Graduate School of Business

Integrating *Lean* and *Green* Supply Chain Management Systems in Manufacturing

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Statement of Authentication

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made. This thesis contains no material that has been accepted for the award of any other degree or diploma in any university.

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Table of Abbreviations

3P	Production, Preparation and Process
5S	Sort, Straighten, Sweep, Standardise and Sustain
GSCMS	Green Supply Chain Management System
JIT	Just in Time
KPIs	Key Performance Indicators
LCA	Life Cycle Analysis
LSCMS	Lean Supply Chain Management System
SCM	Supply Chain Management
TPM	Total Productive Maintenance
United States	United States of America
U.S.	United States of America
VSM	Value Stream Mapping

Preface

Abstract

At a time where social and environmental systems are showing evidence of damage, sustainable development has the potential to influence or be influenced by human development (Goldie, Douglas, and Furnass 2005). The notion of sustainable development can be traced back to the 18th Century as people began to question the impact of rising populations and rapid resource consumption on the Earth's natural assets (Meadows, Randers, and Meadows 1972; Mebratu 1998; Bell and Morse 1999). The United Nations Conference on the Human Environment in 1972 was the first major conference raising the notion of sustainability as a critical condition for enjoying life (Blackburn 2007). Since the 1970s it has become increasingly agreed that approaching sustainable development requires consideration of the three dimensions of economic, environmental and social development in decision making (Alam 2010).

In 1987, the Brundtland Report drew international attention towards the notion of sustainability as a rational human objective (Werback 2009; Leonard 2010). In 1994, John Elkington introduced the Triple Bottom Line (TBL) to reflect the ultimate goal of sustainability by measuring and reporting corporate performance against economic, social and environmental parameters and engaging communities in its implementation (Elkington 1997; Potts 2004). Since then, public disclosure of sustainability-related information has been practiced throughout industries and organisations. Sustainability practices needed to be integrated into an organisation's strategy in order to provide insights into the underlying enhancements and trade-offs in its environmental, economic and social dimensions (Faisal 2010; Frost and Martinov-Bennie 2010). However, for the purpose of this research, sustainability is limited to incorporating only financial and environmental perspectives due to the difficulty in defining and measuring economic and social aspects.

The literature shows that manufacturing plays a key role in aiding the transition towards sustainable development. By taking full environmental responsibility for the impact of manufactured products while maintaining profitability and productivity, sustainable manufacturing organisations can address sustainability in their strategies

and operations. In this respect, reaching sustainability in manufacturing requires a holistic view spanning the entire supply chain to target sustainability all the way through the life cycle of a product. Researchers have indicated that modifying manufacturers' supply chains to integrate both *lean* and *green* supply chain management systems presents a major key to gaining a sustainable future. But a review of the existing literature has highlighted a need for further empirical research to validate the *lean–green* relationship and better understand the relationship between *lean* and *green* manufacturing systems (i.e. points of conflict and synergies that may result from an integrated approach).

Procurement has also been increasingly identified as a key business process contributing to enhanced industrial sustainability due to the value of its purchasing expenditure and direct input into manufacturers' performance. As demonstrated in the literature review, sustainable procurement elevates the procurement function to embrace the broader goals of sustainable development, by considering life-cycle costs and balancing the economic, social and environmental elements of procurement decision making, rather than solely focusing on the traditional financial parameters.

The principal objectives of this research are therefore to examine the relationship between *lean* and *green* supply chain management practices and business performance outcomes; identify factors that may contribute to successful integration and attainment of enhanced levels of sustainability; and examine the role of procurement to embrace the broader goals of sustainable development and enhance an organisation's sustainable performance.

The findings that arose from the literature review were considered with the context of the research objectives and the following hypotheses were developed. First, manufacturing adopting an integrated approach utilising both LSCMS and GSCMS can exhibit significantly higher levels of sustainability than manufacturing implementing only *lean* or *green* principles. Second, significant environmental benefits can be typically derived from lean initiatives. Third, an integrated approach encompassing both LSCMS and GSCMS my result in trade-offs of either system. Fourth, key factors may contribute to successful integration of *lean* and *green* supply chain management systems and attainment of enhanced levels of sustainability within an implemented supply chain management system. Fifth, the procurement function within an organisation has a significant impact on achieving sustainability goals.

Attempts to gain data from Australia and New Zealand was largely unsuccessful and so the United States was selected for review due to its strong manufacturing base. Data was collected from 49 U.S. manufacturing organisations using an online survey to reflect on their implantation of *lean* and *green* practices and the degree to which their organisations utilise procurement and work with suppliers to improve the sustainability of the supply chain.

Research findings demonstrated that manufacturers adopting an integrated approach, utilising both LSCMS and GSCMS, exhibit significantly higher levels of sustainability than manufacturers implementing only *lean* or *green* principles. Research findings also identified key factors contributing to effective integration. Organisational philosophy, throughput improvement, management and culture, and a focus on product quality and design, suppliers, customers and having reliable and efficient equipment and infrastructure appear to be key factors to a successful integrated approach. Finally, research findings supported the role of the procurement function in bringing about sustainability outcomes.

This research provides a number of contributions to the theoretical debate in this field. The research demonstrated that reaching sustainability in manufacturing requires a holistic view spanning not just the product but also the entire supply chain. With an empirical analysis, the research also established that efficient production and environmental impacts are closely linked, synergising the implementation of *lean* and *green* philosophies to achieve financial and environmental sustainability. Additionally, key factors were identified to effectively integrate *lean* and *green* supply chain management systems, contributing to existing literature. Finally, the research illustrated that the major role that the procurement function plays within an organisation appears to facilitate achieving sustainability goals through overall costs reduction and minimising products' emission rates.

This research also provides a number of contributions to practice. The empirical research suggests that supply chain management has potential to reduce costs and improve environmental performance and customer service. The evidence suggests that to increase financial gains while simultaneously reducing environmental impact of an organisation, *both lean* and *green* manufacturing systems could be integrated and continuously adjusted to fit a particular organisational environment. Research findings also indicate that the cornerstone of *lean* and *green* implementation is an organisational philosophy that supports positive environmental outcomes. The evidence from this study also supported the need to incorporate a focus on sustainability into an organisation's day-to-day procurement processes.

Operational Definitions

In this research, key terms have been defined as:

Competitive advantage

The result of a business being either a particularly talented player in its market, offering lower prices than competitors for equivalent products, and/or being positively differentiated in what it offers, offsetting higher prices.

Efficiency

Efficiency is a measurable concept determined by the ratio of output to input. In manufacturing, it describes the extent to which resources, assets, time, labour effort and cost are well utilised to produce a specific outcome with minimised quantity of waste, expense and redundant effort.

Environmental performance

An assessment of an organisation's ability to reduce the environmental impact of its resource consumption, processes and finished products in terms of air emissions, solid- toxic waste and resource use.

Financial performance

An assessment of an organisation's ability to utilise its assets to improve productivity, increase profitability and achieve overall market strength while simultaneously reducing costs associated with purchased materials, energy and water consumption, waste disposal, and costs associated with environmental legislation, standards and compliance. The term has been treated as synonymous with economic performance in this research, whenever the term relates to a business organisation.

Green supply chain management system (GSCMS):

GSCMS, or simply *green*, is a production management system that focuses on improving the environmental performance in the different phases of a supply chain, in terms of waste, air emissions, and the consumption of non-renewable resources and toxic materials with the aim of raising ecological efficiency and reducing environmental risks and impacts.

Just-in-Time

A production scheduling concept for managing production flow by calling for any needed item, whether raw material, finished item, or anything in between, to be produced and available precisely when needed.

Lead time

The time between the initiation and the completion of a production process.

Lean supply chain management system (LSCMS):

LSCMS, or simply *lean*, is a production management system that focuses on delivering value to customers, aligning demand to capacity and eliminating non-value added activities (waste) along the different phases of the supply chain through continuous improvement and process changes with an aim of creating a competitive advantage.

Logistics

Activities associated with transport, warehousing and materials handling operations as they move from sourcing of materials through to the production system to the final customer, at the desired time, and in the right quantities.

Supply chain:

An organised set of firms, people, activities, information technology, resources and services involved in transforming natural resources into finished products delivered to the end customer.

Supply chain management (SCM):

The coordination and management of integrated activities throughout the supply chain in order to satisfy customer needs; related activities include procurement, sourcing, manufacturing, logistics, customer service and information flow from source of supply and to the point of consumption.

Sustainability:

In this research, sustainability incorporates only financial and environmental perspectives and is defined as achieving a state of sustainability in which humans and nature exist in productive harmony through a commitment to maintain financial success while protecting the environment in order to secure the wellbeing of future generations on a sustainable basis.

Sustainable development:

Achieving a state of desirable future for human societies through a commitment to act responsibly on behalf of future generations where financial progress and living conditions meet the needs of the present without undermining the ability to meet the needs of future generations.

Sustainable manufacturing:

A responsible approach to manufacturing products through efficient use of resources and reduced environmental impact along the entire life cycle of the manufactured product.

Sustainable procurement:

A process that aims to reduce adverse environmental and financial impact of purchased products and services by seeking resource efficiency, assessing the value for money and considering waste disposal and the cost of operation and maintenance over the life of purchased goods and services.

Waste

Any process or activity that neither meets the needs of customers and stakeholders nor reduces waste disposal or by-products (side effects).

1 Chapter 1

This chapter provides background to the issue of sustainability specifically within the context of supply chain management and serves as an introduction to the research question and the structure of the thesis.

1.1 Significance

Out of several inter-related global issues[1], such as over-population, resource depletion, environmental degradation, inequity and high levels of pollution and waste generation as well as intense consumption of natural resources, the 21st Century has made evident questions about the ongoing capacity of our planet Earth to maintain its resources and safely absorb and process wastes (Bergmiller 2006; Brander 2007). Although technology has greatly decreased industrial environmental impact, the rate of consumption and production has outpaced those innovations, causing major imbalances to Earth's life sustaining systems (Bergmiller 2006; Fagan 2010). The background and literature review detailed in chapters two and three illustrate how such issues have given sustainability considerable importance in policy and research.

The manufacturing industry appears to be one of the major industries recognising the importance of sustainability and growth (Reich-Weiser 2010). Carrying the largest employment and economic multiplier effect of all sectors in the United States economy, manufacturing is under intense pressure from the community, regulators and government to find, implement and manage sustainable solutions (Wezey and McConaghy 2011). Furthermore, due to the enormous amount of energy consumed and waste generated from manufacturing processes, manufacturing as demonstrated by Dornfield (2013) has been causing significant environmental problems – more than any other industrial sector in the United States. Mass production of industrial outputs/products was suggested earlier by Das Gandhi, Selladurai, and Santhi (2006) to be one of the major reasons behind increased consumption and natural resources depletion, on the one hand, and environmental degradation, on the other, as it supplied goods at cheaper price and made society perceive luxury goods as necessities. Thus, sustainable manufacturing emerged as a key to modifying current

[1] To be discussed in Chapter Three.

production and consumption patterns by taking responsible approaches in relation to sustainability for manufactured products (Legette and Carter 2012).

Bergmiller (2006) claimed that meeting sustainability goals by modifying manufacturers' supply chains may be the key to gaining a sustainable future. Contributing towards sustainability through supply chain management has gained increased interest in both academic literature and industry practice (Abbasi and Nilsson 2012; Walker and Jones 2012). A framework developed by Cai, Liu, Xiao, and Liu (2009) illustrated that improving supply chain performance is one of the critical issues to achieving sustainability and gaining a competitive advantage. Two alternative supply chain management systems, *Lean* Supply Chain Management Systems (LSCMS) and *Green* Supply Chain Management System (GSCMS), have gained popularity in addressing sustainability objectives, as they both challenge the way resources are being used and aim at minimising waste across key business processes in the organisation (Bergmiller 2006; Reisman and Burns 2006). So a balance between both systems may hold significant potential for the manufacturing industry to simultaneously realise even greater financial and environmental objectives.

Bergmiller and McCright (2009a) suggested the need for an integrated approach to capitalise on cost savings, product differentiation and environmental performance. The Environmental Protection Agency (EPA) (2000) also acknowledged the possibility of gaining enhanced environmental and economic performance when extending *green* efforts to include those of *lean*. Bergmiller (2006) and Bergmiller and McCright (2009a) argued that if the future challenge is to develop a sustainable global economy, one that the planet can support indefinitely, integrating LSCMS and GSCMS can be the key to gaining a sustainable future through cost savings, product differentiation and enhanced environmental performance.

However, although separate streams of developed research on LSCMS and GSCMS – and the synergies involved as they are integrated – do exist, there is a significant lack of research predicting the optimum balance point to enhance an organisation's ability to successfully integrate both systems and achieve greater competitive advantage. Bergmiller (2006) explained that although *lean* may produce environmental benefits due to its waste elimination culture, *lean* methods do not explicitly incorporate environmental performance considerations which may result in "blind spots" with respect to environmental opportunities, improvements and life-cycle impacts. Likewise, although pollution prevention may "pay", incorporating *green* environmental consideration with *lean* implementation efforts may not always consider financial improvements. Faisal (2010) also illustrated that adopting sustainable practices is a daunting task due to the difficulty in considering the trade-off between the dimensions of sustainability.

Lean and *green* initiatives seem to have a great deal in common as they both challenge the way resources are being used, but the nature of the integration management system is an implementation issue that needs to be addressed with a view to key factors such as management and organisational characteristics. Bergmiller and McCright (2009a) as well as Carvalho, Duarte, and Machado (2011) suggested the need for further empirical research to validate the relationship between *lean* and *green* supply chain management systems to promote cost savings, product differentiation and environmental performance. Thus, a potential improvement will be to harness the synergetic effect of LSCMS and GSCMS integration by better understanding the relationship between *lean* and *green* manufacturing systems and identifying key factors that can help determine successful integration.

The procurement function within an organisation has also been an increasingly identified business process contributing to enhanced industrial sustainability due to the value of procurement expenditure and direct input into manufacturer performance. Sustainable procurement, as Cousins, Lamming, Lawson, and Squire (2008) and Walker and Brammer (2009) suggested, elevates the procurement function to encompass the broader goals of sustainable development by considering life-cycle costs and balancing the financial, social, and environmental elements of procurement decision making, rather than solely focusing on the traditional financial parameters.

The goal of this research is, therefore, to investigate whether manufacturers adopting an integrated approach utilising both LSCMS and GSCMS can exhibit significantly higher levels of sustainability – in terms of reducing an organisation's environmental impact while simultaneously improving profitability and minimising the marginal cost of environmental performance – than manufacturers implementing either *lean* or *green* principles. Another goal of this research is to identify the factors that may contribute to successful implementation and attainment of enhanced levels of sustainability within an implemented supply chain management system as well as investigate the role of the procurement function in enhancing an organisation's sustainable performance by considering life-cycle costs and reducing upstream sources of waste.

1.2 Objectives

This thesis builds upon contemporary research regarding the relationship between *lean* and *green* supply chain management systems as an opportunity to gain a sustainable industrial future. So the overarching research question is:

Will integrating lean and green supply chain management systems simultaneously realise positive financial and environmental outcomes and thus achieve higher levels of sustainability?

The main aim is to help a supply chain preserve the dynamic aspects of *lean* production while assuring harmonisation with the environmental aspects of *green* manufacturing.

In an attempt to answer the overarching research question, the study also sought to answer a number of other questions, such as:

- What factors contribute to successful integration and attainment of enhanced levels of sustainability?
- Do *lean* initiatives spill over to reduce environmental waste due to *lean*'s waste elimination culture?
- Does an integrated approach of both GSCMS and LSCMS result in trade-offs between the environmental and financial dimensions of sustainability?
- Does the procurement function within an organisation have a potentially significant impact on achieving sustainability goals, such as reducing overall costs and emission rates?

1.3 Structure of the Research

This thesis is organised into eight chapters:

Chapter One provides some background to the issue of sustainability specifically within the context of supply chain management and serves as an introduction to the research question and the structure of the thesis.

Chapter Two discusses the evolution of *lean* and *green* manufacturing systems, describing the practices these individual systems involve and the wastes they strive to eliminate.

Chapter Three moves on to provide a comprehensive literature review of sustainability as well as supply chain management, and their evolution over time. It also presents the significance of sustainability in the United Stated manufacturing industry in addition to the critical role that procurement and alternative supply chain management systems play in contributing to sustainability in manufacturing.

Chapter Four highlights the dilemma facing supply chain sustainable initiatives in terms of the compatibility of the environmental objectives of GSCMS with financial viability, and the apparent contradiction between *lean* and *green* supply chain promised benefits. It also provides a summary of the literature review to help identify the research gap stated in the next chapter.

Chapter Five identifies the research gap this study intends to fill, form a conceptual framework, and develops the hypothesis to be examined.

Chapter Six describes the methodology utilised to test the research hypotheses stated in Chapter Five through a discussion of the research design, population and sample, instrumentation, data collection process and ethical consideration.

Chapter Seven presents and analyses the data collected from the survey instrument and then discusses the results to give meaning to statistical findings and provide a brief summary of findings.

Chapter Eight presents the conclusion and contribution this study offers to both theory and practice along with a brief summary of what was learned from this study and a discussion of the limitations of this study and directions for further research.

2 Chapter 2 - Background

This chapter provides a brief historical background to *lean* and *green* manufacturing systems based on research published in scholarly journals and books on *lean* and/or *green* manufacturing. The chapter aims to provide a picture of how these systems evolved over time, the practices these individual systems involve and the waste they strive to eliminate.

2.1 *Green* Manufacturing

2.1.1 Background

Public awareness of environmental quality and the means and measures to offset the damage created by humans' actions gained momentum during the early days of the industrial revolution (Hays 1981). The environmental movement itself can be traced back to the 1960s because of both social changes and alteration in human values after World War II (Hays 1982). According to Brooks (2009), the flood of environmental awareness towards protecting nature is best seen not as a revolutionary event but rather as an evolving process, beginning shortly after World War II, when conservationists, citizen activists and their allies began to agitate for remedial action on behalf of water and air quality, wildlife and human health.

The 1960s has been described as a time of social protest and disturbance, shifting the emphasis away from the earlier conservation movement that focused on the efficient use of natural resources and wildlife management, towards quality-of-life issues and understanding the direct relationship between environmental problems and human society (Merchant 2002). The 1960s was characterised by a great deal of questioning and denial about widely publicised ecological events (DiMento and Oshio 2009). The nuclear fallout caused by nuclear explosion tests at the Bikini Atoll in the 1950s and its radiation effect on the food chain was a major event that raised public concern towards the end of the 1950s and the beginning of the 1960s (Merchant 2002).

The publication of the books *Silent Spring* by Rachel Carson (1962) and *The Population Bomb* by Paul Ehrlich (1968) were other events that raised concerns about ecological interactions, over-population and relentless industrialisation (Carson

1962; Ehrlich 1968; Lamming and Hampson 1996). Carson (1962) warned about the toxic threat from agricultural use of synthetic chemical pesticides and other insecticides on natural ecosystems, while Ehrlich (1968) cautioned against the increase in air pollution, the growing scarcity of resources and untreated human waste. Finally, a primary catalyst for the birth of the modern-day environmental movement was the oil spill that occurred between January and February 1969 in the Santa Barbara Channel in Southern California, spilling an estimated 8,000 to 10,000 barrels of crude oil and killing thousands of birds, fish, sea lions and other marine life (Corwin 1989). The spill raised high levels of public environmental awareness in relation to toxic waste in Santa Barbara County and supported the claim that unregulated industrial activities can cause disastrous consequences (Szasz 1994)[2].

Concern over such problems grew significantly in the 1970s, known as the "environmental decade" (Merchant 2002; Brooks 2009). A wave of national environmental legislation in countries such as the United States, Japan and Germany followed to try to ensure a safe, healthful environment (Schreurs 2004). The U.S Environmental Protection Agency (EPA) was also established in 1970 to enforce environmental regulation based on laws passed by Congress, followed by further initiatives such as celebrating the first Earth Day on April 22, 1970, forming the world's first *Green* Party in Tasmania, Australia, in 1972, issuing the Brundtland Report, *Our Common Future,* in 1987 and launching the Earth Summit in 1992 to reflect a more fundamental concern with environmental issues (Leonard 2010).

On the contrary, the 1980s witnessed a relaxation in environmental performance as industry reacted against the reduced profits due to additional costs of complying with new environmental legislation (Merchant 2002). The reason for this negative relationship was that pollution abatement was addressed at the "end-of-the-pipe" as opposed to more complex approaches such as pollution prevention and the application of cleaner technologies, thus restricting process output and being costly add-ons to existing processes (Lovei 1995). So emissions trading came into action in the 1990s as a policy tool for monitoring pollution levels for a given area and granting permits to polluting facilities (Tribette 2012). Although emission trading has

[2] A detailed discussion of this complex history is beyond the scope of this research, but it is relevant to the growth in concern about the environment.

existed since the mid-1970s as an initiative of the U.S. EPA, the most successful experience with emissions trading was with the sulphur dioxide (SO2) cap-and-trade program created under Title IV of the 1990 Clean Air Act Amendments, referred to as the Acid Rain Program (Ellerman and Joskow 2003). Initially targeting electricity-generating units emitting the largest volume of SO2 and eventually all fossil-fuelled electricity-generating units, the Acid Rain Program issued tradable allowances, in which each allowance authorised one ton of SO2 emissions, while allowances not used in the year for which they were allocated could be banked for future use or sale (US EPA 2002).

By limiting the number of available allowances, significant emissions reduction was achieved and cost savings were also substantial compared to savings that would have been gained to obtain the same emission reductions without emissions trading (Ellerman and Joskow 2003). Intensified environmental awareness in the 1990s also stimulated international interest in developing International Standards by the International Organization for Standardization (ISO) to ensure products and services were safe, reliable and of good quality (Zhu, Geng, Fujita, and Hashimoto 2010). The ISO 14000 family series, for instance, was developed in 1996 to provide a framework for organisations looking to identify and control their environmental footprint, improve their environmental management systems and increase their long-run sustainability (Wall 1997; Zhu *et al.* 2010).

Since then, environmental management has gained increased interest among researchers in supply chain management as a core competitive strategy (Handfield and Nichols 1999; Sarkis 2001). Fundamentals of environmental management or “greening as a competitive initiative” were explained in detail by Porter and van der Linde (1995). Their basic reasoning was that investments in greening could lower the environmental impact of businesses and also lower the total cost of a product, improve its value, eliminate waste and enhance resource productivity. Sarkis (1995) introduced the concept of “environmentally-conscious manufacturing”, due to the ecological damage caused by industry’s enormous resource consumption. The massive amount of waste generated by manufacturing causes reduction from industrial activities to be one of the main objectives to greening the environment (Dornfield 2013).

Green manufacturing emerged as a significant environmental management approach for manufacturing organisations seeking to reduce their environmental impact while also achieving profit and market share objectives (Hoek 1999). Sarkis (2001) argued that profitability, productivity and environmental performance could no longer be isolated from the context of the manufacturing function. As opposed to traditional waste minimisation and pollution prevention strategies, *green* manufacturing responds to the shift in consumers' interest in purchasing *green* products while also ensuring high standards of environmental protection and sustainable business practices (Roarty 1997; Xue, Kumar, and Sutherland 2007). It is "an essential part of sustainable development: Development balanced with the Earth's capacity to supply natural resources and process wastes" (Bergmiller 2006, p.1). In this respect, integrating environmental thinking effectively in business operations and decision making is expected to generate significant competitive advantage as well as create additional value: satisfying customers' expectations and improving the role of business organisations in meeting the challenges of sustainability[3] (ElTayeb, Zailani, and Jayaraman 2010).

Industries ranging from manufacturing to agriculture appear to be at the core of the sustainability debate as they commonly result in contamination or degradation of the environment and surrounding ecosystems (Li, Liu, and Wang 2010). The 21st Century is an era of environmental consciousness, in which manufacturing organisations are inevitably facing increasing pressure to comply with environmental regulations and satisfy the public in regards to environmental issues (Abbasi and Nilsson 2012). *Green* manufacturing as Bergmiller (2006) described is a process by which an organisation's management system identifies the environmental impacts of its operations through a *Green* Supply Chain Management System (GSCMS), assesses current performance, and develops targets and plans to achieve sustainable environmental performance. It simply looks at industrial systems as ecosystems: closing the loop of normally open-ended processes, such as resource extraction and waste disposal, so that the waste of one process becomes the raw material of another (Faisal 2010). Saridogan (2012) claims that a GSCMS plays a critical role in the successful implementation of industrial ecosystems and industrial ecology.

[3] A definition of sustainability as regarded in this study is provided in the list of operational definitions and will be confirmed in the next chapter.

2.1.2 *Green* Manufacturing Practices

To optimise the environmental processes of a supply chain, the most commonly used *green* supply chain practices are: *green* supplier selection and performance evaluation, *green* purchasing, clean production, life cycle analysis, *green* packaging, *green* distribution and *green* logistics (Simpson, Power, and Samson 2007; Curran 2008; Barbar 2010; Fagan 2010; Jamshidi 2011; Saridogan 2012). These will be examined in more detail.

In terms of *green* supplier selection and evaluation, environmental criteria are considered in the selection and evaluation process of suppliers in addition to cost, quality, delivery, reliability and performance (Simpson, Power, and Samson 2007). Supplier selection and performance evaluation refers to approving suppliers in terms of their environmental performance and evaluating them regularly through the procurement function, in order to focus on process improvement while helping to foster environmental performance and avoid environmental risks that may arise from suppliers' environmental performance (Seuring and Müller 2008). Sahu, Datta, and Mahapatra (2012) claimed that suppliers' environmental performance plays a major role in optimising organisational environmental performance against environmental risks and penalties.

Green procurement, therefore, reduces the number of qualified suppliers due to stricter environmental quality standards (Min and Galle 1997). Saridogan (2012) considers *green* procurement as an effective means to address and reduce negative environmental impact by focusing on suppliers' environmental performance in addition to price, quality and delivery to insure purchasing environmentally friendly products. Starting with the product design phase, suppliers are integrated in participative decision making to systematically reduce upstream sources of waste (Bowen, Cousins, Lamming, and Faruk 2001; Saridogan 2012). Erdmenger (2003, p.11) defined *green* purchasing as encompassing "all activities that aim to integrate environmental considerations into the purchasing process, from the identification of the need, through the selection of an alternative, to the provision to the use". The aim is to try to avoid excessive or redundant purchases by reviewing the actual need for the product, or otherwise seek *green*er alternatives of the same (or better) quality and functionality as the conventional choice (Erdmenger 2003).

Clean production is an environmental preventive strategy addressing the generation of pollution as well as optimised use of resources at all stages of the production process (Hicks and Dietmar 2007; Fagan 2010). According to Ghazinoory (2005), clean production practices help conserve raw materials and energy, ensure reduction or elimination of toxic materials, and decrease the quantity and toxicity of emissions and wastes during the production process. Elimination of toxic materials and reduction of resources used can be achieved through activities such as recycling, product redesign, improved operation and maintenance process modification, and input substitution[4] (Thorpe 2009).

Life cycle analysis (LCA) is an analytical tool that goes beyond the boundaries of traditional analyses to asses all aspects of resource use, material extraction and potential environmental impacts that may pose a threat to human health and the environment over the entire life cycle of a product, that is, from raw material acquisition, via production and use phases, to waste management (Socolof and Geibig 2006; Finnvedena, Hauschildb, Ekvallc, Guinéed, Heijungsd, Hellwege, Koehlere, Penningtonf, and Suh 2009). LCA evaluates and considers all stages of a product's life as interdependent phases, meaning that decisions made at one stage can impact another stage in the life cycle (Curran 2008). By providing a comprehensive view of how our choices and decisions are connected to influence each point of the life cycle, a life cycle approach will help detect unintentional impacts of products and actions and take responsibility for those impacts (Vercalsteren, Spirinckx, and Geerken 2010).

Moving to the outbound side of a *green* supply chain, *green* packaging evaluates the potential and quality of any given package design using an expanded framework that adds optimisation of resources, responsible sourcing, use of safe materials and resource recovery[5] to conventional packaging, which only considers performance, cost, appearance and regulatory compliance (Zou, Xiong, and Xie 2009; Qing and Guirong 2012). *Green* packaging refers to environmentally friendly packaging that is

[4] Input substitution: replacing the inputs of a product with nontoxic or less polluting toxic raw materials (Berkel, Williems, and Lafleur 2008).

[5] Resource recovery: Adding value to major waste streams by offering substitutes to landfill disposal through practices such as reusing and recycling.

safe to handle and use, made of degradable and non-hazardous materials and can be reused and recycled after use or otherwise degraded (Barbar 2010).

Green logistics describes all attempts to measure and minimise the ecological impact of both forwards and reverse logistics activities (Jamshidi 2011). In addition to traditional logistics, which seeks to organise forward distribution – that is, the transport, warehousing, packaging and inventory management – *green* logistics works on measuring the environmental impacts arising from product manufacturing and distribution, decreasing the usage of energy and materials in logistics activities, following the guidelines of ISO 14000 and retrieving reusable products for reuse to satisfy the customers' environmental demands (Lai and Wong 2012).

2.1.3 ***Green* Waste**

From an environmental perspective, the primary wastes targeted by a typical GSCMS include hazardous or toxic waste, solid wastes, energy consumption and greenhouse gas emission (Green Jr, Zelbst, Meacham, and Bhadauria 2012). Under a GSCMS, pollution prevention and environmental waste reduction (including recycling) are regarded equally important to other traditional operational measures such as cost, quality and responsiveness (Hart and Milstein 2003; Cousins *et al.* 2008)**.** The logic behind that is that pollution and waste are actually poorly used resources that cost money to dispose of and can lead to potential liabilities (Bergmiller 2006).

The following section provides in-depth definitions of various *green* wastes and their environmental impact. A summary is provided in Table 2-1.

Toxic Hazardous Waste

The issue of toxic hazardous waste has been arguably the most dynamic environmental issue of the past four decades (Szasz 1994; Dornfield 2013). "Toxic materials are widely and heavily used in many manufacturing industries for both product development and process operations" releasing a huge amount of toxic chemical waste into the environment (Dornfield 2013, p.12). According to Yuan (2009), toxic waste refers to substances containing chemicals, heavy metals, radiation, or pathogens or otherwise harmless items that have turned into contaminated substances. Hazardous wastes can be liquids, solids, gases or sludges and, based on their release patterns, they may pollute water, air and land, posing a substantial hazard to human health, living organisms and the environment when improperly disposed because they are non-degradable and persistent in nature (Pankratz 2001; Dornfield 2013). Toxic hazardous waste is directly related to manufacturing's fast growth and can pose long-term risk to health or environment. Thus, almost all *green* manufacturing practices, mentioned above, aim to reduce the toxicity of the waste created at the end of a product's life cycle.

Solid Waste

In addition to toxic waste, the manufacturing industry also produces massive amounts of solid waste (Dornfield 2013). Solid waste, known as trash or garbage, refers to everyday non-hazardous waste, such as general wastes (organics and recyclables), special wastes (medical and industrial waste) and construction and demolition debris (Alhumoud and Al-Kandari 2008; Sharma, Destaw, Negash, Negussie, Endris, Meserte, Fentaw, and Ibrahime 2013). Solid waste directly affects all components of environmental and human health mainly due to inadequate or incomplete collection and recovery of recyclable wastes or from inappropriate design and maintenance of dumps and landfills (USAID 2009). Accordingly, *green* manufacturing practices such as *green* purchasing, LCA and *green* packaging aim to reduce the volume of solid waste sent to landfills in a way that is governed by the best principles of environmental protection and public health.

Fossil Fuel Related Energy Consumption

Since the energy consumed in manufacturing is mainly supplied from fossil fuels burned on-site, such as carbon, sulphur and nitrogen, the electricity generated produces significant amount of pollutants (such as carbon dioxide, sulphur dioxide and nitrogen oxides) which is believed to accelerate significant environmental effects like global warming, acidification and smog (Yuan 2009; Dornfield 2013). Although total energy consumption in the manufacturing sector decreased by 17 per cent from 2002 to 2010, manufacturing is still considered to include energy-intensive industries such as petroleum refining, chemicals, aluminium, iron and steel, paper, wood products and food (MECS 2013). Reducing energy consumption is the focus of clean production, LCA and *green* logistics.

Greenhouse Gas Emissions

Greenhouse gas emissions (such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and sulphur hexafluoride (SF6)) are another by-product of manufacturing, often referred to as the 'carbon footprint', that increases global temperature which, in turn, is believed to raise sea levels and threatens both the survival of the human race and its surrounding ecosystem (Sathiendrakumar 2003). As a catalyst for climate change, governments around the world are increasingly committed to support organisations to reduce their greenhouse gas emissions, particularly CO_2, in order to develop a low carbon economy (MSA 2009). Greenhouse gas emissions stem mainly from on-site burning of fossil-fuel including emissions from industrial processes such as electricity generation, petroleum refining and the production and processing of briquettes and natural gas (Gunasegaram and Tharumarajah 2009). Like toxic waste, all *green* manufacturing practices aim to eliminate greenhouse gases during the manufacturing process and at the end of a product life cycle.

Table 2-1: Summary of *Green* Wastes and their Environmental Impact

Type of Waste	**Environmental Impact**
Toxic waste (Pankratz 2001; Dornfield 2013)	▪ Pollutes water, air and land. ▪ Threatens ecosystems and human health.
Solid wastes (USAID 2009)	▪ Pollutes water, air and land. ▪ Threatens ecosystems and human health.
Fossil fuel related energy consumption (USAID 2009)	▪ Increases global warming, acidification and smog.
Greenhouse gas emission (Sathiendrakumar 2003)	▪ Major cause of climate change: raises global temperature and sea levels. ▪ Threatens ecosystems and human health.

Source: Original

2.1.4 **Conclusion**

The environmental movement in the 1960s is perhaps the most significant contemporary global movement to have emerged raising concerns about the relationship between humankind and nature. Increasing population levels, growing scarcity of resources, and concerns about toxicity and pollution inspired a widespread social movement around environmental issues. As people become more aware of the damage caused to the environment, environmental concerns of industry have been identified as a critical issue that organisations, and manufacturers in particular, must contend with.

Since manufacturing is material, water and energy-intensive – typically generating enormous amount of toxic and solid waste – manufacturers are under high pressure to comply with environmental regulation and behave in ways that reduce their ecological impact. As demonstrated in this chapter, one possible opportunity of incorporating environmental responsibility into manufacturing is through *green* manufacturing which utilises a *green* supply chain management system. Adopting *green* supply chain management practices to eliminate environmental waste in the form of inefficient use of resources or production of scrap from manufacturing processes have been demonstrated as a core environmental management approach for manufacturing organisations seeking to reduce their environmental impact and attract customers who are fundamentally interested in protecting the environment.

The next section will discuss *lean* manufacturing, the practices it involves and the waste it strives to eliminate, as another manufacturing approach towards sustainability.

2.2 ***Lean*** **Manufacturing**

2.2.1 **Background**

In 1890, mass production was emerging and was solidly established in the U.S. as an outgrowth of the Industrial Revolution and the desired need to keep costs down through economies of scale and mechanisation (Skinner 1985; Duguay, Landry, and Pasin 1997). However, mass production was rigid and inflexible because it was mainly concerned with reducing costs by increasing the volume of production (economies of scale) rather than assuring quality (Duguay *et al.* 1997). In Europe, manufacturing was largely based on “craft production” in which products were custom-assembled by master craftsmen to assure high quality, yet sold at very high prices (Hounshell 1984; Skinner 1985). Both manufacturing methods, mass and craft production, showed a trade-off between cross-functional performance criteria of productivity, quality and cost (Holweg 2007). Thus, the Japanese, in particular Toyota, initiated *lean* manufacturing to strike a balance between cost and productivity (availability of products) without compromising quality (Womack, Jones, and Ross 1990).

Lean manufacturing can be traced back to Henry Ford’s Model T automobile in 1908, as he produced an automobile that was very simple to assemble and easy and cheap to repair (Bak 2003). Ford’s goal was to construct an affordable automobile by attaining the productivity and low costs of mass production while sustaining the quality of craft production (Ford 1922; Womack *et al.* 1990). Though process specialisation and elimination of all sources of change[6] and waste[7] may engender additional costs, it was possible to reduce production costs gradually, thereby lowering the selling price of the Model T, with a selling price that would eventually be lowered to $400 (Duguay *et al.* 1997). In *My Life and Work* (Ford 1922, p.15), Ford provided a single-paragraph description that encompasses the entire concept of waste:

> I believe that the average farmer puts to a really useful purpose only about 5 per cent of the energy he expends.... Not only is everything done by hand, but seldom is a thought given to a logical arrangement. A farmer doing his chores will walk up and down a rickety ladder a dozen times. He will carry water for years instead of putting in a few lengths of pipe. His whole idea, when there is extra work to do, is to hire extra men. He thinks of putting money into improvements as an expense.... It is waste motion – waste effort – that makes farm prices high and profits low.

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[6] Change may stem from fluctuations in demand, raw materials availability, and lead times from suppliers (Duguay *et al.* 1997).

[7] Waste: Any activity that absorbs resources but creates no value from the customer’s perspective (Womack *et al.* 1990).

