers. As a result, compliance with regulations set by the firms themselves is the first step before adhering to international legislation to ensure smooth trading of products at both local and international markets. In order to stay at par with the latest industry revolution, the organization must focus on green technologies and systems that enable the implementation of smarter and greener factory.

As revealed in this study, the green practices that are actively being implemented within the supply chain are eco-labelling of products, green supplier selection and green logistics. The findings will guide firms that are in the midst of implementing GSCM or are planning to venture into GSCM to take into consideration the latest movements among ISO 14001-certified manufacturing firms in Malaysia. This will open an avenue of research and development (R&D) among industrial practitioners and policy makers on new formulation of policies, programmes, incentives and international partnerships.

Most organizations used standardized metrics from regulatory bodies, directives and standards to measure environmental performance. Many of the firms improved their environmental performance with an increase in sustainable and CSR projects as well as systematic reporting on green and sustainable practices. However, most firms were still lacking when came to measure and report the use of Green IT and Green IS solutions within the supply chains of non-IT firms and sectors.

The findings from this research provide guidance for the managerial level of firms, industrial practitioners and policy makers on influential factors that drive the implementation of GSCM as well as the effects on environmental performance and technological performance. This study produced a basic guideline in the form of a model that is being copyrighted under Intellectual Property Corporations of Malaysia (myIPO), with the ID CRLY00001813. The official copyright letter is attached in Appendix G.

6.4 Limitations of the Research

This research is not without its limitations. Firstly, generalizations from the findings of this research to all manufacturing firms in Malaysia cannot be made. This is because the samples of this study are only ISO 14001-certified manufacturing firms derived from the Federation of Malaysian Manufacturers (FMM) Directory.

Secondly, the response rate was low as only 165 manufacturing firms participated out of the total of 523 ISO 14001-certified firms that were approached. However, the response rate of 31.5% for this research is sufficient as the common response rate in Malaysia for the same data collection method is in the range of about 10–20% (Ramayah et al., 2005). The low response rate was due to the long tedious process of obtaining approval from the organization's internal management even though company details and information were guaranteed anonymity and confidentiality. Another factor was the limited availability of the person in charge, the manager or executive who was attached to operations/supply chains/environmental units. Thus, the data collection process took much longer than was expected.

Thirdly, the items and scales used are designed and empirically validated for ISO 14001 manufacturing firms in Malaysia. However, a further empirical validation is required for data from other sectors or contexts in order for the instrument to be adopted in other related studies.

6.5 Future Research Directions

This research could be one of few empirical studies that have analyzed the proposed relationships of drivers, practices and outcomes of the seven variables: Green IT, Green IS, internal commitment, regulatory pressure, GSCM, environmental performance and technological performance. As the existing findings cannot be generalized, the replication of this research using samples from other sectors and countries could be a fruitful attempt to confirm a robust conclusion of the findings. Thus, similar studies could be replicated in a few ways: firstly, within manufacturing firms in Malaysia which are non-ISO 14001-certified; secondly, in other non-IT sectors; and, thirdly, in manufacturing firms located other developing or developed countries.

The current research is a snapshot of the existing state among ISO 14001-certified manufacturing firms in Malaysia. Thus, it does not capture the changes that have occurred over time. Change could possibly occur in the precedence of items within each variable that could influence the implementation of green practices within supply chains. Furthermore, a closer observation for a period is needed to assess impact deviations on the performance outcomes. Future research of repeated cross-sectional studies or longitudinal studies should be carried out to develop a more accurate understanding that explains ‘what’, ‘how’ and ‘why’ aspects trigger the changes, to what extent the changes take place; and possible impacts of the changes on organizations.

In addition to the points above, this research was carried out at organizational level of analysis. In order to have a deeper understanding, research using an individual level of analysis and the mixed-methods approach is to be encouraged. The integration of both quantitative and qualitative methods could provide further insight on the drivers, practices and outcomes. New variables could be introduced that address individual level analysis.

Future research should also attempt to focus on specific items within the Green IT and Green IS variables in investigating the direct influence of these individual items on the GSCM implementation, and their consequences for performance outcomes. As discovered in this study, individual items that require further exploration are cloud computing, Internet of Things (IoT), and continuous audit and monitoring as well as green metrics and sustainability reporting for Green IT/Green IS. With the introduction of the “Industry 4.0” concept for the manufacturing sector, new variables and relationships will emerge that require attention from scholarly research.

6.6 Concluding Remarks

This doctoral research has presented a detailed investigation on the drivers, practices and outcomes of green supply chain management (GSCM) implementation among ISO 14001-certified manufacturing firms in Malaysia. This study confirmed that the application of the IPO theory and the TOE framework are valid and useful for investigating and assessing the input, process and output of GSCM implementation. The hypotheses from H1 to H6 were positively supported which indicated that this study successfully addressed RQ1 to RQ3 as well as realizing the research objectives, RO1 to RO3. The SEM-PLS analyses concluded that this research model is good in explaining the research data; thus, it is parsimonious.

LIST OF GRANTS AND PUBLICATIONS

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Universiti Teknologi PETRONAS (Internal Grant – STIRF: 0153AAD86), The Green Information Technologies and Systems Adoption Within Supply Chain of ISO 14001 Manufacturing Firms in Malaysia, Nov 2015-Nov 2016, RM20, 000.

