Lean and Green Parallel Implementation Impact on Outcomes of Supply Chain in Canadian Aerospace Industry

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ABSTRACT

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Roya Kalbassi

Organizational performance improvement is one of the main concerns of companies in the competitive market nowadays. Recently, lean and green production practices have been introduced as the essential elements of performance improvement. Among the most common practices in the lean concept, just-in-time, continues flow, and value stream mapping are selected to be analyzed in this research. Green standards, recycle/reuse, and energy consumption reduction are also the practices considered for green concept. However, parallel implementation of lean and green supply chain management strategies and its impact on supply chain outcomes are rarely studied in the previous works. In this research the effect of this phenomenon on the production quality, customer satisfaction, and overall performance of different tiers of supply chain is investigated. A large scale survey has been performed on the Canadian aerospace industry due to its importance and contribution in the Canadian economy and the collected data was processed. Statistical analysis including both descriptive and inferential analysis is conducted in order to interpret the collected data and verify the hypotheses of the research. In this way, factor analysis has been performed to categorize the gathered data in the required sectors of lean or green or both practitioners. The study provides an empirical insight into the advantages of having a hybrid supply chain management system which consists of both lean and green methods. By means of Kruskal-Wallis and correlation analysis it is proven that performing the lean and green strategies has considerable positive impact on the outcomes of supply chain. Employing the survey as a reliable research instrument resulted in significant conclusions demonstrating that this method can be used for the future research works in similar field.

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Chapter 1

Introduction

1.1. Lean and Green supply chain management strategies

In the highly competitive aerospace market, companies have to minimize the production waste and improve the quality of production by implementing appropriate supply chain management strategies. Among these strategies lean and green strategies are widely considered and attracted the attention of both industrial and academic researchers (Bergmiller & McCright, 2009; Venkat & Wakeland, 2006). Lean strategies are those which provide a systematic approach to reduce the waste in the production system. The major production wastes such as overproduction, and unnecessary inventory can be prevented or reduced by implementing lean manufacturing strategies including just-in-time, value stream mapping and continuous flow. The aforementioned lean strategies are subject of interest in the present study and will be discussed in detail throughout the following chapters.

On the other hand, companies are required to pay careful attention to their environmental impacts and comply with the regulations concerning the environment. They also perform the green supply chain management strategies to differentiate themselves in the competitive market nowadays (Broek & Broek-Serlé, 2010). The set of supply chain strategies which focus on the environmental aspects of the production process are called green supply chain management strategies. These environmental consideration are recently helping the companies to gain both environmental and business benefits. Recycle, reuse, reducing the energy consumption, and standardization of the supply chain to comply with environmental regulations are among the most important practices of green concept. These strategies will be described in detail and analyzed for the purpose of present research.

A hybrid supply chain is a supply chain which consists of two or more management concepts such as lean and green at the same time. In the current research the companies which implement both the lean and green concepts in their supply chain management at the same time are considered as lean-green companies. It is desired to see the effects of these strategies interaction during their parallel implementation in the supply chain.

It is important to determine measures for the outcome of the supply chain and then to investigate the effect of performing these supply chain strategies on the outcomes.

1.2. Supply chain performance outcomes

Supply chain management includes all stakeholders, including manufacturer, supplier, transporter, retailer and the customer. All the parties in a supply chain directly or indirectly contribute in supply chain management goals. In order to measure the goals of the supply chain different parameters can be defined and evaluated (Duarte & Machado, 2013). In the present study careful investigation on the literature as well as consultation with aerospace experts has been performed to determine appropriate measures for evaluating the outcomes of the supply chain with focus on aerospace industry. Overall organization performance, quality of the products and/or services, and also customer satisfaction are among the important measure for the outcome of the supply chain. In the present study considering these supply chain outcomes, the effect of parallel implementation of lean and green management strategies will be evaluated on these supply chain outcomes. This subject with focus on aerospace industry has been rarely investigated by the researchers. Aerospace industry in Canada with over 700 companies contributes in a major portion of Canadian annual revenue.

1.3. Objectives of the present study

The aim of this research is to evaluate the effect of parallel implementation of lean and green supply chain management strategies on the outcomes of the supply chain while there are few previous researches focusing on this phenomenon. By means of survey and analyzing its results, at the first step, the existence of a difference between companies which implement the lean and green strategies and those which do not implement them will be proved. In order to accomplish these objectives the following steps were taken:

- Develop a framework for supply chain management strategies and their outcome based on the literature and interviewing with aerospace experts.
- Hypotheses of the research developed based on the lean and green strategies and the outcomes of the supply chain.

- Research instrument (questionnaire) was developed based on the hypotheses and the target sample was determined.
- The survey has been performed among the participants in the aerospace industry and the data was gathered.
- The survey data was organized and coded and by means of factor analysis different categories of lean and green practitioners were defined and the respondents were placed in these categories.
- Appropriate statistical analysis methods including Kruskal-Wallis test and Correlation Analysis have been performed to validate the hypotheses of the research.
- Conclusions have been made based on the results of the survey and the statistical analysis. The hypotheses of the research were validated and the possible future works in this field have been discussed.

1.4. Thesis outline

The memoire consist of 6 chapters including the introduction. The second chapter is the literature review and the history of the researches on lean and green supply chain management strategies as well as their effect on the supply chain outcomes.

In chapter three the conceptual framework for the lean and green strategies has been developed. Detailed definition of lean and green strategies and their practices as well as the supply chain outcomes is brought and the hypotheses are developed based on these concepts. The conceptual framework in the present study is designed to demonstrate the relationships between the practices in each of the lean and green strategies and the supply chain outcomes.

Research methodology is described in chapter four. The research instrument (survey) along with sampling procedure are discussed and different steps which are taken to validate and verify the questionnaire are explained.

In chapter five the results of the present research are presented in detail. Results of descriptive and statistical analysis are presented providing valuable insight to the Canadian aerospace industry and the tiers in the aerospace supply chain. The hypotheses of the research are validated and the methodology to perform the validation is described. The finalized research hypotheses are validated which demonstrate the significant difference between lean-green practitioners and none-practitioners. The recommendations are made based on the results of the research.

Chapter six summarizes the achievements of the present research including the discussion on the positive effect of implementing lean and green supply chain management strategies and their practices on the outcomes of the supply chain. At the end of this chapter the opportunities for the future works are proposed and discussed.

Chapter 2

Literature Review

2.1. Supply Chain Management

Nowadays companies are competing on how they are managing their supply chain and what supply chain management tools and practices they are using. The competition is not between companies but among supply chains (Li *et al.,* 2006). Also from research perspective, researchers are more concerned with supply chain management strategies and techniques. More research is being done in order to analyze the supply chain management and help improve it in order to stay competitive, as the competition is between supply chains in terms of successful tools and techniques. In this competitive global market, companies more focus on competencies and try to stay competitive by applying more and more techniques and tools. Their aim is to manage all the supply chain in a way to reduce non-value added activities both internally and externally.

The researchers in collaboration with the industry try to identify ways, tools and techniques in a way that the objectives of the whole supply are met. Researchers study the supply chains in order to identify the practices that help the supply chain growth, staying competitive and, in other words, reaching their goals in terms of satisfying customers need at the lowest possible cost. This aim is reached by producing the right amount of products and services at the right time (Duarte *et al.,*2011).

In terms of supply chain management (SCM), all activities along the operations must be analyzed, and the whole supply chain is seen as a system that needs to be studied and improved. In this view exploring new tools and practices such as lean and green strategies in supply chain help to become more efficient and sustainable. Supply chains are therefore more concerned about lean and green strategies (Broek & Broek-Serlé, 2010).

2.2. Lean Supply Chain

Lean manufacturing focuses on the systematic elimination of wastes from the operation of the organization through systematic practices to efficiently produce products and services (Yang *et al.,* 2011). Lean Manufacturing Thinking or "Lean" is a practice that helps companies to identify and eliminate waste through continuous improvement, by controlling their lean tools (Verrier *et al.,* 2014). Lean paradigm in a supply chain management (SCM), is a strategy and tool used to achieve the optimized time and cost and to improve the effectiveness (Duarte *et al.*, 2011). In this study lean manufacturing is defined as a set of practices focused on reduction of wastes and non-value added activities from the operation. Such lean practices include JIT, total quality management, continuous flow, low setup, lead-time reduction, etc. (Yang *et al.*, 2011). Studies of related research indicate that implementing lean practices is associated with performance improvement. The most commonly mentioned benefits of lean practices in companies are improvement in labor productivity, quality and on the other hand reduction in lead time, cycle time and manufacturing costs (Shah & Ward, 2003).

2.3. Green Supply Chain

Firms can successfully reduce their internal waste through lean production methods, but they need also to implement practices for better environmental management (Melnyk *et al.,* 2003; Montabon *et al.*, 2007; SROUFE, 2003). These practices expand the scope of waste reduction efforts beyond efficiency within the organization (Kleindorfer *et al.,* 2005; Zhu & Sarkis, 2004). Environmental management covers from product development to final delivery and ultimate disposal of the product (Klassen & Whybark, 1999; SROUFE, 2003). ISO 14000 standards, an essential element of Environmental Management System (EMS), help firms in assessing, managing, coordinating and monitoring corporate environmental activities (Melnyk *et al.*, 2003; SROUFE, 2003). Here, environmental management practices refer to programs to improve environmental performance of processes and products in the forms of eco-design (*e.g.,* design for environment), recycling, waste management and life-cycle analysis (Matos & Hall, 2007; Miettinen & Hämäläinen, 1997; Montabon *et al.*, 2007; SROUFE, 2003). The green paradigm asks for practices such as reduce, reuse, rework, recycle, return or remanufacture (Srivastava, 2007).

Many companies still consider green and environmental practices as a constraint, and they are a low priority of the company's strategy (Srivastava, 2007). However, the research performed by Verrier *et al.* proved that environmental practices are a real opportunity for progress, especially when considering that green initiatives are not only beneficial for the environment but also for the manufacturers and for the customers. The result of their studies reveals that the existing synergies between lean and green can be used to implement strategies, since the higher level of lean a company reaches, the better results it gets from green initiatives (Verrier *et al.,* 2014).

2.4. Hybrid Supply Chain

The supply chain can be considered as a hybrid system, deploying a number of principles and practices. Duarte *et al.* (2011) use the phrase Hybrid Supply Chain, while integrating lean and green paradigms in supply chain. They suggest that there is a compatibility between lean and green paradigm, because lean practices minimize the wasted material and energy usage and Green practices help enhancement of the environmental performance in the companies (Duarte *et al.*, 2011a). United States Environmental Protection Agency (EPA) adds environmental metrics to lean metrics and refers that "using environmental metrics in lean efforts will allow companies to document the environmental benefits that are part of lean implementation, as well as identify targets for future improvement efforts". Richard Florida (1996) brought up the following question: "Can corporate efforts to innovate and to adopt advanced technological and organizational approaches to manufacturing, be used to achieve simultaneous gains in industrial and environmental performance?" .In his article, he tried to examine the relationship between advanced production practices (Lean) and environmentally friendly practices in order to have "*Environmentally Conscious Manufacturing*". The study performed by Florida (1996) shows the interest of researchers in finding the relationship between the two paradigms; Lean and Green.

The leadership empowerment, continuous improvement, waste elimination, resource optimization, employee engagement, stakeholder relationship and information sharing are further elements discussed in a lean and green supply chain (EPA, 2007; Bergmiller & McCright, 2009; Johansson & Winroth, 2009). The deployment of lean and green elements seems to be vital for the business to stay competitive. However, it is still very difficult to integrate a number of supply chain elements, as they seem to be contradictory and may lead to trade-off situations. A well-known example given often by academicians is the need for frequent replenishment, which requires lean approach with just-in-time delivery or small lot size, but this generates more transportation and high levels of carbon dioxide emissions (Sawhney *et al.,* 2007; Venkat & Wakeland, 2006; Zhu & Sarkis, 2004).

Dües *et al.* (2013) claim that to establish the best lean and green integration, it is necessary to understand the characteristics of the both paradigms. They recognize that lean and green can have a positive influence in current business practices and suggest that lean and green considerations should be part of every business decision and must be aligned with supply chain management. Being aware of the compatibility among lean and green paradigms will assist the integration of lean and green supply chain.

It is concluded from lean and green researches that a systematic approach is needed to create and sustain a lean-green supply chain, which primarily leads to continuous waste reduction. The result of the system should be measureable in order to be able to assess the benefits of the system. Successful implementation of lean-green manufacturing system results in improvement that goes beyond the traditional objectives of the system. Nowadays manufacturers are under pressure to reduce waste (*e.g.* environmental waste and quality defects) associated with both lean and green manufacturing. Thus, this is a great motivation to integrate lean and green systems, in order to achieve the waste reduction in the most efficient manner.

In the literature, there are a few research works done to study and model the lean and green manufacturing systems, their performance measurement and outcomes. In the following section, the most relevant and recent studies are described briefly to show the trend of these concepts.

2.5. Performance Management and Measurement

Corporate performance measurement and its application continue to grow while encompassing both quantitative and qualitative measurements and approaches. The variety and the level of performance measures depend greatly on the goal of the organization or the individual strategic business unit's characteristics. A clear performance measurement definition can help managers go in the right direction and focus on what really matters. According to Moullin (2007) Performance Measurement is "evaluating how well organizations are managed and the value they deliver for customers and other stakeholders". He did a research to show the link of performance measurement and organizational excellence. Moullin defines Organizational Excellence as "outstanding practice in managing organizations and delivering value for customers and other stakeholders". His findings show that there is a clear relationship between performance measurement and organizational excellence.