Henry Ford clearly understood forms of waste and the concepts of value-added time and effort. His methods of production made a limited range of standardised cars in massive assembly plants for mass-market customers in which each worker performed a highly specialised task very quickly and with endless repetition, giving Ford tremendous advantage over his competition (Gerrefi 1999). In the preface to Arnold and Faurote (1915) *Ford Methods and the Ford Shops*, Buxton Going wrote:

> Ford's success has startled the country, almost the world, financially, industrially, mechanically. It exhibits in higher degree than most persons would have thought possible the seemingly contradictory requirements of true efficiency, which are: constant increase of quality, great increase of pay to the workers, repeated reduction in cost to the consumer. And with these appears, as at once cause and effect, an absolutely incredible enlargement of output reaching something like one hundredfold in less than ten years, and an enormous profit to the manufacturer.

However, due to rapid change in customers' demands, Ford's early success began to decline (Womack and Jones 1996). The Model T, as Nevins and Hill (1957) explained, was not only limited in colour, but it was also limited to one specification so that all Model T frameworks were essentially identical through to the end of production in 1926. Accordingly, to improve operational performance by better adapting to rapid change in customers demand, *lean* manufacturing emerged from Japan during the 1950s and 1960s as an alternative to the traditional Fordism manufacturing model (Krafcik 1988; Taj and Morosan 2011).

The term "lean" as Womack and his colleagues describe it denotes a system pioneered by the Japanese engineers Taiichi Ohno and Shigeo Shingo to use less, in terms of all inputs, to create similar outputs to those of traditional mass production systems, while maintaining quality and offering increased varieties and a wider range of products to the final customer (Womack and Jones 1996). The concept and acceptance of *lean* manufacturing gained momentum in the early 1990s with the publication of the book *The Machine that Changed the World*, by Womack *et al.* (1990). The book gave an in-depth description of the most competitive auto manufacturers in the world, such as Toyota and Ford, and explained how Toyota, based on Ford's purest principles, was able to minimise waste and identify customers' needs through *lean* manufacturing practices. Since then, *lean* principles have become closely associated with Toyota's Production System (TPS) and a leading manufacturing paradigm in many other manufacturing industries (James-Moore and Gibbons 1997).

For this research, the interest in *lean* manufacturing lies in its well-developed supply chain management system and smooth optimised production flow that aim for cost reduction, quality improvement and rapid responsiveness via waste elimination and employee empowerment (Abdulmalek, Rajgopal, and Needy 2006). Optimising and smoothing production flow exposes quality problems that already exist so that waste reduction naturally takes a system-wide perspective (Holweg 2007). Meyer (2010), Torielli, Abrahams, Smillie, and Voigt (2011) and Carvalho *et al.* (2011) also indicated that a *lean* supply chain management system (LSCMS) aims to restructure suppliers and organise manufacturing facilities and processes to achieve flexibility, efficiency as well as satisfy customers' needs that may range from price, quality, availability, speed of delivery to a number of other factors like environmental sustainability and reacting to market changes.

2.2.2 ***Lean* Manufacturing Practices**

The most commonly used tools critical to optimising the processes of an LSCMS are: Just in Time (JIT), 5S (Sort, Straighten, Sweep, Standardise, and Sustain), Kaizen, VSM (Value Stream Mapping), Total Productive Maintenance (TPM), 3P (Production, Preparation and Process) and Six Sigma (Rahman, Laosirihongthong, and Sohal 2010; Singh, Garg, Sharma, and Grewel 2010).

Just in Time (JIT) is one of the main principles of *lean* that is directly associated with the elimination of waste including excess inventory and associated cost, defects, indirect labour, non-value adding activities and quality of materials (Aghazadeh 2003). The underlying philosophy is that storing unused inventory is a waste of resources. Denese, Romano, and Bortolotti (2012) explain that JIT practices allow organisations to effectively align deliveries from suppliers with manufacturers' and customers' needs while ensuring high-quality products at lowest possible cost with shortest possible lead time. Amoako-Gyampah and Gargeya (2001) describe it as a production strategy that strives to improve an organisation's financial and lead time performance by having close ties with suppliers and customers to meet production needs, improve performance and maintain high-quality control that consistently and continually satisfies customer needs while reducing in-process and completed inventory and associated carrying costs. Thus, JIT makes outstanding improvements in the areas of cost, quality and lead time through best use of inventory management, human resources, waste elimination and continuous improvement in process management (Kumar 2010).

The 5S approach (Sort, Straighten, Sweep, Standardise, and Sustain) is also a widely used methodology to improve performance in terms of productivity and quality because it is easily adopted and its implementation can yield immediate results (Ho, Cicmil, and Fung 1995). Its cyclical nature optimises productivity by maximising both efficiency and effectiveness and exposing hidden problems that may have otherwise remained unnoticed (Gapp, Fisher, and Kobayashi 2008). Bayo-Moriones, Bello-Pintado, and Javier Merino-Díaz (2010) break 5S down as follows: *Sort* focuses on eliminating items and/or activities that are not needed for current production operations; while *Straighten* or Set focuses on creating storage methods to arrange items so that they are easy to locate, use and store. On the other hand, *Sweep* or Shine, is to thoroughly clean the working area to sustain new improvements. Then to *Standardise* best practices, responsibilities and tasks are to be clearly assigned to personnel. The fifth and most difficult step is to *Sustain* or maintain the new procedures until they become 'the way things are done'. Finally, an additional sixth S, *Safety*, has evolved to maximise the level of workplace health and safety in conjunction with increased productivity (Gapp *et al.* 2008).

Kaizen is a set of continuous improvements of processes in manufacturing by engaging everyone from top managers to lowest skilled workers to drive and sustain performance improvement along three dimensions: quality, cost and delivery; with quality being given top priority (Ruin 2000; Al Smadi 2009). Liker and Convis (2011) outlined two types of Kaizen. The first is *Maintenance Kaizen*, which mainly deals with unexpected matters or inevitable mistakes that occur at the workplace, such as breakdowns, changes and variations, in an effort to bring the system back to the standard quickly (Liker and Convis 2011). Rothenberg, Pil, and Maxwell (2001) described Kaizen as engaging workers in detecting arising quality problems found on the production line, and contrary to the underlying philosophy of mass production, workers are able to stop the production line, identify and correct defects that occur in a process, prevent the production of defective products and investigate the root cause for such problems. The second type of Kaizen is *Improvement Kaizen,* which involves empowering employees to improve work methods, routines and procedures by cutting down waste with the aim of achieving perfection (Liker and Convis, 2011). Suarez-Barraza, Ramis-Pujol, and Kerbache (2011, p.300-301) state that cutting waste through Kaizen is "intended to improve the quality of processes and products, reduce lead time, optimise JIT delivery of goods and even enhance cash flow".

Value Stream Mapping (VSM) is another improvement tool but one which works on the big picture, focusing on the entire production process rather than individual processes (McDonalds, Van Aken, and Rentes 2002). VSM is based on the fundamental principle of *lean* manufacturing, which Garcia (2007, p.2) described as: "any activity or action which does not add value to the product is a form of waste and must be eliminated or minimized". VSM is a map that summarises the present and future state of a production system, allowing manufacturers to understand where they are and what wasteful activities need to be eliminated (based around *lean's* seven wastes discussed in the following section) in order to remain competitive and satisfy customers' needs (Lovelle 2001; Lasa, Laburu, and Vila 2008). Once the current state map has been analysed, the future state map can then be produced to show how the organisation could operate more effectively by adding value to the production process and making the most of its available resources (Pavnaskar, Gershenson, and Jambekar 2003; Manos 2006). Garcia (2007, p.2) clarified this view by stating that value is added at any time "the product is physically changed towards what the customer is planning to purchase" or "when a service is provided for which the customer is willing to pay".

Total Productive Maintenance (TPM) is a partnership approach between all organisational functions, particularly between production and maintenance, to constantly improve the performance of maintenance activities and equipment reliability (Maggard and Rhyne 1992). Total, in TPM, entails total employee involvement and total equipment effectiveness to achieve better results (Maggard and Rhyne 1992). The goal is to optimise equipment effectiveness throughout its lifetime and thus reduce as many production interruptions as possible due to unscheduled maintenance (Pascal 2010). TPM strives to maintain equipment in optimum condition in order to prevent unexpected breakdown, speed losses and quality defects caused by equipment degradation (Ahuja and Khamba 2008). Under TPM, maintenance is no longer an add-on non-profit activity but a necessary and vitally important part of the production (Pascal 2010). It is very much about ensuring safety, asset utilisation, low-cost maintenance and increased productivity without investing in new equipment or people (Ahuja and Khamba 2008). TPM has proved to control manufacturing cost, increase the life span of the manufacturing facilities, optimise quality and lead times while effectively managing safety and environmental issues by addressing potentially dangerous conditions and activities before they cause accidents, damage and unexpected costs (McKone, Schroeder, and Cua 2001; Ahuja and Khamba 2007).

Production Preparation Process (3P) is one of the most powerful advanced manufacturing tools that is typically used by organisations that have good experience in practicing *lean* tools and techniques to eliminate multiple process steps (US EPA 2003). Unlike the previous practices, 3P can improve performance, save capital and eliminate waste to a level beyond that which can be achieved through continual improvement processes, by focusing on waste elimination at the front end of product design. 3P encourages testing innovative ideas and challenges throughout the entire product development process (Ramakrishnan and Testani 2011; Coletta 2012). It is a highly disciplined, consistent model that results in the development of an improved production process with minimum waste levels (Rooney and Rooney 2005). The goal here is to ensure quality, safety, flow and efficiencies are built into the product new design (US EPA 2003).

Six Sigma is an improvement management approach to improve business profitability and enhance the organisation's products, services and processes performance by continually reducing defects and associated rework and replacement costs in the organisation (Kwak and Anbari 2006; Tjahjono, Ball, Vitanov, Scorzafave, Nogueira, Calleja, Minguet, Narasimha, Rivas, Srivastava, Srivastava, and Yadav 2010). Harry and Schroeder (2005, p.vii) define Six Sigma as “a business process that enables companies to increase profits dramatically by streamlining operations, improving quality and eliminating defects or mistakes in everything a company does, from filling out purchase orders to manufacturing airplane engines”. Unlike traditional quality management programs that have focused on detecting and correcting defects, Six Sigma focuses on reducing variation in processes and eliminating the causes of quality problems to prevent producing defects in the first place (Antony 2006).

2.2.3 **Conclusion**

Manufacturing has gone a long way during the past century. From craft production to mass production, the Japanese-pioneered *lean* production as a means to attain the benefits while avoiding the pitfalls of earlier production practices. *Lean* supply chain management practices optimise organisational processes by enabling *lean* organisations to eliminate waste and non-value added activities from organisational operations, reduce manufacturing costs, make the most of available resources, and optimise quality and lead times while effectively managing safety and environmental issues.

The next section will define the *lean* wastes that *lean* manufacturing techniques strive to eliminate.

2.2.4 ***Lean* Waste**

In *lean* manufacturing, as demonstrated above, the focus is on eliminating any non-value added activity that consumes resources and does not add value from the customer's perspective (US EPA 2003; Bergmiller 2006; Monczka, Hanfield, Giunipero, and Petterson 2009; Kuriger and Chen 2010). The customer in this case can either be internal or external to the manufacturing operation (Bergmiller 2006). Thus, waste stems mainly from unnecessary intensity of time, tasks, costs, errors and capital required for meeting customers’ needs (US EPA 2003; Cudney and Elrod 2011).

To be more specific, *lean* typically targets seven wastes. These could be defined along with their associated environmental impact as follows. A summary is provided in Table 2-2.

Defects

Any type of undesired result or failure to meet customers' demands is a defect (Nash and Poling 2008). It is a sign of an inefficient product design that either slows or stops the progress of an assembly line, causing other processes to wait until it is resolved or leads to unnecessary transportation if the product has made it to the customer and must be returned (Porter and van der Linde 1995; Bergmiller 2006). Defects incur additional non-value added use of labour and resources since the defective product is either scrapped or requires rework in order to bring it up to the desired standard (Nash and Poling 2008). Defects can also result in negative environmental impact: requiring additional resources for repair, more energy use for heating, cooling and lighting or even recycling or disposal (US EPA 2003). Defects, therefore, carry high-risk potential especially when a defect gets out to the field. Almost all *lean* practices (such as JIT, Kaizen, 3P, TPM and Six Sigma) aim to identify and eliminate root causes of defects, making it less likely for defects to recur.

Over-production

Over-production refers to "producing more than what is needed or making items before they are needed" (Kuriger and Chen 2010, p.2). Over-production is considered the worst of *lean* wastes because it either hides or generates all the other forms of *lean* waste mentioned in this section (LEI 2003). Besides the financial cost incurred from overproduction, overproduction affects the environment in three different ways. First, it increases the amount of raw materials and resources that must be consumed in production. Second, it increases the number of products that must be scrapped or discarded as waste. Finally, it increases the amount of energy, emissions and wastes (solid and hazardous) that are generated by processing the unneeded output (US EPA 2007). Thus, over production ties up valuable labour and material resources that might otherwise be used to respond to customer demand. The principles of *lean* manufacturing require aligning production with demand by pulling only what is the customer's need and JIT appears to be the main *lean* practice striving to minimise it.

Waiting

Waiting is any time spent adding no value to the production flow (Nash and Poling 2008). It results from inefficient layouts, bottlenecks or inability to match demand with output levels (Monczka *et al.* 2009). From an environmental perspective, waiting may cause products to spoil or get damaged and cause wasted energy from heating, cooling and lighting during production downtime (US EPA 2003). TPM and JIT work to eliminate non-value added time spent in the organisation because waiting causes delayed realisation of value to the organisation, further delaying the financial returns from products waiting throughout the supply chain.

Excess Inventory

Excess inventory indicates incompatible demand and supply (Hendricks and Singhal 2009). Kuriger and Chen (2010, p.75) stated that “excess inventory refers to any storage of supplies, raw materials, work-in-process, or finished goods that is not required to sustain a smooth flow of production”. Holding excessive inventory ties up capital which means reduced cash flow to the organisation (Hendricks and Singhal 2009; Steinker and Hoberg 2013). Excess inventory also impacts the environment negatively as it requires more packaging to be stored and more energy used to heat, cool and light inventory space (US EPA 2003). Organisations may even need to dispose of excess inventory if they no longer seems to meet market demand (Hendricks and Singhal 2009). Related to overproduction is excess inventory, which negatively impacts cash flow, uses valuable floor space and contributes to slowing supply chain response to changes in demand. Thus, JIT is once again the main *lean* practice that aims to minimise excess inventory.

Movement

Movement in the *lean* philosophy refers to unnecessary/non-value added movement of humans or products which could, otherwise, be used more productively (Kuriger and Chen 2010). The rationale of this *lean* element is that unnecessary transportation will lead to increased greenhouse gas emission as well as packaging to protect the product, which will eventually end in waste disposal. It also entails more energy consumption and emissions, which are significant contributors to negative environmental performance (US EPA 2007). Furthermore, Bergmiller (2006) suggested that excess human movement consumes human energy and may lead to fatigue that can cause defects and all of the problems that go with defects. Therefore, this *lean* principle calls for manufacturing operations to be as close as reasonably possible to suppliers and customers (Venkat and Wakeland 2006). *Lean* practices such as VSM, 5S and Kaizen are used to eliminate this type of waste because in supply chain management, missing a single on-time opportunity can be costly.

Over-processing

Over-processing refers to an overly complex process that surpasses the customer's requirement to produce a product even though more efficiently produced products would do (Torielli *et al.* 2011). Environmentally speaking, unnecessary processing increases wastes, energy use and emissions which entails consuming more raw materials per unit of production (US EPA 2003). Over-processing wastes can be difficult to identify because well-established processes are often overlooked. Yet VSM is frequently used to help identify non-value added steps in the process.

Table 2-2: Summary of *Lean* Wastes and their Environmental Impact

Type of Waste	**Environmental Impact**
Defects	▪ Additional resources and energy are consumed for reworking and repairing products. ▪ Defective products or parts may require recycling or disposal.
Over-production	▪ Additional raw materials and resources consumed in production. ▪ Increased waste, energy and emissions.
Waiting	▪ Wasted energy from heating, cooling and lighting during production downtime. ▪ Possible material spoilage or damage causing extra waste disposal.
Excess Inventory	▪ More packaging to be stored ▪ More energy used to heat, cool and light inventory space. ▪ Extra waste and disposal from undemanded inventory.
Movement	▪ More packaging required to protect components during movement. ▪ Increased risk of damage and spills of hazardous materials during transport. ▪ Increased waste, energy and greenhouse gas emission.
Over Processing	▪ More raw materials per unit of production. ▪ Increased wastes, energy use and emissions.

Source: Adapted from United States Environmental Protection Agency (US EPA 2003, 2007)

2.3 Conclusion

In the light of the explanation and description of both *green* and *lean* provided in this chapter, one can move towards the relationship between *green* and *lean* paradigms in supply chain management. Although each paradigm defines waste differently, the main similarity can be found in the objective of waste elimination in both paradigms.

Both *green* and *lean* target the elimination of excess waste in its broadest form: *green* targets environmental wastes in the form of inefficient use of resources or production of scrap, while *lean* targets all non-value adding activities summarised under seven wastes.

However, despite the different targets behind waste elimination in *green* and *lean* paradigms, they both indirectly target the same type of waste. As illustrated earlier in this chapter, all *lean* waste has a negative environmental impact, which signifies the implementation of *green* practices to eliminate them. For instance, inventory and movement are considered waste under both *lean* and *green* paradigms. While *lean* practices work to eliminate excess inventory as it ties up capital*, green* practices will also work to eliminate excess inventory as it requires more packaging to be stored and more energy used to heat, cool and light inventory space. It may also need to be disposed of because of a decrease in customers' demand, causing financial loss and impacting the environment. In terms of movement, both paradigms also aim for less movement to save cost and reduce greenhouse gas emission.

Therefore, integrating *green* and *lean* supply chain management systems appears to be the way forward in order to have even less waste in manufacturing by extending the application of *green* and *lean* paradigms to the entire supply chain and increasing the value delivered to customers. Since a *lean* supply chain does not directly target environmental waste, adding *green* practices to existing *lean* practices may extend the reach of the supply chain to eliminate both environmental and non-value added waste without much additional investment. The aim of this research is to demonstrate the synergy gained from an integrated approach.

The following chapter provides an extensive literature review around the topic of sustainability and supply chain management to better understand the relationship between *green* and *lean* supply chain management practices and how they can help organisations achieve sustainability and achieve better business performance outcomes.

3 Chapter 3 - Literature Review

This chapter provides a comprehensive literature review of the sustainability literature in addition to the direction of sustainability research in the context of supply chain management and procurement in the U.S. manufacturing industry and describes how alternative supply chain management systems (LSCMS-GSCMS) contribute to sustainable development.

3.1 **Sustainability**

3.1.1 **The Birth of Sustainability**

As noted in the introduction to the research, sustainability has grown out of several inter-related global issues: over-population, resource depletion, environmental degradation as well as poverty and inequality (Brander 2007). The notion of sustainable development can be traced back to the 18th Century when Enlightenment thinkers began to question the impact of rising population and resource depletion that could exceed available resources and cause a catastrophic failure of food supplies and infrastructure (Bell and Morse 1999). Thomas Robert Malthus was the first to foresee the limits to growth on the grounds of increased resource scarcity and rising population (Mebratu 1998). Although Malthus did not consider environmental issues, he did draw the public's attention to the Earth's finite capacity (Brander 2007). In his book *An Essay on the Principle of Population*, Malthus predicted that the fixed land base could not sustain the continuing growth in human population; and so population growth could not remain unchecked indefinitely (Malthus 1798; Brander 2007). Malthus argued that if people did not restrain their reproduction through preventive checks like late marriage and birth control to lower fertility, the population would be controlled by grim forces like war, disease, and starvation so as to meet food availability constraints (Bell and Morse 1999). Within this context, 'over-population' is considered the driving force behind environmental degradation and resource depletion. Yet it is an issue that is gaining less significance in academic and public debate due to the significant fall in fertility during the past decade (Brander 2007). The issue of over-population was raised again by Paul Ehrlich in his book *The Population Bomb* (1968), but this time in relation to its social and environmental impact (Cherfas 1980).

As mentioned in Chapter Two, Ehrlich cautioned against the rapid shift in the nation's development strategy from agriculture to manufacturing and heavy industries which intensified air pollution and added to the growing load of untreated human waste due to increased coal consumption and other fossil fuels as well as industrial chemical discharges (Leman, Omar, Jung, and Yusof 2010). The same issue was raised once again by Meadows *et al.* (1972) in their book *Limits to Growth.* The authors argued that unchecked population, consumption and economic growth could severely damage the ecosystem and social system on Earth**,** resulting in a sudden and uncontrollable decline in both population and industrial capacity (Meadows *et al.* 1972).

Another topic that increased public awareness to the issue of sustainability was the focus on environmental degradation (Brander 2007). The 1960s witnessed an increase in environmental awareness due to the post-war consumer boom and a dramatic increase in the consumption of resources (Hays 1982). As previously mentioned in Chapter Two, the year 1960 was described as a time of questioning and denial against widely publicised ecological events (DiMento and Oshio 2009). Rachel Carson (1962), through her book *Silent Spring*, was the first to launch the modern environmental movement when she called for a change in the way humankind viewed the natural world (Lamming and Hampson 1996). *Silent Spring* not only raised awareness about the issues of pesticides but also explained the ecological interactions, encouraging society to re-examine its relationship to the natural world (Carson 1962).

By the year 1970, known as the "environmental decade", environmental awareness grew considerably and a wave of national environmental legislation was put forward to ensure a safe, healthful environment (Merchant 2002; Brooks 2009). The U.S. Environmental Protection Agency (EPA) was also formed to enforce environmental law and the first Earth Day was born on April 22, 1970 to reflect a more fundamental concern with environmental issues (Merchant 2002). Under this setting, sustainability first emerged in the 1972 United Nations Conference on the Human Environment (UNCHE), held in Stockholm, Sweden, which was the first major conference proclaiming that the preservation of the environment is essential to the continued enjoyment of life itself and that humans throughout the world are to shape their actions with care for their environmental consequences (Blackburn 2007). Representatives to the 1972 Stockholm UNCHE believed that environmental and economic issues are to be resolved together in order to achieve sustainable outcomes (Ahern 2011).

At around the same time, development specialists realised that physical capital itself was not sufficient and that human capital was equally important (Duraiappah 2000). So while the concept of "sustainability" was often considered with environmental issues, the fledgling sustainability movement began to broaden as environmental campaigns started to encompass social and financial dimensions (Ahern 2011). Reducing inequality and poverty (resulting from racial discrimination, inequitable land tenure and access to natural resources) became one of the most socially and economically loaded concepts towards promoting sustainable development outcomes (Andrews 2011). Wilson (1987), in his book *The Truly Disadvantaged: The Inner City, The Underclass, and Public Policy,* revealed the dramatic increase of concentrated poverty throughout metropolitan areas of the United States during the 1970s. His book makes significant contributions to the state of knowledge regarding the growing poverty in the black community due to social and economic forces causing inequality of opportunities with regards to education, work and distribution of goods and resources (Wilson 1987).

The Apartheid racial segregation policies of South Africa in 1977, marking racial discrimination, was also coming under attack from Rev. Leon Sullivan, an African-American minister, and from other religious activists as they demanded equal treatment of employees regardless of their race both within and outside of the workplace (Clark and Worger 2004). Durning (1989) argued that poverty and inequality are both a cause and an effect of environmental degradation: poverty and inequality cause environmental degradation because poor people are far more reliant on natural resources; conversely, a degraded resource base directly contributes to further poverty, and so the process continues in a 'downward spiral'. Ramphal (1992, p.16) also stated that "Poverty and the environment are inextricably linked in a chain of cause and effect" which explains why Ramphal believed that the incidence of poverty is actually increasing in already poor countries. Thus, since the 1970s it has been almost universally agreed that approaching sustainable development requires expanding the original concept of sustainable development, meeting environmental concerns whilst maintaining economic development, to a more holistic concept where environmental, social and economic considerations are to be considered concurrently in decision making (Alam 2010).

The notion of sustainability as a rational human objective drew international attention in 1987 in a report titled *Our Common Future*, by the World Commission on Environment and Development, commonly referred to as the Brundtland Report (Werback 2009; Leonard 2010). The report included the "classic" definition of sustainable development most widely used today: "development which meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland 1987, p.8). Implicit in this definition is the recognition that sustainability is a complex challenge involving the intersection and interrelations among economic growth, environmental protection and social development to secure the wellbeing of the future rising population on a sustainable basis (Blackburn 2007). The Brundtland Report focused primarily on the needs and interests of humans, and was concerned with securing a global equity for future generations by redistributing resources towards poorer nations to encourage their economic growth (Brundtland 1987). Five years later leaders of 79 countries set out the principles of sustainable development, in 1992, at the United Nations Conference on Environment and Development in Rio de Janeiro, Brazil (Verrengia 2002). The Conference adopted several major agreements. Agenda 21, for example, was a global plan of action to promote sustainable development, the Rio Declaration on Environment and Development, a series of principles defining the rights and responsibilities of States and the United Nations Framework Convention on Climate Change to tackle the challenge posed by climate change as they recognised that the climate system is a shared resource whose stability can be affected by industrial and other emissions of carbon dioxide and other greenhouse gases (Keating 1994).

However, because sustainability practices in the 1980s were mainly implemented by choice in businesses, John Elkington introduced the Triple bottom Line (TBL) in 1994 as a more integrated and responsible way of conducting business and measuring corporate performance (Elkington 1997; Blackburn 2007). Unlike conventional business reports that focused mainly on financial performances**,** TBL (being inherently tied to the Local Agenda 21) is used as a framework for reporting on sustainability by measuring and reporting corporate performance against economic, social and environmental parameters and engaging communities over its implementation (Potts 2004). According to (Blackburn 2007), the financial or economic performance of an organisation is the easiest of the three parameters to measure accurately.

Financial performance takes into account the inflow and outflow of resources from the business, generally including cash and finances, assets, liabilities and other easily definable business resources. The economic criteria can then be used to determine how much an organisation generates in monetary value and can also be used to determine the net worth of the business at a given point in time. Meanwhile, environmental performance might be more difficult to measure as it is concerned with a business's total impact on the natural environment, entailing the efficient use of natural and economic resources along the life cycle of the product, from material extraction to manufacture, use and post-use disposal. The social performance of an organisation is also more difficult to define and measure taking into account the impact that a business has on people within the business (employees) and people outside of the business (the community). The interactions of financial and environmental perspectives will therefore be the focus in this study, while the social issues have been deferred to future research. Accordingly, for the purpose of this research, being a “sustainable business” means pursuing a “bottom line” strategy to save costs, reach new customers and increase profit while protecting the environment.

3.1.2 **Sustainability in a Manufacturing Context**

Sustainability can be regarded as a contemporary, core business strategy that refers to the long-term maintenance of responsibility towards environmental, economic and social performance (Fauzi, Svensson, and Abdul Rahman 2010). Public disclosure of sustainability-related information has been practiced throughout industries and organisations since the 1990s (Frost and Martinov-Bennie 2010). A recent global survey of CEOs by the United Nations found that 96 per cent believe that sustainability issues are critical to the future success of organisations (Worley 2011). Nevertheless, regardless of the number of initiatives and advertisements about organisations’ commitment to sustainable behaviour, Faisal (2010) and Bonn and

Fisher (2011) indicated that sustainability practices need to be integrated into an organisation's strategy, that is, throughout the entire organisational strategic supply chain, in order to be effective and achieve positive outcomes from the various trade-offs between environmental, economic and social dimension of a business. Frost and Martinov-Bennie (2010) reported that the aim to provide insights into the underlying activities of organisations (above and beyond financial performance) and their interactions with other parties.

The United States economy has been selected for review because it features among the most competitive and productive economies worldwide (United Nations 2011). Although the U.S. has slipped in terms of competitiveness in recent years (specifically in terms of environmental sustainability), it still maintains a strong manufacturing base, and continues to be well placed on most indicators related to living standards and quality of life (Sala-i-Martín, Bilbao-Osorio, Blanke, Crotti, Hanouz, Geiger, and Ko 2012; United Nations 2013). The World Economic Forum ranked the U.S. economy seventh out of 144 countries in the 2012–13 Global Competitiveness Report which triggers the debate about the importance of manufacturing as a foundation of economic development, employment, social stability and national security (Sala-i-Martín *et al.* 2012).

The U.S. manufacturing sector is still recognised as one of America's most vital industries, leading the current U.S. economic recovery in terms of employment and output gains, in 2010 and 2011 (Hemphill and Perry 2012). Manufacturing in the United States also supports activities like research and development (R&D) that has spill-over benefits for innovation and productivity, both for specific communities as well as for the broader economy, that cannot be captured by any single private sector, partly because knowledge and competences gained by production motivate the design and innovation of new products and new processes (Langdon and Lehrman 2012; Sperling 2013). Despite representing 12 per cent of U.S. GDP, manufacturing spill-over benefits include accounting for roughly 70 per cent of private sector research and development, 60 per cent of all US R&D employees, over 90 per cent of patents issued, and the majority of all U.S. exports (Sperling 2013). Manufacturing even holds the largest employment and economic multiplier effect of all sectors (Wezey and McConaghy 2011). A report by Considine (2012) suggests that the American steel industry, for instance, directly employed 150,700 in 2011, and given the potential multiplier effect, supported more than 1,022,009 jobs elsewhere, creating a 'multiplier' effect of x7. If the notion of the multiplier is accurate, then manufacturing is a significant engine of economic growth and a major component of a competitive economy (Dunham 2003). The U.S. Secretary, Bryson, discussed the importance of manufacturing in boosting U.S. economic growth, job creation and exports, providing fresh evidence that manufacturing jobs encourage innovation and support economic security for America’s middle class (United States Department of Commerce 2012).

Yet given the fact that manufacturing still depends mainly on the extraction and conversion of natural resources, availability of energy and water as well as space, air, rivers and seas are necessary to absorb the environmental waste manufacturing creates (Gutberlet 2000). Manufacturing appears to be at the forefront of those industries that need to address the issue of sustainability (Reich-Weiser 2010). Scientists released data showing that 2012 was the warmest decade since records began in 1850, arguably due to green-house gas emissions from industrial processes and post-consumption disposal products (Gillis 2013). Christopher, Khan, and Yurt (2011) supported the view that greenhouse gases are mainly caused by industrial activities such as manufacturing, energy production and transportation.

Improving environmental stewardship while maintaining financial sustainability and productivity remain viewed as strategic goals of manufacturing organisations (Davis 2012; Pham and Thomas 2012). Manufacturing organisations are being required to understand, evaluate, quantify and mitigate their externalities (environmental and societal impacts), through incentives, regulation or market pressures (Leahu-Aluas, Burstein, and Durham 2010). To maintain a state of dynamic balance in the long run, sustainable business practices in the manufacturing industry are increasingly becoming critical elements in supplier selection and performance evaluation to realise financial and environmental benefits (Robinson and Wilcox 2008).

The International Trade Administration, U.S. Department of Commerce (2011), described sustainable manufacturing as creating products through manufacturing processes with optimised use of natural resources and minimised environmental impact, while maintaining the health of the natural world. Sustainable manufacturing, as a concept, evolved from the concept of sustainable development coined at the

1992 UNCED conference in Rio de Janeiro to address concerns about issues such as environmental impact, economic development, globalisation and social inequities (Legette and Carter 2012). While the concept of manufacturing (everything from knitting to oil extraction to steel production) rests upon the idea of transforming raw materials into usable products (AMP 2012), sustainable manufacturing extends the concept of manufacturing to include a comprehensive strategy that nurtures a healthier environment by reducing the intensity of materials use, energy consumption, gas emissions and inventory while improving or at least maintaining financial performance (OECD 2011). In this respect, a focus on supply chain management is critical to target sustainability all the way through the life cycle of a product (Bergmiller 2006).

3.2 **Supply Chain Management**

The concept of Supply Chain Management (SCM) first appeared in the logistics literature as a suitable approach to meet the objectives of logistics while additionally focusing on integration and visibility of buyers and suppliers as well as minimising inventory buffers and related costs (Cooper and Ellram 1993). The Council of Supply Chain Management Professionals (CSCMP) defined logistics management as "that part of supply chain management that plans, implements and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements"[8] (Council of Logistics Management 2003). It also defined supply chain management as encompassing "the planning and management of all activities involved in sourcing and procurement, conversion and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers and customers. In essence, supply chain management integrates supply and demand management within and across companies" (Council of Logistics Management 2003).

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[8] This is a modified definition that has resulted from several changes in the process to understanding logistics which is beyond the scope of this research study.

The notion of logistics can be traced back to the Punic Wars of 218 B.C., when the Carthaginian general Hannibal took his infantry and cavalry across the Alps to conquer Rome (Jenkis 1995). Illustrating what we would regard as the business practice of Partnership Logistics to accomplish key objectives, Hannibal outsourced the transportation aspect to a logistics "partner" who supplied him with 37 elephants to cross the Alps, while he concentrated on his core competency-military tactics (Pappu and Mundy 2002). Since then, logistics has been used in military industries as military forces needed to use logistics models to move troops, equipment and supplies to the battlefield and ensure required materials, arms and supplies are available at the right place and on right time, that is, by focusing primary on physical distribution and warehouse management (Robenson, Copacino, and Howe 1994; Habib 2011).

In the 1960s, the term logistics merged into business language so as to manage the flow of information and product distribution within an organisation (Robenson *et al.* 1994). Yet during the 1970 and 1980s, many organisations came to realise the need for integrating different functional areas and business operations involved in the product development process that goes beyond logistics. Organisation recognised that sub-optimisation follows the attempt to optimise each business function’s output individually rather than integrating its goals and activities with other functions to optimise the output of the organisation as whole (Ellram and Cooper 1990).

The term “supply chain management” was therefore introduced to lift the mission of logistics to manage operations and extend the concept of functional integration to coordinate all processes and activities with and across suppliers, intermediaries (e.g. warehouses and transportation), third party providers (outside parties providing functions not performed by the firm) and customers in order to make the chain more efficient and competitive (Christopher 1992). The term "supply chain management" was first presented by Oliver while giving an interview to the Financial Times in 1982 as he defined SCM as the process of planning, implementing and controlling the operations of the supply chain in order to satisfy customer needs efficiently (Oliver and Webber 1982). The scope of the supply chain, as Stevens (1989) illustrates, extends beyond managing physical distribution to managing suppliers, procurement, materials, manufacturing, customer service and information flow from source of supply to point of consumption.

SCM gained its prominence in the 1990s and many authors have developed their own definitions, since then. To Scott and Westbrook (1991) SCM is “the chain linking each element of the production and supply process from raw materials through to the end customer”, illustrating that such a chain would cross several organisational boundaries (Scott and Westbrook 1991, p.23). Similarly, Christopher defined SCM as "the management of upstream and downstream relationships with suppliers and customers to deliver superior customer value at less cost to the supply chain as a whole" (Christopher 1992, p.3).

The four major objectives of SCM have been shown to be waste reduction, time compression, flexibility and unit cost reduction (Brewer and Speh 2000). It has also been claimed that a supply chain that achieves those goals will ultimately create financial and other tangible benefits including reduced operational expenses, lead time compression, increased efficiency and productivity and meeting customers’ demands (Duarte, Cabrita, and Machado 2011). So it appears that SCM is more than just logistics as it involves an integrative management approach seeking to use resources more efficiently and make the flows of products and information between firms a strategic matter by synchronising customers’ needs with suppliers’ material flow (Habib 2011).

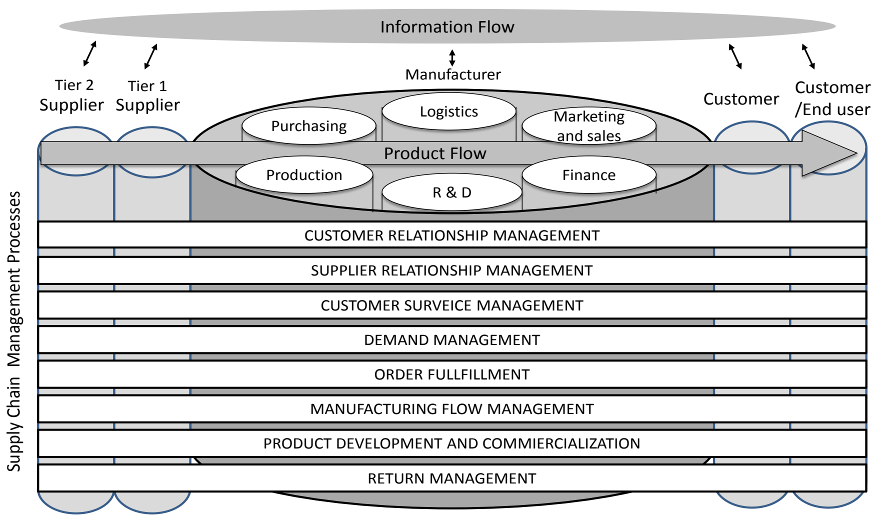

Figure 3-1: A Framework of Supply Chain Management

Source: Cooper, Lambert, and Pagh (1997, p.10)

As shown in Figure 3-1, Cooper *et al.* (1997, p.10) proposed a three-part framework that depicts a simple high-level summary view of the supply chain structure without being diverted by the infinite number of fine details that exist in complex supply chains. Managing a supply chain includes three inter-related essentials: Upstream suppliers, supply chain processes that must be integrated across organisations in the supply chain through common management components and downstream customers. Lambert, Cooper, and Pagh (1998) developed this model suggesting that implementing SCM entails identifying the critical supply chain members that deliver value (either directly or indirectly) to the end customers, implementing business processes and integrating them with key members of the supply chain in order to achieve specific supply chain objectives. To this end, both the left and right hand side of the model (see Figure 3-1) are critical given that suppliers' capabilities can have a direct impact on a customer's critical dimensions of cost, quality, technology, delivery, flexibility and profits, while customers' satisfaction is the main focus of a supply chain (Simpson and Power 2005).