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BOOK CHAPTER

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3-Minute Thesis (3MT) 2015 at UTM KL Campus – Presenter for Universiti Teknologi PETRONAS

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APPENDICES

Appendix A: Summary of Drivers that Influence GSCM Implementation

Reviewed from previous literature from 2012 to 2017			
No.	**Findings – Drivers for GSCM Implementation**	**Scope**	**Source**
1.	**Internal:** 1. Technological capabilities 2. Use of information technology (IT) 3. Capabilities of Purchasing department 4. Size of the company 5. Functional integration 6. Top management commitment 7. Employees' education and training 8. Employees' empowerment, involvement and incentives 9. Applying quality management principles 10. Knowledge management and sharing 11. Alignment of company strategy with purchasing strategy 12. Monitoring performance **External:** 1. Cooperation and support from supply chain (SC) partners 2. Information and knowledge sharing with SC partners 3. Assessing and monitoring supplier performance and practising supplier selection 4. Integration with SC partners and formation of cross-functional cross-company teams 5. Trustful relationships with SC partners 6. Dependence relationships with SC partners 7. Long-term relationships with SC partners **GSCM:** 1. GSCM Practices **Performance Outcome:** 1. Environmental performance	Green supply chain management (GSCM); drivers; interpretive structural modelling (ISM)	(Agi & Nishant, 2017)

	2. Operational performance 3. Economic performance		
2.	**Internal:** 1. Internal management support 2. Industrial symbiosis 3. Carbon management 4. Green information technology and systems (GITS) **External:** 1. ISO 14001 certification 2. Supplier environmental collaboration 3. Customer environmental collaboration **GSCM:** 1. Green design 2. Green procurement 3. Green manufacturing 4. Green packaging 5. Green logistics 6. Green outsourcing 7. Green warehousing 8. Reverse logistics	GSCM; green practices	(Islam et al., 2017)
3.	**Internal:** 1. Internal management **External:** 1. Customer management 2. Regulatory 3. Supplier management 4. Social 5. Competitiveness **GSCM:** 1. Green design 2. Green purchasing 3. Green production 4. Green management 5. Green marketing 6. Green logistics	Critical success factors (CSFs); green supply chain management (GSCM); sustainability	(Luthra et al., 2014)

	Performance Outcome: 1. Environmental performance 2. Economic performance 3. Operational performance 4. Social performance		
4.	**Internal:** 1. Technological context • Relative advantage • Complexity (ease of use) • Compatibility 2. Organizational context • Organizational resources • Organizational innovativeness • Internal stakeholders **External:** 1. Environmental context • Government regulation • Customers of the firm and firm's products and services • Competitors • Social community		(Hwang et al., 2016)
5.	**Internal:** 1. People • Top management commitment • Middle management commitment • Employee involvement • Commitment of individuals 2. Organizational • Fostering of culture • On-the-job training • Cross-departmental communication 3. Resources • Larger organizations • Knowledge of environmental issues • Long-term investment in technology • Capabilities within purchasing and		(Stremlau & Tao, 2016)

	supply function 4. Strategic • Gaining competitive advantage • Reducing environmental and reputational risk • Alignments with other strategies • Desire to reduce hidden costs 5. Administrative • Performance and reward system 6. GSCM readiness • Existence of sustainable SCM strategy • EMS adoption • Other internal CSR practices **External:** 1. Governmental • Government policies and incentives 2. Customers • Customer demands for sustainability 3. Suppliers • Collaboration with suppliers 4. Competitors • Pressure from competitors 5. Other actors • Pressure from investors • Pressure from NGOs 6. Culture 7. Technology		
6.	**Internal:** 1. Personal and individual employees' commitment 2. Involvement and support from top to bottom	GSCM; SMEs; manufacturing industry that covers 12 sectors; Chinese e-marketplace (e.g. Alibaba.com)	(X. Huang, Tan, & Ding, 2015)

	3. Internal recognition and support 4. Internal environmentally-friendly image 5. Desire to reduce costs and save energy **External:** 1. Pressure from regulations 2. Pressure from customers 3. Pressure from the public 4. Pressure from suppliers 5. Pressure from different sectors **GSCM:** 1. Design and materials selection 2. Manufacturing 3. Use 4. Distribution 5. End-of-life (EOL) management		
7.	**Internal:** 1. Internal readiness **External:** 1. Government regulation 2. Buyer/supply chain influence 3. Corporate social responsibility (CSR) 4. Competitive advantage **GSCM:** 1. GSC practices	Green supply chain (GSC); manufacturing; other industries; members of Council of Supply Chain Management Professionals (CSCMP)	(Kohli & Hawkins, 2015)
8.	**Internal:** 1. Establish procedures of production/ operation for greater efficiency 2. Minimization and commitment to abolish non-compliance problems 3. Update documentation for workers to carry out 4. Top management commitment 5. Identify problems of non-conformance 6. Involvement/training of employees 7. Ensure employee commitment 8. Ascertain identity of provider of choice and use information systems (IS) to inform	GSCM; Malaysian Standard (MS) ISO 14001; Malaysia	(Mohd Rozar, Wan Mahmood, Ibrahim, & Razik, 2015)

	9. Ensure training needs and attendance by topic 10. Benchmarking **External:** 1. Identify requirements/customer focus 2. Ensure customers' complaints are handled		
9.	**Internal:** 1. Technological factors: relative advantage; compatibility; complexity of green practices 2. Organizational factors: organizational support; quality of human resources **External:** 1. Environmental factors: customer pressure; regulatory pressure; government support; environmental uncertainty **GSCM, Green Practices:** 1. Upstream (green purchasing, collaboration with suppliers and green design) 2. Focal (green-related programmes) 3. Downstream firms (collaboration with customers, green packaging, green product portfolio and reverse logistics) **Performance Outcome:** 1. Process efficiency 2. Product quality 3. Economic performance 4. Green performance 5. Environmental management capability	GSCM; performance measures; Chinese firms; China	(Kuei et al., 2015)
10.	**Internal:** 1. Top management support 2. Organizational structure for environmental management 3. Interaction with other functional areas 4. Environmental goals 5. Environmental concern in the company's vision or mission	Environmental management (EM); GSCM practices; electro-electronics companies; Brazil	(Jabbour et al., 2014)