To meet the objectives of the organization, the output of the processes enabled by the supply chain must be measured and compared with a set of standards. In order to be controlled, the process parameter values need to be kept within a set limit and remain relatively constant. This will allow comparison of planned and actual parameter values, and once done, the parameter values can be influenced through certain reactive measures in order to improve the performance or re-align the monitored value to the defined value. Control of processes in a supply chain is crucial in improving performance and can be achieved, at least in part, through measurement. Well-defined and controlled processes are essential to better SCM. Based on a research done in 2004 by Gunasekaran *et al.,* there are a number of conceptual frameworks and discussions on supply chain performance measurements in the literature; however, there is a lack of empirical analysis and case studies on performance metrics and measurements in a supply chain environment.

Quite often companies have a large number of performance measures to which they continue to add based on suggestions from employees and consultants. They fail to realize that performance assessment can be better addressed using a trivial few, focusing on those few areas which are most critical to success (A Gunasekaran *et al.,* 2004).

One of the most difficult areas of performance measurement selection is the development of performance measurement systems.

2.5.1. Performance Measurement System Design

"When you can measure what you are speaking about, and express it in numbers, you know something about it . . . otherwise your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of science" (Lord Kelvin, 1824-1907).

Andy Neely, Mike Gregory, and Ken Platts 2005 define measurement as the process of quantifying; it is often discussed but rarely defined. Most of the organizations achieve their goals by satisfying their customers and maximize their efficiency and effectiveness. These two terms, efficiency and effectiveness are defined by Slack in 1991, the former is referring to the level of meeting the customer requirements and the latter is a measure of how economically the firms' recourses are utilized while meeting the customer satisfaction (Slack, 1991).

The three main fundamentals of performance measurements design are defined by Neely et al. (2005) as the followings:

- *Performance measurement* is referring to the process of quantifying the efficiency and effectiveness of an action.

- *A performance measure* is the metrics used to quantify the desired variable, which defines the efficiency and effectiveness of an action.
- *A performance measurement system* is a set of performance measures and metrics defined to quantify both the efficiency and effectiveness of an action.

The following Figure (Fig.1) demonstrates a schematic view of the general framework for performance measurement system design, which needs to be specifically designed for each supply chain.

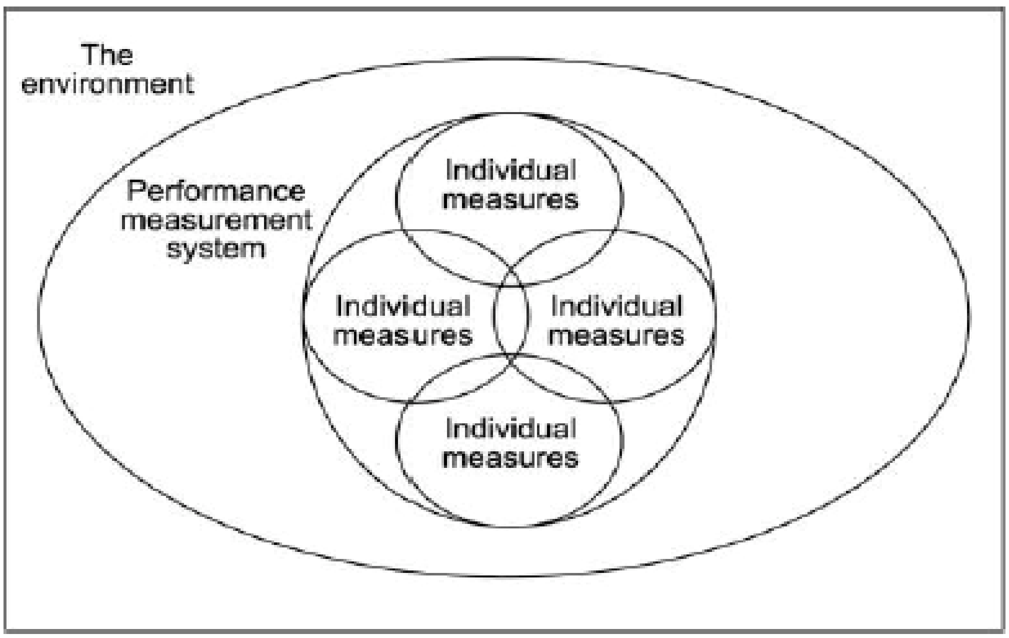

Figure 1- A framework for performance measurement system design (Neely et al., 2005)

As shown in Figure 1, performance measurement starts from individual measures, which form the performance measurement system. There are various types of categorization of these individual measures. Researchers have tried to categorize these measures in many ways, ranging from Kaplan and Norton's (1992) balanced scorecard to Fitzgerald *et al.*'s (1991) framework. As Neely *et al.* (2005) discuss in their research each author focused on a specific aspect of performance measurement system. They also mentioned that the organizational behavior is more explored in terms of performance measurement rather than production and operation management. Among the tools and techniques, which are used to gather data for performance measurement system design, is a survey, which examines the use of performance measures in a certain amount of enterprises (Neely *et al.*, 2005).

2.5.2. Environmental Performance Management

In this information age, with the increasing social demand of environmental sustainability and new technology solutions and organizational skills, the aim of the businesses is to deliver products and services to a global marketplace in less time, with higher quality, and at a lower cost. One of the recommended areas for improvement in most businesses is fulfilling the requirements of environmental management with a systematic approach. Opportunities of improvement are expanded along the supply chain while exploring environmental management aspects and production and operation management (Duarte *et al.*, 2011a).

Environmental strategies and policies have influenced not only the business level of an organization, but also functional and operational levels (Aragon-Correa & Sharma, 2003; Shrivastava, 1995; Starik & Rands, 1995). In the past, environmental concerns have been categorized as a constraint in manufacturing operations (Klassen & Whybark, 1999). Yet, researchers believe that in many ways pollution and inefficiency are the same problem, and there is a lack of research in the relationship between manufacturing process with environmental management and performance. Environmental efficiency, *i.e.* the reduction of environmental impact by using material and resources in a more efficient way, is accompanied by total quality management (TQM), which is a useful tool to examine the efficiency and effectiveness of operation (Rothenberg *et al.,* 2001). Researchers look for approaches to assess the role of operation in improving environmental performance (Shrivastava, 1995). One such approach is to use the elements of lean production to undertake a broad examination of the role that management systems, practices, and policies play in enhancing environmental efficiency (Rothenberg *et al.*, 2001).

It is vital to measure what is important to the enterprise. The measures need to focus on the key strategies such as cash flow or growth; accordingly, the organization can take action. The problem many organizations fail to conquer is translating qualitative targets into quantitative metrics. The relationship between the qualitative and quantitative measures has not been fully explored. An explicit prerequisite is the need to align the metrics with strategy (Sanjay Bhasin, 2008).

Neely *et al.* (2005) and Kaplan & Norton (2005) studies indicate that often organizations collect a considerable amount of information, but do not have a systematic method to transfer this data and feedbacks into new strategies and management techniques to improve their performance.. Their researches suggest that organizations need to employ new techniques of information technology as a part of their management strategies for performance measurement.

2.5.3. Lean Performance Measurement

Lean manufacturing and related tools become popular among both academics and practitioners. Many organizations all around the world have attempted to implement and practice Lean tools and techniques, but they failed. Lack of information and clear understanding of lean and its measurement system result in unsuccessful supply chain management. Many papers studies lean performance and its evolution, but few studies focus on lean performance measurement systems and its measures. Researchers mentioned in their research that the main reason for failing lean practices is the lack of clear understanding of lean performance and its measurement (Behrouzi & Wong, 2011). Managing lean supply chain without measuring its performance is not possible.

In order to measure the degree of leanness of the firm, researchers choose variables such as: elimination of waste, continuous improvement, defects, pull of material and lean measures. In this way the leanness of the organization is measured and quantifies by these variables (Behrouzi & Wong, 2011).

2.5.4. Hybrid Performance Measurement

Several factors which may greatly influence the company's business are nowadays becoming increasingly critical. These include globalization, technology innovation, new organizational skills, design of products and services, and environmental protection and resource scarcity (Azevedo *et al.,* 2011; Broek & Broek-Serlé, 2010). There are difficulties in measuring performance within organizations and even more difficulties arise in inter-organizational environmental performance measurement. The reasons for lack of systems to measure performance across organizations are multidimensional, including non-standardized data, poor technological integration, geographical and cultural differences, differences in organizational policy, lack of agreed upon metrics, or poor understanding of the need for inter-organizational performance measurement. To become and remain competitive, companies must adopt evolving strategies. Companies should however achieve efficiency not only by implementing practices such as lean, but also by improving their environmental impact (Verrier *et al.,* 2014).

The literature has provided some evidence of the synergistic interaction of lean practices and green practices to improve plant performance. However, few studies provide a thorough and in-depth examination of such processes' interactions (Galeazzo *et al.,* 2014). Lean identifies seven types of waste: overproduction, waiting, transportation, defects, inappropriate processing, unnecessary inventory and unnecessary motion. The aim of eliminating those types of waste is to increase efficiency, reduce costs, improve customer response time, and contribute to improved quality, greater profitability, and an enhanced public image (Bergmiller & McCright, 2009). Companies should however achieve efficiency not only by implementing practices such as lean, but also by improving their environmental impact. As with lean, seven types of waste can be identified with green: excessive water usage, excessive power usage, excessive resource usage, pollution, rubbish, greenhouse effects and eutrophication. Some authors also define an eighth type of waste for green: poor health and safety. Lean is now mastered by a large number of companies. Lean and green could provide a method for companies to develop a tool to measure both productivity and environmental performance based on qualitative and quantitative analysis. The purpose of this method would be to adapt the tools of lean manufacturing to environmental performance, as shown in Bergmiller and McCright from a modelling point of view (Bergmiller & McCright, 2009).

The lean paradigm focuses on improving the production process, by continuous improvement methodologies, simplifying by reducing non-value adding activities, and in parallel reducing wastes (Duarte *et al.,* 2011). Some researchers like Bergmiller & McCright (2009), suggest that lean and green objectives, if pursued together, have more chances of success. Cost reduction by elimination of wastes, both lean and green perspective of waste, is more successful than while considering each separately.

Although there have been research studies in the field of lean and green and supply chain performance, there are still questions which need to be answered in order to get the best results from performance measurement system, such as followings:

- Can we easily transpose and apply the lean methodology to sustainable development goals?

- Which repository is able to make a reliable link between lean maturity and the level of commitment to green, in various companies?

- Is the link between lean and green a real advantage as opposed to implementing two distinct approaches? What are the benefits of joint practices?

In order to answer these questions, it is particularly important to define the relevant performance indicators.

2.6. Research Background

Nowadays, the lean and green concepts are well established, both within academic and industrial environments. Even though there are multiple interpretations of lean and green, researchers and authors tried to define these two strategies based on their concepts. The origin of lean can be traced back to Japan, in particular, Toyota Motor Corporation. Green concept was one of the pillars of sustainable development or sustainability, which was first introduced by World Commission on Environment and Development (Johansson & Sundin, 2014).

Lean and green concepts are introduced as the essential ingredients for the business to become competitive and successful. But there are a limited number of papers that consider two concepts in an integrated way, and the two research fields have developed relatively independently from each other. Table 1 is the summary of recent papers focusing on integration of lean and green paradigms.

Table 1- Recent papers on Lean and Green topic

No.	Author	Methodology (Description)	Conclusion
1	(Govindan, Azevedo, Carvalho, & Cruz-Machado, 2015)	The interpretive structural modeling approach is used as a useful methodology to identify inter-relationships among lean, green and resilient practices and supply chain performance	Customer satisfaction is the performance measure with strong dependence and weak driving power; that is, it is strongly influenced by the other researched variables but does not affect them.
2	(Verrier et al., 2014)	• Case study research methodology • Assess how Lean and Green actions could be enhanced when used together	Lean and Green manufacturing can provide the competitive advantage and profitability.

No.	Author	Methodology (Description)	Conclusion
3	(Galeazzo *et al.*, 2013)	• <u>Case study</u> research methodology • Discern how the synergy between Lean and Green works to improve the performance	The way lean and green practices interact leads to differences in terms of operational performance.
4	(Johansson & Sundin, 2014)	<u>A systematic literature review</u> including 102 journal publications	Differences between Lean and Green concepts lie in: their goal and focus, value construct, process structure, performance metrics, and tools/techniques used.
5	(Dhingra, Kress, & Upreti, 2014)	• <u>Review paper</u> of the Journal of Cleaner Production • Examining the interrelationships among Lean, Green, and Sustainability	The previously held notion that lean leads to green, but not necessarily vice versa, is reiterated and confirmed.
6	(Pampanelli, Found, & Bernardes, 2014)	A new model for Lean & Green is proposed, which integrates environmental sustainability into pure lean thinking	This work confirms the Lean & Green Model's potential for cost savings.
7	(Kurdve, Zackrisson, Wiktorsson, & Harlin, 2014)	5 company as case studies in order to perform empirical research on integration of operations management, specifically production system models with environmental management	The research highlights the benefits of combining management systems with environmental management and a holistic perspective and a defined integration strategy.
8	(Martínez-Jurado & Moyano-Fuentes, 2014)	<u>State-of-the-art of research</u> into the links between Lean Management, Supply Chain Management and Sustainability	There is a significant gap regarding research into social sustainability in Lean Supply Chain Management.
9	(Chiarini, 2014)	Empirical observation on 5 motorcycle companies to see whether or not Lean Production tools can help reduce the environmental impacts production.	Lean implementation, in general, brings benefits to environmental management.
10	(Faulkner & Badurdeen, 2014)	A comprehensive methodology to develop Sustainable Value Stream Mapping by identifying suitable metrics and methods to visually present them	Methodology to visualize and assess manufacturing sustainability performance is proposed
11	(Hajmohammad, Vachon, Klassen, & Gavronski, 2013a)	A conceptual model proposes that the magnitude of environmental practices mediates the relationship between lean and supply management with environmental performance.	The impact of lean management, and to a lesser extent supply management, on environmental performance is mediated by environmental practices.
12	(Dües *et al.*, 2013)	A systematic review and evaluate previous work focusing on the relationship and links between Lean and Green supply chain management practices	Lean is beneficial for Green practices and the implementation of Green practices in turn also has a positive influence on existing Lean business practices.