Business processes were clearly defined by Zhou and Chen (2008, p.97) as "a set of interrelated activities that collectively accomplish specific business objectives, and accordingly convert inputs into outputs with the utilisation or consumption and incurred flow of human and physical resources, information, capital, etc.". In a manufacturing context, typical organisational support processes include purchasing, production, logistics, marketing and research and development, all focusing mainly on cost, time and output quality. Meanwhile, the eight supply chain management processes identified in Figure 10-1 seek to integrate business processes with the two critical ends of the supply chain in order to achieve supply chain objectives. Executives, in research conducted by Lambert (2008), expressed the view that organisational success requires key internal activities and business processes to be integrated and managed across multiple organisations. Supply chain management, as argued by Markley and Davis (2007) and Green, McGaughey, and Casey (2006), requires the integration of business process and activities as well as collaboration by all supply chain members to reduce total inventory level, reduce transaction costs and respond quickly to customers' demands. Based on the literature review and the Cooper *et al.* (1997) supply chain model, it is possible to identify the principal characteristics of *lean* and *green* supply chain management systems, which will be discussed in the following sections.

3.2.1 ***Lean* Supply Chain Management System**

A *Lean* Supply Chain Management System (LSCMS) is a production management system that focuses on optimising production flow, reducing production cost and resource needs while eliminating wasteful inefficiencies in every facet of the manufacturing supply chain (Simpson and Power 2005). The main objective of an LSCMS is to help align demand to capacity while optimising production lines, maximising energy and raw product utilisation and insuring a better quality product at minimum possible cost (Friedman 2008). Based on the Cooper *et al.* (1997) three-stage supply chain model, *lean* suppliers are known for their preventive maintenance, ordering flexibility and overall efficiency in converting resource inputs into outputs (Lewis 2000). *Lean* suppliers are also expected to be responsive to quality problems on the shop floor since *lean* production focuses on preventing defects, not just detecting them (US EPA 2003).

Lean supply chain processes such as procurement, are characterised by working with key suppliers that have a responsive production system to ensure low transaction cost and continuous improvement in technical and human capabilities (Boyle and Scherrer-Rathje 2009). By engaging directly with suppliers, organisations can gain visibility into resource management practices and waste minimisation and so add business value to *lean* production as well as meet customer demands (Fargo and MacAvoy 2010). *Lean* production, as opposed to mass manufacturing which stresses economies of scale, is based on a pull system in which nothing is produced by the upstream supplier until the downstream customer signals a need[9] (Jones, Hines, and Rich 1997). The Shingo Prize for Operational Excellence defined *pull* as “the concept of matching the rate of production to the level of demand” (The Shingo Prize 2012, p.18). For *pull* to be viable, *lean* production focuses on JIT delivery, minimised inventory levels, zero defects and flexibility to insure smooth production flow and short lead times (Levy 1997; Boyle and Scherrer-Rathje 2009).

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[9] The needs of the customer may be in terms of price, quality, availability, speed of delivery or a number of other factors, including environmental sustainability.

Therefore, *lean* logistics aims to minimise production and transportation lead times by eliminating all of the varying wastes in the system as well as managing and controlling the movement and geographical positioning of raw materials, work-in-process, and finished inventories at the lowest possible cost (Karlin 2006). *Lean* management, in this context, calls for distances within a supply chain to be as short as possible in order to react more flexibly to market changes and make the right product available to the end customer at the right time (Reichhart and Holweg 2007). Where supply chain members are in different countries, distance becomes a major inhibiting factor and increases risk to manufacturer. An LSCMS is, therefore, a continuous improvement approach to manage supply chains and ensure optimised level of production flow and cost savings, as well as minimise inefficiencies and quality defects in every facet of the supply chain to enhance an organisation's financial performance.

3.2.2 ***Green* Supply Chain Management System**

A *Green* Supply Chain Management System (GSCMS) is a production management system which integrates environmental criteria along the different phases of the supply chain (Lenny, Shi, Baldwin, and Cucchiella 2012). The main objective is to ensure minimum environmental impact along the life cycle of products (Lee 2008). Based on the Cooper *et al.* (1997) three-stage supply chain model, *green* suppliers are known to consistently improve environmental performance and comply with environmental regulations (Walton, Handfield, and Melnyk 1998).

Green supply chain processes, such as procurement, are characterised by working with key environmentally friendly raw material suppliers to control quality, reduce the use of hazardous materials and minimise unnecessary packaging (Rao 2007). Seuring and Müller (2008) found that collaborating with and evaluating suppliers helps organisations avoid environmental risks that may arise from suppliers' activities and thus improve overall supply chain performance. Meanwhile, *green* production is focused on increased efficiency through the reduction of energy consumption and the use of clean technologies (Bergmiller and McCright 2009b). *Green* production also includes eco-design or life cycle design which focuses on "products' environmental attributes, including energy efficiency, disassembly, long life and recyclability, maintainability and reusability" (Zongguang and Dayan 2011, p.73).

Green logistics also plays a critical role in reducing an organisation's environmental impact by working to minimise the environmental impact of logistics activities[10] such as air emissions, noise pollution and the use of large amount of land in addition to recapturing value of utilised materials and products though reverse logistics (Szymankiewicz 1993; Cojocariu 2013). Fleischmann, Bloemhf-Ruwaard, Dekker, Laan, Nunen, and Wassenhove (1997, p.1) defined reverse logistics as "the management of return flows induced by the various forms of reuse of products and materials in industrial production processes". According to Johnson (1998), reverse logistics represents the process by which organisations recapture value from by-products through recycling, reusing and reducing the amount of materials used. *Green* management, in this context, calls for improving environmental performance along the supply chain to support the overall environmental mission of the organisation (Zhu, Sarkis, and Geng 2005).

Changes in the state of the environment, rising public environmental awareness and stricter legislations necessitated an extended structure of a supply chain management system to consider the direct and indirect effects of products and processes through a GSCMS. Consideration of those environmental effects may eventually enhance an organisation's environmental performance.

3.3 Sustainability: A Key Element in Supply Chains

Production and consumption growth have generated unstable levels of wasting and pollution (Fagan 2010). Yet, as indicated by Fagan (2010), practicing an "end of pipe"[11] waste reduction technique is not sufficient without governing the production at source with sustainable strategies. The Congressional Budget Office (1985) indicated in their study that although end of pipe methods may seem easier to implement and enforce, they often transfer waste from one environmental medium to

[10] Logistical activities include freight, warehousing and materials handling operations.

[11] End-of-pipe: Waste is to be treated at the end of the production process by implementing add-on measures to comply with environmental regulations, like implementing filters and recycling materials (Frondel, Horbach, and Rennings 2007)

another. Waste reduction methods, such as the use of environmentally friendly materials on the other hand, minimise the chances of human exposure to toxic substances by eliminating waste at their point of source, rather than at the point of generation (CBO 1985). Faisal (2010a) suggested that by identifying exactly what, where and how industrial waste is produced in a supply chain, an effective supply chain management system can improve manufacturing efficiencies, reduce waste and greenhouse gas emission.

Traditionally, managing activities across the supply chain have been committed solely to increase financial gains (Shuaib, Metta, Lu, Badurdeen, Jawahir, and Goldsby 2011). Yet towards the end of the 20th Century and the start of the 21st Century, the critical role that supply chain management can play in contributing towards sustainability has gained increased interest in both academic literature and industry practice (Abbasi and Nilsson 2012; Walker and Jones 2012). As long ago as 1995, Bloemhof-Ruwaard, Beek, Hordijk, and Wassenhov (1995) observed that waste and emissions caused by the supply chain have become the main sources of serious environmental problems including global warming and acid rain. Policy makers increasingly support the fact that an organisation's success could be measured beyond the traditional financial bottom line to include social, ethical and environmental performance, all of which fall under the corporate jurisdiction of supply chain management (Markley and Davis 2007).

Since supply chains consider the product from initial processing of raw materials to delivery to the end customer, a focus on supply chains can target sustainability all the way through the life cycle of a product (Faisal 2010). Carter and Rogers (2008, p.368) defined sustainable SCM as "the strategic, transparent integration and achievement of an organisation's social, environmental, and economic goals in the systemic coordination of key inter-organisational business processes for improving the long-term economic performance of the individual company and its supply chains". Yet as mentioned earlier, the focus of this research will be limited to exploring the environmental and financial[12] goals of sustainability within SCM.

[12] A more precise and measurable sustainable performance indicator is the financial perspective arising from economic performance.

Two supply chain management systems have gained popularity in aiming for sustainability: *Lean Supply Chain Management Systems* (LSCMS) and *Green Supply Chain Management Systems* (GSCMS) (Bergmiller 2006; Reisman and Burns 2006). Although each system addresses different aspect of sustainability, both challenge the way resources are being used and aim to reduce waste within a supply chain (King and Lenox 2001; Bergmiller 2006). Rao (2005) indicated that for many organisations in South East Asia, implementing *green* supply chain management practices is a way to demonstrate their commitment to sustainability. Likewise, Found (2008) argued that by implementing the principles of *lean*, manufacturing companies can proactively enable sustainability across all key business processes in their organisation. So if the future challenge is to develop a sustainable global economy, one that the planet can support indefinitely, integrating LSCMS and GSCMS presents a major advance for supply chain managers in the 21st Century, and is claimed to be the key to gaining a sustainable future (Bergmiller 2006).

3.3.1 ***Lean*** **Supply Chains and Financial Sustainability**

Short-term financial returns, such as profit and return on investment, always outweigh longer term objectives such as caring for the environment, until natural events, such as Hurricane Katrina, occur and the long-term suddenly becomes the short-term (Langenwalter 2006). As might be expected, in order to deliver perceived value for money to stakeholders, financial savings and improved business performance seem to remain the prime motivations for manufacturers, according to Otley (2002). Thus, sustainable strategies are likely to fail unless they increase stakeholder value and create tangible financial gains followed by environmental and social benefits (Holliday 2001). As indicated in the previous section, sustainable business success today requires more than a robust bottom line, but rather a need to simultaneously balance social, environmental and financial goals.

To achieve financial sustainability, Holweg (2007) claimed that *lean* manufacturing which utilises a *lean* supply chain management system, can achieve financial sustainability. According to Wang (2010), financial sustainability in business is to achieve a balance between revenues and expenditures, with long-term profitability taking priority over short- term gains. The underlying philosophy of *lean*, as Friedman (2008) clarified, is to ensure that manufacturing equipment runs at peak efficiency, which is a key component of enabling financial sustainability. Simons and Mason (2003) as well as Cudney and Elrod (2011) demonstrated that implementing *lean* principles has shown considerable financial improvements to an organisation owing to optimised supply chain efficiency. Furthermore, focusing on the products flowing through the supply chain and allowing only strictly necessary materials to flow through the supply chain will lead to consistent improvements in quality, fewer defects, increases in on-time delivery and flexibility (Jones *et al.* 1997; Levy 1997). LSCMS may, therefore, enhance organisations' ability to achieve financial sustainability.

3.3.2 ***Green* Supply Chain and Environmental Sustainability**

Although financial performance is inevitably a major consideration, environmental performance is gaining increased attention due high levels of industrial pollution, ecological crises and disasters (Leszczynska 2010). Pollution problems have been found to occur even in the production of ice-cream with all-natural ingredients, as illustrated by Kassaye (2001) when he explained how Ben & Jerry's (an American ice cream company) struggled with waste disposal associated with by-products of the company's "premium" labels. Environmental management to proactively manage arising environmental issues has become critical for manufacturers to limit the impact of their operations and products on the natural environment (Vachon and Klassen 2008). A case study, carried out by Lee and Cheong (2011), showed that in the early 1990s the Republic of Korea Government established a policy to implement environmental management throughout the entire supply chain, and to improve public organisations' environmental performance the government set up national GSCM initiatives in 2003 based on that policy.

Many researchers have recognised the interrelationship between supply chain improvement and achieving environmental sustainability (Florida 1996; Lamming and Hampson 1996). *Green* manufacturing which utilises a *green* supply chain management system can proactively enable environmental sustainability across all key business processes (Lee and Cheong 2011). Mollenkopf *et al.* (2010) indicated that the concept of GSCMS within organisations has been increasingly accepted and implemented by organisations as a systematic approach to integrate environmental concerns into the supply chain management process. Lamming and Hampson (1996) as well as Florida (1996) identified the environment as a strategic SCM issue. Utsav (2012) supported the fact that environmental pollution due to industrial development is to be addressed together with supply chain management, thus contributing to GSCMS. Many organisations are reorganising and streamlining their supply chains so as to better face environmental strategic challenges and enhance ecological efficiency (Lee and Cheong 2011). GSCMS may, therefore, enhance organisations' ability to achieve environmental sustainability.

3.4 Sustainable Procurement

The increasing profile of SCM in the academic literature has been equally matched by a rise in procurement's strategic function within an organisation in response to global concerns regarding pollution, depletion of non-renewable resources, environmental degradation and increased global competition (King 2005; Cousins, Lawson, and Squire 2006). Emission of toxic or hazardous substances, waste generation, consumption of natural resources and the destruction of ecosystems are all impacts demonstrating unrestricted consumption according to (UNEP 2008). The World Summit on Sustainable Development (2002) signified the importance of changing current production and consumption patterns and identified procurement as a significant business process for achieving sustainable development. The United Nations Environment Programme (UNEP 2008) reported that a key role in promoting sustainable production and consumption patterns is through sustainable procurement. Krause *et al.* (2009) also asserted that an organisation is no more sustainable than the suppliers it sources from. This, according to Miemczyk, Johnsen, and Macquet (2012), makes procurement central to achieving sustainability.

Following the differentiation made by Murray (2009) and Van Weele (2010) between the terms *purchasing* and *procurement*, the term *procurement* will be used in this research as a more inclusive and strategic term than *purchasing.* Procurement includes questions about the need to spend, cut waste and seek innovative solutions. Van Weele (2010) defines procurement as purchasing products from the supplier which encompasses the purchasing function (determining specification, selecting suppliers, contracting), transportation and inspection, as well as quality control and assurance. Contract management was even included in the definition of procurement by the Department of Finance (2013) as well as the one provided by Callender (Callender and Matthews 2000). The Department of Finance (2013) defines procurement as “the entire process for obtaining all classes of resources (human, material, facilities and services). It can include planning, design, standards determination, specification writing, preparation of quotation and tender documentation, selection of suppliers, financing, contract administration, disposals, and other related functions”. So, unlike purchasing, procurement has a broader scope including responsibility for materials scheduling, inventory management, incoming inspections, and maintenance and quality control as well as managing contracts and selecting suppliers based on the life cycle cost of purchased goods rather than price.

Procurement was traditionally regarded as a clerical function concerned with transactions, order placement, inventory control and negotiating low cost contracts, rather than as a significant function to deliver organisational objectives (Pearson and Gritzmacher 1990). But as organisations struggle to increase customer value by improving their performance, many organisations are turning their attention to sustainable procurement as a significant way to deliver efficiency, sustainability and gain competitive advantage due to the way in which value of its procurement expenditure is managed (Robinson and Strandberg 2007; Cousins *et al.* 2008). Considering sustainability at an early stage of procurement, decision making can help avoid unnecessary consumption and identify opportunities that will lead to improved sustainability outcomes (QGCPO 2009).

In *Procuring the Future*, the output from Sustainable Procurement National Action Plan, the Sustainable Procurement Task Force (SPTF) defined sustainable procurement as “a process whereby organisations meet their needs for goods, services, works and utilities in a way that achieves value for money on a whole life basis in terms of generating benefits not only to the organisation, but also to society and the economy, whilst minimising damage to the environment” (SPTF 2006, p.11). The definition then elaborates on the meaning of ‘whole life basis’ by stating that “sustainable procurement should consider the environmental, social and economic consequences of design, non-renewable material use, manufacture and production methods, logistics, service, delivery, use, operation, maintenance, reuse, recycling options, disposal and suppliers’ capabilities to address these consequences throughout the supply chain” (SPTF 2006, p.11).

Sustainable procurement, as Cousins *et al.* (2008) and Walker and Brammer (2009) suggested, elevates procurement into a more strategic role by stretching the objectives of procurement beyond considering the traditional financial parameters to embrace the broader goals of sustainable development. It considers life-cycle costs while carefully evaluating the economic, social and environmental elements of every procurement decision (Kennards 2006). Put simply, Walker and Brammer (2012, p.257) defined sustainable procurement as “the pursuit of sustainable development objectives through the purchasing and supply process, incorporating social, environmental and economic aspects”.

Nijaki and Worrel (2012) found that procurement can be used as a valuable tool in moving towards the implementation of sustainability goals. Benefits flowing from sustainable procurement initiatives range from increasing supply chain efficiency to minimising supply disruption and enhancing the corporate image (Krause *et al.* 2009). It can also have a wider range of indirect benefits such as reduced landfill, CO_2 emissions and conserving non-renewable resources (SPTF 2006). Sustainable procurement, it is suggested, will extend the responsibility of business organisations from reactively reducing excess waste to proactively taking full responsibility for the sustainability of their products.

3.5 **Conclusion**

Sustainable development evolved as a result of significant concerns about the unintended social, environmental and economic consequences of rapid population growth, environmental degradation, social inequity and high levels of pollution and waste generation as well as intense consumption of natural resources. The background and literature review detailed in Chapters Two and Three illustrate how such concerns have given sustainability considerable importance in policy and research. In 1987, the Brundtland Report alerted the world to the urgent need for economic development that could be sustained without exhausting natural resources or harming the environment. The report defined sustainable development by highlighting the three fundamental components to sustainable development: reaching the best possible compromise between economic growth and social evolution, while respecting the natural environment.

The literature shows that manufacturing plays a key role in aiding the transition towards sustainable development. As one key to a robust economy, the concept of sustainable manufacturing has emerged to modify current production and consumption patterns and take greater responsibility for the impact of manufactured products by incorporating numerous approaches aimed at bringing about sustainability including sustainable supply chain management, sustainable procurement, environmental sustainability and financial sustainability. The critical role that supply chain management can play in contributing towards sustainability gained increased interest by the end of the 20th Century, as it could target sustainability all the way through the life cycle of a product.

Researchers have also indicated that modifying manufacturers' supply chains to integrate both *lean* and *green* supply chain management systems can help generate sustainable success beyond the scope of a given manufacturing system. While a GSCMS ensures minimum environmental impact along the life cycle of products in an aim to achieve environmental sustainability, an LSCMS ensures optimised levels of production flow and cost savings as well as minimised inefficiencies and quality defects in every facet of the manufacturing supply chain to achieve financial sustainability. Therefore, integrating LSCMS and GSCMS, as found in the literature, presents a major key to gaining a sustainable future.

Procurement has also been increasingly significant as a business process contributing to enhanced industrial sustainability due to the value of procurement expenditure and direct input into manufacturer performance. As demonstrated by the literature review, sustainable procurement elevates the procurement function to embrace the broader goals of sustainable development by considering life-cycle costs and balancing the financial, social and environmental elements of procurement decision making, rather than solely focusing on the traditional financial parameters.

This chapter has provided a comprehensive literature review of the sustainability literature within the context of supply chain management and procurement in the United States manufacturing industry and describes how alternative supply chain management systems (LSCMS-GSCMS) contribute to sustainable development. In an increasingly complex business environment, organisations may struggle to understand the various trade-offs when integrating both systems, as each system focuses on a different aspect of sustainability. Thus, developing a supply chain management system that allows for meaningful correlation between major principles of the two systems while realising the dynamics of an integrated approach is useful to simultaneously reduce a firm's environmental impact while achieving financial improvements.

The following are two questions used to stimulate the debate, which appears in the next chapter:

- Among the three pillars of sustainable development, short-term financial returns, such as profit and return on investment, seem to outweigh longer term objectives derived by environmental and social performance. So are the financial benefits derived from environmental performance high enough to tip the balance between an organisation's environmental and financial performance?

- Since *lean* and *green* supply chain management systems target different aspects of sustainability, can *lean* principals work synergetically with *green* practices or does integrating them entail trade-offs?

4 Chapter 4 - The Dilemma

This chapter highlights the most common challenges facing supply chain sustainability initiatives. In terms of the research into LSCMS and GSCMS, this chapter sheds light upon the ongoing debate regarding the compatibility of the environmental objectives of GSCMS with financial viability as well as the apparent contradiction between the promised benefits of *lean* and *green* supply chains. The chapter also synthesises previous *lean* and *green* manufacturing studies to help identify the research gap presented in the next chapter.

4.1 *Green* and Financial Performance: Does environmental sustainability pay?

The most frequently mentioned challenge in supply chain sustainability initiatives seems to be cost (McIntyre, Smith, Henham, and Pretlove 1998). In spite of the improvement in environmental performance resulting from a GSCMS, Bowen *et al.* (2001) indicated that organisations will only adopt *green* practices if they positively affect financial and operational performance. Walker and Brammer (2009, p.130) recognise the challenge around the cost-effectiveness of sustainable procurement that "are expected to play a crucial role in shaping the degree to which sustainable procurement policies are acted upon since *green*/socially responsible production methods are often perceived of as being inherently more expensive than other methods". The dilemma is, therefore, whether *green* environmental efforts will ultimately translate into improved market share and profitability (Tohamy 2009).

Due to the high costs of environmental compliance, the traditional view among economists and managers is that environmental initiatives impose additional costs on organisations and divert capital away from productive investments (Ambec, Cohen, Elgie, and Lanoie 2012). Tohamy (2009) argued that even though GSCMS is sometimes thought to be aligned with traditional business objectives, it can sometimes be contradictory. Dornfeld (2010) demonstrated that cutting down the transportation carbon footprint, for instance, is helpful as long as it does not affect other supply chain areas, such as inventory management and transportation lead-time. He further claimed that if one chooses rail as a lower carbon shipping mode option, the carbon emission per product will decrease while the longer lead-time delivery that may result will require greater safety inventory stock at the retailer or production facility. Meanwhile, greater inventory will need more floor space and that creates related impacts on energy and carbon emissions for their storage facility and warehouses. In that sense, as Tohamy (2009) found, *green*ing the supply chain must be based on strategies that examine the trade-offs between supply chain environmental initiatives and business objectives like profitability and efficiency across the integrated supply chain. Ambec *et al.* (2012) also explained that environmental regulations to reduce an externality such as pollution through technological standards, environmental taxes or tradable emissions permits drive organisations to assign some inputs (labour, capital) to an externality (pollution reduction) which is unproductive from a business perspective.

On the other hand, the early work of Porter (1991), Porter and Van der Linde (1995), Clelland, Dean, and Douglas (2000), Rao and Holt (2005) and Zhu (2010) challenged this traditional view and offered the view that organisations' profitability and pollution prevention are not mutually exclusive goals since a GSCMS has a great effect on increasing environmental performance, minimising waste and achieving cost savings. The authors suggest that pollution is often a waste of resources and that a reduction in pollution may lead to an improvement in the productivity with which resources are used. According to Porter (1991), "Strict environmental regulations do not inevitably hinder competitive advantage against rivals; indeed, they often enhance it" (Porter 1991, p.168). He went on to suggest various mechanisms by which environmental regulations might enhance competitiveness, such as reducing the use of costly chemicals or minimising waste disposal costs. Likewise, Porter and van der Linde (1995, p.120) argued that "properly designed environmental standards can trigger innovations that lower the total cost of a product or improve its value". Just as in the core of defects, they illustrate that pollution is a form of waste where resources have not been used completely and thus customers bear additional costs when they use products that pollute or waste energy (Porter and van der Linde 1995). An analysis by Clelland *et al.* (2000) also demonstrated that reducing pollution at the source provides a double bonus-enhanced operational efficiency and efficient pollution reduction which indicates that firms can obtain consistent operational-efficiency and gain spill-over effects from *green* waste-minimisation efforts.

Rao and Holt (2005) identified greening supply chains as a potential factor in the enhancement of financial performance and competitiveness of the organisation. Through their analysis, they demonstrated that greening both procurement and production enhances competitiveness and financial performance as operational costs are reduced. For instance, they explained that integrating suppliers and greening their operations greatly helps cut down production of waste at the source and so the organisation gains in terms of having less hazardous waste and air emissions to deal with. They note that "when waste, both hazardous and non-hazardous, is minimized as part of environmental management, it results in better utilization of natural resources, improved efficiency and higher productivity and reduces operating costs" (Rao and Holt 2005, p.907). Zhu (2010) also demonstrated, in an investigation of several Japanese manufacturers, that a GSCMS has resulted in significant environmental and financial improvements.

Although implementing a GSCMS may conflict with traditional business objectives, a GSCMS may better utilise natural resources, enhance sales, and exploit new market opportunities, all of which contribute to greater profitability and enhance the financial performance of an organisation. Taking a holistic view to understanding where the contradictory points and financial benefits actually occur seems to be critical to achieving financial feasibility. Tohamy (2009) suggests that *green* practitioners could take a supply chain wide view to ensure improvements in one area do not cause negative effects on another. Furthermore, Boyden (2004) believes that one of the threats to the validity of this *green*-financial performance link is that its success as a market instrument is totally reliant on having a large proportion of the market adopting these principles constantly in order to stimulate market shifts. Otherwise, in Boyden's (2004) view, the *green*-financial performance link will fail in its objectives and organisations that have adopted these sustainable initiatives may be at a financial disadvantage to those who do not adopt sustainable approaches, an outcome that could corrupt the market and create unfair cost advantage over manufacturers which have made the sustainability innovation in their products and services.

4.2 *Green* and *Lean* Practices

To gain both environmental and financial sustainability, integrating *green* and *lean* supply chain management systems has been the subject of significant debate and discussion. King and Lenox (2001, p.244) found strong evidence that "lean production, as measured by ISO 9000 adoption and low chemical inventories, is complementary to waste reduction and pollution reduction". They proposed, through an empirical analysis, that *lean* production may reduce the marginal cost of pollution reduction either by lowering the costs of implementing environmental improvement or by providing information about the value of pollution reduction (King and Lenox 2001). The U.S. Environmental Protection Authority (2003) promoted the link between *lean* practices and environmental innovation as a key approach to recognise new opportunities and embrace environmental sustainability.

A case study of General Motors Corporation (GM) revealed that GM has worked actively to integrate *lean* manufacturing and environmental systems since the early 1990s and by implementing Kanban, GM saved 17 tons per year in air emissions, eliminated 258 tons per year of solid waste and reduced hazardous waste generation from 4 kg per car to 1.5 kg per car (US EPA 2003). Likewise, Simon and Mason (2003, p.84) believe that "by taking a holistic approach to remove waste from the whole supply chain process, end-to-end, *lean* enterprises can deliver increased value for the end consumer while using up fewer resources". They argued that Value Stream Mapping (VSM), one of the *lean* strategies, can help organisations evaluate supply chain decisions in terms of environmental impact as well as quality, cost and delivery. VSM can also achieve end-to-end CO_2 minimisation and time to market, thus gaining *lean* and *green* benefits (Simons and Mason 2003).

According to the United States Environmental Protection Authority (2003), *lean* organisations already have waste reducing infrastructure within their supply chain, puts them well on their way to improve *green* results, even though environmental wastes such as pollution, resource consumption and hazardous materials are not explicitly included in the seven wastes of the Toyota Production System. Bergmiller and McCright (2009a) and Torielli *et al.* (2011) pointed out that from a sustainability perspective, most, if not all, environmental impacts can be viewed as waste and therefore it seems natural to use the *lean* philosophy as a powerful tool to improve environmental sustainability. Torielli *et al.* (2011) additionally argued that the manufacturing industry, in particular, is an industry where efficient production and environmental impacts are closely tied, synergising the implementation of *lean* and *green* philosophies to achieve financial and environmental sustainability.

However, despite the significance of the synergistic relationship between *lean* and *green* practices, Faisal (2010) illustrated that adopting sustainable practices is a daunting task due to the difficulty in considering the trade-off between the dimensions of sustainability. Franchetti, Bedal, Ulloa, and Grodek (2009) stated that the trade-off lies in the different views these practices have of the nature of the environment, where the environment is viewed as constraint in the *green* paradigm rather than a valuable resource as in the *lean* paradigm. A case study sponsored by the U.S. Environmental Protection Agency (EPA) (2003) to explore the relationship between *lean* production and environmental performance at the Boeing Company found that while *lean* production resulted in significant resource productivity and environmental improvements, it is more difficult for *lean* to realise such improvements when dealing with environmentally sensitive processes such as painting and chemical treatment.

Venkat and Wakeland (2006) analysed the environmental performance of *lean* supply chains, using CO_2 emissions as the key performance indicator. The authors found even though *lean* supply chains typically have lower emissions due to reduced inventory levels, they are not necessarily *green* due to the frequent inventory turnover at every point in the provision stream generally. Therefore, Venkat and Wakeland (2006) concluded that within a small regional supply chain *lean* would almost certainly be *green* due to the low levels of inventory required. However, as the supply chain increases in length and stretches farther geographically, emissions also increase leading to a *lean* and *green* conflict (Venkat and Wakeland 2006).

Bergmiller (2006) explained that although *lean's* focus on waste elimination potentially includes a decline of environmental waste, *lean* methods do not explicitly incorporate environmental performance considerations, which may result in “blind spots” with respect to environmental opportunities, improvements and life-cycle impacts. Likewise, although pollution prevention may “pay”, incorporating environmental consideration with *lean* implementation efforts may not always consider financial improvements. So there seem to be many synergies to be gained by an integrated approach, but there are also points of conflict that will need to be understood more clearly. The following chapter will synthesise previous *lean* and *green* manufacturing studies to form the research model for this study which will clarify the compatibility and trade-offs between *lean* and *green* supply chain paradigms that must be understood by defining supply chain attributes and understanding the relationship between those attributes and various supply chain key performance indicators (KPIs).

4.3 **Summary of the Literature Review**

Summarising the findings of the most recent sustainable development research in the manufacturing industry yields the following conclusions.

- Fully understanding an organisation's sustainability profile requires an understanding of an organisation's suppliers (Krause *et al.* 2009; Miemczyk *et al.* 2012) and the extended supply chain in which it operates (Markley and Davis 2007; Krause *et al.* 2009; Faisal 2010).
- Central to the sustainable development of organisations is the financial viability (Holliday 2001; Otley 2002; Langenwalter 2006; Walker and Brammer 2009) and environmental effectiveness of organisational activities (Leszczynska 2010; Abbasi and Nilsson 2012; Utsav 2012).
- The critical role that supply chain management can play in contributing towards sustainability has gained increased interest certainly by the end of the 20th Century, as it can target sustainability all the way through the life cycle of a product (Faisal 2010; Abbasi and Nilsson 2012; Walker and Jones 2012).
- Two supply chain management systems have gained popularity in targeting sustainability: *lean supply chain management systems* (LSCMS) and *green supply chain management system* (GSCMS) (Bergmiller 2006; Reisman and Burns 2006).
- *Green* manufacturing utilises a GSCMS to ensure minimum environmental impact along the life cycle of products (Mollenkopf *et al.* 2010; Lee and Cheong 2011). Meanwhile, *lean* manufacturing utilises an LSCMS to ensure an optimised level of production flow and cost savings as well as minimised inefficiencies and

quality defects in every facet of the manufacturing supply chain which is regarded as a key component to achieving financial sustainability (Simons and Mason 2003; Holweg 2007; Cudney and Elrod 2011).

- Researchers have indicated that modifying manufacturers' supply chains to integrate both *lean* and *green* supply chain management systems can help generate sustainable success outside of the typical scope of a given manufacturing system by capitalising on cost savings, product differentiation and environmental performance (King and Lenox 2001; Simons and Mason 2003; Bergmiller and McCright 2009a; Taubitz 2010; Torielli *et al.* 2011).
- As each of *lean* and *green* supply chain management systems focuses on a different aspect of sustainability, an integrated approach of both systems my result in blind spots or points of conflict when working to achieve sustainable results (Rothenberg *et al.* 2001; US EPA 2003; Bergmiller 2006; Venkat and Wakeland 2006; Faisal 2010).
- Procurement has been increasingly signified as a key business process contributing to enhanced industrial sustainability due to the value of its expenditure (King 2005; Cousins *et al.* 2006; UNEP 2008; Nijaki and Worrel 2012).
- Sustainable procurement elevates the procurement function to embrace the broader goals of sustainable development, by considering life-cycle costs and balancing the economic, social and environmental elements of procurement decision making, rather than solely focusing on the traditional financial parameters (Cousins *et al.* 2006; Kennards 2006; Walker and Brammer 2009).

4.4 **Conclusion**

From a managerial perspective, there are questions regarding trade-offs and potential synergies between environmental supply chain initiatives and financial objectives and between *lean* and *green* supply chain management systems.

With seemingly increasing demand for environmental sustainability, organisations are realising the strategic importance of environmental supply chain management practices to achieve a competitive advantage. Yet the issue of costs and revenues will probably remain the predominant drivers for either supporting competitiveness through improvements in environmental performance or ignoring the possibilities.

Due to the high costs of environmental compliance, there are questions regarding the trade-offs and potential synergies between supply chain environmental initiatives and an organisation's financial performance. Although a GSCMS may better utilise natural resources, enhance sales and exploit new market opportunities, all of which contribute to greater profitability and enhancing the financial performance of an organisation, there is an ongoing debate about the conflict between environmental management and financial objectives.

It was traditionally believed that investing in environmental goals is against a sound business strategy and a poor allocation of an organisation's investments. However, researchers have challenged this traditional view and offered the view that an organisation's profitability and pollution sustainability prevention are not mutually exclusive goals since a GSCMS is believed to have a great effect on increasing environmental performance, minimising waste and achieving cost savings for a manufacturing organisation (Porter 1991; Porter and van der Linde 1995; Clelland *et al.* 2000; Rao and Holt 2005; Zhu *et al.* 2010). By improving environmental performance, a GSCMS may help a manufacturer go beyond the standard environmental focus to increase capital efficiency and enhance sales which contribute to greater profitability and enhanced financial performance.

Moreover, to gain both environmental and financial sustainability, researchers investigated the complex relationship between *lean* and *green* performance (King and Lenox 2001; Simons and Mason 2003; US EPA 2003; Bergmiller and McCright 2009a; Torielli *et al.* 2011). Although the prevailing view is that there is an inherent trade-off between *lean* and *green* supply chain management systems, it has been argued that identifying environmental wastes via a LSCMS can help recognise financial and environmental improvement and provide new opportunities for competition while reducing the marginal cost of environmental performance (Simons and Mason 2003; Bergmiller 2006; US EPA 2007). An LSCMS already has waste reducing infrastructure and elimination methods that can extend to encompass environmental waste, such as pollution, resource consumption and hazardous materials since most of those environmental impacts reflect waste. *Lean* production may also reduce the marginal cost of pollution reduction either by lowering the costs of implementing environmental improvement or by providing information about the value of pollution reduction (King and Lenox 2001). The *lean* philosophy, therefore, can act as a powerful tool to improve environmental sustainability, synergising the relationship between *lean* and *green* performance to achieve financial and environmental sustainability. The aim of this research is therefore to demonstrate the synergies gained from an integrated approach and identify key factors for successful integration.

With regard to the literature review so far completed, achieving industrial sustainability seems possible through an integration of *lean* and *green* supply chain management systems. Yet the challenge is whether an integrated approach encompassing *lean* and *green* supply chain management systems can help achieve higher levels of industrial sustainability through a reduction of both operational and environmental waste while simultaneously enhancing or at least maintaining financial performance. At this point in the literature review, an integrated approach seems to hold a complex relationship that might end up in trade-offs between the two integrated supply chain management systems. Yet it seems that developing a supply chain management system that allows for meaningful correlation between the major principles of the two systems while realising the dynamics of an integrated approach could result in considerable financial and environmental improvements.

5 Chapter 5 - Research Model Construction

Chapter Five provides a description of the research gap this study seeks to fulfil. Identification of the research gap will guide the formation of the conceptual framework and proposal of the hypotheses this study seeks to examine, followed by identification of supply chain attributes and supply chain key performance indicators (KPIs) to understand the overlaps and trade-offs between *lean* and *green* supply chain paradigms and clarify their dynamic relationship.