<table>
<tr><td></td><td>GSCM:
1. Internal environmental management
2. Green purchasing
3. Cooperation with customers
4. Eco-design
5. Investment recovery

Performance Outcome:
1. Environmental performance</td><td></td><td></td></tr>
<tr><td>11.</td><td>Internal:
1. Strategy
2. Culture
3. Resource base

External:
1. Environmental regulations
2. Societal values and norms
3. Market

GSCM:
1. Green products
2. New manufacturing technology
3. Supply chain initiatives

Performance Outcome:
1. Firm performance</td><td>Sustainability drivers; performance; manufacturing industry; new manufacturing technologies to make manufacturing processes more sustainable; development of green products; integration of green practices in the supply chain</td><td>(Schrettle, Hinz, Scherrer-Rathje, & Friedli, 2014)</td></tr>
<tr><td>12.</td><td>Internal:
1. Leadership
2. Total quality management (TQM)

External:
1. Supplier relationship management (SRM)

Other:
1. Institutional pressures (coercive, mimetic and normative): regulatory pressure, market pressure, brand consciousness and profit motive</td><td>GSCM; performance measures; licensed rubber goods manufacturing firms; India</td><td>(Dubey et al., 2014)</td></tr>
</table>

	Performance Outcome: 1. Environmental performance		
13.	**Internal:** 1. Information technology (IT) and information systems (IS) 2. Human resource and knowledge management **External:** 1. Collaboration and integration 2. Government support **GSCM:** 1. Green purchasing 2. Green materials management 3. Green distribution 4. Green reverse logistics **Performance Outcome:** 1. Environmental performance 2. Financial performance	GSC initiatives; Malaysia	(Ab Talib & Muniandy, 2013)
14.	**Internal:** 1. Internal environmental management 2. Technology integration **External:** 1. Logistics management 2. Customer focus and supplier focus **Performance Outcome:** 1. Green performance • Environmental performance • Economic performance • Operational performance • Innovation performance	Green practices; green performance; automotive industry; Malaysia	(Conding, Habidin, Mohd Zubir, Hashim & Sri Lanang, 2013)
15.	**External:** 1. Regulations and incentives • Threat of legislation with non-compliance	Eco-design; environmental performance; EMS ISO 14001 certified manufacturing firms;	(Zailani et al., 2012)

	• Parent company's environmental standards • Government environmental inspections • Financial incentives from government • Financial incentives from international organizations • Government environmental regulations 2. Customer pressure • Customers' green supply chain requirements • Customers' threats to withhold contracts • Customers' commitment to the environment • Customers' encouragement to go green • Customer associations' green requirements **GSCM:** 1. Eco-design **Performance Outcome:** 1. Environmental performance **Based on Eltayeb et al. (2010), GSCM drivers and practices are:** **Internal (Drivers):** 1. Expected business benefits 2. Social responsibility **External (Drivers):** 1. Regulations 2. Customer pressures 3. Supplier pressures 4. Competition 5. Market demand 6. Community pressures 7. Employee pressures **GSCM:** 1. Eco-design	Malaysia.	

	2. Green purchasing 3. Suppliers' environmental collaboration 4. Customers' environmental collaboration 5. Reverse logistics **Performance Outcome:** 1. Environmental outcome 2. Economic outcome 3. Operational outcome 4. Intangible outcome		
16.	**Internal:** 1. Organizational support **External:** 1. Social capital 2. Government involvement **Other institutional pressures:** 1. Market pressure 2. Regulatory pressure 3. Competitive pressure **GSCM:** 1. Green purchasing 2. Cooperation with customers 3. Eco-design 4. Investment recovery **Performance Outcome:** 1. GSCM performance	GSCM practices; textile and apparel manufacturers; Taiwan	(G.-C. Wu et al., 2012)
17.	**Internal Stimuli:** 1. Supply chain related • Reduce cost of processing (materials purchasing, manufacturing, packaging, distribution, etc.) • Reduce cost of energy consumption • Reduce cost of waste treatment and disposal • Reduce fines for environmental accidents • Scarce resources	GSCM; stimuli; enablers; performance	(More & Mitra, 2012)

	• Reduce rejection and scrap rate • Improve product quality from environmental point of view • Increase product life • Improve capacity utilization • Improve health and safety of employees **External Stimuli:** 1. Environment related • Reduce air pollution/carbon emissions • Reduce water pollution • Reduce solid waste • Reduce energy waste • Reduce consumption of hazardous/harmful/toxic materials • Reduce frequency of environmental accidents • Improve enterprise's environment • Reduce depletion of natural resources • Increase effort to reduce carbon emissions 2. Other • Stronger governmental regulations (ILO, GATT, WTO, EU, national laws) • National green regulatory compliance • Investors' demands for socially responsible investment (SRI); Dow Jones Sustainability Index (DJSI), etc. • Global environmental legislation • Pressures regarding the environment, health and safety from society and from consumers to go green/market pressure to buy green products • Organizations' focus on CSR activities • Government subsidies for green initiatives **Internal Enablers:** 1. Process related • Product stewardship re-assembly • Repair reverse logistics		