No.	Author	Methodology (Description)	Conclusion
13	(Aguado, Alvarez, & Domingo, 2013)	Develops a general approach, based on environmental innovation, to help firms harmonize efficiency and sustainability.	When environmental innovation is applied the system improves, the authors propose transforming the traditional production system into a lean system.
14	(Jabbour, Jabbour, Govindan, Teixeira, & Freitas, 2013)	Evaluate combining environmental management, operational performance, human resources and lean manufacturing applied to the Brazilian motorcycle companies by means of survey and quantitative study.	• By means of survey and validation of a conceptual frame work the influence of Environmental Management (EM) on Operational Performance (OP) in Brazilian automotive companies was validated • The interference of Lean management and Human resource in the greening of the studied companies was validated

In 1996 Richard Florida brought up the topic of Environmentally Conscious Manufacturing. In his research he studied the relationship between new production practices and environmentally conscious manufacturing approaches. His article argues that innovative firms are more likely to be competitive in terms of environmental practices. He also claims that adoption of advanced manufacturing systems has the same underlying principles as environmental strategies. He did a survey which resulted in following key points:

- Firms are moving toward strategies for environmental policies, as it is important to overall corporate performance.
- There is a close relationship between green practices and advanced manufacturing practices.
- The survey responses clearly indicate the connection between environmental and industrial strategies and performance.
- Supply chain production chain facilitates the adoption of advanced manufacturing practices across the production chain (Florida, 1996).

Lapinski *et al.* (2005) indicate that project budget increases often as a result of complex design and disciplines. Their research was conducted in Toyota Motor Corporation, which is considered to be a successful company in terms of high performance green facility delivery. By mapping the process of the company, they found that the success of the company is a result of the processes that create more value and customer satisfaction rate.

Rothenberg *et al.,* (2001), examined the relationship between Lean manufacturing practices and environmental performance. The focus of their research was only on two parameters of environmental performance which are air emissions and resource use. They did a survey in 31 companies in North America and Japan. Their research found existing links between lean practices and environmental performance, and they found three aspects of lean management (buffer minimization, work systems, and human resource management) somehow related to environmental practices and performance. They conclude that a complex relation links lean manufacturing to environmental performance which depends on the measure being used for performance examination.

In the same year, King and Lenox (2001) did an empirical study on the environmental performance of companies between 1991 and 1996, and concluded that those corporations adopting the quality management standards, ISO 9000, are more likely to adopt the environmental management standards, ISO 14000. They provide a strong evidence that lean production practices, measured by ISO 9000, are complementary to waste and pollution reduction (green practices) (King & Lenox, 2001).

Herrmann *et al.* (2008) conducted a research regarding environmental perspective on lean production. Based on their simulation approach, integration of management systems is necessary to support sustainable lean production system, and not necessarily all lean practices and activities are optimal from environmental perspective.

In 2000 the Environmental Protection Agency in the United States issued a practical guide called "The Lean and Green Supply Chain", which indicates the opportunities for improving environmental performance (Kainuma & Tawara, 2006). Many researchers tried to combine lean and green, and evaluate the impacts of the two paradigms on environmental performance, such as (Kainuma & Tawara, 2006; Venkat & Wakeland, 2006; Sawhney *et al.*, 2007; Herrmann et al., 2008; Parveen *et al.,* 2011).

In Parveen *et al.* (2011) research, lean manufacturing was used as an approach to maximize the productivity. Their aim was to integrate lean and green supply chain and explore their impact on environmental efficiency. They considered waste reduction as the key performance indicator of the environmental performance of the lean supply chain. Their study is comprehensive in terms of investigating most important lean and green manufacturing tools. A list of major lean tools provided by this article is presented in Figure 2.

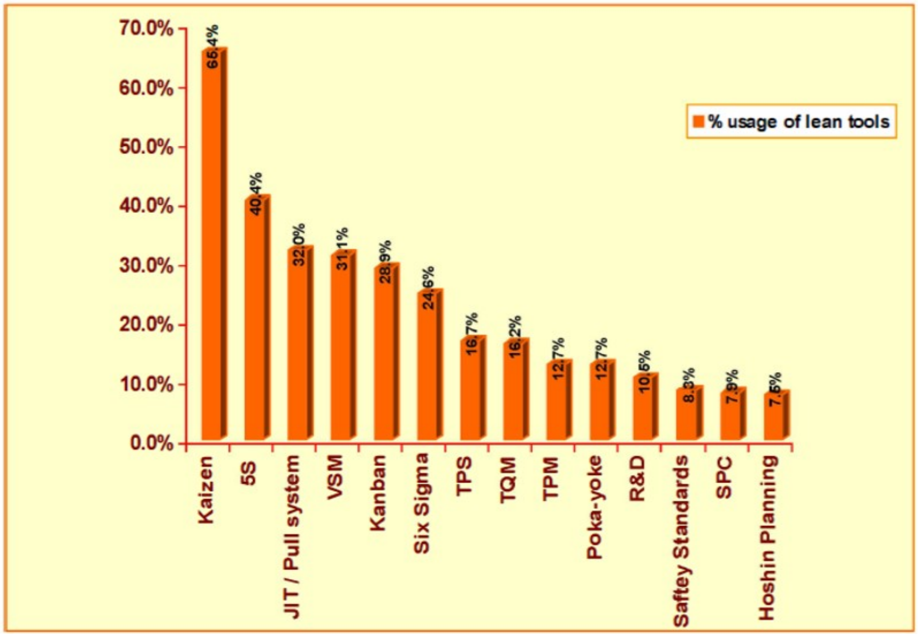

Figure 2 - Lean Practices (Parveen et al., 2011)

The research shows that the most important and common lean manufacturing tools are Kaizen, 5S, just-in-time, value stream mapping, and the Kanban consecutively.

Duarte *et al.* (2011), applied balanced scorecard methodology to explore lean and green and their impact on supply chain performance. They conclude that the operation from lean and green perspective is not only beneficial to the environment, but also to manufacturer and customers. Their conceptual model using balanced scorecard approach may help companies better succeed in their supply chain initiatives. But balanced scorecard is not the only performance measurement system which can be aligned with lean and green strategies and it is only a starting point to incorporate lean and green supply chain into a performance measurement system. In their model they split the measures into two groups of financial and non-financial performance measures, which are proper for strategic decision and operational decisions accordingly. The following table lists the found measures based on Duarte *et al.* (2011).

Table 2- list of performance meaures for lean and green paradigms (Duarte *et al.*, 2011)

Financial performance measures	Non-financial performance measures
Revenue Profit Return on asset Return on investment Total sales Labor cost per hour Training cost Operational cost Transportation costs Environmental costs	Air emission Energy use Waste Hazardous material Effectiveness Flexibility Green image On-time delivery Inventory levels Product development Product quality Capacity utilization Lead time Employee efficiency Employee morale and satisfaction Customer satisfaction

Recent research focuses is more on sustainability of the supply chain, as the companies are facing more pressure to compete in terms of sustainability and green management. More and more companies are integrating environmental principles into their strategies in order to develop their social and environmental dimension. Some researchers such as Hajmohammad *et al.* tried to develop conceptual models in order to integrate lean and green practices and concepts. The models studied the role of lean and green practices in the supply chain management. They developed a model, which shows the relationship between lean and supply management and their impact on environmental performance (Figure 3).

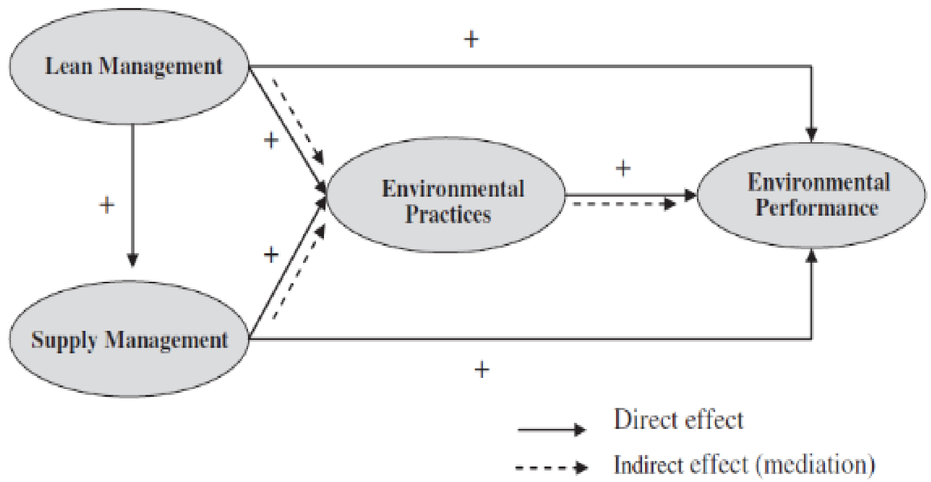

Figure 3- Conceptual model for lean, environmental and supply management (Hajmohammad *et al*., 2013)

Based on their model, lean management and supply management can have an indirect effect on environmental performance. Also environmental practices mediate the impact of lean and supply management relationship with the performance. Their model also reveals the links from lean management and supply management are non-sufficient, and the main driver of the environmental performance are the (environmental) green practices (Hajmohammad *et al.*, 2013).

The majority of the literature called lean as the catalyst for greening the supply chain. In fact, researchers are trying to find ways to understand where lean practices are synergistic for green. Some evidence suggests that not only lean is beneficial for green practices but also the implementation of green practices has positive influence on current lean practices (Dües *et al.,* 2013). Dües *et al*. (2013) did a literature review on the background of lean and green and supply chain. Their research resulted in a holistic comparison of lean and green paradigms and distinguishing attributes. The following figure (Fig. 4) summarizes their exploration and evaluation of previous work in lean and green supply chain practices.

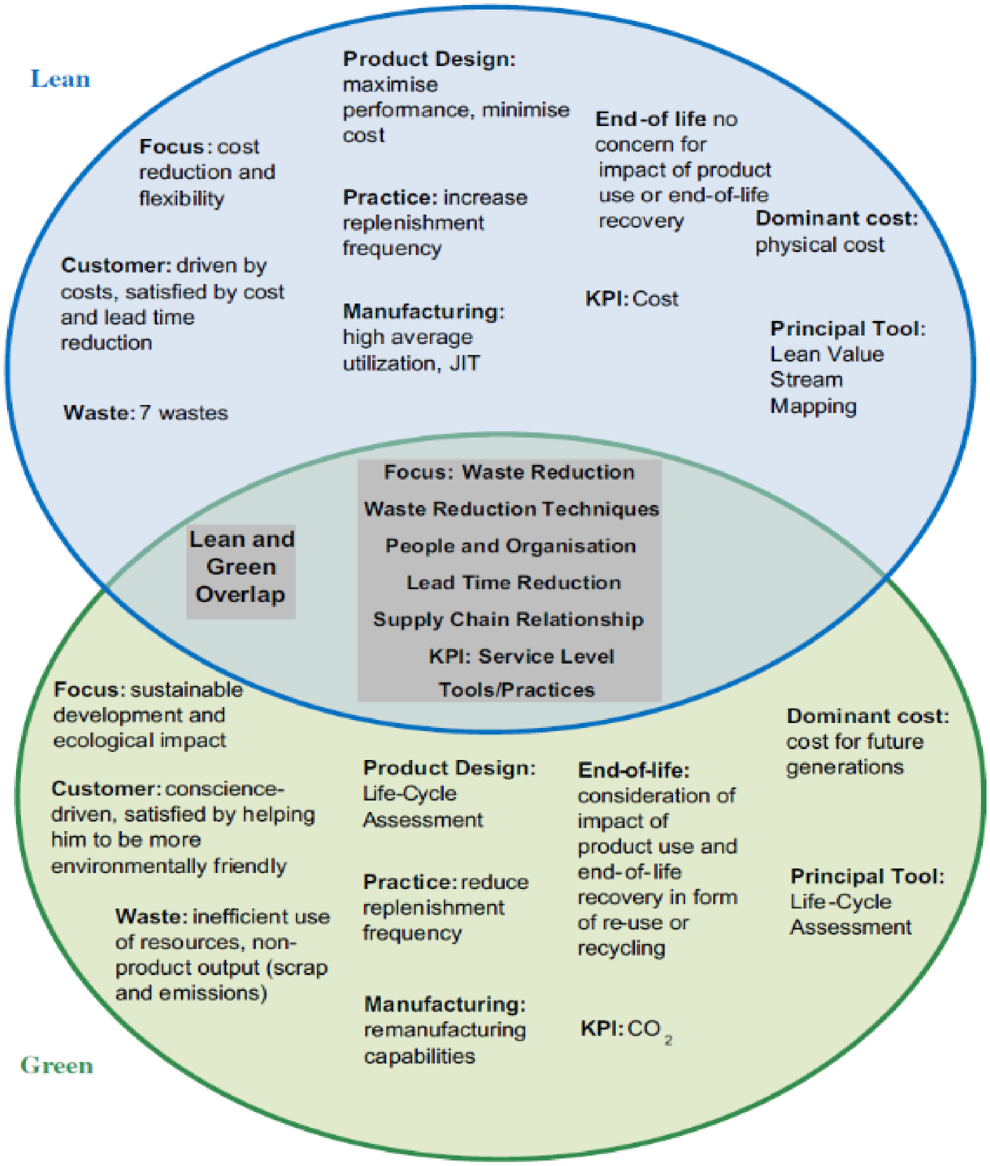

Figure 4- Lean and Green paradigms (Dües *et al.*, 2013)

To determine the best lean and green integration, it is better to study each paradigm and its attributes separately, and then discuss the similarities and synergies. As the Figure 5 shows, the lean and green paradigms have an overlap, which shows the section where they can be considered synergistic. And their performances in this part are aligned and could be correlated in some extent. Waste reduction and lead time reduction are samples of these in common part between the two paradigms. Customer satisfaction is also introduced as the Key Performance Indicator of these two paradigms.