5.1 Research Gap

The literature review demonstrates motivation, means and opportunity on the part of manufacturers to address the issue of sustainability, so as to modify current production and consumption patterns and take full responsibility of manufactured products by incorporating numerous approaches in bringing about sustainability such as LSCMS, GSCMS and sustainable procurement. Researchers have indicated that modifying manufacturers' supply chains to integrate both *lean* and *green* supply chain management systems holds significant potential for manufacturing industry to simultaneously realise sustainable success outside of the normal scope of a single manufacturing system by capitalising on cost savings, product differentiation and environmental performance (King and Lenox 2001; Simons and Mason 2003; Bergmiller and McCright 2009a; Taubitz 2010; Torielli *et al.* 2011). Yet the dilemma presented in Chapter Four shows that although there seems to be many synergies to be gained by an integrated approach, there are also points of conflict and blind spots that may occur and will need to be understood more clearly (Rothenberg *et al.* 2001; Bergmiller 2006; Venkat and Wakeland 2006). Studies have fallen short in presenting an approach that effectively merges *lean* and *green* paradigms in managing supply chains to help transform a supply chain and consequently transform an organisation into a sustainable entity.

A potential improvement will be to harness the synergetic effect of LSCMS and GSCMS integration by better understanding the relationship between *lean* and *green* supply chain management systems and identifying key factors that can help determine successful integration. Developing a supply chain management system that allows for meaningful correlation between the major principles of the two systems while realising the dynamics of an integrated approach is critical to achieve considerable financial and environmental improvements through an increase in capital efficiency, reduction of environmental impact and associated costs and enhancement in market reputation. For although *lean* and *green* thinking seem to have a great deal in common as they both challenge the way resources are being used, the nature of the integration management system is an implementation issue that needs to be addressed with a view to key factors such as management and organisational characteristics.

This research gap was captured by both Bergmiller (2006) and Carvalho *et al.* (2011). While Bergmiller's study acknowledged that *lean* and *green* paradigms exhibit synergies and have great potential for integration, he stated that "work must now begin to better understand integration points", indicating the significance of creating a single management system to "satisfy the requirements of both *Lean* and *Green* management system standards while maximizing synergies between these systems" (Bergmiller 2006, p.255). Bergmiller and McCright (2009a) suggested the need for an integrated approach to promote cost savings, product differentiation and environmental performance. Moreover, Carvalho *et al.* (2011), who investigated the synergies and divergences between the *lean*, agile, resilient and *green* paradigms and their effect within supply chain attributes using an anecdotal approach derived from their literature review, also stressed the necessity for further empirical research to validate their proposed relationship model that aimed to investigate the cause-effect relationship between supply chain attributes and supply chain measures under the impact of different supply chain management systems.

Thus, this research extends their studies both theoretically and empirically to better understand the relationship between *lean* and *green* manufacturing systems (i.e. points of conflict and synergies that may result from an integrated approach). It specifically investigates whether manufacturers adopting an integrated approach utilising both LSCMS and GSCMS can exhibit significantly higher levels of sustainability than manufacturers implementing either *lean* <u>or</u> *green* principles. In terms of reducing an organisation's lead time and environmental impact while simultaneously increasing supply chain responsiveness to customers and improving profitability, what factors contributing to successful implementation and attaining satisfaction with an implemented system? The research also takes a step forward in this knowledge by investigating the role of the procurement function in embrace the broader goals of sustainable development and enhancing an organisation's sustainable performance.

5.2 Research Framework

Philosophically speaking, *lean* and *green* manufacturing systems may start off targeting different types of waste. However, it appears that most wastes affect the objectives of the other system (Simons and Mason 2003). Therefore, an integrated approach, as depicted in Figure 5-1, is needed to capitalise on cost savings, product differentiation and environmental performance. The Venn diagram presented in Figure 5-1 also suggests that having sustainable procurement strategies in place may enhance the achievement of these objectives.

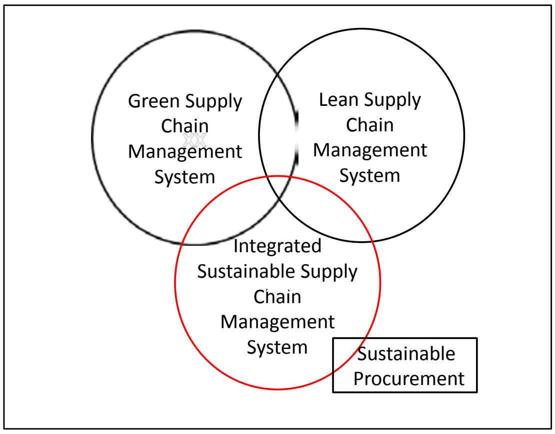


Figure 5-1: The Integrated Supply Chain Management System

Source: Original.

5.3 Hypotheses

An exhaustive literature review informed the development of the following hypotheses and further provided the base of the content of the survey instrument to be used to undertake a quantitative analysis.

Based on the literature review, integrating *green* and *lean* supply chain management systems has been shown to be the subject of significant debate and discussion in order to gain both environmental and financial sustainability. Researchers have indicated that modifying manufacturers' supply chains to integrate both *lean* and *green* supply chain management systems can help generate sustainable success beyond the normal scope of a given manufacturing system by capitalizing on cost savings, product differentiation and reduced environmental impact (King and Lenox 2001; Simons and Mason 2003; Bergmiller and McCright 2009a; Taubitz 2010; Torielli *et al.* 2011). King and Lenox (2001) proposed, through an empirical analysis, that *lean* production may reduce the marginal cost of pollution reduction either by lowering the costs of implementing environmental improvement or by providing information about the value of pollution reduction. Simon and Mason (2003, p.84) believed that "by taking a holistic approach to remove waste from the whole supply chain process, end-to-end, *lean* enterprises can deliver increased value for the end consumer while using up fewer resources". The U.S. Environmental Protection Authority (2003) also promoted the link between *lean* and *green* practices as a key approach to recognise new opportunities and embrace environmental sustainability. Torielli *et al.* (2011) additionally argued that the manufacturing industry, in particular, is an industry where efficient production and environmental impacts are closely tied, synergising the implementation of *lean* and *green* philosophies to achieve financial and environmental sustainability. Thus, the following hypothesis is proposed:

Hypothesis I: Manufacturers adopting an integrated approach utilising both LSCMS and GSCMS can exhibit significantly higher levels of sustainability than manufacturers implementing only *lean* or *green* principles in terms of reducing an organisation's environmental impact while simultaneously improving profitability and minimising the marginal cost of environmental performance.

The United States Environmental Protection Authority (2003) argued that since an LSCMS already aims to reduce waste along the supply chain, *lean* waste identification and elimination methods can spill over to reduce environmental waste, such as pollution, resource consumption and hazardous materials. Bergmiller and McCright (2009a) and Torielli *et al.* (2011) clarified that from a sustainability perspective, most if not all environmental impacts can be viewed as waste; therefore, it seems natural to use the *lean* philosophy as a powerful tool to improve environmental sustainability. In this respect, the following hypothesis is suggested:

Hypothesis II: Significant environmental benefits can be typically derived from *lean* initiatives due to *lean*'s waste elimination culture.

It is an argument consistently made by a number of prior studies that that there is an inherent trade-off between *lean* and *green* supply chain management systems (Rothenberg *et al.* 2001; US EPA 2003; Bergmiller 2006; Venkat and Wakeland 2006; Faisal 2010). Faisal (2010) argued that adopting sustainable practices is a daunting task due to the difficulty in considering the trade-off between the dimensions of sustainability. According to Bergmiller (2006), although *lean* may produce environmental benefits, *lean* methods do not explicitly incorporate environmental performance considerations which may result in "blind spots" with respect to environmental opportunities, improvements and life-cycle impacts. Thus, the following hypotheses are proposed:

Hypothesis III: An integrated approach encompassing both GSCMS and LSCMS may result in trade-offs of either system.

Hypothesis IV: Key factors may contribute to successful integration of *lean* and *green* supply chain management system and attainment of enhanced levels of sustainability within an implemented supply chain management system.

Finally, in response to global concerns regarding pollution, depletion of non-renewable resources, environmental degradation and increased global competition, the literature demonstrates that procurement has been increasingly signified as a key business process contributing to enhance industrial sustainability due to the value of procurement expenditure (King 2005; Cousins *et al.* 2006; UNEP 2008; Nijaki and Worrel 2012). Accordingly, the following hypothesis was developed:

Hypothesis V: The procurement function within an organisation has a significant impact on achieving sustainability goals by considering life-cycle costs and reducing upstream sources of waste.

5.4 Supply Chain Attributes

Supply chain management attributes are the enablers or features that characterise a supply chain and enable a supply chain paradigm to achieve core competencies and sustained competitive advantage over competitors (Morash, Droge, and Vickery 1996; Carvalho *et al.* 2011). The constitution of such enablers could determine entire supply chain behaviour and enable the measurement of supply chain performance. Thus, for the purpose of this research, an enabler is considered as a variable that enables the attainment of sustainability in a supply chain.

It is apparent from the literature review that various enablers influence organisations in their approach to sustainable supply chain management. Based on research by Carvalho, Daurte, and Machado (2011), the following supply chain attributes were considered: surplus capacity[13], inventory level, turnover frequency, production lead time and transportation lead time. In addition, the procurement function will also be considered as a supply chain attribute since it appears to have a significant impact on achieving sustainability goals, such as reducing overall costs and emission rates. The value of those attributes is altered by adapting different supply chain paradigms (Carvalho *et al.* 2011), including LSCMS and GSCMS.

5.5 Supply Chain Key Performance Indicators (KPIs)

To develop an efficient supply chain, it is necessary to assess its performance. The literature demonstrates the importance of performance indicators to give managers the information they need in managing their organisations and understanding the extent to which their supply chains are financially and environmentally sustainable and competitive (Morgan 2007; Duarte *et al.* 2011). Consequently, it is necessary to identify which KPIs are crucial to the target industry (Morgan, 2007). Yet a holistic approach could be adopted in approaching the topic of KPIs in order to encompass the different entities of the supply chain, show which aspects of performance must be improved and indicate the direction of change (Chia, Goh, and Hum 2009; Duarte *et al.* 2011). Again, following Carvalho, Daurte, and Machado (2011), cost, service level and lead time were considered to be the three most representative KPIs to evaluate the effect of a supply chain paradigm, whereas, quality is a prerequisite for *lean* and *green* paradigms to sustain the supply chain performance (Carvalho *et al.*

[13] Surplus capacity refers to materials, water, energy, personnel, and equipment that are either excessive or not working to maximum capacity.

2011). In this context, lead time refers to the time required to either produce or deliver an item, cost refers to the overall, cost of manufacturing a product and delivering it to the ultimate customer, while service level accounts for the per cent of orders that customers receive on time.

Yet since those three KPIs focus mainly on the financial side of a supply chain's sustainable performance, three additional KPIs were considered in this research to evaluate the environmental impact of a supply chain's sustainable performance. Based on the literature review, greenhouse gas emission, resource utilisation and solid or toxic waste are the three main KPIs to assess the environmental impact of a supply chain paradigm. In this context, greenhouse gas emission refers to carbon foot print of an organisation's production process, resource utilisation accounts for the per cent of energy, water and raw materials utilised per unit of production, while solid/toxic wastes refer to the amount of non-hazardous or contaminating substances resulting during the life cycle of a manufactured product.

5.6 Relationships between KPIs, Supply Chain Attributes and Paradigms

The overlaps and trade-offs between *lean* and *green* supply chain paradigms need to be understood to help organisations and supply chains become more efficient, streamlined and sustainable. To this end, it is necessary to develop a deep understanding of the cause-effect relationship between various supply chain characteristics and supply chain attributes, and their effect on supply chain key performance indicators (Cai *et al.* 2009; Carvalho *et al.* 2011). Table 5-1 depicts the effect of supply chain attributes on supply chain KPIs, in which a positive link means that the two nodes move in the same direction, whereas, a negative link means an increase in one node will cause a decrease in another node (if all else remains equal).

Table 5-1: The Effect of Supply Chain Attributes on Supply Chain Key Performance Indicators

KPI / Attributes	Responsiveness /service level	Cost	Lead time	Resource utilisation	Gas emission	Solid/ toxic waste
Inventory level	+/-	+		+	+	+
Turnover frequency	+	+			+	
Transportation lead time	–	–	+		-	
Production lead time	–	+	+	-	+	+
Surplus capacity	+	+		-	+	+
Procurement sustainable performance	+	-	-	-	-	-

Source: Original Table

Inspired by Carvalho, Daurte, and Machado (2011) and based on the outcomes shown in Table 3, The following section will discuss the cause-effect relationships between supply chain attributes and supply chain KPIs mentioned above, under the impact of *lean* and *green* supply chain management practices.

5.6.1 ***Lean* Conceptual Model: The impact of *lean* paradigm on supply chain KPIs and supply chain attributes' inter-relationship**

Based on the literature review presented in Chapter Three, an LSCMS is a paradigm based on cost reduction and flexibility, inventory minimisation, lead time reduction, optimised use of resources, optimised production flow and Just-in-Time (JIT) practices (Simpson and Power 2005). Lewis (2000) indicated that *lean* suppliers are characterised by their preventive maintenance, ordering flexibility and optimised use of resources. Meanwhile, *lean* production is based on a pull system[14] and a JIT strategy to reduce inventory levels and the cost of holding inventory[15] as well as to minimise movement distances and surplus capacity[16] to ensure smooth flow of materials (Aghazadeh 2003; Jeffery, Butler, and Malone 2008). Accordingly, *lean* logistics aims to reduce surplus capacity as well as production and transportation

[14] In a pull system nothing is produced by the upstream supplier until the downstream customer signals a need. The Shingo Prize for Operational Excellence defined *pull* as "the concept of matching the rate of production to the level of demand" (The Shingo Prize 2012, p.18).
[15] Cost of holding inventory: Warehousing costs and the decrease in the value of products from the time they are manufactured until sold.
[16] Surplus capacity: Redundant materials, machines and processes.

lead times to ensure efficient flows of materials from the point of consumption to production at the lowest possible cost (Karlin 2006).

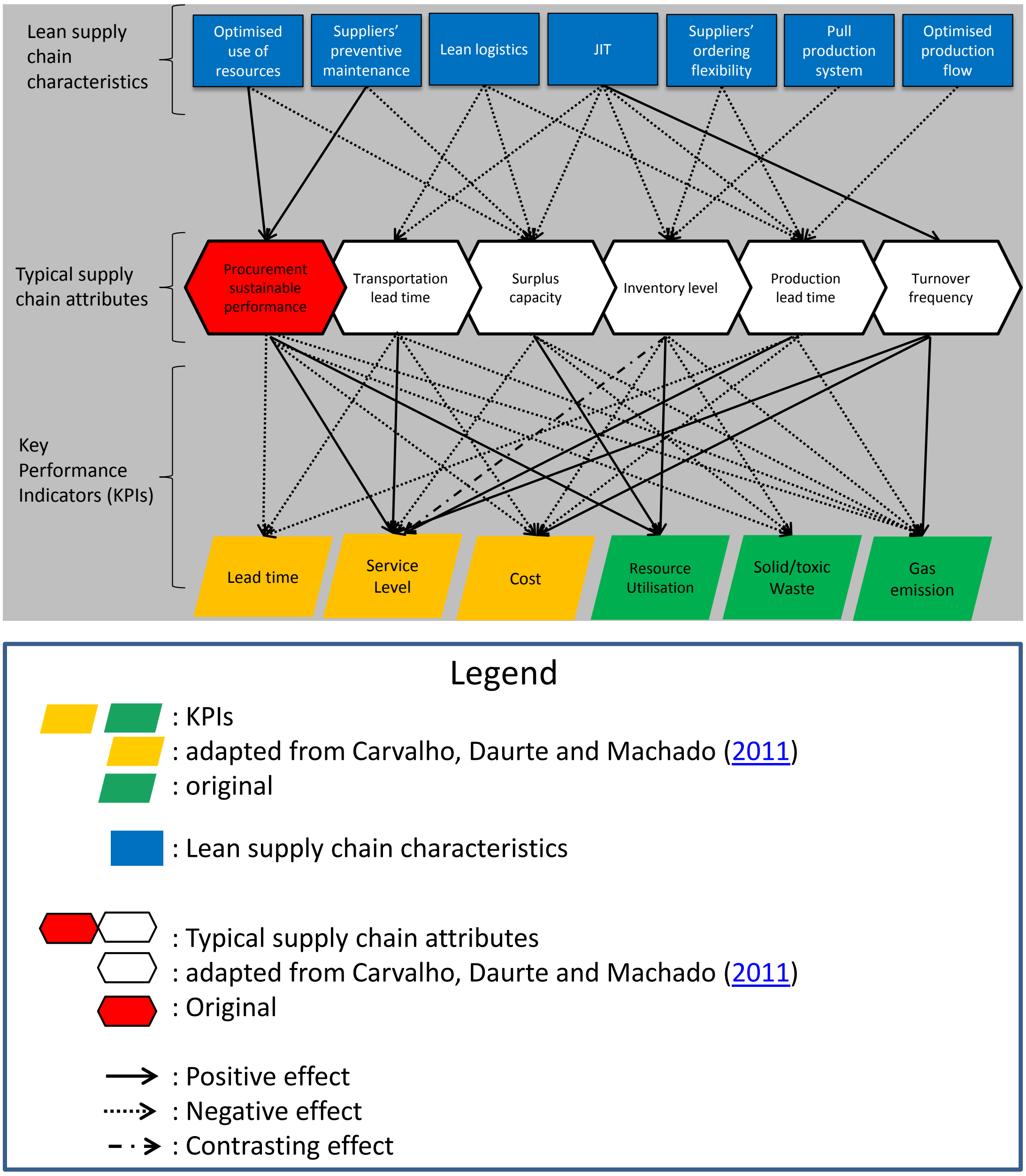


Figure 5-2: A Dynamic Model of the Outcomes of *Lean* Characteristics on Supply Chain Attributes

Source: Original

Figure 5-2 depicts the following interpretations derived from the literature:

- Suppliers' ordering flexibility decreases production lead time which is helpful in reducing unnecessary inventory.
- Suppliers' preventive maintenance approach and optimised use of resources increases procurement sustainable performance and decreases surplus capacity.
- *Lean*'s production pull system causes a decrease in an organisation's surplus capacity and inventory levels.
- *Lean*'s optimised production flow decreases production lead time.
- JIT practices increase turnover frequency while simultaneously reducing inventory levels and associated costs, lead times and surplus capacity to ensure smooth flow of materials.
- *Lean* logistics works to streamline activities so as to reduce transportation and production lead time and surplus capacity.

Accordingly, in terms of the cause-effect relationship among supply chain attributes and the KPIs, significant cost-savings can be achieved by all of the supply chain attributes that an LSCMS aims for, except for turnover frequency. Short production and transportation lead time minimises the overall supply chain cost because short lead times reduce inventory levels which in turn reduces the cost of holding inventory. Reducing inventory levels also reduces unnecessary expenses to the supply chain. Similarly, reducing surplus capacity decreases cost by better utilising capacity. Although keeping higher capacity reduces stock-out costs, it still creates additional costs because of the cost of investing in extra capacity. Similarly, although sustainable procurement might sometimes be seen as causing higher initial costs, a decrease in cost is actually achieved in the long run by focusing on value for money over the whole-of-life of products. Meanwhile, an increase in turnover frequency entails an increase in cost due to frequent transport of small quantities of inventory.

In terms of supply chain responsiveness to customers (service level), enhancement in supply chain service level can be achieved from *lean*'s effect on supply chain attributes except from *lean*'s reduction of surplus capacity and inventory levels. As demonstrated in Figure 5-2, minimising production and transportation lead time, while increasing turn over frequency and procurement sustainable performance, increases supply chain service level. Yet a decrease in surplus capacity reduces service levels and responsiveness to growing customer needs, since excess capacity works as a buffer against production or demand shocks. Yet in terms of inventory levels, *lean*'s reduction of inventory levels has two contrasting effects on the service level. A decrease in inventory levels enhances flexibility to respond to sudden changes in customers' demands and therefore increases service level without incurring additional costs of holding unnecessary inventory and so decreases the potential for waste in volatile conditions, whereas a decrease in inventory levels may result in stock outs and thus decrease in service level when there is an increase in customers' demand.

Moving to the lead time performance indicator, an LSCMS affects lead time performance negatively as it works to ensure smooth flow of materials by working with flexible suppliers, implementing JIT practices, and calling for distances on a supply chain to be as short as possible in order to react more flexibly to market changes.

Finally, in terms of *lean*'s impact on the environment, a reduction of surplus capacity, production and transportation lead times, inventory levels through JIT practices and pull production entails a reduction in the overall supply chain environmental impact by reducing gas emission and solid toxic waste while increasing resource utilisation per unit of production. An increase in procurement sustainable performance through suppliers' optimised use of resources also reduces gas emission and solid toxic waste. However, an increase in inventory turnovers causes an increase in gas emission.

5.6.2 ***Green* Conceptual Model: The impact of *green* paradigm on supply chain KPIs and supply chain attributes' inter-relationship**

Based on the literature review presented in Chapter Three, a GSCMS is a paradigm based on ensuring minimum environmental impact along the life cycle of a product (Lee 2008). *Green* suppliers are characterised by their reduced use of hazardous materials and unnecessary packaging (Rao 2007; Zongguang and Dayan 2011). In terms of production, a GSCMS is also known for its clean production, use of LCA as well as minimised redundancies and unnecessary materials and processes in the supply chain to ensure optimised use of resources and address the generation of pollution and waste over the entire life cycle of a product (Socolof and Geibig 2006; Finnvedena *et al.* 2009; Bergmiller and McCright 2009b; Fagan 2010). *Green* logistics, which aims to reduce surplus capacity, contributes to environmental protection by focusing on minimising the environmental impact of logistics activities[17] such as air emissions, noise pollution and land occupation in addition to recapturing value of utilised materials and products through recycling and reusing activities (Szymankiewicz 1993; Cojocariu 2013).

[17] Logistics activities: Freight, warehousing and materials handling operations.

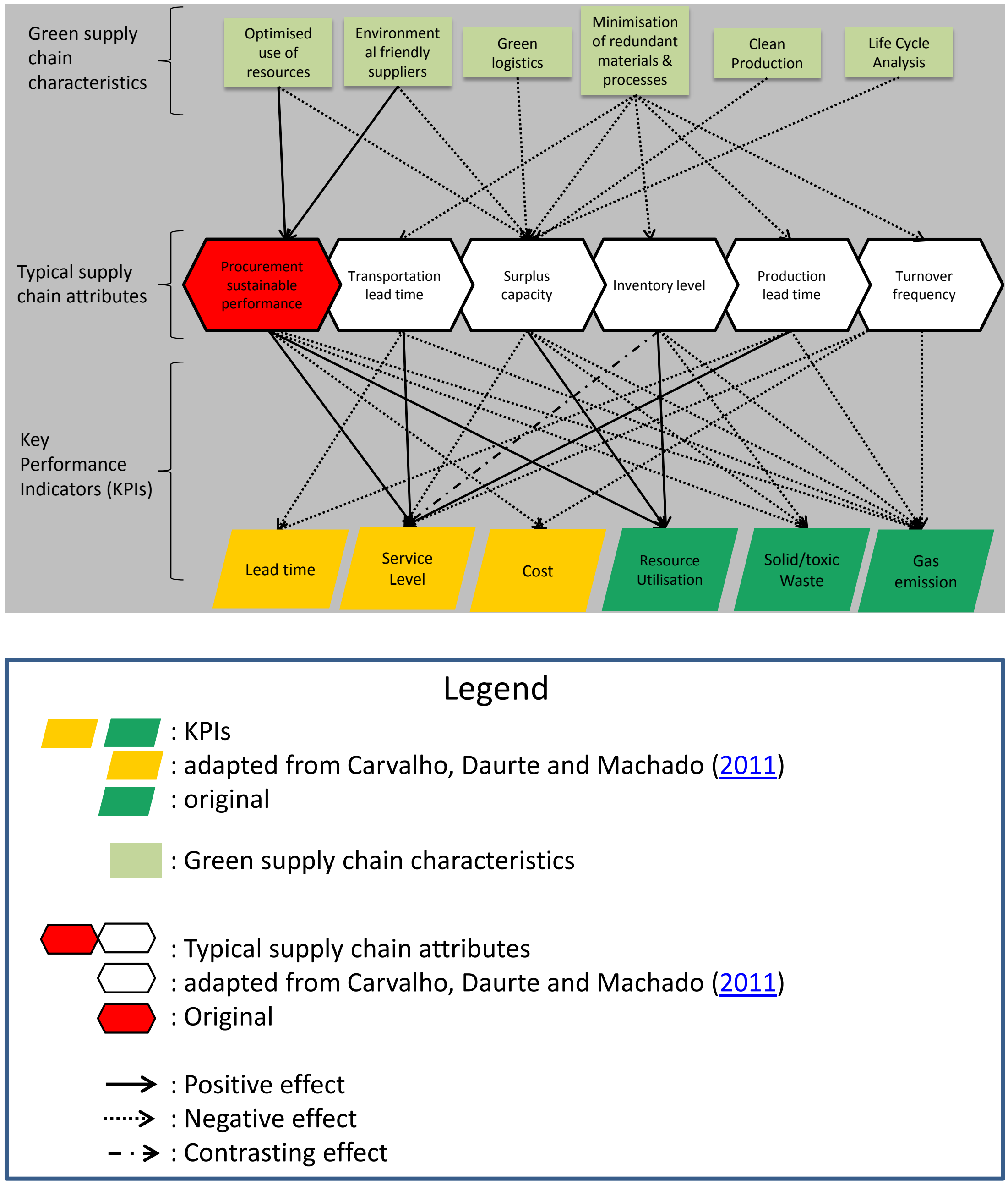


Figure 5-3: A Dynamic Model of the Outcomes of *Green* Characteristics on Supply Chain Attributes

Source: Original

Figure 5-3 depicts the following interpretations derived from the literature:

- Working with environmentally friendly suppliers enhance procurement sustainable performance and decreases surplus capacity.
- Clean production and LCA reduce supply chain's surplus capacity.
- The minimisation of redundant and unnecessary materials and processes in the supply chain, which *green* production aims for in order to reduce production lead time and surplus capacity. It also provokes a reduction in transportation lead time as well as inventory levels and turnover frequency as long as that does not entail an increase in gas emission.
- *Green* logistics reduces turnover frequency and contributes supply chain surplus capacity reduction.

In terms of the cause-effect relationship among supply chain attributes and the KPIs, an increase in procurement sustainable performance and a reduction in turnover frequency through *green* logistics reduces the overall supply chain cost due to improved resources utilisation and a focus over the whole-of-life of products and minimised transport of inventory. In terms of supply chain responsiveness to customers (service level), reduction of transportation and production lead time and enhancement of procurement sustainable performance improves responsiveness to customers' demands. However, a reduction in surplus capacity reduces service levels and responsiveness to growing customer needs, since excess capacity works as a buffer against production or demand shocks. Similarly, a reduction in turnover frequency decreases service level in terms of responding quickly to volatile customers' demands. Moving to the lead time performance indicator, a GSCMS affects it negatively as it works to ensure a minimisation of redundant and unnecessary materials and processes in the supply chain in order to reduce an organisation's environmental impact. Finally, like LSCMS, reduction of inventory levels enhances flexibility to respond to sudden changes in customers' demands and therefore increases service level, while it may also result in stock outs, decreasing service level when there is an increase in customers' demand.

Regarding *green*'s impact on the environment, a reduction of surplus capacity and inventory levels entails a reduction in the overall supply chain environmental impact by reducing gas emission and solid toxic waste while increasing resource utilisation per unit of production. An increase in procurement sustainable performance by working with environmentally friendly suppliers also reduces gas emission and solid toxic waste while enhances resource utilisation. Finally, a reduction of production and transportation lead time as well as inventory turnover entails a reduction in gas emission.

5.6.3 Overall Conceptual Model: The impact of both *lean* and *green* paradigms on supply chain KPIs and supply chain attributes' inter-relationships

To visually depict and elaborate the overlaps, trade-offs and the cause-effect relationships between *lean* and *green* supply chain paradigms and their effect on supply chain performance, an overlap of the diagrams above was developed. Figure 5-4 integrates the *lean* and *green* characteristics to clarify their integrated impact on supply chain attributes and KPIs.

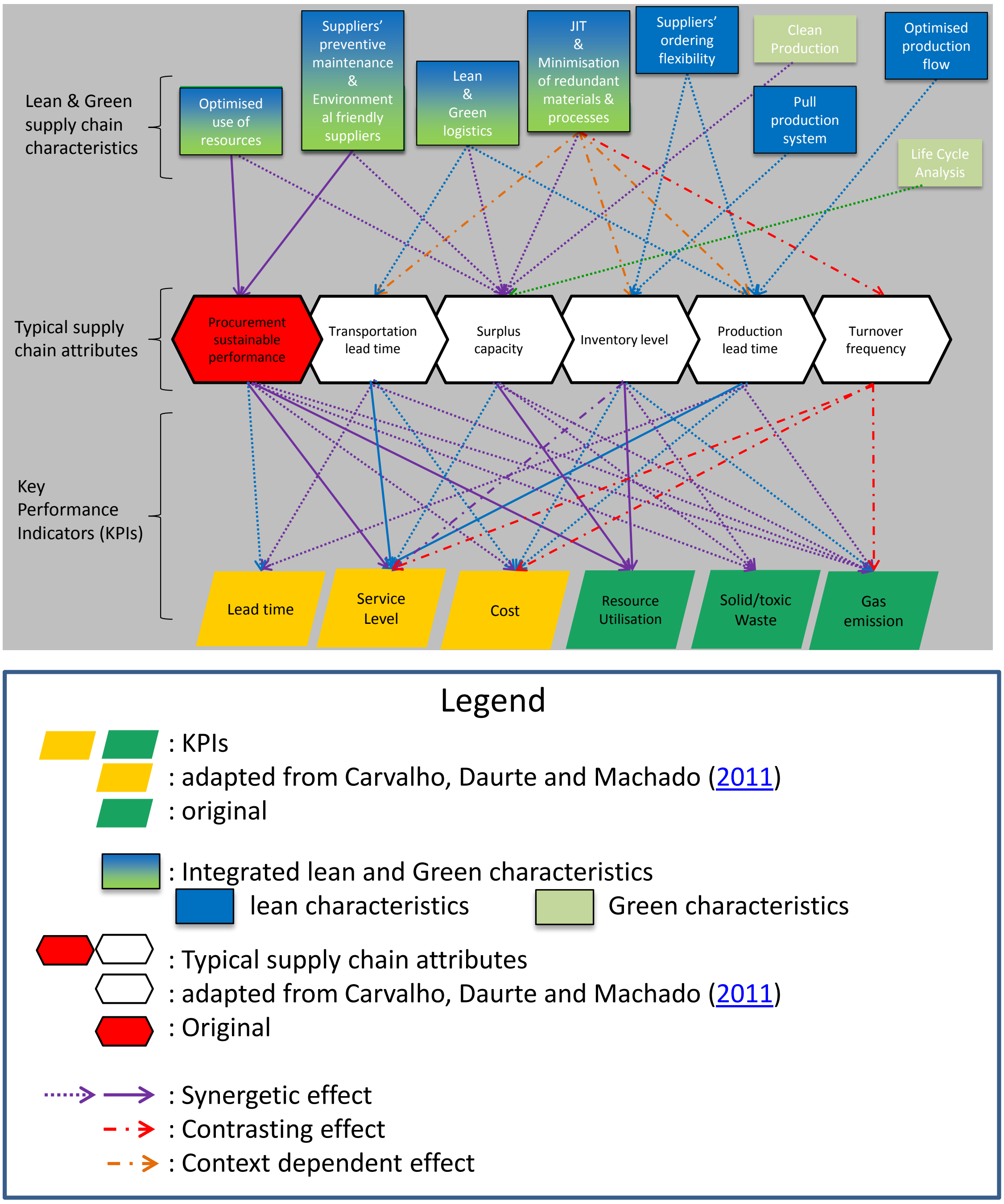


Figure 5-4: A Dynamic Model of the Outcomes of Integrated *Lean* and *Green* Characteristics on Supply Chain Attributes on Supply Attributes

Source: Original

As shown in the Figure 5-4 above, *lean* and *green* supply chain characteristics overlap or even add on to the same effect of a particular SCM paradigm on particular supply chain attributes and KPIs, indicating a synergy of integration. Both *lean* and *green* paradigms, for example, prescribe a minimisation of surplus capacity and an increase in procurement sustainable performance in order to promote an optimised use of resource consumption and reduce upstream sources of waste and.

However, the effect on some other attributes appears to be context dependent (illustrated by the orange lines). An LSCMS seeks compulsively the reduction of inventory levels as well as the reduction of production and transportation lead times to promote supply chain responsiveness, while a GSCMS only reduces those attributes as long as they do not entail an increase in gas emission. Thus, within an integrated supply chain management system, inventory levels as well as production and transportation lead times are to be managed in a way that do not conflict with both paradigms by considering key factors that may contribute to successful integration.

In terms of turnover frequency, *lean* and *green* implementation result in different behaviours that lead in different directions regarding turnover frequency, affecting the gas emission performance indicator. The *lean* paradigm, for instance, prescribes an increase in turnover frequency in order to control inventory levels and increase supply chain responsiveness, while the *green* paradigm prescribes a reduction in turnover frequency to reduce transportation gas emissions.

So the conceptual model, in Figure 5-4, clarifies that there are points of synergies to be gained by integrating *lean* and *green* supply chain management systems but there are also points of conflict that need to understood and managed with regards to some key factors in order to offset the trade-offs by attained synergies.

5.7 **Conclusion**

The literature review demonstrates the significance of the issue of sustainability in the manufacturing industry. It suggests that modifying manufacturers’ supply chains to integrate both *lean* and *green* supply chain management systems and incorporating sustainability into an organisation's day-to-day procurement processes holds significant potential for manufacturers to take full responsibility of their manufactured products while simultaneously realising sustainable success beyond the scope of a single supply chain management system. Based on the literature review, integrating *green* and *lean* supply chain management systems has been shown to be the subject of significant debate and discussion in order to gain both environmental and financial sustainability. However, a research gap exists in presenting an approach that clarifies the characteristics of successful implementation and the factors determining the level of implementation when integrating *lean* and *green* supply chain management systems. Bergmiller (2006) indicated the significance of understanding the synergies and divergences between both paradigms. Carvalho *et al.* (2011) also signified the need for further empirical research to validate the relationship between LSCMS and GSCMS.

This research therefore aims to better understand the relationship between *lean* and *green* manufacturing systems (i.e. points of conflict and synergies that may result from an integrated approach). It specifically investigates whether manufacturers adopting an integrated approach utilising both LSCMS and GSCMS can exhibit significantly higher levels of sustainability than manufacturers implementing only *lean* or *green* principles, in terms of reducing an organisation's environmental impact while simultaneously improving profitability and minimising the marginal cost of environmental performance. It also takes a step forward by investigating the role of the procurement function in embracing the broader goals of sustainable development and enhancing an organisation's sustainable performance.

The literature review also informed the development of the hypotheses proposed earlier in this chapter. Five hypotheses were stated:

1. Manufacturers adopting an integrated approach utilising both LSCMS and GSCMS can exhibit significantly higher levels of sustainability than manufacturers implementing only *lean* or *green* principles, in terms of reducing an organisation's environmental impact while simultaneously improving profitability and minimising the marginal cost of environmental performance.
2. Significant environmental benefits can be typically derived from lean initiatives due to a waste elimination culture

3. An integrated approach encompassing both GSCMS and LSCMS may result in trade-offs of either system.
4. Key factors may contribute to successful integration of *lean* and *green* supply chain management system and attainment enhanced levels of sustainability within an implemented supply chain management system.
5. The procurement function within an organisation has a significant impact on achieving sustainability goals by considering life-cycle costs and reducing upstream sources of waste.

Based on a synthesis of earlier studies, this chapter ended with identification of supply chain attributes and supply chain key performance indicators to understand both the cause-effect relationship between various supply chain characteristics and supply chain attributes – and their effect on supply chain key performance indicators – and the overlaps and trade-offs between *lean* and *green* supply chain paradigms in an effort to clarify their dynamic relationship.

6 Chapter 6 - Methodology

Chapter Six describes the research methodology to test the research hypotheses defined at the end of Chapter Five. This entails the description of research design, population and sample, validation of research instruments, data collection process and ethical considerations.

6.1 Research Design

This study was undertaken to paint a picture of the current industrial sustainability within the context of supply chain management and procurement in manufacturing organisations. The research commenced with in-depth review of the sustainability literature to investigate the numerous approaches incorporated to enhance industrial sustainability by exploring and understanding the critical role that supply chain management can play in contributing towards sustainability. It also encompassed the fulfilling of significant objectives of industrial sustainability through *lean* and *green* supply chain management systems and the various trade-offs involved during integration.

The evidence suggests that to increase financial gains while simultaneously reducing the environmental impact of an organisation, both *lean* and *green* manufacturing systems need to be integrated and continuously adjusted to fit a particular organisational environment. Arguably, modifying manufacturers' supply chains to integrate both *lean* and *green* supply chain practices can help reduce operational and environmental waste. This is achieved by capitalising on cost savings, product differentiation and environmental protection and so achieving even higher levels of industrial sustainability, which are seemingly outside the normal scope of a single manufacturing system. The research also investigates the role of the procurement function in enhancing an organisation's sustainable performance.