	• Product recovery process related • Process modifications remanufacturing • Recycling; reuse • Redesign manufacturing equipment to reduce waste • Green processes • Eco-labelling 2. Human resources related • Seminar to customers to buy environmentally-friendly products • Educate consumers: point-of- sale demonstrations and knowledgeable salespeople • Employee training for awareness about going green and minimizing spills 3. Product related • Design of products for reduced consumption of materials/energy • Design of products for reuse, recycling, recovery of materials, component parts • Design of products to avoid or reduce use of hazardous products and/or their manufacturing process • Design of refurbished products 4. Technology related • Pollution control technologies (installing equipment at the end of a process, such as discharge stack or effluent pipe) • Use of waste treatment equipment • Use of latest technology, such as IT, automation, etc. 5. Other • Facility retrofitting (e.g. energy conservation from the ventilation system) • In-store displays and labels (advertising) • Giving out free samples of recycled, refurbished items • Forming green initiatives team with		

	government subsidiaries **External Enablers:** 1. Environment related • Manage for eco-efficiency (pollution prevention instead of pollution control) • Reduce waste and disposal rate • Decrease or eliminate the use of potentially hazardous substances • Proper disposal of waste • Eliminate all classes of ozone depleting gases 2. Cooperation/collaboration related • Coordinate with supply chain players and/or end-consumers for eco-design, cleaner production, sourcing, packaging, distribution, reverse logistics, etc. • Coordinate/collaborate with suppliers for designing and developing green products • Cooperate with members of reverse logistics channels **GSCM:** 1. Eco-design 2. Cleaner production 3. Purchasing, sourcing, manufacturing, packaging and distribution 4. Waste management 5. Reverse logistics **Performance Outcome:** 1. Environmental performance		
18.	**Internal:** 1. Commitment and support from top management **External:** 1. Compliance with the law and regulations 2. Customer requirements	GSCM; ISO 14001-certified manufacturers; Malaysia	(Rusli et al., 2012)

	GSCM: 1. Green business strategy 2. Green purchasing 3. Internal green practices of supply chain 4. Eco-design 5. Reverse logistics 6. Cooperate with supply chain partners **Performance Outcome:** 1. Environmental performance		
19.	**Internal:** 1. Green philosophy of the firm 2. Corporate culture, core values and a sense of purpose 3. Proper working conditions that comply with the labour law. 4. Information systems (IS)/software **External:** 1. Compliance with environmental regulations (from mandatory and voluntary perspectives) 2. Compliance with appropriate standards, such as governmental standards, and voluntary industry standards, such as ISO 14001 3. Consumer–supplier's collaboration and interactions 4. Corporate social responsibility (CSR) **GSCM:** 1. Green design 2. Green operation • Green manufacturing and remanufacturing • Reverse logistics and network design • Waste management **Performance Outcome:** 1. Environmental performance 2. Economic performance 3. Social performance	GSCM	(Nelson et al., 2012)
20.	**Internal:**	GSCM practices;	(Green, Zelbst,

	1. Internal environmental management 2. Green information systems (IS) 3. Cooperation with customers **GSCM:** 1. Green purchasing 2. Eco-design 3. Investment recovery **Performance Outcome:** 1. Environmental performance 2. Economic performance 3. Operational performance 4. Organizational performance	performance model; manufacturing organizations; United States (US)	Meacham, & Bhadauria, 2012)
21.	**Internal:** 1. Intra-organizational environmental practices (internal resources and strategy): • environmental policy • use of environmentally-friendly raw materials • substitution of environmentally-questionable materials • taking environmental criteria into consideration in production processes • optimization of processes to reduce solid waste and emissions • internal recycling of materials within the production phase • incorporating environmental TQM principles, such as worker empowerment • environmental management procedures for internal use • use of advanced hazard prevention and safety systems at work **External:** 2. Inter-organizational environmental practices with multiple supply chain members • Green purchasing • Design for the environment (DfE) • Green distribution practices	Environmental management (EM); GSCM; performance measures	(Guang et al., 2012)

	GSCM: 1. Green purchasing 2. Design for the environment (DfE) 3. Green distribution practices **Performance Outcome:** 1. Environmental performance 2. Financial performance 3. Operational performance		
22.	**Internal:** 1. Understanding and support of top management 2. Environmental policy for GSCM 3. Cross-functional integration 4. Green purchasing 5. Green design **External:** 1. Education and training to employees and suppliers 2. Compliance statements that indicate supplier's requirement and method of verification 3. Meeting suppliers regularly 4. Effective collaboration in R&D with suppliers 5. Environmental audit for suppliers **GSCM:** 1. Green procurement 2. Green manufacturing 3. Green distribution 4. Reverse logistics **Performance Outcome:** 1. Environmental benefits 2. Economic benefits	GSCM; performance measures; Heineken International; Amsterdam	(Ekane & Nshimirimana, 2012)
23.	**Internal:** 1. Economic benefits 2. Financial incentives 3. Resources, motivation and knowledge **External:**	Green practices; SMEs; Malaysia	(Moorthy, Yacob, Chelliah, & Lawrence, 2012)