There are also differences between lean and green, and researchers indicate that the analysis of those areas proves that for these attributes it is not impossible to combine lean and green practices. Introducing green as the new lean and considering the integration of these two paradigms along the supply chain is the focus of many researchers recently (Dües *et al.*, 2013; King & Lenox, 2001; Kurdve *et al.,* 2014; Lapinski et al., n.d.; Parveen *et al.,* 2011).

Some researchers focus only on one or two aspects of each paradigm. For example, Azadegan *et al*. (2013) did a statistical analysis to understand the environment dynamism effect on lean operation and lean purchasing performance. Based on their regression analysis on data from US manufacturers, a positive relationship between lean and performance exist.

Aguado *et al.* (2013), based on a case study, develop a model for efficient and sustainable improvement in a lean production system. They could demonstrate that the environmental innovation and transformation of a production system into a lean system can improve cost, income, social responsibility and sustainability. In their model, based on the consequence of reduced consumption of the raw materials and decrease in the environmental impact, the company becomes more efficient in environmental sustainability.

Some authors believe that going lean and green is introducing new business strategies to the companies, while providing new opportunities for improvement and competitiveness. Duarte and Cruz-Machado (2013) mentioned quality awards or organizations to improve their performance, such as Shingo Prize, the Malcom Baldrige National Quality Award, and the European Foundation for Quality Management. By studying these awards, the authors develop a conceptual framework for lean and green business organizations. By this framework the managers can perform a self-assessment in terms of a lean-green approach.

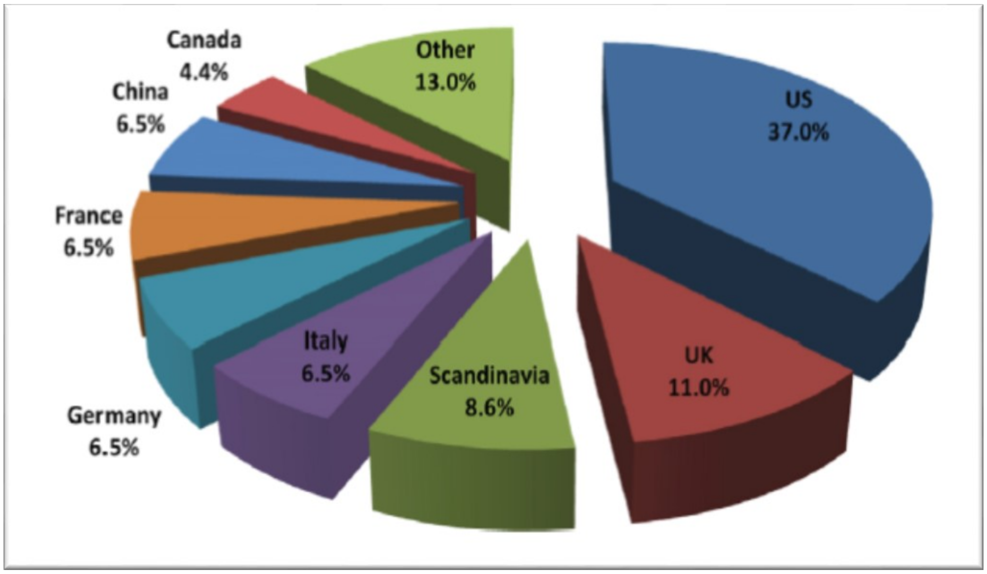

Figure 5- Geographical origins of Lean and Green contributions (Verrier *et al., 2014)*

Verrier *et al.* (2014) adopted a holistic approach on lean and green research in order to provide a lean and green project benchmarking repository. Based on their paper the following pie chart (see Figure 5) provides the geographical origins of the lean and green contributions. According to their findings US with 37% of the total publications in the field of lean and green has the highest contributions. Canada, however, has only 4.4% of the total research share in this field.

2.7. Aerospace in Canada

Based on research in Canadian industry data bases such as Industry Canada and Statistics Canada data bases, and targeted industry (aerospace industry), there are around 700 companies in this field. Aerospace Industries Association of Canada (AIAC), indicated that in 2012, there were more than 700 companies of all sizes in Canada, with more than 172,000 employees through Canada. This numbers indicate the companies working in the field of production and related areas in aerospace industry ('The State of Canadian Aerospace Industry', 2015).

Aerospace industry in Canada contributes $28B of GDP in Canadian economy and reached the revenue of $25.1B in 2013. Based on the same resource, 70% of the aerospace industry is in the manufacturing area, while the other 30% is dedicated to Maintenance, Repair and Overhaul (MRO) (' The State of Canadian Aerospace Industry', 2015).

2.8. Research Gap

The literature review is done by using two main search engines in this field of research: "Google Scholar" and "Science Direct". The main key words used to search data bases are "lean and green supply chain", "lean and green performance management", and "lean and green performance measurement". Research in this domain is however growing and has become more interesting as the related papers are growing in number in recent years. Although around 90 related papers were found which were dealing with the related concepts, this research focused predominantly on those that have directly studied lean and green and their relation in the performance management framework.

The research in this area shows that most studies focus only on single paradigm, lean or green practices and approach, rather than considering both practices and analyzing multiple measures at the same time. There are only a few studies that consider the relationship between lean and green practices and outcomes. But in Canadian aerospace no study has been performed to analyze the impact of lean and green paradigms on supply chain outcomes. Furthermore, regarding the performance measurement system design, there is a lack of hybrid systems which consider both lean and green practices as a means of evaluating the outcomes of the supply chain.

2.9. Objectives

Nowadays corporations develop strategies and know-how for cleaner environment and production. On the same path, researches focus more on the quest for better understanding of the relation between new business strategies and environmentally friendly performance. In the field of production and industry, there is a greater focus on the potential linkages between operations in supply chain systems and strategies and the environmental performance.

The aim of this research is to examine how these strategies, namely lean production practices and management and green practices and management impact the supply chain management in terms of quality, customer satisfaction and overall performance. Lean and green policies can provide the company opportunities to be more efficient and profitable. The intent is to study how lean and green can be compatible to improve the overall production performance and quality in the context of a supply chain and in alignment with its goals.

2.10. Chapter Overview

This chapter provided a brief introduction into the topics of supply chain and its strategies with a specific focus on lean and green supply chain. The fundamental definition of supply chain and management strategies were presented. Lean and green practices and their importance in staying competitive between supply chains are brought up. And, finally, the recent studies implementing both lean and green in the supply chain are discussed.

By studying the recent research, the gap that exists in the studies is found and more specifically defined. Studying both lean and green strategies at the same time in today's supply chain is needed. In order to start the research on the parallel implementation of lean and green strategies in the supply chain, this fundamental literature review was done to find the existing gap which need to be further studied.

Chapter 3

Conceptual Framework for Lean-Green Supply Chain

The purpose of this chapter is to describe the development of a conceptual framework which demonstrates the impact of parallel implantation of lean and green practices on the quality and performance of the production, and customer satisfaction throughout the supply chain. Based on the previous work in this field, the major lean and green constructs in the aerospace industry were identified. Then the leanness and greenness of the companies were defined accordingly and the conceptual framework was predefined to show the relationship between the lean and green constructs and the outcomes of the supply chain. Hypotheses were developed based on the conceptual framework and a questionnaire was designed to perform the survey and statistical analysis.

3.1. Fundamentals of Framework

The importance of lean and green paradigms was described in detail in the previous chapters. However, bringing a specific definition for lean and green paradigms is a challenging subject, researchers consider the lean paradigm as a set of practices focusing on eliminating any non-value added activity in the supply chain which results in cost reduction. On the other hand, green paradigm focuses on environmental sustainability by performing waste reduction practices. However, the practices are different, both these concepts are of high importance in terms of overall production performance and have significant effects on the supply chain.

In the recent competitive market, implementing lean and green strategies not only is considered as a competitive advantage, but also helps improving the supply chain process. In an article published on internet, Van den Broek has said :"Today's economic, social and regulatory dynamics are putting real pressures on companies to be both lean and green in their product sourcing, logistics, distribution and operational practices" (Broek & Broek-Serlé, 2010).

The desire of being cost effective by all the members of the supply chain, is another reason for considering the lean-green practices supply chain management strategies. Based on this desire in some companies, special departments with the task of implementing and assessing these practices are created. Moreover, integration of the lean and green practices and parallel implementation of these concepts is a new phenomenon which needs to be further studied and investigated in the business literature.

In order to reach a preliminary conceptual framework and its elements, one can take advantage of the comprehensive previous work in this field. A conceptual framework has its fundamentals existing in the literature but in order to reach to a comprehensive model a careful investigation should be made to validate the theories and ideas of the previous researchers. In the nine year period ending to 2009, more than 400 papers have been published assessing the lean and green practices. Among these papers, the major portion is devoted to separate implementation of lean and green practices where only a few of them have considered the integration of these two paradigms (Susana Duarte & V. Cruz- Machado, 2013). It can be concluded that the research on the integration of these paradigms is not developed sufficiently. However, as it is discussed before, due to high demand on the cost reduction, the combination of these concepts is highly important for the companies in the supply chain. In this research work, the conceptual framework is defined based on the integration of lean and green practices to demonstrate the advantages of parallel implementation of the two concepts.

3.2. Fundamentals of Lean and Green Integration Framework

In this research a conceptual framework is developed to better understand the impact of integrated lean and green paradigms on the supply chain improvement approaches. Implementation of these concepts requires a change in the culture of the organizations (Johansson & Winroth, 2009). The relevancy and compatibility of lean and green practices to the organizations' operations has to be identified in order to realize the best way to implement these practices (Dües *et al.,* 2013).

In the present study, a new approach for the organization and its supply chain will be developed. The combination of lean and green practices is also known as hybrid supply chain. In defining an approach to implement the lean and green practice, transformation suggestions should be made for the organization operations as well as the connections between these practices and the management framework. In this section, the literature studies of the previous chapters is employed in order to reach the conceptual framework.

The lean and green supply chain framework has been developed in three consecutive steps as follows:

- The main constructs should be clearly identified in the first step with careful investigation on the relevant literature. In this study our main constructs are lean and green and the performance and quality of the production, and customer satisfaction.
- Then the corresponding practices for lean and green paradigms will be outlined in order to proceed with framework development.
- The relationship between the constructs will then be evaluated carefully to verify in what extent they will affect each other in the supply chain.

In this study, the main paradigms are the lean and green management strategies. The desired outcomes would be performance, quality and customer satisfaction. In the next sections a brief discussion on these paradigms is brought.

3.2.1. Lean Production

As noted in the previous section, lean production includes a set of operating and management practices in order to reduce non-value-added activities within the organization (Hajmohammad *et al.,* 2013). In the recent years many researchers focused on the content of lean production. Based on Shah and Ward (2003) review of existing literature, there are a number of practices which are commonly associated with lean production. Based on their review, JIT (Just in Time), and continuous improvement are the practices which were used in the literature most frequently. They also mentioned lean production practices as a bundle of operational performance. They concluded that related researches show that implementation of lean practices is somehow associated with operational performance improvement (Shah & Ward, 2003). The most commonly benefits of implementing lean practices are productivity and quality improvement (White *et al.,* 1999). Most of empirical studies about lean production and its outcomes focus on one or two facets of lean management (Shah & Ward, 2003). Rose *et al.* (2011) concluded that implementation of lean production practices in SMEs (Small, Medium Enterprises) will effect quality improvement and good customer responsiveness. The three most implemented lean practices mentioned by researchers are reduced set up time, Kanban and small lot size. These practices are necessary to maintain continuous flow (Rose *et al.,* 2011). Based on this research, the relationship between the lean fundamental practices and manufacturing performance is a gap which researchers have not pointed at it.

For the evaluations in this study, the lean manufacturing is defined as a set of practices which are supposed to reduce the waste and non-value added activities. The most important practices applicable for aerospace supply chain have been identified based on the literature and interviews with the experts in the field. A brief discussion on these practices is brought in the following material.

3.2.1.1. Just-in-Time (JIT)

Just-in-Time has been investigated by various researchers. It can be conferred from the literature that the setup time reduction and production smoothening activities are the key components of the just-in systems (Monden, 1981). The just-in time practice is associated with delivering the right amount of products at the right time and right quality. The elimination of waste and full utilization of the people's capacity are also mentioned as the important components of the JIT systems. In order to match the description of JIT system, the manufacturing process has to be simplified somehow to eliminate extra inventories in order to avoid longer lead time (Hopp & Spearman, 2004; Monden, 2011; Ōno, 1988; Spear & Bowen, 1999; Womack *et al.,* 2008).