Because the two major themes in this study are *lean* and *green* management systems, and owing to the large number of contextual contributing factors (such as age of the supply chain management system, structure of the organisation, employees' involvement and management commitment) and the interactions of multiple variables that may appear to be interdependent with the other system, a system approach was followed to display the characteristics of *lean* and *green* management systems. The Oxford English Dictionary (2006, p.1462) defines a *system* as "a set of things *working together* as parts of a mechanism or interconnecting *network*; a *complex* whole"[18].

Stressing the importance of considering an organisation's context for success may indicate the use of a case study design. However, in this research study a case study was not the best method to be adopted because the intent was to gain a broad picture of how *lean* and *green* supply chain practices, together, contribute to enhancing levels of industrial sustainability. A case study on one or few organisations may provide some evidence of synergies or conflicts in a given context, but it cannot be generalised to the industry as a whole (Robson 2002). For instance, a case study of an organisation that has a mature GSCMS might provide similar positive environmental results to those found in a recently formed organisation, indicating that the success of adopting a GSCMS can be attained regardless of the age of an organisation while the similarity in results can be attributed to the effect of another existing supply chain management system such as *lean*.

A survey has an advantage over case study research in this regard since a case study cannot provide enough evidence to confirm a relationship whereas, as Robson (2002) has indicated, a survey methodology is an appropriate means of discovering variations that occur between cases amongst the participants, potentially providing both descriptive and interpretive explanations. Creswell (2003) argues that when the purpose of a study is to determine the factors that influence an outcome and determining the best predictors of an outcome, then the best method is quantitative rather than qualitative. A survey could provide a viable amount of data to establish the existence, if any, of a relationship between two variables. Although the picture provided, as demonstrated by Creswell (2003), would represent just a small part of the complex systems under study, it is believed that this picture still provides information that could lead to a better understanding of the phenomenon being explored.

Based on an in-depth review of relevant literature on sustainability and supply chain management, an online survey was developed to explore the key areas of *green* and

[18] The words in italics highlight those aspects of the definition that characterise supply chains

lean supply chain management systems, their scope, the extent of their implementation, the driving forces, waste and concerns, business processes and benefits achieved from implementing each system. The survey also aimed to investigate the tendency of manufacturing organisations to integrate *lean* and *green* supply chain management systems to achieve higher levels of sustainable objectives and whether sustainable procurement can enhance the achievement of those objectives.

As the procurement function has the potential to exercise substantial power to gain a competitive advantage for the organisation due to the enormous value of its expenditure, an online survey was addressed to 100 procurement professionals of major organisations in Australia and New Zealand. However, drew a very limited response, with a total of only 13 out of 100 respondents. The decision was made to approach manufacturers in a country which had a substantial manufacturing sector, and further to approach relevant organisations directly. After careful consideration, it was decided that approaching procurement professionals carried the risk that it was possible that the latter would not have a substantial grasp of *lean* and *green* principles within the context of this research. The decision was reinforced by data such as that published by Levinson (2013) demonstrating the scale and R&D investment of the US manufacturing sector.

An online survey was sent to 233 manufacturing organisations in the Unites States on the 13th and 17th of September 2012, yielding 49 responses. A follow-up email was then sent a week later to try to increase the response rate but yielded no further responses. The results achieved were considered adequate enough to justify the decision made at both levels: a survey of US-based manufacturing organisations and a direct approach to each organisation. Forty-nine respondents were treated as a total population (manufacturing businesses) and given that the total population were relatively homogeneous, the response rate was considered sufficient and statistically reliable following the earlier experience in Australia. The data collection process was managed by Qualtrics and was then analysed using SPSS.

6.2 Population

Manufacturers in the United States formed the population for this study. The United States was chosen because it is one of the most competitive economies in the world (Sala-i-Martín *et al.* 2012). In terms of industries, the manufacturing industry was chosen for four main reasons. Firstly, it is one of the main industries leading to current U.S. economic development, employment, social stability and national security (Durham 2003; US Department of Commerce 2011; Wezey and McConaghy 2011; Considine 2012; Hemphill and Perry 2012; Langdon and Lehrman 2012). Secondly, generally speaking, the manufacturing industry has shown to be one of the main causes of the world's intensified air pollution and resource exhaustion as well as high levels of untreated waste due to production processes of industrial activities and post-consumption disposal of products (Leman *et al.* 2010; Christopher *et al.* 2011). Thirdly, manufacturing appears to be under regulatory pressure to mitigate its environmental impact and so it is at the forefront of those industries that seeks to address the issue of sustainability (Sarkis 2001; Leahu-Aluas *et al.* 2010; Reich-Weiser 2010). Fourthly, manufacturing organisations have been the first and focal industry to benefit from *lean* production and so do not require much effort modifying *lean* to benefit (Ford 1922; Womack *et al.* 1990; James-Moore and Gibbons 1997; Abdulmalek *et al.* 2006). Finally, the anticipated response rate was another consideration when choosing manufacturers since one of the key elements that determines high response rate is relevancy (Frohlich 2002). Frohlich (2002) found that addressing subjects and concepts that are common or important to the respondents of a survey improves response rate. Therefore, manufacturers in the United States were considered one the best populations to target for this research study.

6.3 Instrumentation / Measures

The survey instrument for this research had five objectives directly related to the hypotheses of this study. The first objective, related to hypothesis I, was to determine if manufacturers adopting an integrated approach utilising both LSCMS and GSCMS can exhibit significantly higher levels of sustainability in terms of improving profitability, market reputation, robustness and responsiveness to consumers than manufacturers implementing only *lean* <u>or</u> *green* principles. The second objective, related to hypothesis II, was to determine if significant environmental benefits can be typically derived from *lean* initiatives. The third objective, related to hypotheses III and IV, was to determine if an integrated approach encompassing both GSCMS and LSCMS may result in trade-offs of either system and identify the factors that may contribute to successful integration and attainment of enhanced levels of sustainability within an implemented supply chain management system. The fourth objective, related to hypothesis V, was to determine if the procurement function within an organisation has significant impact on achieving sustainability goals.

The survey consisted of four sections:

- The first section gathered information about the respondent's organisation: sector, location and size.
- The second section focused on the status of *lean* and *green* initiatives, scope and impact of implementation. Questions were grouped into seven key areas: supply chain practices, waste and concerns, external parties involved, drivers and benefits achieved, and degree of satisfaction around *lean* or *green* initiatives.
- The third section gathered information about the organisation's management system, sustainability efforts, and key factors used to improve sustainable performance through an integrated approach.
- The final section dealt with the procurement function and suppliers' engagement to enhance sustainable performance.

To reduce respondent fatigue while retaining a high level of validity and reliability, the survey, on average, took ten minutes to complete and organisations were given one month to respond. Questions were designed around the review of literature and all of the questions in this study were close-ended questions to help respondents answer in less time. A copy of the survey questionnaire can be found in the Appendix.

6.4 Data Collection Process

An online survey was the most appropriate means for this study both in regards to time and providing descriptive and interpretive explanations, which this research study seeks. Yet due to the decline in response rates for all types of surveys (Kelly, Fraze, and Hornic 2010), a mailing list was used to obtain a large enough initial sample of e-mail addresses of manufacturers within the Unites States to achieve the predicted return rate and acquire enough data to perform the analysis. The survey was sent to 233 manufacturing organisations in the Unites States on the 13th and 17th September 2012. To improve return rate further, a follow-up note was sent a week later to consider completing the survey. The deadline was a month after the initial mailing.

The data was cross-tabulated to depict the interrelation of given variables and explore the interactions between them. Correlation was also used to explore more relationships between variables and understand the strength of such relationships. To follow up on correlations, multiple regression tests were performed to understand the relationships and possible multi-variant effects of several independent variables on a certain dependent variable. Then, to assess whether the means of two groups are statistically different from each other, t-tests were conducted. Cronbach's alpha was also conducted to measure internal consistency and reliability of the questionnaire's main key areas.

6.5 Limitations of the Research Instrument

The main limitation of the instrument chosen for this research is that:

1. Declining survey response rates continue to plague surveys as a research instrument.
2. Surveys are charged for their limited access to the population, not conveying the details of what is really going behind the scenes that led to the results seen in the survey data.

6.6 Ethical Issues

As in all research, consideration will be given to construct validity and reliability. Permission was sought from the University Ethics Committee to ensure privacy and confidentially where appropriate and permission was granted.

6.7 **Conclusion**

For the purpose of this study, a survey was the most applicable instrument in regards both to time and to providing descriptive and interpretive explanations, which this research study seeks. The content of the survey instrument was designed around the review of literature and a copy of the survey was provided.

An online survey was used to provide data necessary to investigate the tendency of manufacturing organisations to integrate *lean* and *green* supply chain management systems to achieve higher levels of sustainable objectives and whether sustainable procurement can enhance the achievement of those objectives. The survey was directed to 233 manufacturing organisations in the Unites States in September 2012 using a commercial mailing list, and 49 responses were received. In terms of ethics, permission was taken from the University Ethics Committee to ensure the privacy and confidentially where appropriate.

The following chapter presents and tests the data gathered from the survey instrument to offer statistical findings.

7 Chapter 7 - Survey Analysis

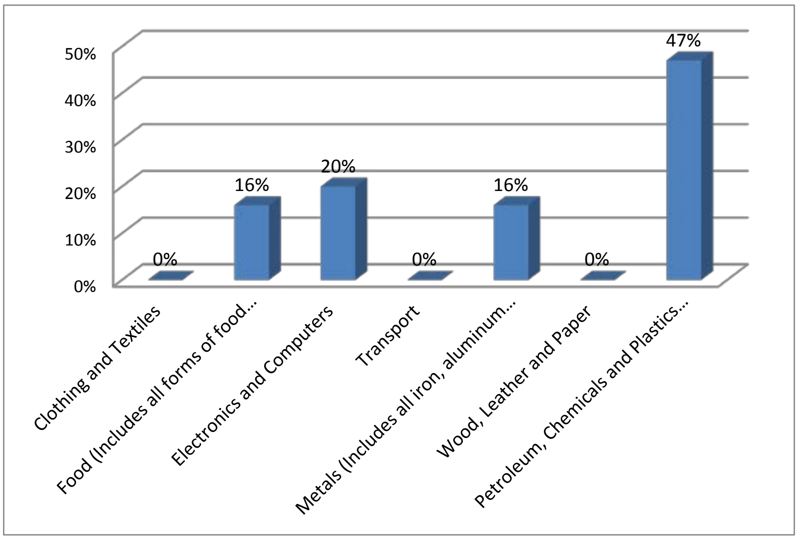
Chapter seven presents and tests the data gathered from the survey instrument followed by statistical reasoning behind these outcomes to give meaning to statistical findings. A summary of finding is provided at the end of this chapter to verify main hypotheses stated in Chapter Five.

7.1 Overview

7.1.1 Industry Sector

The American Bureau of Labour Statistics classifies manufacturing into many sub-sectors (Bureau of Labor Statistics 2012).Yet to simplify the issue, this study summarises the manufacturing industry into seven general sectors (Clothing and Textile, Food[19], Electronics and Computers, Transport, Metals, Wood, Petrochemicals and Plastics[20]).

Figure 7-1 shows that almost half of the results – 47 per cent – were comprised of responses from the Petroleum, Chemicals and Plastics sectors, compared to 20 per cent from Electronics and Computers and 18 per cent from both Food and Metals. Thus, responses were mainly from continuous process manufacturing environments, which are often characterised by high-volume, low-variety products, and inflexible processes.



[19] Food includes all forms of food including agriculture.
[20] Petrochemicals and Plastics include the making of soaps, paints, pesticides as well as medicines and rubber.

Figure 7-1 Participation by Industry Sector (Expressed as a per cent of total responses)
Source: Original

7.1.2 **Size of Organisation**

Size was re-coded into small, medium and large organisations based on the total number of employees. Following Adams and Ponthieu (1978) and White, Pearson, and Wilson (1999), organisations with fewer than 250 employees were coded as "small", organisations with more than 1000 employees were coded as "large" and organisations with employees between 250 and 1000 were coded as "medium". As shown in Figure 7-2 below, 74 per cent of the respondents were from medium-sized organisations while 22 per cent were from small organisations and only 4 per cent were from large organisations.

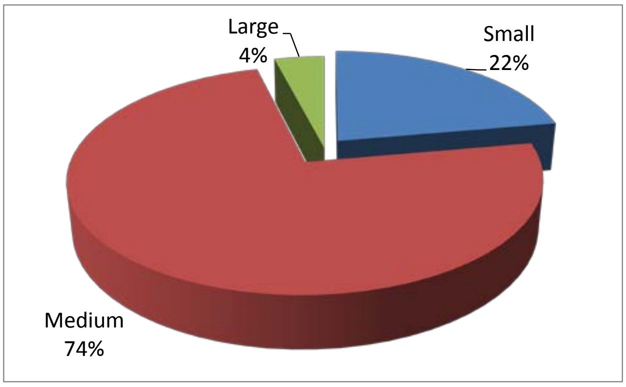


Figure 7-2 Size of Participating Organisations
Source: Original

7.1.3 **Location of Organisation**

The sample is as diverse as intended. Respondents were scattered mostly in the Western, Northern and Eastern parts of the United States. Table 7-1 displays the sample demographics.

Table 7-1: Sample Demographics by State

	California	Texas	New York	Florida	Pennsylvania
Total per cent of Respondents	33%	33%	14%	12%	8%

7.2 Lean Supply Chain Management System (LSCMS)

7.2.1 Sector, Size and Age

Figure 7-3 demonstrates that the electronics and computers, the metal sector as well as the food sector are in the lead among all other sectors in implementing *lean* principles[21].

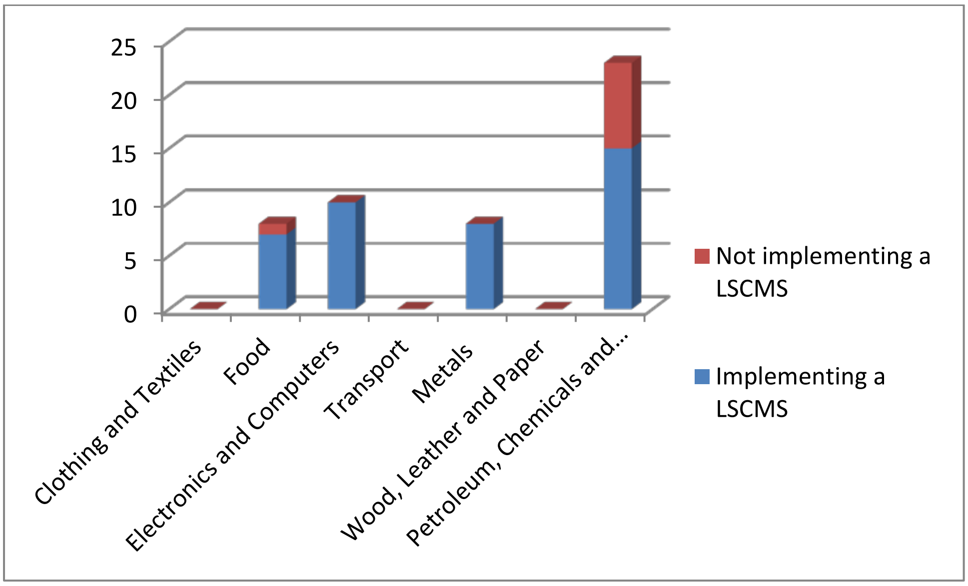


Figure 7-3 LSCMS in Different Manufacturing Sectors
Source: Original

As shown in Table 7-2 and Figure 7-4 below, 82 per cent of the respondents reported using an LSCMS, in which 48 per cent are in the advanced stage (10+ yrs.), 40 per cent in the middle stage (5-10 yrs.) and only 13 per cent are in the early stages (1-5 yrs.).

[21] Comparison with literature will be provided in the next section.

Table 7-2: Status of LSCMS (Expressed as a per cent of Total Responses)

LSCMS	Response	per cent
Yes	40	82 per cent
No	9	18 per cent
Total	49	100 per cent

Source: Original

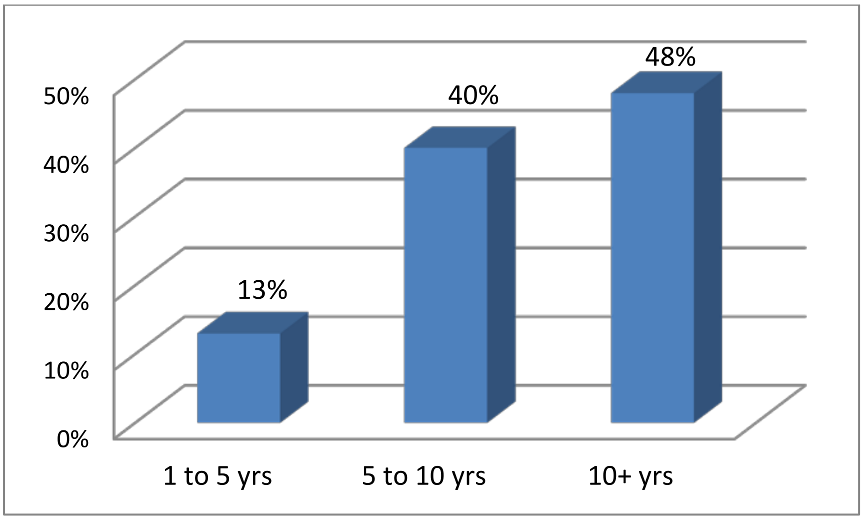


Figure 7-4 Age of Existing LSCMS

Source: Original

7.2.2 ***Lean* Practices**

Analysis revealed that out of the respondents that had an LSCMS in place, 90 per cent of the organisations appear to utilise 5S and JIT, followed by VSM and Kanban (60-63 per cent), TPM (53 per cent) and finally Six Sigma (38 per cent). Meanwhile, surprisingly, none of the organisations were implementing 3P. See Figure 7-5 below.

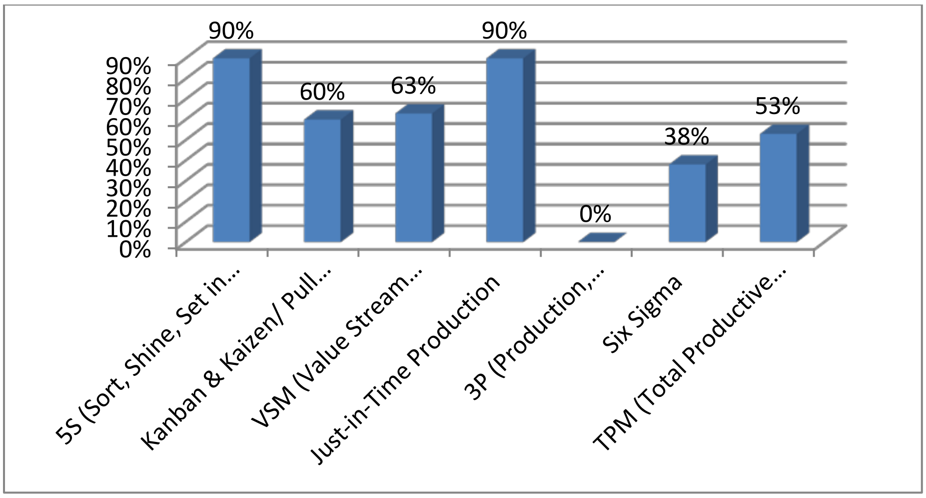


Figure 7-5 Common *Lean* Practices

Source: Original

7.2.3 ***Lean* Wastes**

The majority (88 per cent) reported defects to be the main waste targeted by their LSCMS, followed by excess inventory (60 per cent), over-production (43 per cent), waiting, lead time and over-processing (33-25 per cent) and, finally, unnecessary transportation (8 per cent).

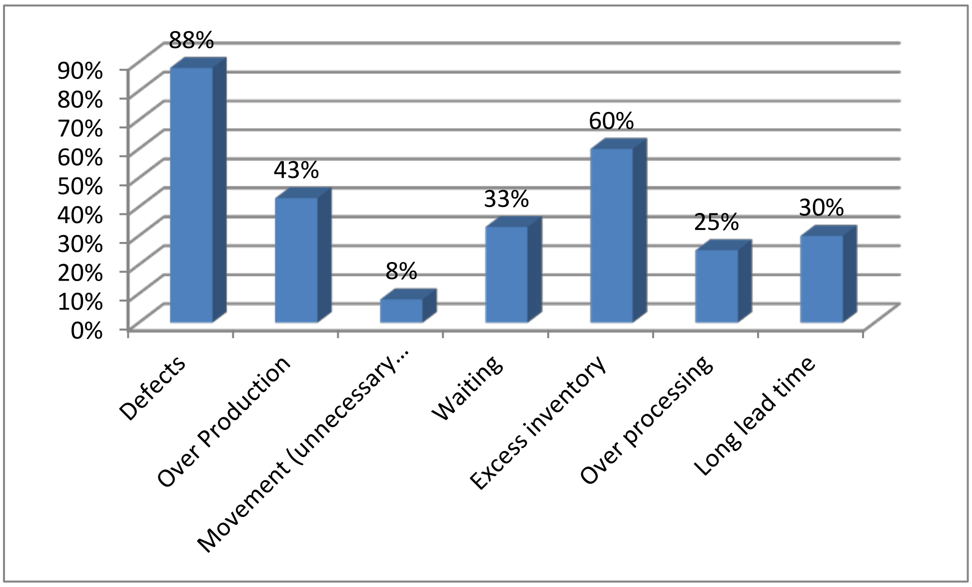


Figure 7-6 Main Waste Targeted by LSCMS

Source: Original

7.2.4 **External Parties Involved in *Lean* Initiatives**

Analysis revealed that 78 per cent of the respondents that have an LSCMS in place work with suppliers on their *lean* initiatives while the rest – 23 per cent – work with transportation companies. See Figure 7-7.

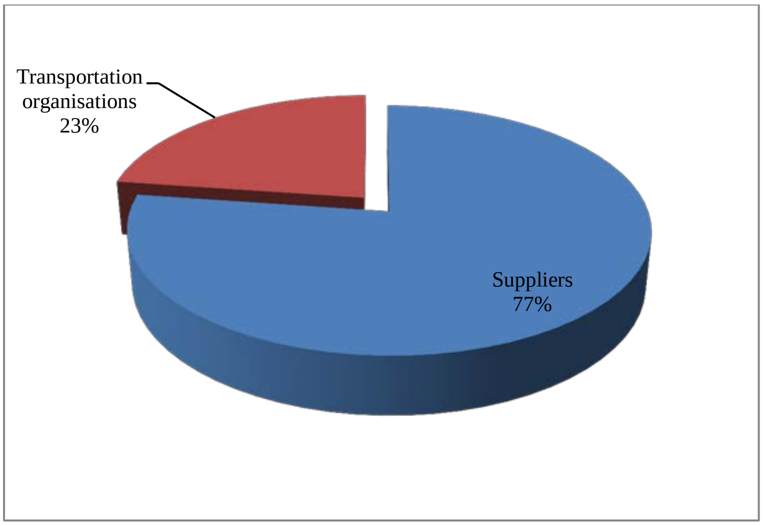


Figure 7-7 External Parties Involved in *Lean* Initiatives

Source: Original

7.2.5 **Key Factors to Successful *Lean* Implementation**

As demonstrated in Figure 7-5, all respondents believe that a focus on product quality and design is the major key factor for successful *lean* implementation followed by having reliable and efficient equipment, standardising work processes and effective scheduling (83-78 per cent), utilising *lean* tools and techniques, working with suppliers as well as focusing on management and culture (65-63 per cent), focusing on safety, on facility layout and inventory levels (55-50 per cent) and, finally, on having steady materials flow, customers and employees (43-38 per cent).

Table 7-3 Key Factors to Successful *Lean* Implementation

Key Factors	Highly focused upon	Focused upon	Not focused upon	Responses	per cent
Effective scheduling	31	9	0	40	77.5
Steady material flow	17	14	9	40	42.5
Low inventory levels	20	17	3	40	50
Reliable and efficient equipment	34	6	0	40	85
Standardization of work processes	33	7	0	40	82.5
Product quality and design	40	0	0	40	100
Employees	15	18	7	40	37.5
Flexible facility layout	22	15	3	40	55
Suppliers	26	13	1	40	65
Customers	16	23	1	40	40
Safety	23	17	0	40	57.5
Management and culture	25	12	3	40	62.5
Lean tools and techniques	27	13	0	40	67.5

Source: Original

7.2.6 ***Lean* Drivers**

Remarkably, as illustrated in Figure 7-8, 85 per cent identified pressure to achieve competitive advantage in price and service level as the main driver for *lean* manufacturing, while 75 per cent identified customers' demand for shorter (lead) times (in production or transportation) as the main driver, followed by improved quality of the manufactured product (63 per cent), customers' demand for production flexibility (58 per cent), pressure to efficiently consume resources contributing to supply chain "capacity surplus" reduction (43 per cent) and, finally, pressure to achieve significantly improved inventory turns (only 3 per cent).

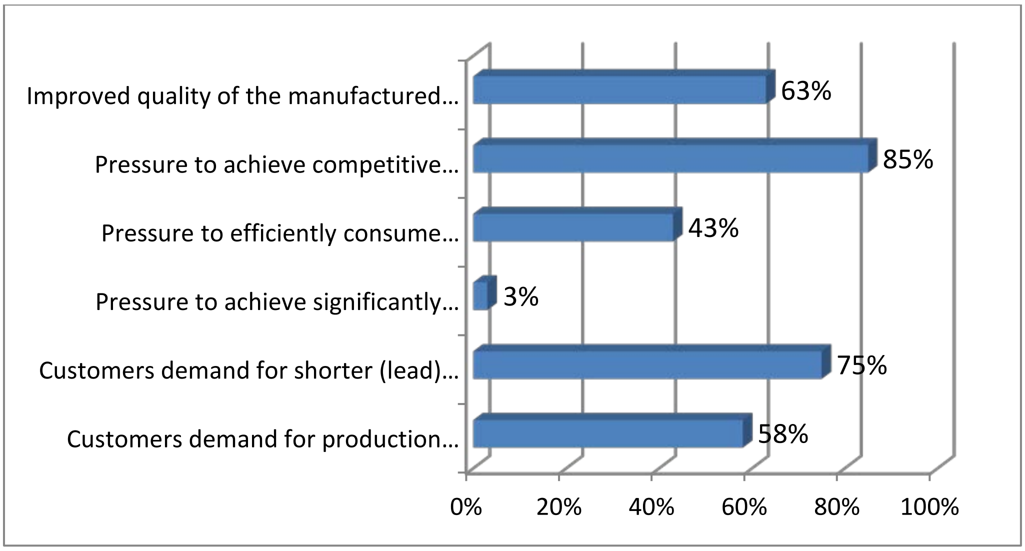


Figure 7-8 Drivers for *Lean* Implementation

Source: Original

7.2.7 *Lean* Benefits

Table 7-4 reveals that 83 per cent reported higher efficiency and productivity levels as the main gain from *lean* implementing, followed by reduction of overall costs and production lead time (65-60 per cent). Meanwhile, 53-58 per cent reported an increase in customer satisfaction and loyalty and higher flexibility. This was followed by reduced inventory levels and waste throughout the supply chain (35-28 per cent), reduced environmental incidents, capacity surplus and an increased in energy and water savings (20-13 per cent) and, finally, reduced transportation lead time (3 per cent).

Table 7-4: Benefits from Implementing *Lean* Manufacturing

LSCMS Benefits	Responses	Per cent
Higher efficiency and productivity	33	83
Higher flexibility	21	53
Reduced inventory levels	14	35
Reduced overall costs	26	65
Reduced environmental incidents	8	20
Reduced production lead time	24	60
Reduced transportation lead time	1	3
Reduced waste throughout the supply chain	11	28
Reduced capacity surplus	5	13
Increased energy and water savings	5	13
Increased customer satisfaction/ loyalty	23	58
Improved corporate image	5	13

Source: Original

7.2.8 *Lean* and the Environment

Notably 50 per cent of the respondents that have an LSCMS in place stated that they had never faced environmental problems when implementing *lean*, while 43 per cent chose rarely and only 8 per cent stated that they sometimes faced environmental problems. See Figure 7-9.

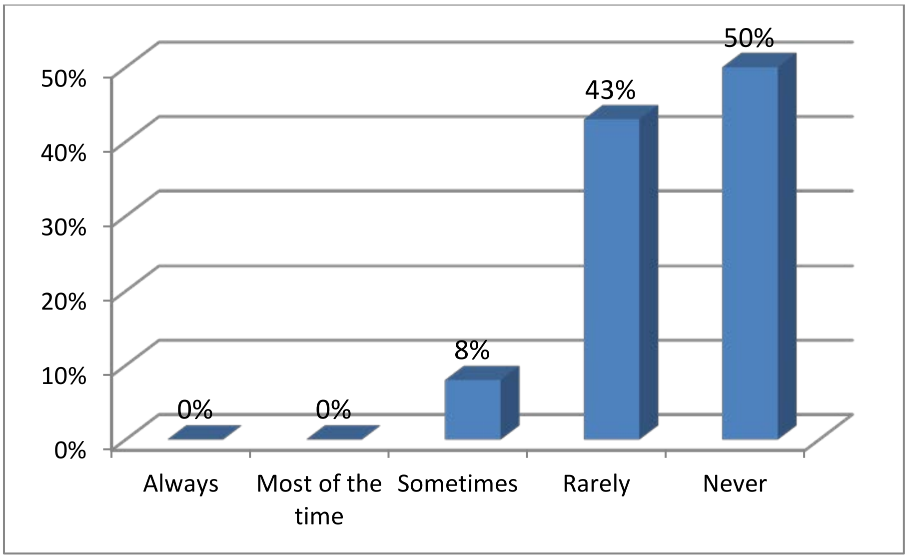


Figure 7-9 Environmental Problems from *Lean* Implementation

Source: Original

As shown in Figure 7-10, 28 per cent identified decreased material usage and improved resource utilisation per unit of production as the main environmental benefit achieved from *lean* practices whereas 24-19 per cent reported lower gas emissions of hazardous air pollutants and reduced inventory levels as the main environmental gain, followed by reduced waste and hazardous materials throughout the supply chain and improved handling and storage (16-13 per cent).

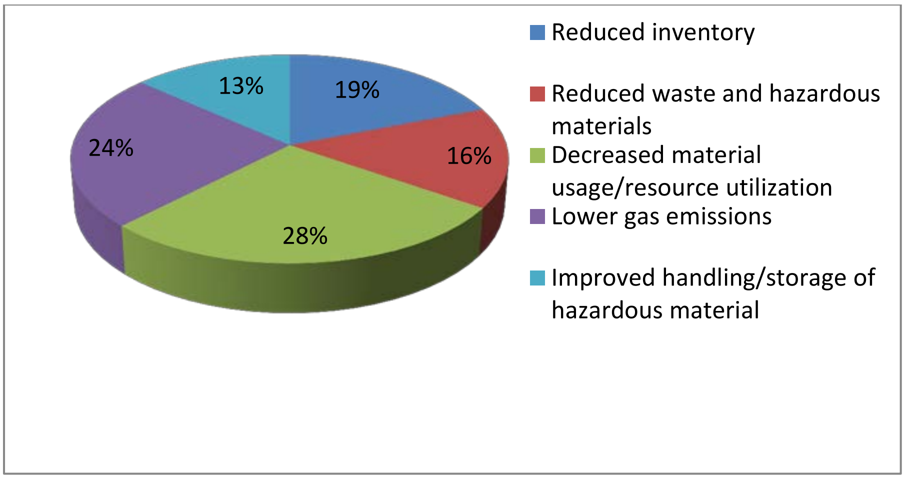


Figure 7-10 Environmental Benefits from *Lean* Implementation

Source: Original

7.2.9 Satisfaction with LSCMS

In regard to the degree of satisfaction, analysis reveal that 85 per cent of the respondents that had an LSCMS in place were satisfied with their *lean* manufacturing initiative compared to only 10 per cent who were partially satisfied and 5 per cent who were not satisfied with their *lean* system. See Figure 7-11.

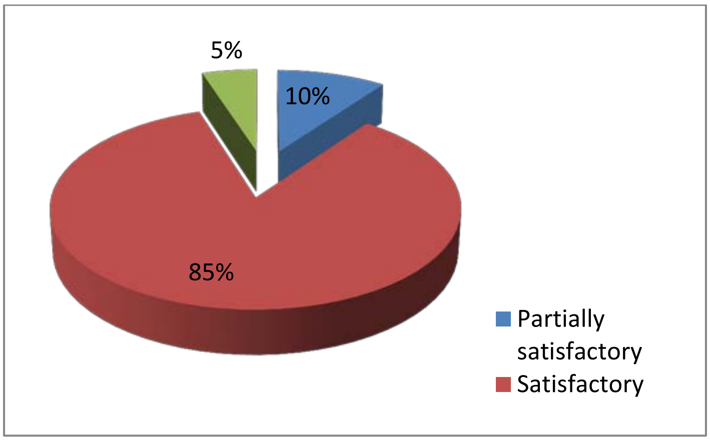


Figure 7-11 Satisfaction with *Lean* Initiatives
Source: Original

7.3 Green Supply Chain Management System (LSCMS)

7.3.1 Sector, Size and Age

Figure 7-12 demonstrates that the metals sector as well as the petroleum, chemicals and plastics sector are in the lead among all other sectors, in terms of implementing a GSCMS. These are followed by the majority of electronics and computers organisations (80 per cent) and, finally, those in the food sector (63 per cent).

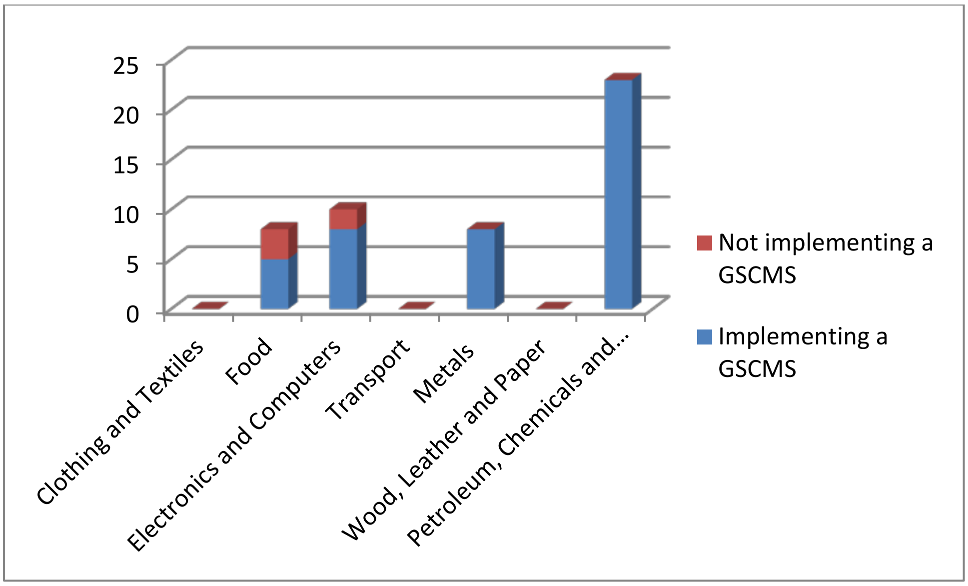


Figure 7-12 GSCMS in Different Manufacturing Sectors

Source: Original

As shown in Table 7-5 and Figure 7-13 below, 90 per cent of the respondents reported using a GSCMS, of which only 11 per cent were in the advanced stage (10+ yrs.), 50 per cent in the middle stage (5-10 yrs.) and 39 per cent in their early stages (1-5 yrs.). Thus, unlike *lean*, *green* manufacturing is still in its infancy.

Table 7-5 Status of GSCMS (Expressed as per cent of Total Responses)

GSCMS	Response	per cent
Yes	44	90 per cent
No	5	10 per cent
Total	49	100 per cent

Source: Original

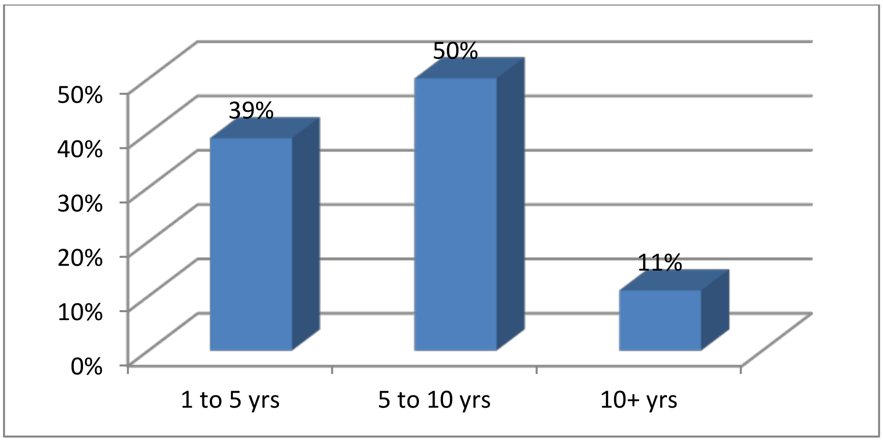


Figure 7-13 Age of Existing GSCMS

Source: Original

7.3.2 *Green* Practices

3Rs, as indicated in Figure 7-14, appears to be the major *green* practice implemented, by 82 per cent of *green* organisations, followed by supplier evaluation (77 per cent), life cycle analysis (59 per cent) and, finally, the use of clean production (23 per cent). Meanwhile, in regards to *green* distribution, 81 per cent of the organisation had one in place. See Table 7-8.