	1. Stakeholders' demands 2. Legislation		

Appendix B: Instrument's Item Development

Variables	Types	Scale	Items	Sources (Adopted and Adapted from)
Technological Context				
Green Information Technology	Formative	1: Not considering 2: Considering it currently 3: Initiating implementation 4: Currently implementing 5: Implementing successfully	**GreenIT1**: Enforce power management (office equipment, facilities and data centre) **GreenIT2**: Enforce paperless office **GreenIT3**: Use energy-efficient lights **GreenIT4**: Use virtualization technology **GreenIT5**: Purchase environmentally-friendly IT hardware and equipment **GreenIT6**: Dispose of electronic waste (e-waste) in environmentally-friendly way **GreenIT7**: Use environmentally-friendly technologies to reduce carbon emission and energy production (GENERAL)	(Jenkin et al., 2011; Faucheux & Nicolaï, 2011; Molla & Abareshi, 2012)
Technological Context				
Green Information Systems	Formative	1: Not considering 2: Considering it currently 3: Initiating implementation 4: Currently implementing	**GreenIS1**: Use of software to monitor and record environmental indicators **GreenIS2**: Use of software for environmentally-friendly practices in development and design of product/material procurement	(A. J. W. Chen et al., 2010; Melville, 2010; Dedrick, 2010); Molla & Abareshi, 2012)

		5: Implementing successfully	activities/manufacturing activities **GreenIS3**: Use of software for environmentally-friendly practices in logistics activities **GreenIS4**: Use of video conferencing and/or telecommuting tools **GreenIS5**: Use of online groupware and collaboration tools **GreenIS6**: Use of software to enable environmentally-friendly practices for larger scale improvements in supply chain management (GENERAL)	
Organizational Context				
Internal Commitment	Formative	1:Not at all 2:Very little 3:To some degree 4:Relatively significant 5:Significant	**IntComm1**: Commitment from top management **IntComm2**: Cross-functional cooperation between departments for environmental improvements **IntComm3**: Inspection and audits by internal management **IntComm4**: Internal programmes (training/seminar) on green and environmentally-friendly practices **IntComm5**: Dedication of top management and employees towards environmentally-friendly practices (GENERAL)	(Q. Zhu et al., 2008a, 2008b; Holt & Ghobadian, 2009; G.-C. Wu et al., 2012)
Environmental Context				
Regulatory Pressure	Formative	1:Not at all 2:Very little 3:To some degree	**RegPres1**: Compliance with environmental regulations set by company	(Q. Zhu et al., 2008a, 2008b; Holt &

		4:Relatively significant 5:Significant	**RegPres2**: Compliance with environmental regulations set by government **RegPres3**: Inspection and audits by government agencies or certification bodies **RegPres4**: Compliance with international environmental directives and standards (such as ISO/WEEE/RoHs/REACH/EuP) **RegPres5**: Regulation by local and international agencies has greatly influenced company's commitment towards environmentally-friendly practices (GENERAL)	Ghobadian, 2009; Zailani et al., 2012; G.-C. Wu et al., 2012)
Green Manufacturing				
Green Supply Chain Management	Formative	1:Not considering 2:Considering it currently 3:Initiating implementation 4:Currently implementing 5:Implementing successfully	**GSCM1**: Provide specifications to suppliers that include environmental requirements **GSCM2**: Choose suppliers based on environmental criteria **GSCM3**: Use environmentally-friendly raw materials **GSCM4**: Design products based on environmental criteria **GSCM5**: Use cleaner technology to reduce environmental impacts **GSCM6**: Cooperate closely with customers to ensure product meets environmental criteria-conscious products **GSCM7**: Eco-labelling of products **GSCM8**: Use improved or environmentally-friendly packaging	(Rao & Holt, 2005; Q. Zhu et al., 2008a, 2008b; Eltayeb et al., 2010; G.-C. Wu et al., 2012);

			GSCM9: Reuse or recycle materials or components **GSCM10**: Recover company's end-of-life (EOL) products **GSCM11**: Use environmentally-friendly waste management **GSCM12**: Use environmentally-friendly transportation **GSCM13**: Produce products with reduced impacts on the environment (GENERAL)	
Performance Measurement				
Environmental Performance	Formative	1:Not at all 2:Very little 3:To some degree 4:Relatively significant 5:Significant	**EnvPerf1**: Reduction in emissions generated **EnvPerf2**: Reduction in the amount of waste generated **EnvPerf3**: Decrease in consumption of hazardous/ harmful/toxic materials or components **EnvPerf4**: Efficient use of water **EnvPerf5**: Increase in sustainable and CSR projects **EnvPerf6**: Improvement in firm's reporting capabilities on sustainable practices **EnvPerf7**: Improvement of corporate image **EnvPerf8**: Overall improvement of firm's environmental situation and sustainable practices (GENERAL)	(Hervani et al., 2005; Q. Zhu et al., 2008a, 2008b; Eltayeb et al., 2011; Zailani et al., 2012)
Performance Measurement				
Technological Performance	Formative	1:Not at all 2:Very little 3:To some degree	**TecPerf1**: Increase in deployment of Green IT and Green IS solutions	(OECD, 2009; Erek, 2011; Löser et al.,

		4:Relatively significant 5:Significant	**TecPerf2**: Increase in digitalization, automation, integration and optimization within supply chain processes **TecPerf3**: Increase in safe disposal of electronic wastes (e-wastes) **TecPerf4**: Improvement in power usage of office IT equipment and total facility (e.g. lighting, uninterruptible power supply [UPS], cooling system, network) **TecPerf5**: Improvement in firm's reporting capabilities on Green IT and Green IS practices **TecPerf6**: Increased compliance with IT and IS environmental indicators or standards (e.g. ISO, EPEAT, Energy Star 4.0, the Green Grid, power usage effectiveness [PUE], carbon use effectiveness [CUE], electronics disposal efficiency [EDE] and IT energy efficiency [ITEE]) **TecPer7**: Overall improvement of firm's IT and IS performance and sustainable practices (GENERAL)	2012; Trimi & Park, 2012)