3.2.1.2. Continuous Flow

Continuous flow strategy is one of the lean manufacturing strategies which focuses on reducing production interruptions and the congestion of parts and materials in the production line. The concept is to have only one working unit at a time between each manufacturing step. This will reduce any breaks in time, flow of material in the production. The concept of continuous flow is basically associated with reduction of wasted time in the production. Time is considered as a non-renewable resource in the production which has to be optimized and its waste has to be minimized. The reduction in time would be accompanied by reduction of energy and consequently the costs. The continuous flow would also enable the companies to realize and fix any errors in the production lines as well (Rother & Harris, 2001).

3.2.1.3. Value stream mapping

Value stream mapping is one of the major lean manufacturing methods whose purpose is to analyze the current state of the production system and to plan for the future state. This method considers a series of consecutive steps through which a product reaches to its final planned destination and a customer. One of the pioneers of this strategy is Toyota Inc. which recognizes this strategy as “Material and Information Flow Mapping”. By employing these strategies the improvement of inventory and information would be achieved and the waste of production can be predicted. Therefore the companies can plan for elimination of the waste in their system of production (Faulkner & Badurdeen, 2014).

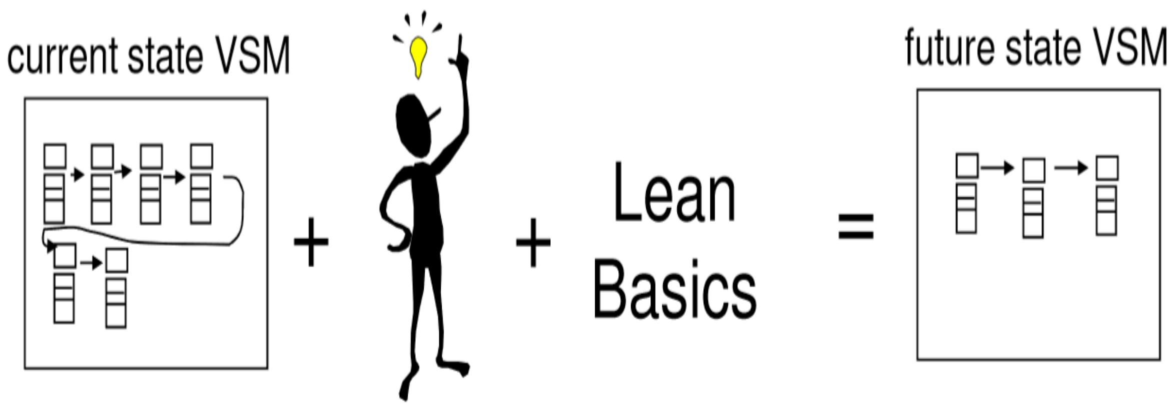

Figure 6- Lean Practice, Value Stream Mapping

3.2.2. Green Production

An organization can directly invest its own resources to improve the environmental practices of supply chain members. Environmental monitoring involves activities of gathering and processing information through supply chain, whether through publicly disclosed environmental records, company specific questionnaires or audits (Vachon & Klassen, 2006). Similar to the concept of supply chain management, the concept of green management and its boundaries are dependent on the goal of the research, which level of supply chain it considers, which practices it considers as the main practices of green supply chain. There are models and frameworks regarding green management of supply chain, considering a variety of characteristics, attributes, and scales for green supply chain management (Hervani *et al.,* 2005; Zhu *et al.*, 2007).

It is desired by the organizations to perform environmental and green practices while they reduce the waste by lean manufacturing methods. These organizations think beyond the internal performance and try to contribute by improving the environmental aspects of their activities. Some of the green strategies are also obligatory by the government regulations while some of them are desired from the customers' side. Environmental management practices include a wide range of activities from the stage of product design to final production and delivery of the products. Green environmental management strategies can be performed by different types of practices such as production aligned with ISO standards, eco-design of the products and recycling and waste management. In this research, the main green practices have been selected based on the careful literature review and consultation with experts.

3.2.2.1. Reducing Energy Consumption

Human activities have some harmful effects on the environment which are gaining an increasing interest of scientists. Manufacturing processes are one of the major sources of these environmental impacts because of the large amount of energy consumption throughout the production process. Almost 27 percent of the global CO2 production is due to industrial activities which are related to the energy consumption. This statistics indicates the significant contribution of industrial activities on the global environment. It is observed that some of the production activities contribute to more than 90 percent of the overall CO2 emission which is due to amount of required energy for the production process (Duarte & Machado, 2013; Zhu & Sarkis, 2004; Zhu *et al.*, 2007).

The investigations show that the major part of the energy consumption in the manufacturing process, is not due to the process itself but is due to how the process is managed and performed. So little changes in the operational process can have considerable effects causing the energy consumption to be reduced by large amounts (Zhu *et al.,* 2007).

Applying new technologies in every element of the production cycle and using new sources of energy in the production system are among the reliable methods to reduce the energy consumption. By doing so, companies are little by little starting to implement green production practices in their management infrastructure.

3.2.2.2. Recycling/Reusing

Recycling is known as a form of waste management practice where the undesirable outputs of a production cycle and the wastes of the production will be used as the input for the same process of production. Another form is to use the recyclable materials for the purpose of producing energy for the production cycle. Most of the raw materials used in the production are recyclable. These include glass, papers and metals which are buried in the landfills instead of being used for the recycle.

It should be noticed that generally there are two terms in this field. Recycle and Reuse are the terms which are different in some aspects. Recycle is a process in which some treatments are required on the wastes and undesirable products, whereas the Reuse is a process with the minimum treatment. The recycled materials will undergo considerable treatments to be prepared for return to the production cycle. The quality of the recycled materials are also of importance. However, in some cases the quality of the recycled materials is better than the original material (Kopicki *et al.*, 1993).

3.2.2.3. Environmental Standards

Environmental standards consist of a set of documents listing the main management elements which help the organizations to address the environmental issues. Since these standards are voluntary, it is usually the decision of company to implement these regulations and register to obtain the corresponding standards. The standards generally contain the core environmental management systems as well as the verification strategies.

One of the most popular environmental standards is ISO 14001 which introduces a comprehensive approach to reduce the impact of industrial activities on the environment. This standard contains some major components such as:

- The first element is to identify the impacts of manufacturing activities on the surrounding environment

- The second element is the verification and inspection. For this purpose the goals are defined and the progress measurement steps are introduced. Then the progress review is presented.
- In order to reduce the risk of environmental impacts, training the employees and other components of the supply chain, some procedures are introduced.
- The procedures of documenting and recording the activities are established
- The compliance with the regulations and standards are inspected and verified (MacDonald, 2005).

3.2.3. Framework Outcomes

In this section the major outcomes of the conceptual framework are introduced. These outcomes are selected based on a careful study on the literature considering the main needs of the customers in the considered sector for the evaluations. Besides, the objectives and capabilities of the supply chain are taken into account. The purpose of considering and analyzing these outcome parameters is to differentiate the supply chain from its competitors by improving its outcomes.

3.2.3.1. Production Quality

The quality of the products and services is of high importance in the supply chain. As far as the production quality is concerned, performing the practices such as just in time system is highly affective and is of high importance. The final production quality which results in the delivered quality to the customers is a result of performing the lean and green practices which are described in the previous sections. In aerospace industry, like in the other sectors, the quality of the operations in the organization is subject of attention of many companies, especially when the markets are unstable. The companies should always perform practices to improve their production quality and to be able to successfully compete with other companies in the sector (Robinson & Malhotra, 2005).

3.2.3.2. Overall Performance

The overall performance of an organization consists of a few important parameters. The parameters such as use of resources and response of the system to the uncertainty are among the most important overall performance factors. The performance measures of an organization must match with the organization goal itself as well as the customer goals in order to stay competitive in the market. Companies generally measure three parameters to determine the overall performance of their supply chain (Beamon, 1999):

- Resource measures
- Output measures
- Flexibility measures

3.2.3.3. Customer Satisfaction

The customer satisfaction is considered as one of the measures of performance which is a major source of competitive advantage. As an example, reduction in order cycle time leads to a shorter response time, which is an advantage as far as the customer satisfaction is concerned. This was also confirmed by Gunasekaran *et al.* (2001), who found that the response time to the orders and needs has direct relation to the customer satisfaction. Lee and Billington (1992) have performed a comprehensive study showing that the performance measurement metrics are directly related to customer satisfaction. They proposed response time and service fill rates as measures for performance, while they argue that all metrics must be oriented to customer satisfaction. On the other hand, studies in the field of environmental management, for example the study performed by Saeidi *et al.* (2015), have shown that customer satisfaction is the outcome of social responsibility of the corporation which is a major outcome of the supply chain.

Table 3 demonstrates a summary of the above discussed outcomes. As it was mentioned before, in order to define the framework the main constructs including their practices should be carefully investigated and listed as the first step to perform further statistical analysis.

Table 3- Definition of the variables and practices

Variables	Definition	Supporting literature
Lean Production	Lean production is an approach with the focus on reduction of non-value added activities and waste by implementing a set of management and operation practices.	(Yang et al., 2011),(Shah & Ward, 2003), (Li et al., 2006), (Hajmohammad et al., 2013a), (Susana Duarte and V. Cruz-Machado, 2013)

Variables	Definition	Supporting literature
Just-in-Time (JIT)	JIT basically is referring to manufacturing the right product, in the right amount and at the right time. By implementing JIT, organizations can reduce a considerable amount of their production lead-time. The fundamental objective of JIT is to eliminate waste.	(Monden, 2011), (SUGIMORI, KUSUNOKI, CHO, & UCHIKAWA, 1977), (Frazier, Spekman, & O'Neal, 1988), (Christer Karlsson and Pär Åhlström, 1996), (Huson & Nanda, 1995)
Value stream mapping	VSM is a lean practice to identify the flow of material and information, it demonstrate the current state and future state of the procedure in order to identify and reduce non-value added activities.	(Chen & Meng, 2010), (Faulkner & Badurdeen, 2014), (Hines & Rich, 1997), (Keyte & Locher, 2004)
Continuous flow	Manufacturing where work-in-process smoothly flows through production with minimal (or no) buffers between steps of the manufacturing process. Eliminates many forms of waste (e.g. inventory, waiting time, and transport).	(Bowers, 1991), (Rother & Harris, 2001), (Alvarez-Vargas, Dallery, & David, 1994),
Green Production	Green production is a set of practices which are implemented in order to minimize waste and environmental pollution. These practices are considered to be any method or action which is performed across the supply chain to eliminate or reduce any kind of negative environmental impact.	(Azevedo et al., 2011), (Aref A. Hervani et al., 2005), (Johansson & Winroth, 2009), (Susana Duarte and V. Cruz- Machado, 2013)
Reducing energy consumption	Green manufacturing as a positive environmental improvement include practicing which cause reduction in energy consumption of the supply chain.	(Zhu & Sarkis, 2004), (Susana Duarte and V. Cruz- Machado, 2013), (Zhu et al., 2007)
Recycling/Reusing	Waste management policies and recycling systems are green practices which reduce the environmental impact of the production. This practice focus on the waste generated by the supply chain.	(Zhu & Sarkis, 2004), (Sarkis, 2003), (Purba Rao and Diane Holt, 2005)

Variables	Definition	Supporting literature
Environmental standards	Environmental standards define an organized approach to reduce the impact of environmental aspects. They describe a system to help an organization achieve its own environmental objectives. ISO 14001 is "a useful tool in the management of environmental supply chain issues"	(Susana Duarte and V. Cruz- Machado, 2013), (Welford & Starkey, 1996), (Dowell, Hart, & Yeung, 2000)

The mentioned constructs in the above table are selected based on studying the literature and the previous work in the field. They are also revised based on the specific category of industry subject of this research work. In the next section the conceptual framework is presented and further relationship between the constructs and outcome are discussed.

3.3. Schematic of Lean and Green Conceptual Framework

Considering the major lean and green practices as described in the previous section as well as the major outcomes of the supply chain a schematic for the conceptual framework has been derived and described. As it is mentioned before, this framework is developed based on integration of lean and green supply chain activities. It means the effect of parallel implementation of these two paradigms is considered in the following framework. The lean and green approaches and their parallel implementation have significant impact on the supply chain. In Figure 8 a conceptual framework which assists understanding of the relationship between lean and green concepts as well as the outcomes of the supply chain is presented.

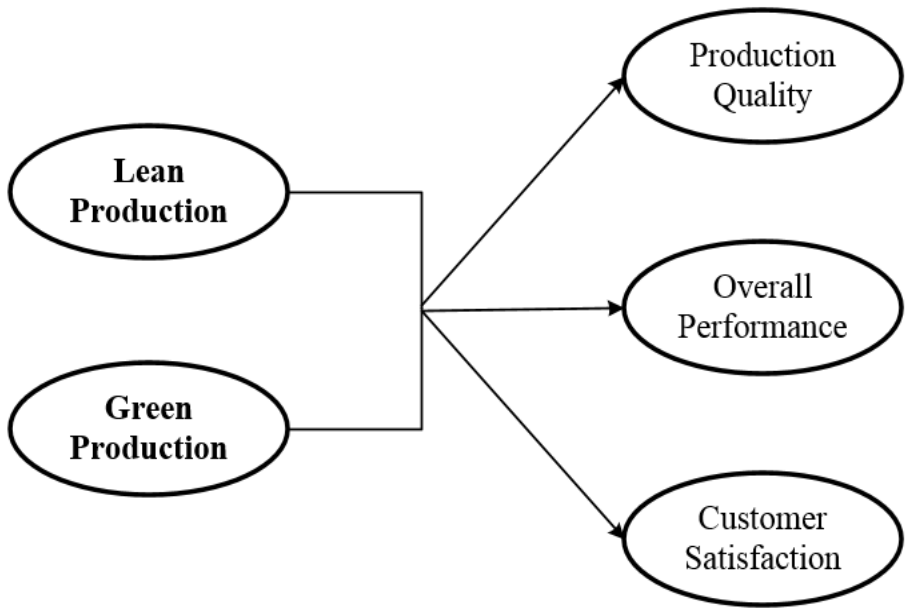

Figure 7- Conceptual Framework of lean and green performance measurement system

In the above figure, the main paradigms and outcomes of the supply chain are schematically shown as the conceptual framework which supports this study. The relationship between the lean and green management practices and the main outcome parameters including the quality, performance and the customer satisfaction are demonstrated. This framework is the basis for further hypothesis development and statistical analysis.