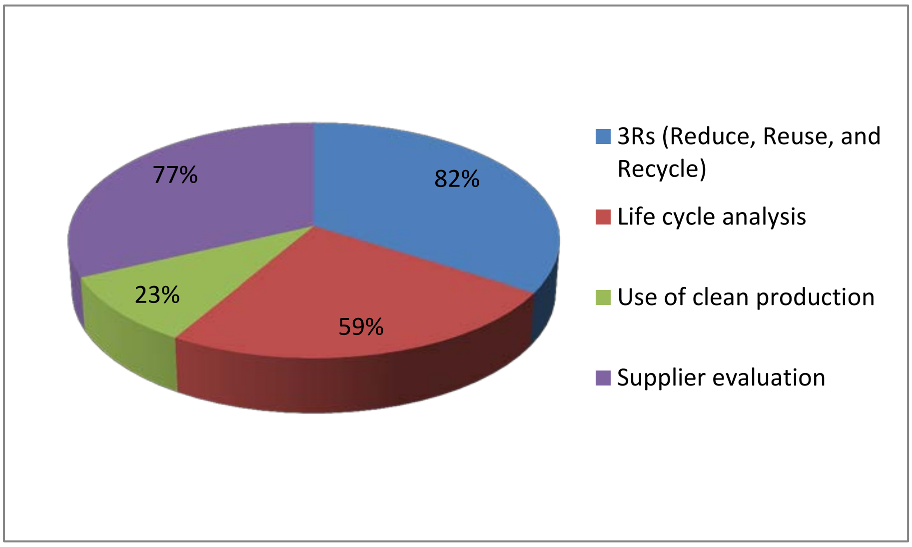


Figure 7-14 Common *Green* Practices

Source: Original

Table 7-6 Implementation of *Green* Distribution

Green Distribution Responses	Response	per cent
Yes	35	81 per cent
No	8	19 per cent
Total	43	100 per cent

Source: Original

7.3.3 Environmental Concerns

As illustrated in Figure 7-15 below, 98 per cent out of the respondents that had a GSCMS in place, have reported toxic chemical waste as the main environmental concern, followed by *green*house gas emission (55 per cent), solid waste (43 per cent) and, finally, energy consumption (5 per cent).

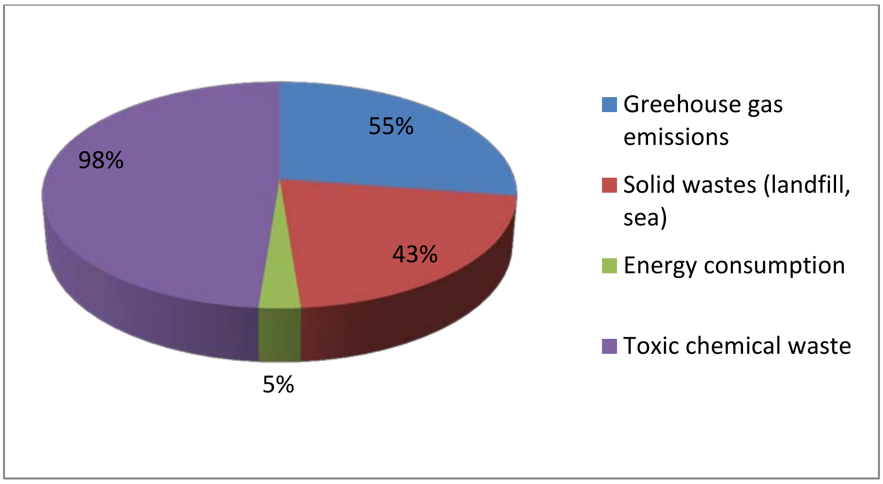


Figure 7-15 Main Environmental Concerns

Source: Original

7.3.4 External Parties Involved in *Green* Initiatives

As with *lean* manufacturers, analysis revealed – see Figure 7-16 – that 75 per cent of the respondents have a GSCMS in place work with suppliers on *green* initiatives while 14 per cent reported working with customers. Meanwhile, 7 per cent of *green* organisations seem to be working with transportation companies in addition to 2 per cent who are interested in working with technology companies in regards to *green* initiatives.

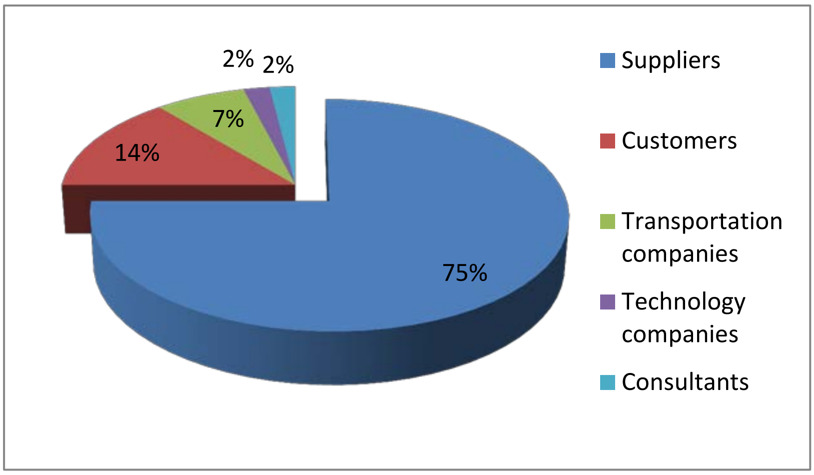


Figure 7-16 External Parties Involved in *Green* Initiatives
Source: Original

7.3.5 Key Factors to Successful *Green* Implementation

Just like *lean* organisations, as shown in Table 7-9, a focus on product quality and design was believed to be the major key factors for successful *green* implementation by 91 per cent of *green* organisations. Meanwhile, 82-80 per cent identified corporate image, suppliers' involvement and having reliable and efficient equipment as being the main factors, followed by gas emission and resource consumption, management and culture as well as utilising *green* tools and techniques (66-55 per cent), and finally delivering and handling plus customers' involvement (48-43 per cent).

Table 7-7 Key Factors to Successful *Green* Implementation

Key Factors	Highly focused upon	Focused upon	Not focused upon	Responses	per cent
Gas emission and resource consumption	29	13	2	44	66
Reliable and efficient equipment	35	9	0	44	80
Product quality and design	40	4	0	44	91
Suppliers	35	7	2	44	80
Customers	19	23	2	44	43
Management and culture	24	19	1	44	55
Delivering and handling	21	21	2	44	48
Green tools and techniques	24	19	1	44	55
Corporate image	36	8	0	44	82

Source: Original

7.3.6 *Green* Drivers

As demonstrated in Figure 7-17, 70 per cent of *green* organisations stated that customers' demand for sustainable behaviour is the main driver for implementing a GSCMS, while 61 per cent stated pressure to reduce carbon gas emissions from production and transportation as the main driver, followed by the aim to differentiation/ establish a competitive advantage and manage risk (57-50 per cent), improve quality of the manufactured product (43 per cent), comply with government/regulations (39 per cent) and, finally, consume resources more efficiently (9 per cent).

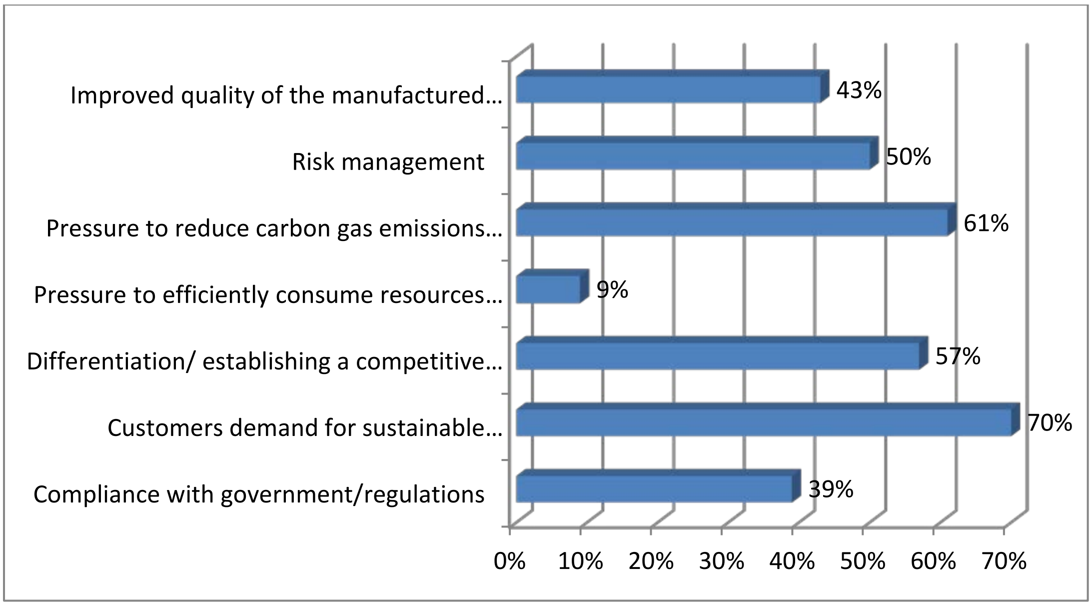


Figure 7-17 Drivers for *Green* Implementation

Source: Original

7.3.7 ***Green* Benefits**

The majority of *green* organisations (77 per cent) reported to have improved their corporate image due to *green* efforts, followed by reduced amount of solid wastes (61 per cent), reduced gas emission and environmental incidents (50 per cent), increased customer satisfaction (40 per cent), increased energy and water savings (39 per cent), higher efficiency and productivity rates as well as reduced waste throughout their supply chain (34-32 per cent), reduced production lead time (20 per cent) and, finally, reduced overall costs and reduced capacity surplus (7-2 per cent). See Figure 7-18.

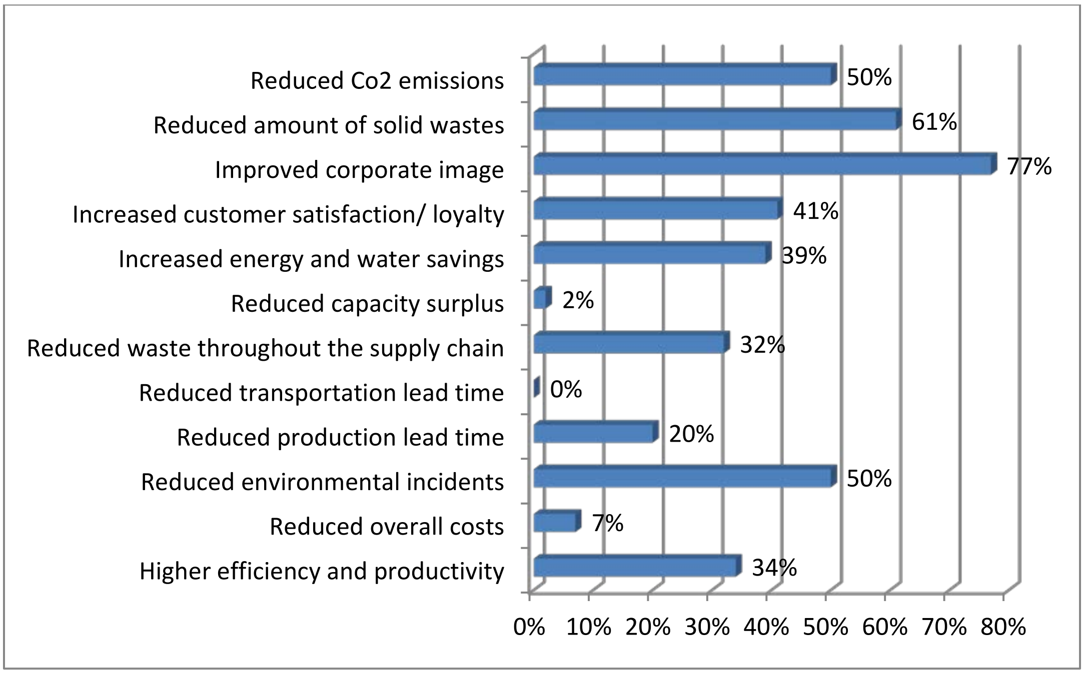


Figure 7-18 Benefits from *Green* Implementation

Source: Original

Furthermore, in regards to achieving efficiency, 86 per cent of *green* organisations stated that their *green* supply chain initiatives has led to supply chain efficiency gains as shown in Figure 7-19.

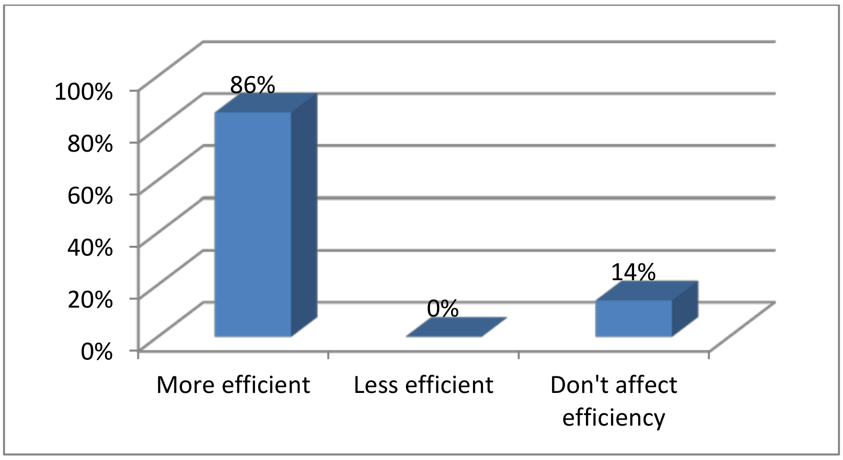


Figure 7-19 *Green* Implementation and Supply Chain Efficiency Gains

Source: Original

7.3.8 *Green* and *Lean* Supply Chain Management Systems

As indicated in Table 7-8, 84 per cent of respondents in *green* organisations believe that having a GSCMS in place can enhance the environmental performance of *lean* activities.

Table 7-8: The Ability of a GSCMS to Enhance *Lean*'s Environmental Performance

Green* enhances *Lean	**Response**	**per cent**
Yes	37	84 per cent
No	7	16 per cent
Total	44	100 per cent

Source: Original

7.3.9 Satisfaction with GSCMS

In regard to the degree of satisfaction with current GSCMS, analysis revealed that 80 per cent out of the respondents that had a GSCMS in place were satisfied with their *green* initiatives compared to 18 per cent were partially satisfied and only 2 per cent who were not satisfied with their *green* system. See Figure 7-20

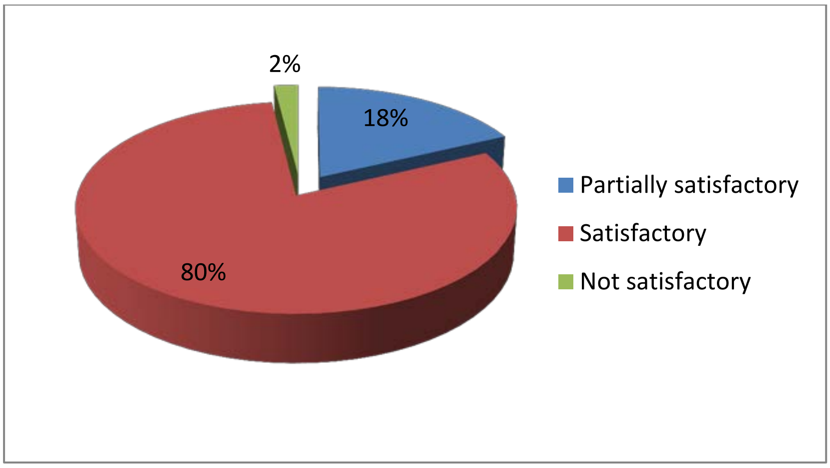


Figure 7-20 Satisfaction with *Green* Initiatives

Source: Original

7.4 The Management System and Sustainability Efforts

7.4.1 Addressing Sustainability

Interestingly, as shown in Table 7-9 below, 96 per cent of all respondents to the survey indicated that their organisations addressed the importance of developing and implementing a sustainable supply chain management system.

Table 7-9: The Status of Addressing the Significance of Implementing a Sustainable Supply Chain (Expressed as a per cent of Total Responses)

Sustainable Supply Chain	Response	per cent
Yes	47	96 per cent
No	2	4 per cent
Total	49	100 per cent

Source: Original

7.4.2 Integrated Approach

As demonstrated in Table 7-10, 82 per cent of respondents believed that an integrated approach to integrate *lean* and *green* initiatives can exhibit higher levels of sustainability.

Table 7-10 The Ability of an Integrated Approach to Enhance Sustainability

Integration enhances Sustainability	Response	per cent
Yes	40	82 per cent
No	9	18 per cent
Total	49	100 per cent

Source: Original

7.4.3 Efforts to Drive Sustainability

In terms of driving sustainability, the majority of organisations (78 per cent), as demonstrated in Figure 7-21, appear to have made an effort to improve material and resource utilisation while 51-59 per cent have made an effort to reduce CO_2 emission and hazardous materials from products as well as unnecessary packaging. 37 per cent, on other hand, increased their use of renewable energy while 6 per cent invested in capital infrastructure.

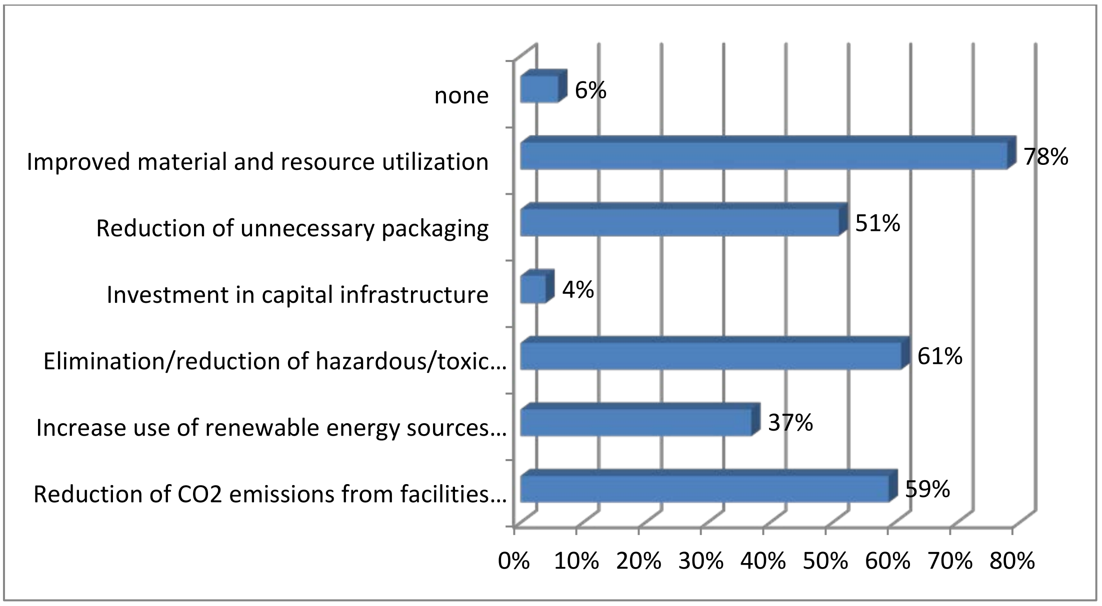


Figure 7-21 Efforts to Drive Sustainability

Source: Original

7.4.4 Coordinating *Lean* and *Green* Operations

The majority of respondents (76 per cent) that have both *green* and *lean* SCMS in place stated that their *lean* team cooperate and coordinate with the *green* team to achieve sustainable objectives. See Table 7-11.

Table 7-11 Coordination of *Lean* and *Green* Teams to Achieve Sustainable Objectives

LSCMS work with GSCPM	Response	per cent
Yes	26	76 per cent
No	8	24 per cent
Total	34	100 per cent

Source: Original

7.4.5 The Business Function that Best Coordinates *Lean* and *Green* Operations

Figure 7-22 shows that 59 per cent of the respondents to the survey believed that procurement is the best function to coordinate different aspects of lean and *green* operations to satisfy customers' needs while 34 per cent stated elected design and production to be the best function and the rest of the 7 per cent selected marketing.

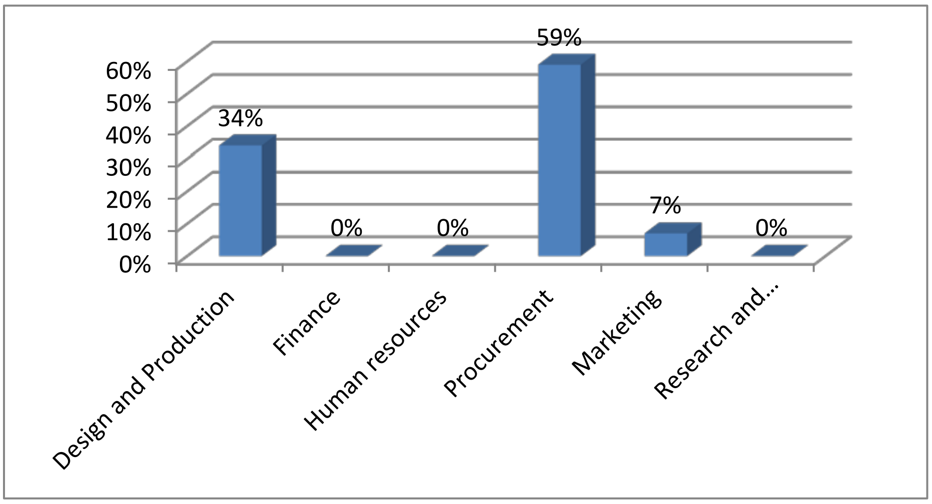


Figure 7-22 Best Function to Coordinate *Lean* and *Green* Operations (Expressed as a per cent of Total Responses)

Source: Original

7.4.6 **Key Factors to Successful Integration**

In regards to the main factors that respondents believe are essential to successfully integrate lean manufacturing with environmental sustainability, analysis revealed that 73 per cent of the respondents to the survey believed in organisational philosophy while 67 per cent believed in throughput improvement, followed by community partnership (43 per cent) and finally innovative technology as well as energy efficiency (29 per cent). See Figure 7-23.

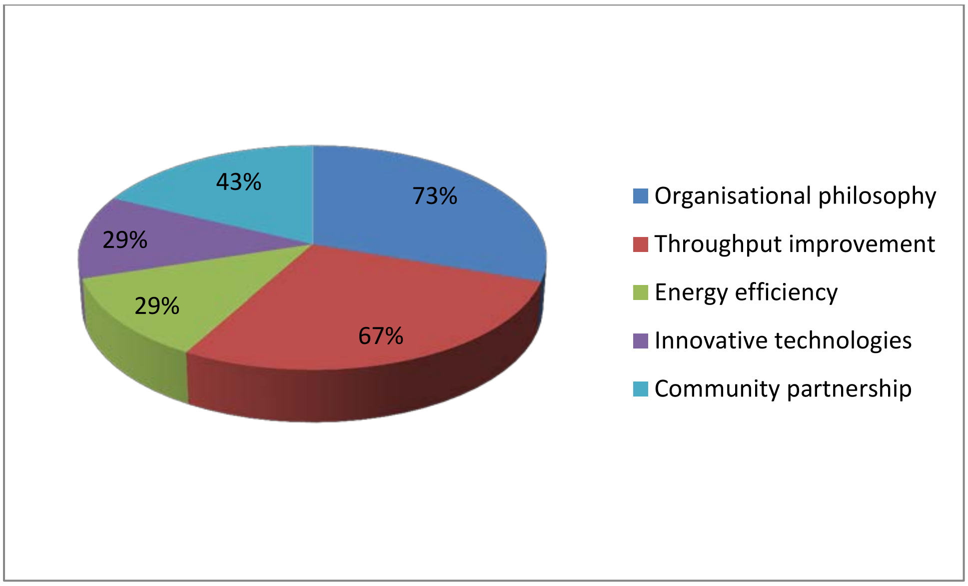


Figure 7-23 Key Factors to Successful *Lean* and *Green* Integration

Source: Original

7.5 Procurement

7.5.1 Status

As shown in Table 7-12, the majority of organisations (98 per cent) utilised procurement to achieve sustainable objectives.

Table 7-12 Status of Sustainable Procurement (Expressed as per cent of Total Responses)

Sustainable Procurement	Response	per cent
Yes	48	98 per cent
No	1	2 per cent
Total	49	100 per cent

Source: Original

7.5.2 Suppliers

Table 7-13 shows that 62 per cent of the organisations being surveyed certify suppliers to enhance sustainable performance.

Table 7-13 Certifying Suppliers to Enhance Sustainable Performance (Expressed as a per cent of Total Responses)

Certifying Suppliers	Response	per cent
Yes	45	92 per cent
No	4	8 per cent
Total	49	100 per cent

Source: Original

7.5.3 **Practices**

Figure 7-24 below shows the degree to which organisations engage suppliers to achieve sustainable objectives. The majority of surveyed organisations (92 per cent) set environmental criteria that suppliers must meet yet accordingly only 82 per cent actively consider switching to more sustainable suppliers. Furthermore, 71 per cent work with key suppliers to ensure continuous improvement in technical and human capabilities while 61 per cent actively monitor and evaluate suppliers' environmental performance and risks. Finally, 59 per cent encourage suppliers to be highly responsive to customer demand while producing quality products in the most efficient and economical manner.

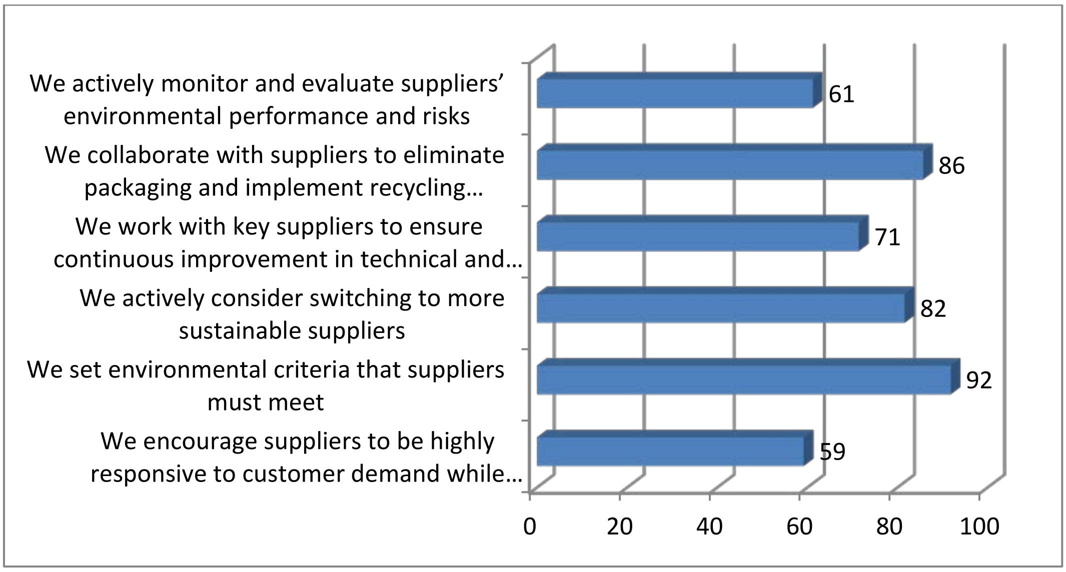


Figure 7-24 Supplier's Engagement in Achieving Sustainable Objectives (Expressed as a per cent of Total Responses)

Source: Original

7.6 Variable Analysis, Reliability and Significance

7.6.1 Cross tabs/Chi-square Tests

Cross tabulation was used to depict the interrelation of two variables and explore the interactions between them.

- *Relationship between lean or green implementation with the size of the organisation*

The survey revealed that the level of interest in *lean* supply chains was directly proportional to the size of the company, with a significance level of (0.029)[22]. Table 7-14 shows that all large organisations as well as 89 per cent of medium organisation with more than 300 employees have established *lean* initiatives, dropping to 54.5 per cent for small organisations with fewer than 300 employees. On the other hand, a significance level of 0.102 indicated that the size of an organisation doesn't seem to be relevant in pursuing a GSCMS. See Table 7-15. Although all large organisations as well as 94.4 per cent of medium organisations with more than 300 employees companies have established *green* initiatives, this has only dropped to 73 per cent for their smaller sized counterparts.

[22] Significance levels are expressions of the likelihood of the relationship between two variables. (0.05) is the minimum acceptable significance level.

Table 7-14 Cross tabulation: Relationship between *lean* implementation and size of the organisation

			Size of your organisation determined by the number of staff			
			Small (Less than 250)	Medium (250-1000)	Large (More than 1000)	Total
Considering that a Green Supply Chain Management System (GSCMS) is an organisational management mode...	Yes	Count	8	34	2	44
		% within Size of your organisation determined by the number of staff	72.7%	94.4%	100.0%	89.8%
	No	Count	3	2	0	5
		% within Size of your organisation determined by the number of staff	27.3%	5.6%	0.0%	10.2%

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	7.097[a]	2	.029
Likelihood Ratio	6.464	2	.039
Linear-by-Linear Association	6.450	1	.011
N of Valid Cases	49		

Source: Original

Table 7-15 Cross tabulation: Relationship between *green* implementation and size of the organisation

			Size of your organisation determined by the number of staff			
			Small (Up to 300)	Medium (301-10,000)	Large (10,000-40,000+)	Total
Considering that a Green Supply Chain Management System (GSCMS) is an organisational management mode...	Yes	Count	8	34	2	44
		% within Size of your organisation determined by the number of staff	72.7%	94.4%	100.0%	89.8%
	No	Count	3	2	0	5
		% within Size of your organisation determined by the number of staff	27.3%	5.6%	0.0%	10.2%

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.574[a]	2	.102
Likelihood Ratio	3.956	2	.138
Linear-by-Linear Association	4.083	1	.043
N of Valid Cases	49		

Source: Original

- *Relationship between the age of the organisation and the level of satisfaction with a supply chain management system*

Through a Chi-square test we can see that there is no significant relationship between the age of a particular SCMS and levels of satisfaction revealed. Although cross tabulation shows that satisfaction with *green* initiatives seems to increase as the maturity of the *green* system rises, no specific pattern can be concluded from the LSCMS as the level of satisfaction seems to drop slightly midway through maturity. See Table 7-16 and Table 7-17. Therefore, it appears that the age of a supply chain management system cannot be generalised to act as a discriminating factor in gaining required levels of satisfaction.

Table 7-16 Cross tabulation: Relationship between the age of the organisation and the level of satisfaction with GSCMS

			If yes, how long have your organisation used the green system?			Total
			1 to 5 yrs	5 to 10 yrs	10+ yrs	
In general, compared to the expectations you had at the beginning, the results of using green princi...	Partially satisfactory	Count	6	2	0	8
		% within If yes, how long have your organisation used the	35.3%	9.1%	0.0%	18.2%
	Satisfactory	Count	10	20	5	35
		% within If yes, how long have your organisation used the	58.8%	90.9%	100.0%	79.5%
	Not satisfactory	Count	1	0	0	1
		% within If yes, how long have your organisation used the	5.9%	0.0%	0.0%	2.3%

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	7.773[a]	4	.100
Likelihood Ratio	8.683	4	.070
Linear-by-Linear Association	2.782	1	.095
N of Valid Cases	44		

Source: Original

Table 7-17 Cross tabulation: Relationship between the age of the organisation and the level of satisfaction with LSCMS

			If yes, how long have your organisation used the lean system?			Total
			1 to 5 yrs	5 to 10 yrs	10+ yrs	
In general, compared to the expectations you had at the beginning, the results of using lean princip...	Partially satisfactory	Count	1	2	1	4
		% within If yes, how long have your organisation used the	20.0%	12.5%	5.3%	10.0%
	Satisfactory	Count	4	12	18	34
		% within If yes, how long have your organisation used the	80.0%	75.0%	94.7%	85.0%
	Not satisfactory	Count	0	2	0	2
		% within If yes, how long have your organisation used the	0.0%	12.5%	0.0%	5.0%

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.441[a]	4	.350
Likelihood Ratio	5.076	4	.280
Linear-by-Linear Association	.170	1	.680
N of Valid Cases	40		

Source: Original

- *The Relationship between the level of satisfaction with a supply chain management system and having an integrated approach*

Levels of satisfaction with LSCMS and GSCMS seem to be strongly related to having a well-integrated approach in place (with both *lean* and *green* teams working together). As demonstrated in Table 7-18 below, with a significance level of (0.020), 96 per cent of well-integrated organisations are satisfied with their *lean* initiative, as opposed to 80 per cent if only *lean* was adopted. Similarly, Table 7-19 demonstrates that with a significance level of (0.008), 96 per cent of integrated organisations are satisfied with their *green* initiatives, as opposed to 57 per cent if only *green* was adopted.

Table 7-18 Cross tabulation: Relationship between the level of satisfaction with LSCMS and having an integrated approach

			If both LSCMS and GSCMS do exist in your organisation, does the lean team work together with the gre...			Total
			Yes	No	N/A	
In general, compared to the expectations you had at the beginning, the results of using lean princip...	Partially satisfactory	Count	0	3	1	4
		% within If both LSCMS and GSCMS do exist in your organisation, does the lean team work together with the gre...	0.0%	37.5%	20.0%	10.3%
	Satisfactory	Count	25	4	4	33
		% within If both LSCMS and GSCMS do exist in your organisation, does the lean team work together with the gre...	96.2%	50.0%	80.0%	84.6%
	Not satisfactory	Count	1	1	0	2
		% within If both LSCMS and GSCMS do exist in your organisation, does the lean team work together with the gre...	3.8%	12.5%	0.0%	5.1%

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	11.661[a]	4	.020
Likelihood Ratio	12.055	4	.017
Linear-by-Linear Association	3.098	1	.078
N of Valid Cases	39		

Source: Origina

Table 7-19 Cross tabulation: Relationship between the level of satisfaction with GSCMS and having an integrated approach

			If both LSCMS and GSCMS do exist in your organisation, does the lean team work together with the gre...			Total
			Yes	No	N/A	
In general, compared to the expectations you had at the beginning, the results of using green princi...	Partially satisfactory	Count	1	3	3	7
		% within If both LSCMS and GSCMS do exist in your organisation, does the lean team work together with the gre...	3.8%	37.5%	42.9%	17.1%
	Satisfactory	Count	25	4	4	33
		% within If both LSCMS and GSCMS do exist in your organisation, does the lean team work together with the gre...	96.2%	50.0%	57.1%	80.5%
	Not satisfactory	Count	0	1	0	1
		% within If both LSCMS and GSCMS do exist in your organisation, does the lean team work together with the gre...	0.0%	12.5%	0.0%	2.4%

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	13.661[a]	4	.008
Likelihood Ratio	12.874	4	.012
Linear-by-Linear Association	5.305	1	.021
N of Valid Cases	41		

Source: Original

Interestingly, the tables above also show that if both systems do exist in an organisation but *green* and *lean* teams don't work and coordinate well together (existing in parallel), satisfaction drops by 50 per cent towards both initiatives. Thus, a good integrating management system has to be in place; otherwise, organisations would be much more satisfied with their *lean* or *green* approach when only one supply chain management system exists.

- *The relationship between the level of satisfaction with a supply chain management system and Procurement*

A higher significance level in regards to attaining satisfaction towards a particular supply chain management system appears to be found in organisations utilising procurement to achieve sustainable objectives. Cross tabulation shows that almost 80 per cent of organisations with sustainable procurement are satisfied with their GSCMS, a significance level of (0.000). See Table 7-20. Likewise, 87 per cent of organisations utilising procurement to achieve sustainable objectives are satisfied with their LSCMS, a significance level of (0.010). See Table 7-21.

Table 7-20 Cross tabulation: Relationship between the level of satisfaction with GSCMS and utilising procurement to achieve sustainable objectives

			Does your organisation utilise procurement to achieve sustainable objectives? In other words, does t...	
			Yes	Total
In general, compared to the expectations you had at the beginning, the results of using green princi...	Partially satisfactory	Count	8	8
		% within Does your organisation utilise procurement to achieve sustainable objectives? In other words, does t...	18.2%	18.2%
	Satisfactory	Count	35	35
		% within Does your organisation utilise procurement to achieve sustainable objectives? In other words, does t...	79.5%	79.5%
	Not satisfactory	Count	1	1
		% within Does your organisation utilise procurement to achieve sustainable objectives? In other words, does t...	2.3%	2.3%

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	14.224[a]	2	.000*
Likelihood Ratio	12.537	2	.006
Linear-by-Linear Association	5.412	1	.020
N of Valid Cases	41		

Source: Original

Table 7-21 Cross tabulation: Relationship between the level of satisfaction with LSCMS and utilising procurement to achieve sustainable objectives

			Does your organisation utilise procurement to achieve sustainable objectives? In other words,		Total
			Yes	No	
In general, compared to the expectations you had at the beginning, the results of using lean princip...	Partially satisfactory	Count	3	1	4
		% within Does your organisation utilise procurement to achieve sustainable objectives? In other words, does t...	7.7%	100.0%	10.0%
	Satisfactory	Count	34	0	34
		% within Does your organisation utilise procurement to achieve sustainable objectives? In other words, does t...	87.2%	0.0%	85.0%
	Not satisfactory	Count	2	0	2
		% within Does your organisation utilise procurement to achieve sustainable objectives? In other words, does t...	5.1%	0.0%	5.0%

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	9.231[a]	2	.010
Likelihood Ratio	4.854	2	.088
Linear-by-Linear Association	6.119	1	.013
N of Valid Cases	40		

Source: Original

- *The relationship between having an integrated approach and attaining higher levels of sustainability*

As shown in Table 7-22 below, a significance level of (0.003) shows that in order to drive higher levels of sustainability through an integrated approach, it is best to utilise procurement to coordinate different aspects of *lean* and *green* initiatives. The crosstab table shows that 58 per cent of those who believe that an integrated approach can enhance sustainability levels are utilising procurement to do so.