Appendix C: Interview Letter and Sample of Survey Questionnaire

Appendix D: Cognitive Interview Results

Categories of Measurement	Original Items	Revised Items
General Formatting	The wording is too small.	Increase the font size from 10 to 12.
	Is a lengthy questionnaire.	Reduce the pages with reduction of constructs/items.
	Since the items are adapted from previous literature, the usage of English in the survey questionnaire is at high level which causes difficulty for some of the participants to interpret the meaning of the survey question.	Use simple wording and shorten sentence structure to draft the questions.
Instructions	The given instructions are too long with few paragraphs and many specific terms in used.	Shorten the instructions. Includes definitions of terms prior to the instructions.
Response Category and Scale	The response is based on Strongly Disagree to Strongly Agree on 7-point Likert Scale The existing response categories are irrelevant in measuring the influencing aspects of the items. The 7-point Likert scale is confusing and rarely used by participants before in answering survey.	Two new categories of are introduced with 5-point Likert Scale 1: Not considering 2: Considering it currently 3: Initiating implementation 4: Currently implementing 5: Implementing successfully and 1: Not at all 2: Very little 3: To some degree 4: Relatively Significant 5: Significant

Terminology and Item Interpretation	Item comprehension issues: Word Meaning and Ambiguous Words/ Phrases Too many technical terms with no definition or explanation given. E.g. 1: Electronic Product Assessment Tool (EPEAT) E.g. 2: Install software to reduce overall waste, emissions, hazardous and toxic materials. E.g. 3 Desktop Visualization and Storage Virtualization E.g. 4 Data Air Flow Management E.g. 5: Water Cooled Chillers with variable speed fans and pumps. E.g. 6: Comply with environmental regulation in other countries such as Europe, Japan, Us, China etc. E.g. 7: Cross-functional cooperation exist for environment improvements. E.g. 8: Environmental compliance and auditing programmes exist.	Includes definition / explanation for some of the technical terms. Reduces number of terms used in the questionnaire. E.g. 1 Electronic Product Assessment Tool (EPEAT) – Evaluate selections of electronic products based on environmental performance E.g 2: Increased compliance with Information Technology and Systems environmental indicators or standards (e.g. ISO, EPEAT, Energy Star 4.0, Green Grid (The)) E.g. 3: Use of software to monitor and record environmental indicators E.g. 4: Use virtualization technology E.g. 5: Enforce Power Management (Office Equipment, Facilities and Data Centre) E.g. 6: Compliance to international environmental directives and standards (such as ISO / WEEE / RoHs / REACH / EuP) E.g. 7: Cross-functional cooperation between departments for environmental improvements. E.g 8: Inspection and audits by internal management.

Time Frame	Due to the length of questionnaire and variable interpretation of the terms/phases, participants took approximately an hour to complete it	The changes made on the instructions, terminology phases, response category and scale has tremendously improved the completion time in responding the questionnaire to 30 minutes.
Overall impression of content and coverage	The coverage of the contents is too broad and technical in nature, in which address multidisciplinary areas. Therefore, higher level management are receptive to be the respondent as compared to the manager or executive level.	The content of questionnaire was designed to be more focused and specific. The terms and phases used are much common to the participants, with clearer and shorter structure of sentences. The executive, manager and higher-level management are in position to respond to the survey.

Appendix E: Normal Distribution Test

Items	z-scores (range)	Mean	Skewness	Kurtosis
Green Information Technology (IT)				
GreenIT1: Enforce power management (office equipment, facilities and data centre)	-2.234 to 1.636	3.310	-0.470	-0.644
GreenIT2: Enforce paperless office	-2.758 to 1.332	3.700	-0.586	0.184
GreenIT3: Use energy-efficient lights	-1.058 to 1.792	2.480	0.399	-1.170
GreenIT4: Use virtualization technology	-1.459 to 1.617	2.900	0.008	-1.120
GreenIT5: Purchase environmentally-friendly IT hardware and equipment	-1.388 to 1.599	3.390	0.131	-1.046
GreenIT6: Dispose of electronic waste (e-waste) in environmentally-friendly way	-2.530 to 1.359	3.950	-0.158	-0.729
	Standard Deviation	**Mean**	**Skewness**	**Kurtosis**
Green IT (Average)	**0.880**	**3.289**	**0.071**	**-0.899**
Green Information Systems (IS)				
GreenIS1: Use of software to monitor and record environmental indicators	-1.420 to 1.746	3.350	0.127	-0.900
GreenIS2: Use of software for environmentally-friendly practices in development and design of product/material procurement activities/ manufacturing activities	-2.649 to 0.862	4.510	-0.637	-0.596
GreenIS3: Use of software for environmentally-friendly practices in logistics activities	-1.730 to 1.628	3.550	0.043	-0.745
GreenIS4: Use of video conferencing and/or telecommuting tools	-2.811 to 0.970	4.230	0.793	-0.162
GreenIS5: Use of online groupware and collaboration tools	-1.894 to 1.210	3.830	-0.186	-1.108
	Standard Deviation	**Mean**	**Skewness**	**Kurtosis**
Green IS (Average)	**0.732**	**3.892**	**-0.175**	**-1.033**
Internal Commitment				
IntComm1: Commitment from top management	-3.190 to 0.872	4.400	-0.828	-0.028
IntCommt2: Cross-functional cooperation between departments for environmental improvements	-2.102 to 1.139	3.950	-0.218	-1.191
IntComm3: Inspection and audits by internal management	-1.778 to 1.354	3.700	-0.047	-1.040
IntComm4: Internal programmes (training/seminar) on green and environmentally-friendly practices	-1.887 to 1.786	3.050	0.264	-0.900
	Standard Deviation	**Mean**	**Skewness**	**Kurtosis**
Internal Commitment (Average)	**0.804**	**3.776**	**-0.026**	**-1.190**
Regulatory Pressure				
RegPres1: Compliance with environmental	-2.784 to	4.220	-0.572	-0.768