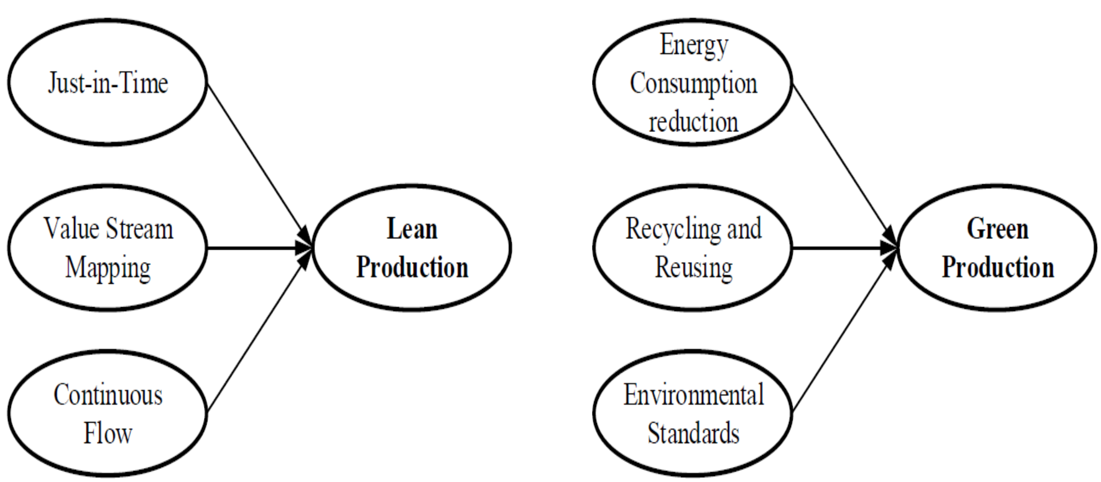

Figure 8- Lean and Green Practices

The purpose of this research is to examine the capability of a lean and green approach to enhance the outcomes of the supply chain. As it can be seen in the Figure 8 the main practices in this study are continuous flow, just in time, and value stream mapping under the category of lean manufacturing strategies and reduction of energy consumption, recycling/reusing, and environmental standards under the category of green manufacturing.

The results of this study will demonstrate what an organization will achieve by implementing the above mentioned activities all in parallel. The findings will help the organizations to develop the right lean and green practices according to their priorities, structure of production system, and their culture. The organizations should always continue to develop and improve their management strategies in order to stay competitive and improve their product or services and achieve their goals.

3.4. Hypothesis Development

Hypotheses are the predictions made about the potential relationship among the variables and will be verified after the completion of the research work including the questionnaire design, data collection and the analysis. In this section the predicted relations between the lean and green practices, described in the previous sections, will be discussed. These hypothesis will provide the basis of the questionnaire design which is the subject of next chapter.

As described in the previous sections, lean manufacturing is a set of activities and practices performed with purpose of waste elimination from the firm's production cycles by continuous performing of improvement and process changes. These strategies will result in reduction of non-value added activities or elimination of wastes (Florida, 1996; Womack et al., 2008). Moreover, lean manufacturing focuses on increasing the employees' sense of responsibility and involvement in waste reduction activities within the organization (Shah & Ward, 2003; Tu *et al.,* 2006).

On the other hand, green activities are those with more focus on the environmental impacts of the production system. The number of organizations which employ these activities in their daily production system is increasing day by day. The implementation of these practices helps the organization to stay competitive in the pioneering market nowadays.

The aim of this research is to consider implementing both lean and green practices and assess their impact on the outcomes of the supply chain. The literature review indicated that implementing lean reduces waste and non-value added activities in terms of time and unnecessary actions. On the other hand, green practices reduce waste in terms of environmental impact, energy consumption and non-recyclable materials.

It was conferred from the comprehensive literature in the field of lean manufacturing that performing lean practices such as just-in-time, value stream mapping, and continuous flow has significant positive impact on the production system by reducing waste and non-value added activities. Also green management practices can improve the quality of the production. By idealizing the production system according to the environmental standards as well as using new energy resources the quality of the production can be increased so that we can wrap up the relation between the parallel implementation of lean and green practices on the production quality as follows:

H1: Parallel implementation of lean and green is positively associated with the production quality of the supply chain

Based on the studies and according to the literature, it was concluded that continuous flow, value stream mapping and just-in-time practices have positive impact on the flexibility of the production systems (Parveen et al., 2011). Furthermore, these practices reduce the waste in the production cycle which results in optimization of resources which is an important factor in the overall performance of the supply chain. Moreover, the green practices such as recycling and reusing, energy resource planning and consumption reduction, and also environmental standards, all contribute to optimizing resource measures, flexibility and output measures of the supply chain. Considering both lean and green practices implementation in the supply chain, the corresponding relationship would be as follows:

H2: Parallel implementation of lean and green is positively associated with the overall performance of the supply chain

As it was described in the previous sections, satisfying the customer requirements is a major goal of an organization. In the set of green practices, the positive effect of each practice on customer satisfaction is obvious. For example, the reduction of energy consumption and resources optimization will result in less negative environmental impact which is clearly of high importance for the clients as well. Also in the set of lean manufacturing practices the response time can be mentioned. The shorter the response time to the customer inquiries is, the higher would be the customer satisfaction. Therefore one can assume that the parallel implementation of lean and green manufacturing practices will have a direct relation to the customer satisfaction, and thus it is hypothesized:

H3: Parallel implementation of lean and green is positively associated with the customer satisfaction rate in the supply chain

The following figure summarises the discussions made in this section. The framework and hypotheses are demonstrated for further clarification.

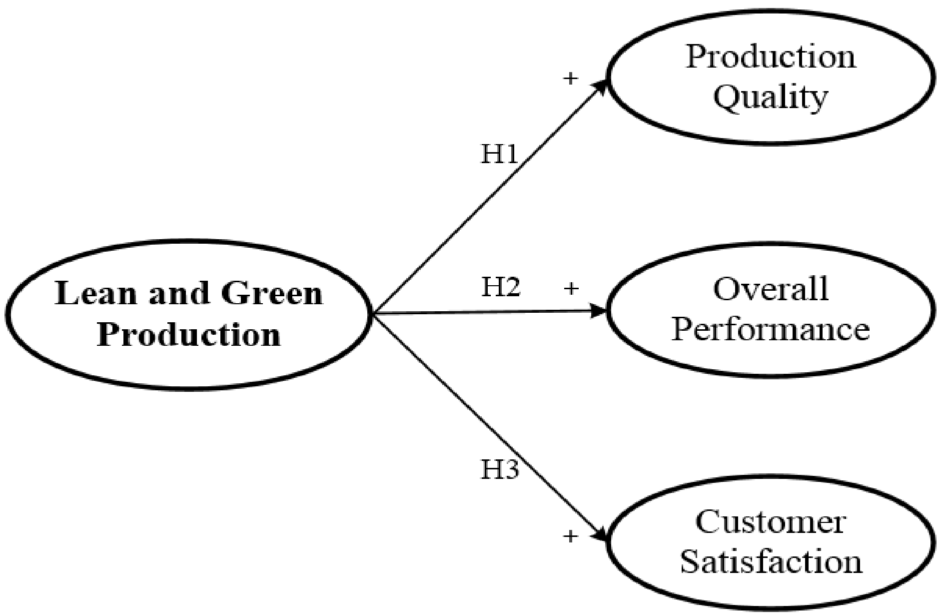

Figure 9 - Framework and Hypotheses

3.5. Chapter Overview

This chapter provided the required fundamentals for the next phases of the project which are the data collection and analysis. The definition of lean and green concepts and their practices has been discussed in detail and performance outcomes subject of the current research introduced. In order to analyze the results of statistical analysis and to develop a model, it was necessary to develop a framework based on the management paradigms and the outcomes of the production so that the hypotheses can be developed and verified by performing a survey. This conceptual framework was developed and discussed along with the hypotheses. The next step would be to perform the data collection based on a designed questionnaire and then to perform the statistical analysis.

Chapter 4

Research Methodology

In this chapter, the details of research methodology is described. Different research methodologies are evaluated and discussed in the first section and the selection of survey is explained. The survey design, questionnaire design, data collection and the survey procedure would be described in detail. The data collection is considered here as the most important stage of the statistical analysis. Data from the Canadian aerospace society was collected between September 2014 and March 2015. The data was collected by mail and attending interviews and seminars in this period of time. Starting from 1930, researchers in the fields of social sciences and marketing tried to use the survey and data collection as a tool for their research work (Vaus, 2013).

For the purpose of current research the data was gathered by means of a survey questionnaire (the detail of survey questionnaire is presented in the Appendix I). As it is mentioned before, the focus of the current research is on the aerospace industry supply chain across the country of Canada. As the first step for the survey and data collection, based on the hypotheses and according to the conceptual framework developed in the previous chapter, a questionnaire was designed. Then by receiving feedback from the experts in the field the questionnaire was confirmed. Then a pilot study was performed in order to verify the validity and reliability of the questionnaire. Attending the seminars and using the online survey software, the companies were contacted and the survey questionnaires were distributed among them. The collected data was cleaned and filtered in order to be processed in the next phases of the research.

4.1. Different Research Methodologies

There are different methods by which a research question can be addressed. Figure 10 is a schematic demonstration of the different research methods and their associated techniques. These research methodologies are investigated and among them the most appropriate one for the purpose of current research has been selected. Survey has been selected since the whole population of aerospace industries across the Canada is not accessible to be interviewed and/or interviewed in person.

For the survey, similar to the case study and experiment methods, different techniques exist as shown in the following figure. Questionnaire distribution, interview and in-depth interview, observation and the content analysis are among the most important survey techniques.

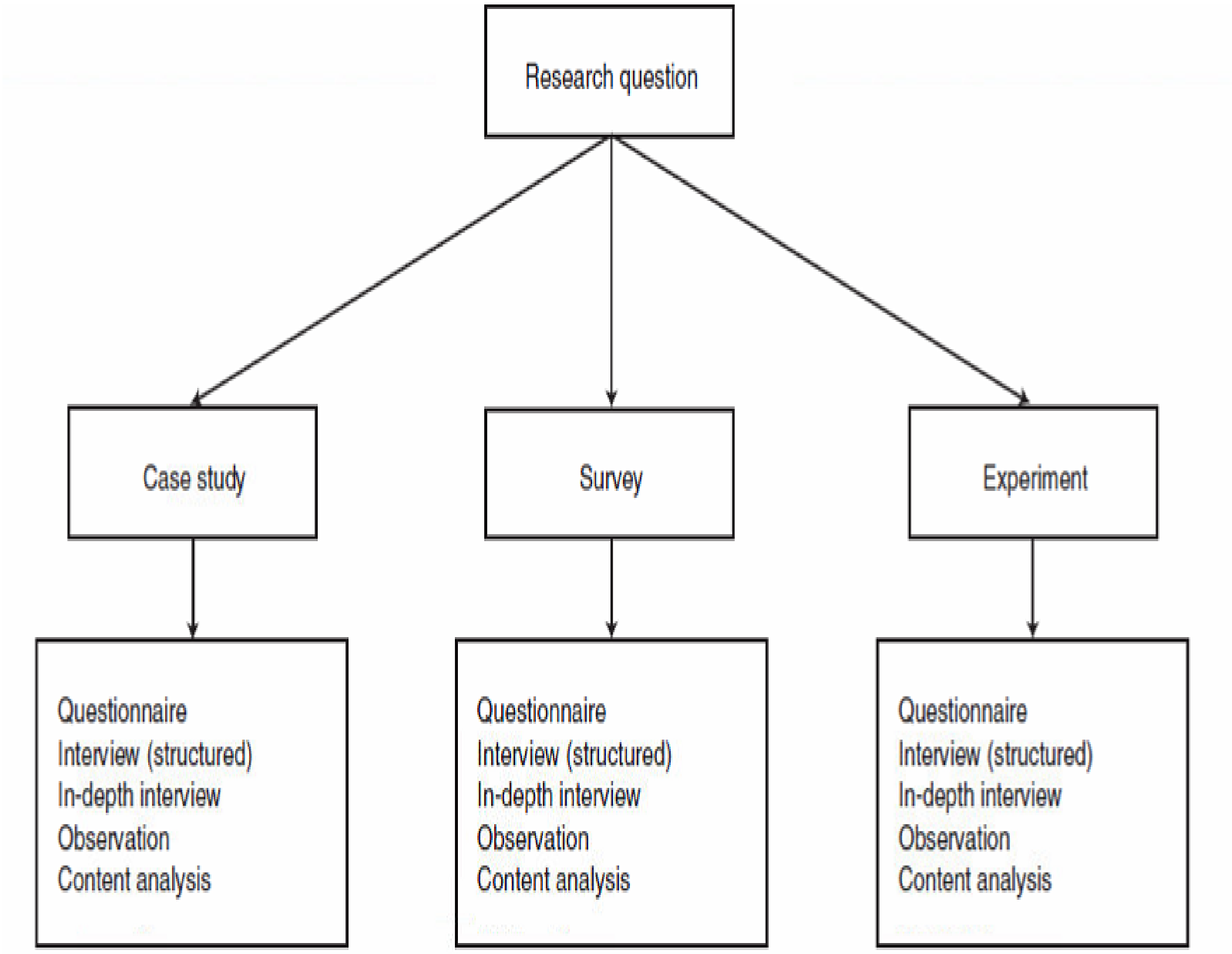

Figure 10- Schematic demonstration of the survey methods and techniques (Vaus, 2013)

4.2. Survey

Survey is known as a set of activities including selecting the samples among the target population, design of questionnaire and the distribution methods. The method of distributing the questionnaires among the samples of the desired community, which is called survey, is a widely used method in the recent research studies (Vehovar & Manfreda, 2008), however, the relevant data can be collected by using a variety of survey techniques such as interview, observation and content analysis (Vaus, 2013). The stages of a reliable and accurate survey research is demonstrated in the Figure 11.