Table 7-22 Cross tabulation: Relationship between having an integrated approach and attaining higher levels of sustainability

			Do you believe that, by integrating LSCMS and GSCMS, your organisation can significantly exhibit hig...		Total
			Yes	No	
What is the function in your organisation that can best coordinate different aspects of lean and gre...	Design and Production	Count	12	2	14
		% within Do you believe that, by integrating LSCMS and GSCMS, your organisation can significantly exhibit hig...	30.0%	22.2%	28.6%
	Procurement	Count	23	1	24
		% within Do you believe that, by integrating LSCMS and GSCMS, your organisation can significantly exhibit hig...	57.5%	11.1%	49.0%
	Marketing	Count	2	1	3
		% within Do you believe that, by integrating LSCMS and GSCMS, your organisation can significantly exhibit hig...	5.0%	11.1%	6.1%
	N/A	Count	3	5	8
		% within Do you believe that, by integrating LSCMS and GSCMS, your organisation can significantly exhibit hig...	7.5%	55.6%	16.3%

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	14.224[a]	3	.003
Likelihood Ratio	12.537	3	.006
Linear-by-Linear Association	5.412	1	.020
N of Valid Cases	49		

Source: Original

- *The Relationship between having GSCMS in place and Lean's environmental performance*

94 per cent of *lean* organisations believe that having a GSCMS in place is very much related to enhancing the environmental performance derived from *lean* activities, with a significance level of (0.002). See Table 7-23.

Table 7-23 Cross tabulation: Relationship between having a GSCMS in place and *Lean*'s environmental performance

			Do you believe that having a Green Supply Chain Management System (GSCMS) in place can		Total
			Yes	No	
Considering that a Lean Supply Chain Management System (LSCMS) is an organisational management model...	Yes	Count	33	2	35
		% within Considering that a Lean Supply Chain Management System (LSCMS) is an organisational management model...	94.3%	5.7%	100.0%
	No	Count	4	5	9
		% within Considering that a Lean Supply Chain Management System (LSCMS) is an organisational management model...	44.4%	55.6%	100.0%

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	13.294[a]	1	.000		
Continuity Correction[b]	9.829	1	.002		
Likelihood Ratio	10.860	1	.001		
Fisher's Exact Test				.002	.002
Linear-by-Linear Association	12.991	1	.000		
N of Valid Cases	44				

Source: Original

7.6.2 **Correlation**

Correlation was also used to explore more relationships between variables and understand the strength of such relationships.

- *Correlation between exhibiting higher levels of sustainability and having lean and green coordination, focusing on procurement and implementing GSCMS*

As indicated in Table 7-24, in order to significantly exhibit higher levels of sustainability through an integrated supply chain management system, a correlation test with a significance level of (0.000-0.034) signifies the importance of having both *lean* and *green* teams working together, choosing the right function in the organisation to facilitate integration, having a GSCMS in place that has the ability to enhance *lean*'s environmental performance and the efficiency of overall supply chain and, finally, utilising procurement to achieve sustainable objectives.

Table 7-24 Correlation between exhibiting higher levels of sustainability and having *lean* and *green* coordination, focusing on procurement and implementing GSCMS

		Do you believe that, by integrating LSCMS and GSCMS, your organisation can significantly exhibit hig...	If both LSCMS and GSCMS do exist in your organisation, does the lean team work together with the gre...	What is the function in your organisation that can best coordinate different aspects of lean and gre...	Do you believe that having a Green Supply Chain Management System (GSCMS) in place can enhance the e...	In your opinion, do green supply chain initiatives make the overall organisation supply chain	Does your organisation utilise procurement to achieve sustainable objectives? In other words, does t...
Do you believe that, by integrating LSCMS and GSCMS, your organisation can	Pearson Correlation	1	.504**	.336*	.600**	.671**	.304*
	Sig. (2-tailed)		.000	.018	.000	.000	.034
	N	49	46	49	44	44	49
If both LSCMS and GSCMS do exist in your organisation, does the lean team work	Pearson Correlation	.504**	1	.436**	.516**	.516**	.227
	Sig. (2-tailed)	.000		.002	.001	.001	.129
	N	46	46	46	41	41	46
What is the function in your organisation that can best coordinate	Pearson Correlation	.336*	.436**	1	.297	.271	.238
	Sig. (2-tailed)	.018	.002		.050	.075	.099
	N	49	46	49	44	44	49
Do you believe that having a Green Supply Chain Management System (GSCMS) in	Pearson Correlation	.600**	.516**	.297	1	.189	.c
	Sig. (2-tailed)	.000	.001	.050		.218	0.000
	N	44	41	44	44	44	44
In your opinion, do green supply chain initiatives make the	Pearson Correlation	.671**	.516**	.271	.189	1	.c
	Sig. (2-tailed)	.000	.001	.075	.218		0.000
	N	44	41	44	44	44	44
Does your organisation utilise procurement to achieve sustainable objectives? In other	Pearson Correlation	.304*	.227	.238	.c	.c	1
	Sig. (2-tailed)	.034	.129	.099	0.000	0.000	
	N	49	46	49	44	44	49

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

c. Cannot be computed because at least one of the variables is constant.

Source: Original

- *Correlation between implementation a sustainable supply chain and coordination lean and green efforts*

As revealed in Table 7-25, a significance level of (0.000-0.028) demonstrates that implementing a sustainable supply chain is highly correlated to having both *lean* and *green* teams working together while utilising procurement to address sustainable objectives and certifying suppliers for their sustainability and environmental behaviour.

Table 7-25 Correlation between implementation a sustainable supply chain and coordination *lean* and *green* efforts

		Does your organisation address the importance of developing and implementing a sustainable supply ch...	If both LSCMS and GSCMS do exist in your organisation, does the lean team work together with the gre...	Does your organisation utilise procurement to achieve sustainable objectives? In other words, does t...	Does your organisation certify suppliers for sustainability and environmental behaviour?
Does your organisation address the importance of developing and implementing a sustainable supply ch...	Pearson Correlation	1	.325*	.700**	.315*
	Sig. (2-tailed)		.028	.000	.027
	N	49	46	49	49
If both LSCMS and GSCMS do exist in your organisation, does the lean team work together with the gre...	Pearson Correlation	.325*	1	.227	.470**
	Sig. (2-tailed)	.028		.129	.001
	N	46	46	46	46
Does your organisation utilise procurement to achieve sustainable objectives? In other words, does t...	Pearson Correlation	.700**	.227	1	.484**
	Sig. (2-tailed)	.000	.129		.000
	N	49	46	49	49
Does your organisation certify suppliers for sustainability and environmental behaviour?	Pearson Correlation	.315*	.470**	.484**	1
	Sig. (2-tailed)	.027	.001	.000	
	N	49	46	49	49

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Source: Original

7.6.3 **Regression**

To follow up on the correlations above, multiple regression tests were performed to understand the relationships and possible multi-variant effects of several independent variables on a certain dependent variable.

- *The relationship between successfully implementing a sustainable supply chain and focusing on management and culture, organisational philosophy, throughput improvement, utilising procurement and certifying suppliers, focusing on customers and having efficient infrastructure to achieve sustainable outcomes*

A multiple regression test with an R of (0.924), as shown in Table 7-26, means that all the variables are highly correlated together. In other words, developing and implementing a sustainable supply chain is highly correlated to having a *green* and a *lean* supply chain management in place, working together as well as utilising procurement and certifying suppliers to achieve sustainable objectives. Similarly, an

R square of (0.793) means that 79 per cent of the variation in implementing a sustainable supply chain successfully can be explained by linear regression..

Table 7-26 Regression: The relationship between successfully implementing a sustainable supply chain and focusing on management and culture, organisational philosophy, throughput improvement, utilising procurement and certifying suppliers, focusing on customers and having efficient infrastructure to achieve sustainable outcomes

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.924[a]	.793	.778	.210

a. Predictors: (constant), Please identify the main factors you believe are essential to successfully integrate lean manufacturing with env...-Organisational philosophy, Please identify the main factors you believe are essential to successfully integrate lean manufacturing with env...-Throughput improvement, The following are a set of key factors to successful lean manufacturing implementation. Please indi...-Reliable and efficient equipment and infrastructure, The following are a set of key factors to successful lean manufacturing implementation. Please indi...-Product quality and design, The following are a set of key factors to successful lean manufacturing implementation. Please indi...-Suppliers, The following are a set of key factors to successful lean manufacturing implementation. Please indi...-Customers, The following are a set of key factors to successful lean manufacturing implementation. Please indi...-Management and culture, The following are a set of key factors to successful green manufacturing implementation. Please indi...-Reliable and efficient equipment and infrastructure, The following are a set of key factors to successful green manufacturing implementation. Please indi...-Product quality and design, The following are a set of key factors to successful green manufacturing implementation. Please indi...-Suppliers, The following are a set of key factors to successful green manufacturing implementation. Please indi...-Customers, The following are a set of key factors to successful green manufacturing implementation. Please indi...-Management and culture.

Source: Original

- *The relationship between the ability of an integrated approach to enhance sustainability and coordinate lean and green teams' efforts by certifying suppliers and the utilising procurement function.*

Likewise, the ability of an integrated approach to enhance sustainability and well-coordinate *lean* and *green* teams' efforts is governed by certifying suppliers and utilising the procurement function in order to achieve sustainable objectives, as demonstrated in Table 7-27. An R value of (0.677) means that the variables are correlated, and R square of (0.458) means that 45 per cent of the variation in achieving enhanced sustainability levels through an integrated approach can be explained by linear regression (i.e. caused by the given independent variables).

Table 7-27 Regression: The relationship between the ability of an integrated approach to enhance sustainability and coordinating *lean* and *green* teams' efforts, certifying suppliers and utilising the procurement function.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.677[a]	.458	.391	.283

a. Predictors: (Constant), Does your organisation certify suppliers for sustainability and environmental behaviour?, Considering that a Lean Supply Chain Management System (LSCMS) is an organisational management model..., Does your organisation utilise procurement to achieve sustainable objectives? In other words, does t..., If both LSCMS and GSCMS do exist in your organisation, does the lean team work together with the gre..., Considering that a Green Supply Chain Management System (GSCMS) is an organisational management mode...

Source: Original

- *The relationship between the ability of an integrated approach to enhance sustainability and green's enhancement of lean's environmental performance and the efficiency of overall supply chain*

Table 7-27 demonstrates that for an integrated supply chain to enhance an organisation's ability to achieve higher levels of sustainability, a multiple regression test with an R of (0.826) indicates that a GSCMS shall be able to enhance *lean*'s environmental performance and the efficiency of overall supply chain. An R square of (0.683) means that 68 per cent of the variation in achieving higher sustainability levels through an integrated approach can be explained by linear regression (i.e. through the GSCMS's ability to enhance *lean*'s environmental performance and the efficiency of overall supply chain).

Table 7-28 Regression: The relationship between the ability of an integrated approach to enhance sustainability and *green*'s enhancement of *lean*'s environmental performance and the efficiency of overall supply chain

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.826[a]	.683	.668	.225

a. Predictors: (Constant), In your opinion, do green supply chain initiatives make the overall organisation supply chain, Do you believe that having a Green Supply Chain Management System (GSCMS) in place can enhance the e...

Source: Original

- *The relationship between attaining satisfaction with a GSCMS and coordinating lean and green efforts while focusing on customers, suppliers, management and culture and having reliable infrastructure*

By applying a multiple regression test, an R value of (0.724) reveals that all these variables are highly correlated together. In other words, satisfaction with *green* supply chain management systems is governed by having a *green* distribution and a *lean* supply chain management in place with both teams focusing on suppliers, customers and having reliable infrastructure. An R square of (0.524) means that 52 per cent of the variation in achieving higher satisfactions levels with a GSCMS can be explained by linear regression.

Table 7-29 Regression: The relationship between attaining satisfaction with GSCMS and coordinating *lean* and *green* efforts while focusing on customers, suppliers, reliable infrastructure as well as management and culture

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.724[a]	.524	.444	.323

a. Predictors: (Constant), The following are a set of key factors to successful green manufacturing implementation. Please indi...-Customers, Considering that green distribution consists of green packaging and green logistics/ transportation...., Considering that a Lean Supply Chain Management System (LSCMS) is an organisational management model..., The following are a set of key factors to successful green manufacturing implementation. Please indi...-Delivering and handling, The following are a set of key factors to successful green manufacturing implementation. Please indi...-Management and culture, The following are a set of key factors to successful green manufacturing implementation. Please indi...-Suppliers

Source: Original

7.6.4 **T-tests**

To assess whether the means of two groups are statistically different from each other, t-tests were performed.

- *The ability of an integrated approach to enhance sustainability outcomes by coordinating lean and green efforts*

As demonstrated in Table 7-30, a t-test with a P value of (0.000) rejects the null hypothesis stating that the two groups (who believed and didn't believe that an integrated approach can significantly develop higher levels of sustainability) didn't differ from each other in regards to having both *green* and *lean* teams working together, with 44 degrees of freedom and a t observed of (3.870).

Table 7-30 T-test: The ability of an integrated approach to enhance sustainability outcomes by coordinating *lean* and *green* efforts

Do you believe that, by integrating LSCMS and GSCMS, your organisation can significantly exhibit hig...		N	Mean	Std. Deviation	Std. Error Mean
If both LSCMS and GSCMS do exist in your organisation, does the lean team work together with the gre...	Yes	39	1.51	.790	.127
	No	7	2.71	.488	.184

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
If both LSCMS and GSCMS do exist in your organisation, does the lean team work together with the gre...	Equal variances assumed	3.436	.071	-3.870	44	.000	-1.201	.310	-1.827	-.576
	Equal variances not assumed			-5.371	12.544	.000	-1.201	.224	-1.686	-.716

Source: Original

- *The ability of an integrated approach to enhance sustainability outcomes by utilising the procurement function*

Likewise, a t-test with a P value of (0.034), as shown in Table 7-31, rejects the null hypothesis that indicated that the two groups (who believed and didn't believe that an integrated approach can significantly develop higher levels of sustainability) didn't differ from each other in terms of utilising the procurement function to achieve sustainable objectives, with 47 degrees of freedom and a t observed of (2.190).

Table 7-31 T- test: The ability of an integrated approach to enhance sustainability outcomes by coordinating *lean* and *green* efforts

Do you believe that, by integrating LSCMS and GSCMS, your organisation can significantly exhibit hig...		N	Mean	Std. Deviation	Std. Error Mean
Does your organisation utilise procurement to achieve sustainable objectives? In other words, does t...	Yes	40	1.00	0.000	0.000
	No	9	1.11	.333	.111

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Does your organisation utilise procurement to achieve sustainable objectives? In other words, does t...	Equal variances assumed	25.056	.000	-2.190	47	.034	-.111	.051	-.213	-.009
	Equal variances not assumed			-1.000	8.000	.347	-.111	.111	-.367	.145

Source: Original

- *The ability of a GSCMS to enhance lean's environmental performance by coordinating lean and green efforts*

As illustrated in Table 7-32, a P value of (0.001) rejects the null hypothesis that indicated that the two groups (who believed and didn't believe that GSCMS enhance *lean*'s environmental performance) didn't differ from each other on the variable we are measuring (both *lean* and *green* team are working together), with 39 degrees of freedom and a t observed of (3.761).

Table 7-32 T- test: The ability of a GSCMS to enhance *lean*'s environmental performance by coordinating *lean* and *green* efforts

Do you believe that having a Green Supply Chain Management System (GSCMS) in place can enhance the e...		N	Mean	Std. Deviation	Std. Error Mean
If both LSCMS and GSCMS do exist in your organisation, does the lean team work together with the gre...	Yes	36	1.39	.688	.115
	No	5	2.60	.548	.245

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
If both LSCMS and GSCMS do exist in your organisation, does the lean team work together with the gre...	Equal variances assumed	.218	.643	-3.761	39	.001	-1.211	.322	-1.862	-.560
	Equal variances not assumed			-4.478	5.911	.004	-1.211	.270	-1.875	-.547

Source: Original

7.6.5 **Cronbach’s Alpha:**

To measure internal consistency and reliability of the questionnaire, the following key areas were tested using Cronbach's alpha.

- *An integrated approach enhances levels of sustainability achieved*

To demonstrate that questions 24-25-28-30[23] all reliably measuring the same latent variable (an integrated approach enhances levels of sustainability achieved), Cronbach's alpha was used. An overall alpha of (0.744) indicates strong internal consistency among the four questions, meaning that respondents who tended to select high/positive scores for one item also tended to select high/positive scores for the other. See Table 7-33.

Table 7-33 Cronbach's alpha: An integrated approach enhances levels of sustainability achieved

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.744	.789	4

Source: Original

- *Procurement and suppliers have the potential to improve sustainable outcomes when developing and implementing a sustainable supply chain*

A Cronbach’s alpha of (0.679), as shown in Table 7-34 indicates that questions 27-33-34[24] reliably measure the latent variable, which states that procurement and

[23] Q24: In your opinion, do *green* supply chain initiatives make the overall supply chain more efficient, less efficient or don’t affect efficiency?
Q25: Do you believe that having a GSCMS in place can enhance the environmental benefits derived from *lean* activities?
Q28: Do you believe that, by integrating LSCMS and GSCMS, your organisation can significantly exhibit higher levels of sustainability (in terms of improving profitability, market reputation, responsiveness to consumers as well as obtaining long-term sustainability) than organisations implementing only *lean* or *green* principles?
Q30: If both LSCMS and GSCMS do exist in your organisation, does the *lean* team work together with the *green* team to achieve sustainable objectives?

[24] Q27: Does your organization address the importance of developing and implementing a sustainable supply chain management system?

suppliers have the potential to improve sustainable outcomes when developing and implementing a sustainable supply chain.

Table 7-34 Cronbach's alpha: Procurement and suppliers have the potential to improve sustainable outcomes when developing and implementing a sustainable supply chain

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.679	.750	3

Source: Original

- Engaging *suppliers to achieve sustainable objectives*

An overall alpha of (0.817) demonstrates strong internal consistency of the items within question 35[25] to reliably measure the latent variable (utilising procurement to achieve sustainable objectives). See Table 7-35.

Table 7-35: Cronbach's alpha: Engaging suppliers to achieve sustainable objectives

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.817	.840	6

Source: Original

The next section contains a discussion and interpretation of the results just presented.

Q33: Does your organization utilize procurement to achieve sustainable objectives? In other words, does the purchasing sector within your organization have the potential power to improve sustainable outcomes by avoiding unnecessary consumption?
Q34: Does your organization certify suppliers for sustainability and environmental behaviour?

[25] Q35: Please indicate whether you agree or disagree with the following statements regarding the extent to which organisation engage their suppliers in achieving sustainable performance? See Appendix.

7.7 Discussion of Results

The findings provide a number of insights into current trends in terms of using different supply chain management systems to address industrial sustainability in the United States.

7.7.1 Findings on LSCMS

To begin with, analysis illustrates that almost all of the organisations in the food, metals and electronics and computer sectors have an LSCMS in place compared to 65 per cent in the petroleum, chemicals and plastics sector. In part, as Abdullah and Rajgopal (2003) indicated, it might be argued that this is because continuous process industries are inherently more efficient and thus present relatively less need for *lean* techniques. However, the increase in *lean* implementation in the food sector, despite it being a continuous process industry, might be due to the unique way in which food manufacturing organisations need to be managed. Dudbridge (2011) argued that the tight profit margins[26] of food manufacturing signify the need for the cost control derived from LSCMS.

In terms of pursuing an LSCMS, large-size organisations in addition to most medium-size organisations have shown significant interest towards pursuing LSCMS, compared to small organisations. With a significance level of (0.029), survey results revealed that the level of interest in *lean* supply chains was directly proportional to the size of the organisation. Similar findings were reported by Karim, Aljuhani, Duplock, and Yarlagadda (2011) in their research on Saudi manufacturing. Karim *et al.* (2011) reported that large-size organisations are more likely to implement and gain the benefit of *lean* manufacturing than small and medium-size companies. A possible explanation is that large organisations possess the capital and resources necessary to invest in *lean* initiatives.

The 5S approach and JIT seem to be at the heart of *lean* production for the majority of respondents in all sectors and the first *lean* practices organisations put into effect to ensure philosophical alignment, reduced storage space and solid or toxic waste, maintaining high quality performance and meeting customer demands. Other key *lean* practices being implemented were VSM and Kanban. However, none had 3P in

[26] Tight profit margin occurs when high performance and low cost are the main factors for business survival (Dudbridge 2011).

practice. The literature review clarified that, unlike 3P, which is an advanced manufacturing tool, the 5S approach and JIT are widely used *lean* practices to improve organisational performance in terms of optimising quality and productivity while eliminating waste and non-value adding activities (Ho *et al.* 1995; Aghazadeh 2003) (US EPA 2003).

In terms of targeted waste, eliminating defects and minimising excess inventory appear to be the ultimate goal of *lean* organisations. This is logical since JIT mainly reduces inventory levels, thereby reducing the potential for products to be damaged during handling or storage, or through deterioration or spoilage over time which in turn reduces the potential to dispose of solid or toxic waste (US EPA 2007). In terms of eliminating defects, the potential relationship between 5S, JIT and quality performance has been well documented in the literature (Flynn, Schroeder, Flynn, Sakakibara, and Bates 1997; Gapp *et al.* 2008; Bayo-Moriones *et al.* 2010; Chen and Tan 2011). Gapp *et al.* (2008) and Bayo-Moriones *et al.* (2010) argued that maintaining order and tidiness systematically in the manufacturing plant can lead inevitably to improvements in quality as well as productivity. Likewise, Flynn *et al.* (1997) and Chen and Tan (2011) illustrated that JIT entails improved quality performance by exposing opportunities for process improvement and reducing the potential for spoilage and damage as well as non-value adding activities through the reduction of inventory buffers.

The majority of respondents to the survey emphasized the major role that suppliers play in implementing *lean* initiatives. Geffen (2000) also demonstrated that working with key suppliers ensures maintaining production quality and cost objectives. Krause *et al.* (2009) also identified suppliers as critical players in optimising organisational sustainable performance. In terms of key factors for successful *lean* implementation, heavy emphasis from all respondents was placed upon product quality and design, followed by having reliable and efficient infrastructure, working with suppliers, utilising *lean* practises and, finally, focusing on management and culture. As mentioned earlier, a focus on product quality and design optimises *lean* performance by exposing opportunities for process improvement and reducing the potential for having defects and non-value adding activities throughout the supply chain (Flynn *et al.* 1997; Krause *et al.* 2009; Chen and Tan 2011). Furthermore, a focus on having properly designed, efficient and maintained infrastructure is in line with Zayati, Biennier, Moalla, and Badr (2012) recommendations, as they suggested that *lean* manufacturing approach requires advanced and efficient manufacturing technologies in order to meet customer demands. Dahlgaard and Dahlgaard-Park (2006) also indicated that successful *lean* production requires focusing on organisational culture and management commitment to involve all employees in reducing waste.

In terms of drivers towards adopting an LSCMS, results show that *lean*'s drivers are deeply rooted in achieving business competitiveness, followed by customer satisfaction, improved quality of the manufactured product, production flexibility and, finally, efficient resources consumption. The interest in *lean* manufacturing, as demonstrated in the literature, lies in its well-developed supply chain management system, maximised efficiency and smooth optimised production flow that aim for cost reduction, quality improvement and rapid responsiveness via waste elimination and employee empowerment in order to maintain quality, remain competitive and achieve customers' satisfaction (Ho *et al.* 1995; Lovelle 2001; Abdulmalek *et al.* 2006; Gapp *et al.* 2008; Lasa *et al.* 2008). An LSCMS streamline suppliers and organise manufacturing facilities and processes in order to achieve flexibility, efficiency as well as satisfy customers' needs.

Moving on to the benefits achieved from adopting an LSCMS, the majority reported higher efficiency and productivity levels as the main gain from implementing *lean* practices, followed by reduction of overall costs and production lead time, as well as an increase in customer satisfaction/loyalty and achieving higher flexibility. A possible explanation that can be derived from the literature is that remarkable efficiencies and reduction in overall cost and lead times can result from *lean* practices by managing jobs by their most basic steps, streamlining suppliers and organising manufacturing facilities (Ruffa 2008; Meyer 2010; Carvalho *et al.* 2011; Torielli *et al.* 2011). For instance, JIT seeks to improve quality and lead time performance (in both production and delivery) by minimising work-in-process inventory that inevitably reduces manufacturing costs associated with excessive inventory such as the cost of having a holding space (Watson 2006).

In terms of *lean*'s environmental performance, survey results revealed that *lean* practices resulted in environmental performance gains. Mainly decreased material usage and improved resource utilisation per unit of production was identified as the main environmental gain achieved from *lean* implementation, which is again a natural extension of *lean*'s aim to increase process efficiency (Scott and Walton 2010). Additionally, 24-19 per cent reported lower gas emissions of hazardous air pollutants and reduced inventory levels as the main environmental gain, followed by reduced waste and hazardous materials throughout the supply chain and improved handling and storage (16-13 per cent). That fits well with Simons and Mason (2003) and Bergmiller (2006) arguments in that *lean's* focus on waste elimination potentially includes a decline of environmental waste including reduction in CO_2 emissions and hazardous waste. The literature demonstrate that a focus on product quality and design, as mentioned earlier, is directly related to enhancing a product's lifecycle impact (Zhao, Sutherland, Handwerker, Harrison, Ramani, Ramanujan, Bernstein, and Thurston 2010). Furthermore, a focus on eliminating defects optimises environmental performance which, according to Sarkis (2001), fits well with the concepts of zero emissions for *lean* organisations. Reducing defects eliminates the environmental impacts related to the materials and processing used to create the defective product, as well as the waste and emissions stemming from reworking or disposing of the defective products (US EPA 2003). Similarly, reducing excess inventory reduces the environmental impact associated with facility space requirements, along with water, energy and material use related to heating, cooling, lighting and maintaining storage area (US EPA 2003). Thus, in respect to the environment, 50 per cent of *lean* organisations had 'never' faced environmental problems due to their *lean* initiatives, while 43 per cent 'rarely' did and only 8 per cent stated that they 'sometimes' faced environmental problems.

Finally, in terms of satisfaction with LSCMS, 85 per cent out of the respondents that had an LSCMS in place were satisfied with their *lean* manufacturing initiative compared to only 10 per cent who were partially satisfied and 5 per cent who were not satisfied with their *lean* system. Interestingly, with a significance level of (0.020), 88 per cent of those satisfied had a GSCMS in place with the majority coordinating *lean* and *green* teams' efforts to achieve sustainable objectives. On the other hand, with a significance level of (0.000), 67 per cent of those unsatisfied or just partially satisfied did not focus on employees and 17 per cent neither focused on suppliers nor customers. Similarly, with a significance level of (0.020 to 0.000), 17 per cent did not coordinate *lean* and *green* teams' efforts and did not focus on management and culture. Thus, the level of satisfaction with LSCMS seems to be highly governed by the following factors: employees' empowerment, suppliers' and customers' involvement, commitment of management and culture and having a GSCMS in place where *lean* and *green* teams work together to achieve sustainability goals. Torielli *et al.* (2011) stressed the fact that empowering employees from all levels is significant in order to embrace sustainable initiatives and achieve maximized waste reduction of all forms. In terms of suppliers, it has been demonstrated earlier that working with key suppliers ensures maintaining quality and cost objectives (Geffen 2000). Furthermore, in *lean* manufacturing focusing on customers is critical to eliminate any non-value added activities (US EPA 2003; Bergmiller 2006; Monczka *et al.* 2009; Kuriger and Chen 2010). A study by Dora, Van Goubergen, Molnar, Gellynck, and Kumar (2012) also confirmed the significance of top management commitment and its culture (e.g. communication, respect, discipline) for successful *lean* implementation. Finally, as previously mentioned in the literature review, researchers illustrated that a GSCMS can enhance operational efficiency by reducing environmental waste, and so integrating *lean* and *green* supply chain management systems help capitalise on cost savings, product differentiation and environmental performance (Clelland *et al.* 2000; King and Lenox 2001; Simons and Mason 2003; Bergmiller and McCright 2009a; Taubitz 2010; Torielli *et al.* 2011).

7.7.2 **Findings on GSCMS**

To begin with, large-size organisations in addition to most medium-size organisations have shown significant interest towards pursuing a GSCMS. Yet with a significance level of (0.102), the size of an organisation doesn't seem to be correlated to *green* implementation. A possible explanation might be that manufacturing organisations of all sizes are under regulatory pressure to implement *green* initiatives. In terms of industry sectors, all organisations in the petrochemical and plastic and metal sector have a *green* GSCMS in place compared to almost 60-80 per cent in the food as well as electronics and computers sector. That might be because the petrochemical and plastic sectors are facing greater regulatory pressures due to the critical amount of non-biodegradable waste that they produce which significantly threatens the environment (Wilmshurst and Frost 2000; Golghate and Pawar 2012). Meanwhile, the metal industry has been shown to be an energy intensive industry and so adopting a GSCMS is a natural response to insure the world’s shift towards environmental sustainability (The Zero Emissions Platform 2013).

Reverse logistics, supplier evaluation and life cycle analysis, followed by implementing *green* distribution strategies, seem to be at the heart of *green* production as they seem to be the key steps to pollution prevention, cost savings and environmental protection within a supply chain. As illustrated by Kassaye (2001), the task of becoming *green* calls for proper disposing of hazardous waste, recovering and recycling resources, and reducing packaging, so that generated wastes are processed and recycled back into the production phase. Evaluating and collaborating with suppliers also helps organisations avoid related environmental risks that may arise from their suppliers’ environmental performance and thus improve overall supply chain performance (Seuring and Müller 2008). Moreover, since supply chains consider the product from initial processing of raw materials to delivery to the end customer, life cycle analysis suggests the extension of the boundary of responsibility to target sustainability all the way through the life cycle of a product (Faisal 2010). Zhu, Sarkis, and Lai (2007) argued that all stages of a product’s life cycle influence a supply chain’s environment burden, from resource extraction, to manufacturing, use and reuse, final recycling or disposal. Thus, according to Rao and Holt (2005), by taking a full life-cycle approach, the production phase of a *green* supply chain has a critical role in increasing eco-efficiency and reducing humans’ environmental risks.

In terms of *green* waste, analysis indicates that a GSCMS takes a narrower focus than *lean* by targeting only those wastes that have environmental implications. The main environmental concerns for manufacturing organisations are toxic chemical waste and greenhouse gas emissions. That runs smoothly with the US EPA (2001) (US EPA 2001) view that toxic waste and hazardous air pollutants are the biggest environmental and health concerns. Furthermore, just like *lean* manufacturing, the majority of respondents identified suppliers as critical players in implementing *lean* initiatives, which is well demonstrated in the literature (Geffen 2000). Geffen (2000) and Seuring and Müller (2008) emphasised the critical role that suppliers play in optimising an organisation's environmental performance. Seuring and Müller (2008) found that evaluating and collaborating with suppliers helps organisations avoid environmental risks that may arise from suppliers' activities and thus improve overall supply chain performance.

In terms of key factors for successful *green* implementation, notably 91 per cent focused on product quality and design, similar to *lean* manufacturing. That might be due to the fact that quality and the environment are often closely linked, as quality usually means a longer product life and thus less consumption of resources because of lower replacement rates (Zhao *et al.* 2010). *Green* organisations also appear to focus, in different degrees, on corporate image, suppliers, management and culture, utilising *green* tools and techniques and having reliable and efficient equipment and infrastructure in place. Reviewing the literature, Chang and Tu (2005) demonstrated that promoting a *green* corporate image has significant impact on customer satisfaction which is a key factor to successful implementation. Meanwhile, *green* infrastructure, can guide in prioritising conservation opportunities, facilitating *green* activities, as suggested by Benedict and Mcmahon (2006). The *green* management literature also stressed the importance of organisational culture and management commitment in embracing new environmentally responsible values, beliefs and behaviours (Newton and Harte 1997).

Moving on to *green* drivers, survey analysis identified a broad range of drivers for engaging with *green*. The drivers for GSCMS, while often strong, are not typically of the same magnitude as those behind *lean* implementation. The drivers identified were mostly in response to customers' demands for sustainable behaviour and reduction of carbon gas emissions, followed by the aim to achieving a competitive advantage and better managing potential risk. Abbasi and Nilsson (2012) indicated that manufacturing organisations in the 21st Century are inevitably facing increasing pressure to satisfy the public and comply with environmental regulations in order to optimise organisational environmental performance, attain customers' loyalty and avoid environmental risks and penalties.

Benefits achieved from adopting a GSCMS include improved corporate image, followed by reduced amount of solid wastes, gas emission and environmental impacts. Results also revealed that 86 per cent believed that *green* supply chain initiatives led to production efficiency gains and 84 per cent believed that having a GSCMS in place can enhance the environmental performance from *lean* activities. Rao and Holt (2005) and Testa and Iraldo (2010) identified that *green*ing the different phases of the supply chain contributes to improved environmental performance and ultimately leads to gaining a possible competitive advantage by signalling environmental concern. Furthermore, Clelland *et al.* (2000) demonstrated that *green*'s waste-minimisation efforts enhance operational efficiency, through resource reduction and *green* distribution, which indicates that *green* can deliver consistent operational-efficiency spill-over to *lean* activities.

Finally, in terms of satisfaction with GSCMS, results show that 80 of the respondents that had a GSCMS in place were satisfied with their *green* manufacturing initiative compared to 18 per cent who were partially satisfied and 2 per cent who were not satisfied with their *green* results. Once again, almost 76 per cent of satisfied organisations had an LSCMS in place with the majority coordinating *lean* and *green* teams' efforts to achieve sustainable objectives, a significance level of (0.008). Digging deeper into the analysis, a significance level ranging from (0.010 to 0.000) demonstrates that 67 per cent out of those unsatisfied or just partially satisfied did not have *green* distribution in place, 33 per cent did not coordinate *lean* and *green* efforts and 11 per cent did not focus on suppliers, customers, delivering and handling, or management and culture. Thus, the level of satisfaction with a GSCMS seems to be highly governed by the following factors: implementation of *green* distribution strategies, suppliers' and customers' involvement, commitment of management and culture and having an LSCMS in place where *lean* and *green* teams work together to achieve sustainability goals. As indicated earlier, a focus on supplier evaluation and involvement is critical to optimise the environmental performance of an organisation (Geffen 2000; Seuring and Müller 2008).

Meanwhile, a focus on customers' expectations can help in improving the role of organisations in meeting sustainability objectives (ElTayeb *et al.* 2010). Likewise, a focus on *green* logistics (delivering and handling) decreases the usage of energy and materials in logistics activities to satisfy the customers' environmental demands (Lai and Wong 2012). In terms of management and culture, an empirical research by Zsoka (2007) suggested the need for management commitment and integrating environmental values into organisational culture to optimise environmental performance. Finally, implementing *lean* strategies can help organisations in recognising environmental opportunities and evaluating supply chain decisions in terms of environmental impact, and so integrating *lean* and *green* supply chain management systems may help capitalise on cost savings, product differentiation and environmental performance (King and Lenox 2001; Simons and Mason 2003; Bergmiller and McCright 2009a; Taubitz 2010; Torielli *et al.* 2011).

7.7.3 **Findings on the Management System**

By analysing the survey results, one can readily identify the following trends, which in turn provide an opportunity, to address many aspects of meeting financial and environmental targets.

Survey analysis revealed a strong tendency on the side of manufacturing organisations to develop and implement a sustainable supply chain management system. 82 per cent believed that by integrating LSCMS and GSCMS their organisation could significantly exhibit higher levels of sustainability by reducing costs and being able to better serve customers and changes in environmental requirements, and 76 per cent of the organisations with both systems in place stated that they work on coordinating the efforts of their *lean* and *green* teams to achieve sustainable objectives. As previously illustrated in the literature, modifying manufacturers' supply chains to integrate both *lean* and *green* supply chain management systems can help capitalise on cost savings, product differentiation and environmental performance (King and Lenox 2001; Simons and Mason 2003; Bergmiller and McCright 2009a; Taubitz 2010; Torielli *et al.* 2011). Cross tabulation also illustrated that if both *lean* and *green* supply chain management systems do exist in an organisation but don't work and coordinate well together (existing in parallel), satisfaction drops by 50 per cent towards both initiatives. Thus, a good integrating management system has to be in place; otherwise, organisations would be much better satisfied with their *lean* or *green* approach when only one supply chain management system exists.