regulations set by company	0.971			
RegPres2: Compliance with environmental regulations set by government	-2.760 to 1.258	4.060	-0.366	-0.368
RegPres3: Inspection and audits by government agencies or certification bodies	-2.839 to 2.092	3.730	0.056	-0.325
RegPres4: Compliance with international environmental directives and standards (such as ISO/ WEEE/RoHs/REACH/EuP)	-2.464 to 1.155	4.040	-0.210	-1.193
	Standard Deviation	**Mean**	**Skewness**	**Kurtosis**
Regulatory Pressure (Average)	**0.519**	**4.014**	**0.125**	**-0.919**
Green Supply Chain Management (GSCM)				
GSCM1: Provide specifications to suppliers that include environmental requirements	-2.818 to 1.261	3.760	-0.412	-0.472
GSCM2: Choose suppliers based on environmental criteria	-1.614 to 1.653	2.980	0.047	-0.944
GSCM3: Use environmentally-friendly raw materials	-2.330 to 1.208	3.980	-0.440	-0.494
GSCM4: Design products based on environmental criteria	-1.956 to 1.293	3.810	-0.357	-0.697
GSCM5: Use cleaner technology to reduce environmental impacts	-2.488 to 1.497	3.500	-0.101	-0.763
GSCM6: Cooperate closely with customers to ensure product meets environmental criteria	-2.684 to 1.038	4.160	-0.519	-0.681
GSCM7: Eco-labelling of products	-1.583 to 2.019	2.760	0.169	-0.826
GSCM8: Use improved or environmentally-friendly packaging	-2.129 to 1.764	3.190	0.240	-0.634
GSCM9: Reuse or recycle materials or components	-1.605 to 1.986	2.790	0.188	-0.743
GSCM10: Recover company’s end-of-life (EOL) products	-0.886 to 2.701	1.990	0.985	0.078
GSCM11: Use environmentally-friendly waste management	-2.693 to 1.105	4.130	-0.681	0.108
GSCM12: Use environmentally-friendly transportation	-2.597 to 2.035	3.240	0.026	-0.580
	Standard Deviation	**Mean**	**Skewness**	**Kurtosis**
Green Supply Chain Management (Average)	**0.703**	**3.356**	**-0.051**	**-0.643**
Environmental Performance				
EnvPerf1: Reduction in emissions generated	-1.455 to 1.717	3.380	0.101	-0.893
EnvPerf2: Reduction in the amount of waste generated	-1.648 to 1.681	3.480	0.096	-0.747
EnvPerf3: Decrease in consumption of hazardous/ harmful/toxic materials or components	-2.325 to 1.306	3.920	-0.180	-0.836
EnvPerf4: Efficient use of water	-2.517 to 2.611	2.960	-0.170	-0.368
EnvPerf5: Increase in sustainable and CSR projects	-1.531 to 1.917	2.780	0.329	-0.846
EnvPerf6: Improvement in firm’s reporting capabilities on sustainable practices	-2.301 to 1.534	3.800	-0.173	-0.425
EnvPerf7: Improvement of corporate image	-3.233 to 1.336	3.850	-0.479	-0.008

	Standard Deviation	Mean	Skewness	Kurtosis
Environmental Performance (Average)	**0.660**	**3.454**	**0.051**	**-0.734**
Technological Performance				
TecPerf1: Increase in deployment of Green IT and Green IS solutions	-1.394 to 2.676	2.370	0.409	-0.515
TecPerf2: Increase in digitalization, automation, integration and optimization within supply chain processes	-2.027 to 1.027	4.330	-0.458	-0.711
TecPerf3: Increase in safe disposal of electronic wastes (e-wastes)	-2.884 to 1.770	3.480	0.066	-0.338
TecPerf4: Improvement in power usage of office IT equipment and total facility (e.g. lighting, uninterruptible power supply [UPS], cooling system, network)	-2.250 to 2.054	3.090	0.140	-0.636
TecPerf5: Improvement in firm’s reporting capabilities on Green IT and Green IS practices	-1.507 to 1.750	2.390	0.051	-0.837
TecPerf6: Increased compliance with IT and IS environmental indicators or standards (e.g. ISO, EPEAT, Energy Star 4.0, the Green Grid, power usage effectiveness [PUE], carbon use effectiveness [CUE], electronics disposal efficiency [EDE] and IT energy efficiency [ITEE])	-1.553 to 2.701	2.460	0.293	-0.246
	Standard Deviation	**Mean**	**Skewness**	**Kurtosis**
Technological Performance (Average)	**0.719**	**3.019**	**0.150**	**-0.862**