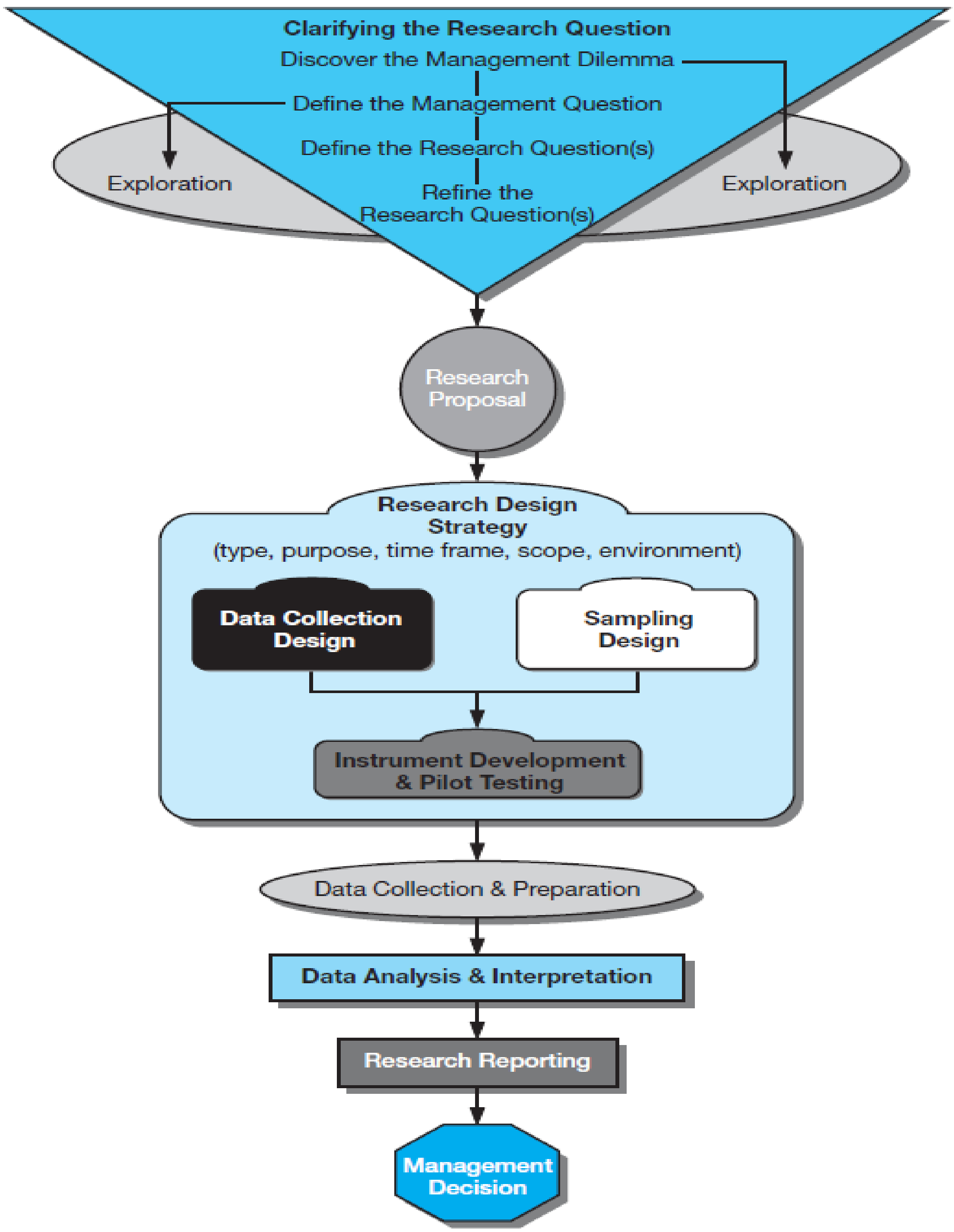

Figure 11- Survey Research Flowchart (Cooper *et al.*, 2006)

4.3. Questionnaire

The questionnaire is the preliminary tool for performing data collection and statistical analysis. It is necessary to design an accurate questionnaire in order to achieve accurate data and make a valid and reliable data base which leads to accurate interpretation of the results.

The most important steps in development and design of a questionnaire based on Mellenbergh (2008) are listed below:

- As the first step, the researcher should have a careful knowledge and definition on the topic and gather the information about all aspects of the work
- Having this information a draft of the questionnaire should be prepared in order to perform more analyses and revisions
- In this stage, the draft of questionnaire has to be carefully evaluated and revised, the more the simple and short sentences are used in the questionnaire the more convenient would be the assessment of the collected data.
- After preparing clear and simple questions pre-test will be performed on the questionnaire, this process is also known as piloting
- The piloting and pre-test provides a good insight for the researcher to perform further revision based on the results of this preliminary testing procedure. At this stage another step of the revision will be performed in order to prepare the final draft of the questionnaire.
- Having the preliminary tests and revisions accomplished, the final draft of the questionnaire can be prepared at this stage.
- Prepare a coding system for the answers which translates the answers to a numbering system is required in order to perform the statistical analysis.
- At this stage the questionnaire should be distributed and the procedure of the distribution has to be administrated carefully.

After performing the above mentioned steps, the final draft of the questionnaire is ready. At this stage we need to consider a procedure that translates the qualitative results into the quantitative data which can be gathered in the appropriate software and analyzed using the statistical analysis techniques. Likert (1932) has introduced a method to address this step which is known as Likert Scale and is discussed in the next section.

4.3.1. Likert Scale

In this section, the Likert scale will be described in detail. This method is a widely used procedure of measuring and assessing the answers obtained from the respondents to a survey by means of scaling. In other words, the method provides the means to quantify the results of questionnaires, which leads to precise assessment and interpretation of the survey data. In this method, the scales shall be constructed based on the careful understanding and assessment of the research questions (Mellenbergh, 2008).

Likert (1932) has proposed a scaling model for assessing the respondent's attitudes in 1932 which is still being used by many researchers around the world. Based on Likert's scale, the answers to the questions can have a range instead of only a positive or negative choice. Each question in Likert's scale can have many response alternatives. The responses could include the strongly approve, approve, undecided, disapprove, and strongly disapprove (Clason & Dormody, 1994). By means of Likert scale the respondents choose not only their agreement or disagreement, but they can indicate the level of agreement and disagreement. This idea increases the reliability of the questionnaire due to providing a wide range of possible choices for the respondents (Vaus, 2013).

For the purpose of the current research, three-point scale Likert is employed in order to code the answers of the questionnaire as followed:

Table 4 - Questionnaire Likert scale

practices	To what extent do you practice just-in-time in your company?	Rarely ○	Occasionally ○	Always ○	Don't apply ○
outcomes	Practicing lean and green, increased the overall performance of the organization.	Agree ○	Neutral ○	Disagree ○	Don't apply ○

By finishing the development of answer indicators based on the Likert scale, we need to reach to a confidence that our questions will lead us through the exact concept that we look for. Also one needs to insure the reliability and validity of the respondents answers. The questions should be designed somehow not to have variable answers in the different time or attitude situations. The respondents should always provide the same answer to the question. This matter ensures the reliability of the questions and consequently the statistical analysis and prevents the measurement errors (Vaus, 2013).

4.3.2. Questionnaire Revision

As it was mentioned before, once the draft of the questionnaire has been prepared, a professional review has to be performed in order to determine the weaknesses and strengths of the questionnaire. In order to do so, an in-depth interview with a senior manager at Bombardier Aerospace was performed. He is a professional person specializing in business development, Six Sigma and operations excellence. Once the questionnaire was prepared based on the hypothesis subject of this research, the person was contacted to have a revision on the questionnaire content. The design procedure was also discussed in order to achieve some ideas from the valuable experience of him. Having an in-depth interview with a person who was an experienced person in the lean manufacturing department of a well-known aerospace company provided a significant insight to the author to revise and validate the quality of the questions. This multiple session interview led to finalizing the questionnaire draft on a professional basis. The finalized draft can be found in Appendix 1.

4.3.3. Pilot Testing

The pilot testing process is an initial stage of the data gathering process. This step provides a preliminary run for the full scale survey and gives some ideas to the researcher to optimize the questionnaire as well. The most efficient questions can be recognized and the ones which are less conclusive and which do not make sense to the participants can be modified or removed from the final version of the questionnaire (Vaus, 2013).

Moreover, performing the pilot testing provides the researchers with a reliable prediction of the costs and time of the survey which helps them to conduct a feasibility study prior to the full scale survey. This information can help the researchers to improve the performance of their survey in advance which results in better ability to interpret the data and improve the reliability and validity of the final concluding remarks (Hulley, Cummings, Browner, Grady, & Newman, 2013). The size of the sample group for performing the pilot test can range between 25 and 100 where the respondents to this pilot test are not statistically selected (Cooper *et al.*, 2006).

There is always a risk associated with use of survey in a research works. One of the great advantages of advance pilot testing is that one can recognize the possible points of failure in the research (van Teijlingen & Hundley, 2002). Performing the pilot test will demonstrate if the survey method is suitable for the current research work or not. In the next sections the details of pilot testing which is performed in the present research is presented.

4.3.4. Reliability

A reliable questionnaire is the one composed of the reliable questions which will have the same answers anytime a response is requested from the respondents. The repeated occasions should provide same data to show that the questionnaire is reliable. One of the main contributors of reliability is the reliable indicator. Likert scale which supposes multi-item indicators is one of the most reliable questionnaire design systems. The consistency of the questions in a questionnaire is also of high importance as far as the reliability of the questionnaire is concerned. Since the all the questions are focusing on a specific topic, so the respondents will provide fairly consistent answers to the questions (Vaus, 2013).

In order to verify and test the reliability of the questionnaire a trial test can be performed among a small sample of the respondents. This small community has to be within the target population of the study. After the trial test (Pilot) is done, the correlation is calculated to see if the questionnaire is reliable or not (Vaus, 2013).

As mentioned earlier, using the Likert scale (multiple-item indicators) will also increase the reliability. There are also other factors which affect reliability of the questionnaire, such as wording, methods of coding and training before the test (Clason & Dormody, 1994).

4.3.5. Reliability Verification Test

As it was mentioned before, the reliability of a research can be evaluated by measuring the consistency of the results in two different occasions. In order to verify the matter a test can be designed. The approach is to assess the consistency of the respondents on an item (item-item correlations). The index which is considered for the reliability is Cronbach's alpha coefficient, which is a number between 0 and 1. The higher is the coefficient, the more reliable the questionnaire is. The rule of thumb for reliability is a Cronbach's alpha coefficient more than "0.7". If the coefficient does not meet the requirements of reliability, the unreliable questions should be dropped (Vaus, 2013). After recognizing the unreliable items in the questionnaire, the test can now be performed on the questionnaire without the unreliable parts. In this case if the Cronbach coefficient is increased to a value above 0.7, one can reach to a confidence that the questionnaire is reliable. Furthermore, the results of the survey performed by a reliable questionnaire can be forwarded to perform the full scale test and achieve the required data (Vaus, 2013).

4.4. Survey Validity Verification

After designing a questionnaire, the problem is how we can verify the validity of our survey. The question is, does our survey really measure what it is supposed to measure? Unlike the reliability of the questionnaire which could be measured by means of a coefficient, the validity of the questionnaire has no statistical test to perform. The survey is valid once the researcher reaches to this opinion that his or her survey is valid, it is measuring what it is supposed to measure correctly, it produces understandable and consistent results, and it provides consistent information to evaluate the construct subject of the survey.

In the current research, the validity of the questionnaire was confirmed before starting the questionnaires distribution. The process was done by paying close attention to what is desired and what is brought in the questionnaire. The consultation from an expert working in the field of lean and green in a big aerospace company (Bombardier) was received and the professional ideas were employed to modify the questionnaire in order to make it as efficient as possible.

4.5. Sampling

Sampling is defined as the process of selecting a small number of units among a population of interest for a survey research so the results can be generalized for the population they have been chosen from (Trochim & Donnelly, 2001).

The sampling and the determination of the sample size for a community is one of the most important stages of a survey. The sample community has to have adequate members in order to provide the researcher with accurate results which can be generalized to the full size population. The gathered data from a sample will be evaluated and the findings would be generalized for the original population (Kotrlik & Higgins, 2001). Sampling is also one of the major advantages of a quantitative methods since performing the survey on the full scale community is much more expensive than a small sample of that community (Holton & Burnett, 1997).

First, we must identify exactly what we intend to study. We must determine our population of interest and its size. In the next stage, we select a representative sample using appropriate sampling techniques. In order to be able to generalize the result, it is necessary to determine the number of samples that we need to study. Inadequate, or excessive number of samples will considerably affect the quality of the research outcomes (Kotrlik & Higgins, 2001).