In terms of driving sustainability, 78 per cent appear to have made an effort to improve material and resource utilisation, while 59-51 per cent have made an effort to reduce CO_2 emission and hazardous materials from products as well as to reduce unnecessary packaging, thus focusing on both environmental and financial perspectives of sustainably. Furthermore, 59 per cent of the respondent to the survey believed that procurement is the best function to coordinate different aspects of *lean* and *green* operations to satisfy customers' needs. Zhu and Geng (2001) argued that purchasers are key personnel for ensuring environmental preferable decisions in supplier selection and that they are the best qualified to adopt a more environmentally friendly purchasing practice.

Finally, according to this research, the supporting pillars to improve supply chain sustainable performance are organisational philosophy and throughput improvement, as identified in the results. That actually fits well with the Torielli *et al.* (2011) argument that in order to embrace sustainable initiatives and maximise waste reduction of all forms, organisational philosophy must define and develop clear objectives and strategies while involving employees from all levels. Byars and Neil (1987) also signified the importance of reinforcing the philosophy by senior management. Torielli *et al.* (2011) also stated that a cornerstone of *lean* and *green* implementation is the efficient use of resources, or the elimination of waste which can be achieved through increased throughput of materials.

7.7.4 **Findings on Procurement**

Having seen the significance of suppliers in ensuring successful implementation of both *lean* and *green* SCMS to achieve better sustainable performance, it is now obvious that incorporating sustainable criteria in the evaluation systems and deciding which suppliers to collaborate with is a crucial decision for organisational performance. That is well reflected in the survey results. With a significance level of 0.003, results reveal that 58 per cent of organisations utilised procurement to achieve sustainable objectives and 62 per cent indicated that their organisations certify suppliers to enhance sustainable performance which signifies the critical role that the procurement function can play in managing the sustainability performance of an organisation and coordinating different aspects of *lean* and *green* initiatives.

A multiple regression test with an R value of (0.685) means that the ability of an integrated approach to enhance an organisation’s ability to achieve higher levels of sustainability is determined by coordinating *lean* and *green* teams’ efforts, certifying suppliers and the utilising procurement function. An R square of (0.469) means that

46 per cent of the variation in achieving higher sustainability levels through an integrated approach can be explained by linear regression (i.e. caused by the given independent variables). While a Cronbach's alpha of (0.679) indicates that questions 27-33-34[27] reliably measure the latent variable which states that procurement and suppliers have the potential to improve sustainable outcomes when developing and implementing a sustainable supply chain.

In terms of the degree to which organisations engage suppliers to achieve sustainable objectives, 92 per cent of surveyed organisations set environmental criteria that suppliers must meet. 82 per cent actively consider switching to more sustainable suppliers. Furthermore, 71 per cent work with key suppliers to ensure continuous improvement in technical and human capabilities while 61 per cent actively monitor and evaluate suppliers' environmental performance and risks. Finally, 59 per cent encourage suppliers to be highly responsive to customer demand while producing quality products in the most efficient and economical manner.

7.8 Summary of Findings in Relation to Proposed Hypothesis

The outcomes of the survey provide a rich picture of successful *lean-green* integration in the Unites States manufacturing industry to simultaneously realise greater financial and environmental objectives. The findings demonstrated the significance of the procurement function and developing a supply chain management system that integrates both *lean* and *green* strategies to help reduce operational and environmental waste and thus achieve even higher levels of industrial sustainability that are beyond the scope of a given manufacturing system:

The majority of organisations, 82 per cent, believe that the synergy of an integrated approach is expected to enhance levels of sustainability, by reducing or even eliminating waste, duplications, inconsistencies and incompatibilities, if both *lean* and *green* personnel are well integrated into operations, **supporting Hypothesis I**. Once environmentally aware personnel gain familiarity and proficiency with *lean*

[27] Q27: Does your organization address the importance of developing and implementing a sustainable supply chain management system?
Q33: Does your organization utilize procurement to achieve sustainable objectives? In other words, does the purchasing sector within your organization have the potential power to improve sustainable outcomes by avoiding unnecessary consumption?
Q34: Does your organization certify suppliers for sustainability and environmental behaviour?

methods and processes, *lean* tools can be used to explicitly address environmental objectives such as hazardous waste minimisation and risk reduction.
Survey results also demonstrated that *lean* provides an excellent platform for incorporating *green*/environmental objectives, **supporting Hypothesis II**. 83 per cent of *lean* organisations reported that *lean* strategies, specifically JIT and 5S, which are at the heart of *lean* production, yielded increased efficiency, while reducing defects, inventory and resource use, which is by its very nature *green*. However, when the benefits of waste reduction efforts are not outweighed by the costs of developing, planning and implementing these reduction efforts, an integrated approach towards encompassing both GSCMS and LSCMS may result in trade-offs of either system, **supporting Hypothesis III**.

Seven key factors were identified to contribute to successful integration of *lean* and *green* supply chain management system and attainment of enhanced levels of sustainability within an implemented supply chain management system, **supporting hypothesis IV.** The majority of respondents to the survey identified organisational philosophy and throughput improvement as the supporting pillars to improve supply chain sustainable performance. Five additional factors can also be derived by merging and capturing the common key factors defined by respondents to successfully implement either *lean* or *green* initiatives. In addition to organisational philosophy and throughput improvement, a focus on product quality and design, suppliers, customers, management and culture and having reliable and efficient equipment and infrastructure are key factors to an integrated approach.

Finally, the procurement function within an organisation appears to hold potential for a significant impact on achieving sustainability goals, such as reducing overall costs and emission rates, **supporting hypothesis V**. Results reveal that 98 per cent of organisations utilised procurement to achieve sustainable objectives and 62 per cent indicated that their organisations certify suppliers to enhance sustainable performance which signifies the critical role that the procurement function can play in managing the sustainability performance of an organisation and coordinating different aspects of *lean* and *green* initiatives.

8 Chapter 8 - Conclusions and Recommendations

Chapter Eight summarises the research and discusses conclusions drawn from this thesis study as well as provides future research directions and managerial recommendations to enhance an organisation's sustainable performance through supply chain management.

8.1 Summary of the Research

8.1.1 Summary of the Background to the Research

Phenomena such as *sustainable development* and *industrial sustainability* have seemingly emerged in response to the need for achieving overall sustainability in industrial activities. It is closely related to those evolving causes such as environmental degradation, rapid population growth, unstable levels of waste, global warming and greenhouse gas emission, all of which signify the fragile and finite nature of our natural environment. There is a need to visualise a future where we create new resources and absorb waste in order to support future generations. Throughout this research, as stated in Chapter Three, the notion of sustainability has been limited to incorporate only financial and environmental perspectives – that is, motivating a bottom line strategy to save costs, reach new customers and increase profit while protecting the environment.

The literature review, detailed in Chapter Three, demonstrated that the manufacturing industry lies at the core of industrial economies and can proactively address sustainability in their strategies and operations in order to preserve the high standard of living achieved by industrialised societies and to enable developing societies to enjoy the benefits of industrialisation while giving future generations the choices, options and opportunities to meet new challenges and secure their wellbeing[28] (Reich-Weiser 2010). As more nations seek to industrialise, adopting and operating on the principles of a sustainable manufacturing system that takes full responsibility for the impact of manufactured goods appears to be more critical than ever before to attain a sustainable future. Sustainable manufacturing acknowledges the equal importance of each of the three aspects of sustainable development

[28] Wellbeing: The state of experiencing health, prosperity and quality of life due to environmental and financial sustainability.

(financial prosperity, environmental sustainability and social equity) throughout a product's life cycle as well as the significant role that supply chain management can play in contributing towards sustainability. Arguably carrying the largest employment and economic multiplier effect of all sectors in the United States economy – because of the enormous amount of energy consumed and waste generated – is the manufacturing industry, with the literature review revealing that modifying manufacturers' supply chains may be the key to guaranteeing a sustainable future.

Meeting sustainability goals by improving manufacturers' supply chain performance to address sustainability objectives – by challenging the way resources are being consumed and minimising waste all the way across key business processes in the organisation – has been a critical issue that has gained increased interest in both academic literature and industry practice (Bergmiller 2006; Cai *et al.* 2009; Abbasi and Nilsson 2012; Walker and Jones 2012) over the past 25 years. Researchers have suggested that *lean supply chain management systems* (LSCMS) and *green supply chain management system* (GSCMS) are two distinct supply chain management systems that address the financial and environmental aspects of sustainability respectively (Bergmiller 2006; Reisman and Burns 2006).

Through *green* manufacturing, a GSCMS aims for environmental sustainability by working to minimise the environmental impact along the life cycle of products. An LSCMS utilised in *lean* manufacturing ensures an optimised level of production flow and cost savings as well as minimised inefficiencies and quality defects in every facet of the manufacturing supply chain, a key component to achieving financial sustainability. Both *lean* and *green* research efforts in recent years have made it clear that modifying manufacturers' supply chains to integrate both *lean* and *green* supply chain management systems may help reduce operational and environmental waste by capitalising on cost savings, product differentiation and environmental protection. The claimed result was to achieve even higher levels of industrial sustainability that are outside of the normal scope of a single manufacturing system (King and Lenox 2001; Simons and Mason 2003; Bergmiller and McCright 2009a; Taubitz 2010; Torielli *et al.* 2011).

Yet the dilemma presented in Chapter Four reveals points of conflict and blind spots that may occur during integration (Rothenberg *et al.* 2001; Bergmiller 2006; Venkat and Wakeland 2006). Thus, developing a supply chain management system that allows for meaningful correlation between major factors of the two systems is critical to simultaneously reducing a firm's environmental impact while positively influencing financial success, thereby fulfilling the significant objectives of industrial sustainable development.

Procurement has also been increasingly identified as a key business process contributing to improved sustainability outcomes due to the value of its purchasing expenditure and proactively taking responsibility for the sustainability of suppliers' products. Rather than solely focusing on the traditional financial parameters, sustainable procurement, as illustrated in the literature review, elevates the procurement function to consider the broader objectives of sustainable development, by considering life-cycle costs and balancing the financial, social and environmental elements of procurement decision making (Cousins *et al.* 2008; Walker and Phillips 2009).

8.1.2 **The Research Purpose**

The overarching research purpose, outlined in Chapter One, was to explore:

Will integrating lean and green supply chain management systems simultaneously realise positive financial and environmental outcomes and thus achieve higher levels of sustainability? Secondly, what factors contribute to successful integration and attainment of enhanced levels of sustainability?

The main aim is to help transform a supply chain into a real sustainable entity that could preserve the dynamic aspects of *lean* production while assuring harmonisation with the environmental aspects of *green* manufacturing, without simply pushing particular environmental issues back to a previous stage in the supply chain.

In an attempt to answer the overarching research question, the study also sought to answer a number of other questions, such as:

- Do *lean* initiatives spill over to reduce environmental waste due to *lean*'s waste elimination culture?

- Does an integrated approach of both GSCMS and LSCMS result in trade-offs between the environmental and financial dimensions of sustainability?
- Does the procurement function within an organisation have a potentially significant impact on achieving sustainability goals, such as reducing overall costs and emission rates?

This research was undertaken by conducting an in-depth literature review of the sustainability literature within the context of supply chain management and procurement in manufacturing industries in U.S., supported by original empirical research. It explicitly investigated the critical role that supply chain management can play in contributing towards sustainability through *lean* and *green* supply chain management systems and the various trade-offs involved during integration. It also investigated the role of the procurement function in enhancing an organisation's sustainable performance.

As a means to better understand *lean* and *green*'s impact on supply chain performance, the available literature was synthesised and used to create a series of diagrams (see Chapter Five) to visually depict and elaborate the overlaps, trade-offs and cause-effect relationships between *lean* and *green* supply chain paradigms and their effect on supply chain performance. The diagrams were helpful in exploring the key areas of *green* and *lean* supply chain management systems, their scope, the extent of their implementation, the driving forces, waste and concerns, business processes and benefits achieved from implementing each system. Survey questions were then developed accordingly. The survey struck a balance between conciseness and depth of both *lean* and *green* manufacturing by covering their supply chain management practices, drivers, waste, benefits and outcomes, along with a focus on the organisation's management system and the procurement function in reaching out to attain sustainability objectives.

8.1.3 **The Research Problem Revisited**

With an increasingly complex business environment, organisations may struggle to understand the various trade-offs acquired when integrating both LSCMS and GSCMs, as each system focuses on a different aspect of sustainability. Studies have fallen short in presenting an approach that effectively merges *lean* and *green* paradigms in managing supply chains to help transform a supply chain and consequently an organisation into a truly sustainable entity.

A potential improvement would be to harness the synergetic effect of LSCMS and GSCMS integration by better understanding the relationship between *lean* and *green* manufacturing systems and presenting an approach of continuous improvement that considers supply chain contextual factors that determine successful integration and high levels of satisfaction. Developing a supply chain management system that allows for meaningful correlation between major principles of the two systems, while realising the dynamics of an integrated approach, can achieve considerable financial and environmental improvements through an increase in capital efficiency, reduction of environmental impact and associated costs, and enhancement in market reputation. Developing a supply chain management system that allows for meaningful correlation between the major principles of the two systems, while realising the dynamics of an integrated approach, is critical to reducing an organisation's environmental impact while simultaneously reducing the marginal cost of environmental performance and enhancing production efficiency. This research gap was captured by both Bergmiller (2006) and Carvalho *et al.* (2011) as they both highlighted the need for empirical research to validate the relationship between *lean* and *green* supply chain management systems to promote cost savings, product differentiation and environmental performance. This is the challenge taken up in this research.

8.1.4 **Summary of the Outcomes of the Research**

The main empirical findings provide answers to five questions relevant to this research. The first three questions represent a capstone to this thesis.

1. Do manufacturers adopting an integrated approach, utilising both LSCMS and GSCMS, exhibit significantly higher levels of sustainability than manufacturers implementing only *lean* or *green* principles?

The survey statistics indicate that organisations integrating *lean* and *green* supply chain management systems realise greater financial and environmental objectives and thus achieve even higher levels of industrial sustainability that are outside of the normal scope of a single manufacturing system, by taking a holistic approach to explicitly eliminating additional waste throughout the manufacturing cycle of a product. This outcome is consistent with that of King and Lenox (2001), Simons and Mason (2003), Bergmiller and McCright (2009a), Taubitz (2010), and Torielli *et al.* (2011). The U.S, Environmental Protection Authority (2003) also promoted the link between *lean* and *green* practices as a key approach to recognising new opportunities and embracing environmental sustainability.

Survey results revealed 94 per cent of *lean* organisations believe that having a GSCMS in place is very much related to enhancing their environmental performance, with a significance level of (0.002). A GSCMS can expand the focus of *lean* activities by redefining "waste" to look beyond typical production waste and thus address environmental "blind spots," such as the risk or toxicity of materials used and the full life cycle impacts of products and processes. A multiple regression test with an R of (0.826) indicates that a GSCMS shall be able to enhance *lean*'s environmental performance and the efficiency of overall supply chain.

2. *What factors contribute to successful integration and attainment of enhanced levels of sustainability*?

Supporting the literature, respondents to the survey focused on seven key factors to successfully implement and integrate *lean* and *green* supply chain management systems. Organisational philosophy, throughput improvement, management and culture, as well as a focus on product quality and design, suppliers, customers, and having reliable and efficient equipment and infrastructure, appear to be key factors to a successful integrated approach. All factors expose opportunities for process improvement and allow for a proactive management to prioritise conservative opportunities during a product's life cycle. This was supported in the research finding by a multiple regression test. An R value of (0.924) means that developing and successfully implementing a sustainable supply chain is highly correlated to a focus on organisational philosophy, throughput improvement, management and culture, as well as product quality and design, suppliers, customers, and having reliable and efficient equipment and infrastructure. Similarly, an R square of (0.793) means there is a perfect fit towards that trend and thus given the value of one term, one can perfectly predict the value of another term.

This finding fits well with the literature. Byars and Neil (1987), Newton and Harte (1997) and Dahlgaard and Dahlgaard-Park (2006) stressed the importance of organisational culture and management commitment in embracing *lean* and *green* initiatives and coordinating their efforts to achieve sustainable objectives and highlighted the significance of reinforcing the organisational philosophy by senior management. Torielli *et al.* (2011) also argued that in order to embrace sustainable initiatives and maximise waste reduction of all forms, the organisational philosophy must involve employees from all levels. Torielli *et al.* (2011) even stated that a cornerstone of the *lean* and *green* implementation is efficient use of resources, or the elimination of waste which can be achieved through increased throughput improvements, efficient manufacturing technologies and reliable infrastructure. Furthermore, apart from being performance measures, product quality and design are directly related to enhancing a product's life-cycle impacts which is the output of the product development process (Zhao *et al.* 2010). Krause *et al.* (2009) also emphasised the major role that suppliers play in optimising organisational sustainable performance. Finally, in order to eliminate any non-value added activities, focusing on customers is critical (US EPA 2003; Bergmiller 2006; Monczka *et al.* 2009; Kuriger and Chen 2010).

3. Does the procurement function within an organisation has a significant impact on achieving sustainability goals?

The procurement function within an organisation appears to have significant impact on achieving sustainability goals, such as reducing overall costs and emission rates. This is consistent with the Miemczyk *et al.* (2012) view, as they considered procurement central to achieving sustainability. A correlation test with a significance level of (0.000-0.028) demonstrates that implementing a sustainable supply chain is highly correlated to having both *lean* and *green* teams working together, utilising procurement to address sustainable objectives and certifying suppliers for their sustainability and environmental behaviour. A cross tabulation table test shows that 58 per cent of those who believe that an integrated approach can enhance sustainability levels are utilising procurement to do so. Furthermore, a higher significance level in regards to attaining satisfaction towards a particular supply chain management system appears to be found in organisations utilising procurement to achieve sustainable objectives. Cross tabulation shows that almost 80 per cent of organisations with sustainable procurement are satisfied with their GSCMS, a significance level of (0.000). Likewise, 87 per cent of organisations utilising procurement to achieve sustainable objectives are satisfied with their LSCMS, a significance level of (0.010). Finally, a multiple regression test with an R value of (0.677) means that the ability of an integrated approach to enhance sustainability and coordinate *lean* and *green* teams' efforts well is highly correlated to certifying suppliers and utilising the procurement function in order to achieve sustainable objectives. An R square of (0.458) also means that 45 per cent of the variation in achieving enhanced sustainability levels through an integrated approach can be explained by linear regression (i.e. caused by supplier evaluation and procurement utilisation.

4. Do *lean* initiatives spill over to reduce environmental waste due to their waste elimination culture?

Lean provides an excellent platform for incorporating *green* objectives, as significant environmental benefits can typically follow *lean* initiatives. The majority of *lean* organisations reported that *lean* strategies yielded increased efficiency, improved resource utilisation and decreased material usage per unit of production. These are the essence of sustainability and by their very nature, *green*. An explanation can be derived from the literature when Bergmiller and McCright (2009a) and Torielli *et al.* (2011) emphasised that from a sustainability perspective, most if not all environmental impacts can be viewed as waste. Thus, it seems natural to use the *lean* philosophy as a powerful tool to improve environmental sustainability, a view supported by the survey findings. Survey results revealed that notably 50 per cent of the respondents to the survey, that have an LSCMS in place, had never faced environmental problems when implementing *lean*, while 43 per cent rarely faced environmental problems.

5. Does an integrated approach of both GSCMS and LSCMS result in trade-offs between the environmental and financial dimensions of sustainability?

An integrated approach of both GSCMS and LSCMS may result in trade-offs of either system. It is an argument consistently made by a number of prior studies that that there is an inherent trade-off between *lean* and *green* supply chain management systems (Rothenberg *et al*. 2001; US EPA 2003; Bergmiller 2006; Venkat and Wakeland 2006; Faisal 2010). The difficulties arise when the benefits of waste reduction efforts are not outweighed by the costs of developing, planning and implementing these reduction efforts. For instance, survey analysis suggests that failure to consider 3P as a significant *lean* practice by all of the *lean* organisations being surveyed decreases the ease of disassembly and recycling for manufactured products due to complex product designs and thus disregards valuable pollution prevention and sustainability options.

However, data analysis indicates that such a trade-off will most likely be offset by the synergetic effect, as only 8 per cent of *lean* organisations reported facing environmental problems. 83 per cent of *lean* organisations reported that *lean* strategies, specifically JIT and 5S, which are at the heart of *lean* production, yielded increased efficiency, reduction of inventory and resource use and prevention of defects, which are by their very nature *green*. In spite of the fact that adopting JIT practices by the majority of *lean* organisations entails increased number of transportation trips, JIT practices help eliminate over-production, which in turn reduces environment impacts in three different ways. First, it reduces inventory levels and thereby reduces solid and toxic waste that may result during handling and storage or through deterioration or spoilage over time. Second, it reduces the amount of raw materials used in production. Third, it reduces facility space requirements, along with water, energy and material use associated with heating, cooling, lighting and maintaining storage area.

Results demonstrated that a GSCMS can also improve or add value to *lean* methods that do not explicitly consider environmental risk factors, such as the toxicity of substances in products and production processes. A GSCMS can enhance operational efficiency derived from *lean* initiatives by redefining “waste” to consider environmental “blind spots,” such as considering the risk or toxicity of materials used and the full life-cycle impacts of products and processes. For instance, results revealed that 81 per cent of *green* organisations implement *green* distribution strategies, by designing smart packages and rearranging loading patterns, which is of value to *lean* as it can reduce materials usage, increase space utilisation in the warehouse and reduce the amount of handling required.

8.2 **Contributions to Theory**

This research provides a number of contributions to the theoretical debate in this field. The first contribution is that it establishes, with an empirical analysis, that efficient production and environmental impacts are closely linked, synergising the implementation of *lean* and *green* philosophies to achieve financial and environmental sustainability. The Second contribution is that, as opposed to some literature on *lean* and *green* supply chain management, trade-offs between LSCMS and GSCMS will likely be offset by the synergetic effect.The Third contribution is that it demonstrates that in order to effectively integrate *lean* and *green* supply chain management systems, there is a need to focus on organisational philosophy and throughput improvement, management and culture, product quality and design, suppliers, customers, and reliable and efficient equipment and infrastructure. Finally, the fourth contribution illustrates that the major role that the procurement function plays within an organisation appears to facilitate achieving sustainability goals and coordinating *lean* and *green* principles through overall costs reduction and minimising products' emission rates.

8.3 **Contributions to Practice**

It is apparent from the responses to the empirical research that supply chain management, per se, is seen to offer significant potential to reduce costs and improve environmental performance and customer service. The evidence suggests that to increase financial gains while simultaneously reducing environmental impact of an organisation, *both lean* and *green* manufacturing systems could be integrated and continuously adjusted to fit a particular organisational environment. According to the results of the study, the cornerstone of *lean* and *green* implementation is an organisational philosophy that supports positive environmental outcomes.

A dilemma exposed by the study is the need to develop a supply chain management system that is robust enough to capture the complexities of both *lean* and *green* systems, while general enough to allow for meaningful correlation between major factors of the two systems. Indeed, the whole idea of a sustainable supply chain is to reduce costs while protecting the environment. It seems that organisations that consciously adopt *lean* methods to achieve their environmental objectives at the least cost, evaluating upstream and downstream process inputs and outputs and analysing how decisions will impact on their manufacturing processes, will enhance the financial and environmental performance of their business. The evidence from this study also shows that there is a need to incorporate focus on sustainability into an organisation's day-to-day procurement processes. Suppliers are critical to the successful development, implementation and maintenance of corporate sustainability in the manufacturing industry, and procurement policy and practices should reflect the organisation’s sustainability policy and seek out suppliers who also support this ethos.

8.4 **Limitations of the Research and Opportunities for Future Research**

The outcomes of this research reveal that this is a work in progress, and offer the beginning of a larger piece of research to explore the nature and implications of the notion of sustainability within a supply chain management context. The main limitation of this research is the sample size. The sample size of 49 organisations seems small to make generalisations on the research subject. Confidence can be driven from the validation process utilised, but there is always greater security in higher numbers. A more extensive survey with a larger respondent pool could provide more statistically significant evidence for the quantitative conclusions reached here.

The survey instrument itself was also a limiting factor because it may not convey the details of what is really going behind the scenes that led to the results seen in the survey data. Having had time to conduct case studies of each organisation, would have possibly yielded a much richer understanding of where integration and conflict were occurring between *lean* and *green* manufacturing systems.

Furthermore, literature review revealed a lack of research in linking sustainable procurement with both *lean* and *green* supply chain management systems which can be considered as a topic for future research.

Finally, the notion of sustainability in this research has been limited to incorporating only the financial and environmental perspectives. So a potential improvement will be to examine the effect of an integrated approach upon the wider aspect of sustainability, by including the social aspect.

9 Appendix

Survey Questionnaire on Integrating *Lean* and *Green* Supply Chain Management Systems in Manufacturing

Supply Chain Management systems are part of the new wave of business development processes that are being explored by many businesses. Practitioners are faced with many choices and it is often not clear whether a new trend will contribute to the bottom line of a business.

As an American citizen, I decided to investigate a number of aspects of lean and green supply chain management systems in the U.S. manufacturing industry as part of my research towards my Doctor of Business Administration (DBA) at Curtin University in Perth, Australia. The aim of the research is to provide business organisations with a guide to the benefits (and shortcomings) of lean and green supply management systems.

You are one of a number of people I have contacted seeking your contribution to the short survey I have prepared. The survey will take about 15 minutes to complete. The approach I have adopted protects the identity of you and your organisation. The survey is contained in the link which appears below and your answers are compiled automatically and will be reported anonymously.

https://curtin.asia.qualtrics.com/SE/?SID=SV_8308LuzhwV98rZz

If you wish to contact my supervisor, Dr Guy Callender, to confirm the details of this survey, he can be contacted on guy.callender@cbs.curtin.edu.au

I would like to thank you, in anticipation, for your contribution to this study. If you would like to receive details of the outcome of the study (due out in 2013) just let Dr Callender know and we will ensure you have access to the outcome. For any further comments or questions, my contact details are shown below.

Best wishes,

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Q1 Manufacturing is a huge component of the modern economy. The American Bureau of Labor Statistics classifies manufacturing into hundreds of fields and sub-fields. Yet the following list will simplify these into seven general sectors. Which of the following sectors mostly describes your type of business?

- ❍ Clothing and Textiles
- ❍ Food (Includes all forms of food processing as well as agriculture)
- ❍ Electronics and Computers
- ❍ Transport
- ❍ Metals (Includes all iron, aluminium and steel manufacturing)
- ❍ Wood, Leather and Paper
- ❍ Petroleum, Chemicals and Plastics (Includes the making of soaps, paints, pesticides as well as medicines and rubber manufacturing)

Q2 Size of your organisation determined by the number of employees

- ❍ Small (Less than 250)
- ❍ Medium (250-1000)
- ❍ Large (More than1000)

Q3 Location of your organisation

- AL
- AK
- AZ
- AR
- CA
- CO
- CT
- DE
- FL
- GA
- HI
- ID
- IL
- IN
- IA
- KS
- KY
- LA
- ME
- MD
- MA
- MI
- MN
- MS
- MO
- MT
- NE
- NV
- NH
- NJ
- NM
- NY
- NC
- ND
- OH
- OK
- OR
- PA
- RI
- SC
- SD
- TN

- TX
- UT
- VT
- VA
- WA
- WV
- WI
- WY

Q4 Considering that a Lean Supply Chain Management System (LSCMS) is an organisational management model based on production flexibility, effectiveness, and reducing inefficiencies to add value from the customer's perspective. Does your organisation have a LSCMS in place?

- ❍ Yes
- ❍ No

If No Is Selected, Then Skip To Considering that a Green Supply Chai...

Q5 If yes, how long have your organisation used the *lean* system?

- ❍ 1 to 5 yrs
- ❍ 5 to 10 yrs
- ❍ 10+ yrs

Q6 Please identify the *lean* practices adopted by your organisation? (tick all applicable)

- ❑ 5S (Sort, Shine, Set in order, Standardise, and Sustain)
- ❑ Kanban & Kaizen/ Pull production
- ❑ VSM (Value Stream Mapping)
- ❑ Just-in-Time Production
- ❑ 3P (Production, Preparation, Process)
- ❑ Six Sigma
- ❑ TPM (Total Productive Maintenance)

Q7 In general, what are the major wastes targeted by your organisation's *lean* supply chain? (tick all applicable)

- ❑ Defects
- ❑ Over Production
- ❑ Movement (unnecessary transportation)
- ❑ Waiting
- ❑ Excess inventory
- ❑ Over processing
- ❑ Long lead time

Q8 Which of the following external parties do you mostly work with on *lean* initiatives?

❍ Suppliers
❍ Customers
❍ Transportation companies
❍ Government agencies
❍ Technology companies
❍ Competitors
❍ Consultants

Q9 What are the benefits achieved from using LSCMS within your organisation? (tick all applicable)

❑ Higher efficiency and productivity
❑ Higher flexibility
❑ Reduced inventory levels
❑ Reduced overall costs
❑ Reduced environmental incidents
❑ Reduced production lead time
❑ Reduced transportation lead time
❑ Reduced waste throughout the supply chain
❑ Reduced capacity surplus
❑ Increased energy and water savings
❑ Increased customer satisfaction/ loyalty
❑ Improved corporate image

Q10 The following are a set of key factors to successful *lean* manufacturing implementation. Please indicate the degree to which these key areas are focused upon in your organisation?

	Highly focused upon	Focused upon	Not focused upon
Effective scheduling	❍	❍	❍
Steady material flow	❍	❍	❍
Low inventory levels	❍	❍	❍
Reliable and efficient equipment and infrastructure	❍	❍	❍
Standardization of work processes	❍	❍	❍
Product quality and design	❍	❍	❍
Employees	❍	❍	❍
Flexible facility layout	❍	❍	❍
Suppliers	❍	❍	❍
Customers	❍	❍	❍
Safety	❍	❍	❍
Management and culture	❍	❍	❍
Lean tools and techniques	❍	❍	❍

Q11 Has the implementation of LSCMS resulted in environmental problems within your organisation?

❍ Always
❍ Most of the time
❍ Sometimes
❍ Rarely
❍ Never

Q12 In your opinion, what is driving organisations towards becoming *lean* ? (tick all applicable)

- ❑ Customers demand for production flexibility
- ❑ Customers demand for shorter (lead) times (either in production or transportation)
- ❑ Pressure to achieve significantly improved inventory turns
- ❑ Pressure to efficiently consume resources contributing to supply chain "capacity surplus" reduction
- ❑ Pressure to achieve competitive advantage in price and service
- ❑ Improved quality of the manufactured product

Q13 Which of the following environmental benefits can be achieved from *lean* practices? (tick all applicable)

- ❑ Reduced inventory levels
- ❑ Reduced waste and hazardous materials throughout the supply chain
- ❑ Decreased material usage (product inputs, including energy, water, metals, chemicals, etc.) and resource utilisation per unit of production
- ❑ Lower gas emissions of hazardous air pollutants
- ❑ Improved handling and storage of hazardous material

Q14 In general, compared to the expectations you had at the beginning, the results of using *lean* principles were

- ❍ Partially satisfactory
- ❍ Satisfactory
- ❍ Not satisfactory

Q15 Considering that a Green Supply Chain Management System (GSCMS) is an organisational management model based on ecological efficiency and using environmentally friendly inputs to reduce environmental risks and impacts. Does your organisation have a GSCMS in place?

- ❍ Yes
- ❍ No

If No Is Selected, Then Skip To Does your organisation address the im...

Q16 If yes, how long have your organisation used the *green* system?

- ❍ 1 to 5 yrs
- ❍ 5 to 10 yrs
- ❍ 10+ yrs

Q17 What are your organisation's biggest environmental concerns? (tick all applicable)

- ❑ Greenhouse gas emissions
- ❑ Solid wastes (landfill, sea)
- ❑ Energy consumption
- ❑ Toxic chemical waste

Q18 What is driving organisations towards becoming *green*? (tick all applicable)

- ❑ Compliance with government/regulations
- ❑ Customers demand for sustainable behaviour
- ❑ Differentiation/ establishing a competitive advantage
- ❑ Pressure to efficiently consume resources contributing to supply chain “capacity surplus” reduction
- ❑ Pressure to reduce carbon gas emissions from production and transportation
- ❑ Risk management
- ❑ Improved quality of the manufactured product

Q19 Please identify the *green* practices adopted by your organisation? (tick all applicable)

- ❑ 3Rs (Reduce, Reuse, and Recycle)
- ❑ Life cycle analysis
- ❑ Use of clean production
- ❑ Supplier evaluation

Q20 The following are a set of key factors to successful *green* manufacturing implementation. Please indicate the degree to which these key areas are focused upon in your organisation?

	Highly focused upon	Focused upon	Not focused upon
Gas emission and resource consumption	❍	❍	❍
Reliable and efficient equipment and infrastructure	❍	❍	❍
Product quality and design	❍	❍	❍
Suppliers	❍	❍	❍
Customers	❍	❍	❍
Management and culture	❍	❍	❍
Delivering and handling	❍	❍	❍
Green tools and techniques	❍	❍	❍
Corporate image	❍	❍	❍

Q21 Which of the following external parties are you mostly working with on *green* sustainable initiatives?

❍ Suppliers
❍ Customers
❍ Transportation companies
❍ Government agencies
❍ Technology companies
❍ Competitors
❍ Consultants

Q22 Considering that *green* distribution consists of *green* packaging and *green* logistics/ transportation. Does your organisation have a *green* distribution in place?

❍ Yes
❍ No

Q23 What are the benefits achieved from using GSCMS within your organisation? (tick all applicable)

- ❑ Higher efficiency and productivity
- ❑ Reduced overall costs
- ❑ Reduced environmental incidents
- ❑ Reduced production lead time
- ❑ Reduced transportation lead time
- ❑ Reduced waste throughout the supply chain
- ❑ Reduced capacity surplus
- ❑ Increased energy and water savings
- ❑ Increased customer satisfaction/ loyalty
- ❑ Improved corporate image
- ❑ Reduced amount of solid wastes
- ❑ Reduced CO_2 emissions

Q24 In your opinion, do *green* supply chain initiatives make the overall supply chain

- ❍ More efficient
- ❍ Less efficient
- ❍ Don't affect efficiency

Q25 Do you believe that having a Green Supply Chain Management System (GSCMS) in place can enhance the environmental benefits derived from *lean* implementation activities?

- ❍ Yes
- ❍ No

Q26 In general, compared to the expectations you had at the beginning, the results of using *green* principles were

- ❍ Partially satisfactory
- ❍ Satisfactory
- ❍ Not satisfactory

Q27 Does your organisation address the importance of developing and implementing a sustainable supply chain management system?

- ❍ Yes
- ❍ No

Q28 Do you believe that, by integrating LSCMS and GSCMS, your organisation can significantly exhibit higher levels of sustainability (in terms of improving profitability, market reputation, responsiveness to consumers as well as obtaining long-term sustainability) than organisations implementing only *lean* or *green* principles?

- ❍ Yes
- ❍ No

Q29 What sustainability efforts is your organisation undertaking? (tick all applicable)

- ❑ Reduction of CO_2 emissions from facilities and transportation
- ❑ Increase use of renewable energy sources (e.g. solar, wind)
- ❑ Elimination/reduction of hazardous/toxic chemicals from products
- ❑ Investment in capital infrastructure
- ❑ Reduction of unnecessary packaging
- ❑ Improved material and resource utilisation
- ❑ none

Q30 If both LSCMS and GSCMS do exist in your organisation, does *lean* team work together with the *green* team to achieve sustainable objectives?

- ❍ Yes
- ❍ No
- ❍ N/A

Q31 What is the function in your organisation that can best coordinate different aspects of *lean* and *green* operations to satisfy customers' needs?

- ❍ Design and Production
- ❍ Finance
- ❍ Human resources
- ❍ Procurement
- ❍ Marketing
- ❍ Research and Development
- ❍ N/A

Q32 Please identify the main factors you believe are essential to successfully integrate *lean* manufacturing with environmental sustainability? (tick all applicable)

- ❑ Organisational philosophy (the involvement of every employee in the organisation)
- ❑ Throughput improvement (the efficient use of resources and materials)
- ❑ Energy efficiency
- ❑ Innovative technologies
- ❑ Community partnership (e.g. through community education activities and partnership with suppliers)

Q33 Does your organisation utilise procurement to achieve sustainable objectives? In other words, does the purchasing sector within your organisation have the potential power to improve sustainable outcomes by avoiding unnecessary consumption?

- ❍ Yes
- ❍ No

Q34 Does your organisation certify suppliers for sustainability and environmental behaviour?

- ❍ Yes
- ❍ No

Q35 Please indicate whether you agree or disagree with the following statements regarding the extent to which organisation engage their suppliers in achieving sustainable performance?

	Agree	Disagree
We encourage suppliers to be highly responsive to customer demand while producing quality products in the most efficient and economical manner	❍	❍
We set environmental criteria that suppliers must meet	❍	❍
We actively consider switching to more sustainable suppliers	❍	❍
We work with key suppliers to ensure continuous improvement in technical and human capabilities	❍	❍
We collaborate with suppliers to eliminate packaging and implement recycling initiatives	❍	❍
We actively monitor and evaluate suppliers' environmental performance and risks	❍	❍

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