Appendix F: Factor Analysis of Common Method Bias Test

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**
1	21.767	49.470	49.470	21.767	49.470	49.470
2	2.463	5.599	55.069			
3	1.980	4.499	59.568			
4	1.724	3.919	63.487			
5	1.633	3.712	67.199			
6	1.358	3.087	70.286			
7	1.012	2.301	72.587			
8	0.898	2.042	74.628			
9	0.855	1.943	76.572			
10	0.701	1.594	78.165			
11	0.650	1.478	79.644			
12	0.581	1.319	80.963			
13	0.554	1.259	82.222			
14	0.519	1.180	83.402			
15	0.507	1.153	84.556			
16	0.472	1.073	85.629			
17	0.442	1.004	86.633			
18	0.430	0.978	87.611			
19	0.379	0.861	88.471			
20	0.360	0.817	89.289			
21	0.356	0.809	90.097			
22	0.336	0.763	90.860			
23	0.318	0.722	91.582			
24	0.311	0.706	92.288			
25	0.293	0.667	92.955			
26	0.285	0.647	93.602			
27	0.242	0.550	94.152			
28	0.236	0.536	94.688			
29	0.228	0.517	95.205			
30	0.218	0.496	95.701			
31	0.215	0.488	96.189			
32	0.199	0.452	96.641			
33	0.184	0.418	97.059			
34	0.168	0.381	97.440			
35	0.151	0.343	97.783			
36	0.150	0.341	98.124			
37	0.128	0.291	98.415			
38	0.124	0.282	98.697			
39	0.117	0.266	98.963			
40	0.107	0.243	99.206			
41	0.102	0.232	99.437			
42	0.095	0.216	99.654			
43	0.079	0.179	99.833			
44	0.074	0.167	100.000			

Extraction Method: Principal Component Analysis.

Appendix G: MyIPO Copyright Letter

Perbadanan Harta Intelek Malaysia
Intellectual Property Corporation of Malaysia
(Diperbadankan)
Unit 1-7 & Mezzanine, Unit 12, 12A, 13, 15, 16, 17, 18, dan 19
Tower B Menara UOA Bangsar, No. 5, Jalan Bangsar Utama 1
59100 Kuala Lumpur
Tel : +603-22998400 Faks: +603-2299 8989
Laman Sesawang : www.myipo.gov.my

LCR01

SAVITA A/P K. SUGATHAN
81A JALAN LAPANGAN HARTAMAS 8
TAMAN LAPANGAN HARTAMAS
31250 IPOH
PERAK

NOTIS PEMBERITAHUAN HAK CIPTA
(Seksyen 26B, Akta Hak Cipta 1987)

Tuan/Puan

Sukacita dimaklumkan, maklumat butiran Pemberitahuan Sukarela Hak Cipta tuan/puan telah direkodkan ke dalam Daftar Hak Cipta sebagaimana diperuntukkan di bawah Seksyen 26B, Akta Hak Cipta 1987. Butiran Pemberitahuan Hak Cipta tersebut dirujukkan seperti berikut:

TARIKH PERMOHONAN	: **02/10/2014**
NO. PERMOHONAN	: **LY2014001433**
NO. PEMBERITAHUAN	: **CRLY00001813**
TAJUK KARYA	: **MODEL OF GREEN SUPPLY CHAIN MANAGEMENT: INTEGRATION OF GREEN INFORMATION TECHNOLOGIES AND SYSTEMS**
KATEGORI KARYA	: **SASTERA**
TARIKH PENERBITAN PERTAMA	: **14/02/2014**
PENCIPTA	: **SAVITA A/P K. SUGATHAN** **ASSOC. PROF. P. DHANAPAL DURAI DOMINIC**
PEMUNYA	: **SAVITA A/P K. SUGATHAN**
PEMEGANG LESEN	: **TIDAK BERKAITAN**

Tuan/Puan boleh memohon Sijil Pemberitahuan Hak Cipta dengan mengemukakan Borang CR-5 seperti dikepilkan bersama. Pihak tuan/puan juga boleh memohon petikan yang diperakui sah daripada Daftar Hak Cipta yang boleh dijadikan satu keterangan *prima facie* mengenai butiran yang direkodkan.

Sukacita dimaklumkan juga, sekiranya terdapat sebarang perubahan maklumat sedia ada, pihak tuan/puan dinasihatkan kemukakan maklumat perubahan tersebut untuk direkodkan dalam Daftar Hak Cipta.

Appendix H: Letter Regarding Professional Editor's Experience

Valerie Williams professional writing services

Ms Valerie Williams
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M: +61 (0) 409 698 973
21 August 2017

To whom it may concern,

I am writing to confirm that I am a professional thesis and academic editor. I began work in this field in 2006 on a self-employed basis, working in my own business. I have worked full time in this role since early 2012. I have set out a few details below that are extracted from my brief professional bio which provide further background.

Qualifications

2002: Advanced Diploma of Arts (Professional Writing)
Adelaide Institute of Technical and Further Education (TAFE), South Australia
(two units of editing)

1994: Graduate Diploma of Business (Management Studies)
Edith Cowan University, Western Australia

1978: Bachelor of Arts (Honours), (English major)
University of Adelaide, South Australia

Key skills and experience

I have over 30 years' experience mainly in the non-government, not-for-profit sector with roles including report and proposal writing; project development and project management; human resources, finance and contract management; marketing; function coordination (including conferences); and strategic planning and governance.

My professional editing experience includes: Master's degree and PhD theses, business editing; technical editing; reports to funding bodies; Annual Reports; proposals for funding and grant applications; business and strategic plans; website content; brochures and publicity material; conference abstracts; letters and correspondence; press releases; and articles.

Consultancies undertaken include consulting with stakeholders and developing written materials, discussion papers and case studies.

I am a published author and a member of both the Society of Editors (SA), a branch of the Institute of Professional Editors Limited (IPEd), and of IPED itself.

If you have further questions or would like to contact me directly, my contact details are listed above.

Yours sincerely,

Ms Valerie Williams