In the following material the procedure to determine the sufficient number of sample members is described and the sample size for the current study is calculated.

Before starting the sampling process, two important factors should be considered,

- The required level of accuracy from the research is a key factor in determining the sample size.
- Also the variation of the main parameters subject of the research in the population will have considerable effects on the sample size (Vaus, 2013).

Probability Sampling Methods

As it was described in the previous sections, researchers select a certain amount of samples in order to obtain the required data and then generalize the acquired information to the population subject of their research question. The selection of sample will be done by performing scientific probability based designs. By mean of these methods, the risk of biased interpretation of the results will be reduced and confidence on the evaluations from the sample data can be achieved (Kalton, 1983).

Different methods exist for performing the sampling as reported in many articles and books. The main four categories of these methods are listed in the following (Vaus, 2013):

- **Random sampling**
- **Systematic Sampling**
- **Stratified Sampling:**
- **Cluster Sampling**

For this study the method that is used is stratified sampling. This method is a modification of random sampling method which has some major advantages and provides with more accurate samples. The data in this method will be divided into sub sections which are called strata. Depending on the number of items, each strata will have contribution in the final sample. The strata can be shaped based on the characteristics such as sex, age, and the education level of the respondents. After dividing sample into subdivisions (strata), simple random sampling will be performed among each strata (Vaus, 2013).

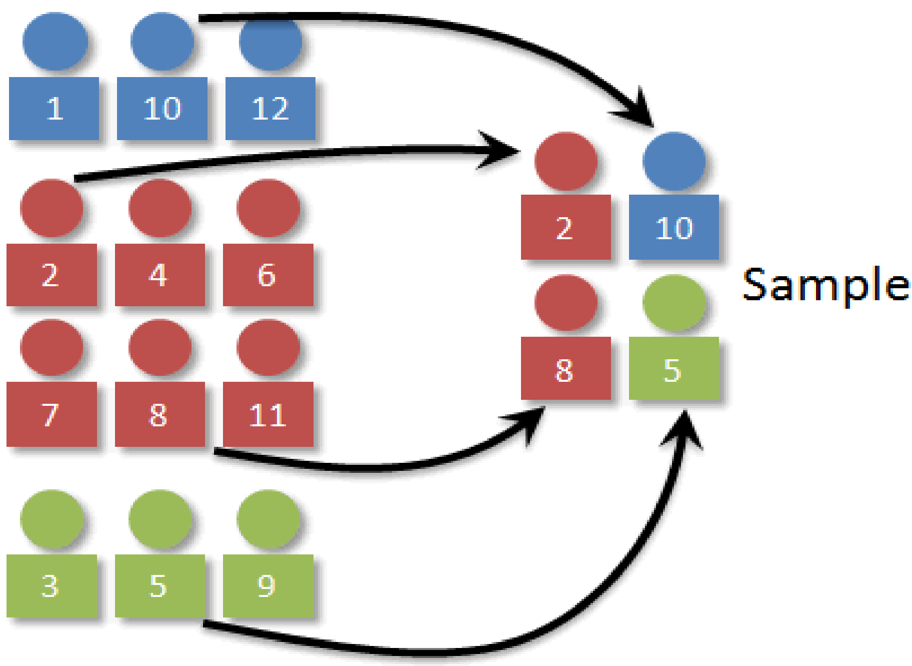

Figure 12- Stratified sampling (Sullivan, 2007)

Figure 12 demonstrates how we select the samples from a population using the stratified sampling method. The figure shows that the larger strata will have more contribution in the final sample in order to achieve more reliable and accurate assessment. For the purpose of current research the *stratified sampling* method has been employed. The selection of this method was based on evaluation of similar works in this field demonstrating more reliable and accurate results achieved from stratified sampling (Quayle, 2003; Salvador *et al.*, 2001).

In the results section, different tiers of aerospace supply chain are described and the survey questionnaire distribution procedure is discussed in detail.

4.6. Internet Survey

Using the internet based methods in order to perform the data collection is recently being more and more common among the research works. One of the method in gathering the data is to send the questionnaires by email. Recently some website have been emerged to automatically perform the process of sending the survey emails to the respondents (Vaus, 2013). Researchers use these web sites which facilitate the process of sending the questionnaires to a list of the desired respondents and provides the final data automatically for them. Use of this web sites helps the users to save considerable amount of time and budget. Also these websites provide the researcher with the features to easily design the questionnaire and gather clean and summarized data prepared for further analysis.

One of the common survey data collection websites is Qualtrics. Qualtrics is a private owned software company, founded in 2002. In this website, the users can design the questionnaire using the design tools provided by the software. The software also provides the opportunity to modify the questionnaire as desired. Then the questionnaire can be distributed automatically throughout an email list which is given by the user. The statistics of the survey progress can be observed by the user in order to have an evaluation of the survey progress at any time during the survey period.

4.7. Missing data

In almost any research you perform, there is the potential for missing or incomplete data. Missing data can occur for many reasons: participants can fail to respond to questions, equipment and data collecting or recording mechanisms can malfunction, subjects can withdraw from studies before they are completed, and data entry errors can occur. There are several methods for dealing with missing data, especially while using survey instrument. One of the most common method used is imputation. Imputation methods involve replacing missing values with estimated ones based on information available in the data set (Batista & Monard, 2003). Imputing conditional means was introduced by Buck in 1960. This method imputes a mean which depends on the values of the recorded variables for the incomplete record. For categorical variables, an alternative to mean imputation is imputation of the mode (the most frequently observed) value for missing values. (Lakshminarayan *et al.,* 1999, Buck, 1960).

In this study the method that was used to deal with missing data is imputation. Since the data for this study is categorical and discrete, the value that was used for imputation was the mode of the recorded data. For instance, in the present study, for each question the mode was calculated and then the missing responses were replaced by the mode obtained from the rest of responses for that specific question.

4.8. Summary of Methodology

In this chapter, the summary of the methods and the procedures chosen for the purpose of current research were described. The final decisions made to design an efficient, reliable and valid survey were introduced.

Based on the conceptual framework developed and described in the previous chapter, the next step was to validate the relationships and the hypotheses of the framework for the target industry which was the Canadian aerospace industry. In order to perform the validation, the aerospace industry has to be reached and the appropriate statistical data has to be collected. Since the population of aerospace industry is quite large and they are distributed across the country, it is difficult to reach the whole population in person in order to perform interviews. Therefore the research was performed by conducting a survey. Survey is a method which is composed of the answers that the sample respondents provide to a pre designed questionnaire. Therefore a detailed questionnaire was designed and all the steps through designing a validated and trustable questionnaire were taken. The preliminary draft was validated by having a face to face interview with an aerospace professional in the field of lean management at Bombardier aerospace. Also the fundamental information about the aerospace industry was acquired from this interview which helped to revise the questionnaire and modify it to increase the validity and reliability.

The final draft of questionnaire was prepared to gather general information about the companies as well as information about the lean and green practices and their corresponding results on the performance outcomes of the company. Likert scale has been used in the questionnaire in order to provide the respondents with a range of answers instead of positive-negative answers. As mentioned before using Likert scale increase the reliability of the questionnaire.

The sampling process in the research was started by determining the sample size using the Cochran's formula. Based on the acquired information about the aerospace industry in Canada which shows a population of more than 700 companies across the country, the minimum sample size was determined to be 196. Based on the existing database and the contact information for the companies the mailing list extracted from Canadian databases with more than 1200 members was composed and the Qualtrics web based survey software was employed to distribute the questionnaire among the respondents. In addition another portion of questionnaires were distributed in a seminar which was attended in École de technologie supérieure (ETS) in Montreal.

The final data was gathered, organized and cleaned. The respond rate of the survey was calculated to be more than 15 percent of the population which was reasonable for the current study. So the data was determined to be sufficient, accurate, and reliable to perform the next phase of the project which are the statistical analysis.

4.9. Chapter Overview

In this chapter the methodology of the research has been described and the final decisions regarding the survey, questionnaire design, and data collection method has been made.

The chapter was started by evaluating different research methodologies and concluding about using the survey as the approach to answer the research questions subject of the present study. The process of questionnaire design and preparation of its final draft is described in detail and the sampling process is investigated carefully. The web based software which is used to perform the survey is introduced and the final data collection steps are listed.

In the next chapter, the gathered data will be processed and the statistical analysis will be performed in order to validate the conceptual framework and interpret the effect of the lean and green management strategies on the outcomes of the supply chain.

Chapter 5

Survey Results and Data Analysis

In the previous chapters the objective and the methodology of the present research was discussed in detail. It was concluded that the survey is an appropriate instrument for the purpose of the research. Conclusion has been made on the procedure of questionnaire design, verification, pilot test and questionnaire revision and sampling method.

In this chapter the results of the survey will be discussed. In the first section the descriptive statistics will be presented. The questionnaire has been analyzed and the descriptive statistics are presented providing a quantitative description of the results and the sample community is summarized including the companies' position in the supply chain and their sizes based on their annual revenue. The descriptive statistical information are then followed by the inferential statistic results. The hypothesis of the conceptual framework are examined to be valid by using Kruskal-Wallis test and the effects of lean and green practices on the supply chain are discussed in detail.

In the present study the strata was defined based on the position of the companies in the aerospace supply chain. Based on the acquired statistics from Canadian aerospace database distribution of the companies in each of the tiers of the supply chain was determined and then the sampling process was performed based on this distribution (Champagne *et al.*, 2013). The survey questionnaire is distributed among the companies according to the pre-evaluated distribution of companies in different strata. 1200 questionnaires were distributed among the sampling community which was the aerospace industry in Canada. Among 245 filled and returned questionnaires, 207 were valid and considerable. This gives the response rate of 17% for the survey which is acceptable based on the similar researches (Hajmohammad *et al.*, 2013).

5.1. Sampling Calculations

For the purpose of current research we have employed the Cochran's formula which is a well-known method of determining the sample size in a research (Sullivan, 2007). Here, the procedure of sample size calculation is described and the final sample size of this research work is presented.

In this process, first we use the below formula to calculate an initial estimation for the sample size. If the value derived by n_0 exceeds the 5% of the full size population then the Cochran's correction formula will be employed to determine the final acceptable sample size. Therefore we first calculate the n_0 as follow:

$$\boldsymbol{n_0} = \frac{(\boldsymbol{t})^2 * (\boldsymbol{p})(\boldsymbol{q})}{(\boldsymbol{d})^2} \qquad \text{(Eq. No.1)}$$

In the above formula, "t" is a value which derived from the tables based on the alpha level. Base on the alpha level we considered in this research which was 0.05, the t value is derived to be 1.65. The "(p) (q)" is the estimation of variance which is considered 0.25 which is the maximum value for the purpose of the current study. Also "d" in the above formula represents the acceptable margin. This value demonstrates the acceptable error from the researcher's point of view and is considered as 0.05 in the current research.

In the current research the population of the aerospace community in Canada is considered where it is assumed to be more than 700 companies. By means of the above formula the n_0 is calculated to be 272. Therefore the value is more than 5% of the population and we have to use the Cochran's correction formula

$$n_0 > 0.05 * 700$$

$$\boldsymbol{n}_1 = \frac{n_0}{(1+n_0/\text{Population})} \qquad \text{(Eq. No.2)}$$

Calculating the n_1 the value of 196 as the final sample size is achieved and considered for the purpose of current research.

$$n_1 = 196$$

The above number provides a minimum value for the sample community size. For the purpose of current research, a number of 207 companies responded to the survey which was considered valid and satisfactory by the author.

5.2. Survey Reliability Test

The SPSS statistical software is used to perform the statistical analysis in this research. The software is capable of calculating the Cronbach coefficient for a set of provided data. The software is also able to predict and calculate the Cronbach alpha coefficient in case of dropping any of the items in the questionnaire. By means of this feature, the user of the software would be able to decide whether to drop and item in order to increase the reliability of the survey.

In Table 5 the results of the Cronbach alpha coefficient for the pilot test performed in this research among a community of aerospace companies with 27 respondents is presented. The results show that the questionnaire is reliable according to the condition of Cronbach alpha coefficient higher than the value of 0.7.

Table 5- Reliability Statistics

Reliability Statistics	
Cronbach's Alpha	Number of items
0.764	27

As mentioned earlier there is an option which calculate the Cronbach’s Alpha if the item was deleted. In this way it could be understandable which item to delete, so that the researcher would find out which item to remove in order to increase the reliability to the intended amount. The following table, present the result of Cronbach’s Alpha for this research questions.

Table 6- Cronbach's Alpha

Questions	Cronbach's Alpha if Item Deleted	Questions	Cronbach's Alpha if Item Deleted
Companytype	0.827	Lean	0.737
annualrevenue	0.749	LeanTraining	0.74
OverallPerformance	0.774	ValueStream	0.747
Green	0.749	PullSystem	0.741
Carbonfootprint	0.74	Leansupplier	0.74
ISO	0.761	ContinuousImprovement	0.743
ReduceEnergy	0.754	IntegratedLean	0.741
Recycle	0.759	LeanLeader	0.754
IntegratedGreen	0.74	LeanPerformance	0.746
GreenLeader	0.745	LeanQuality	0.773
GreenPerformance	0.738	LeanCustomer	0.771
GreenQuality	0.786	LeanOrGreen	0.752
GreenCustomer	0.782	Position	0.752
		WorkExperience	0.785

5.3. Descriptive Analysis on Survey Data

As one of the most strategic industrial sectors in Canada, aerospace industry is made of more than 700 companies and 172,000 employees across Canada. The aerospace industry contributes almost 28 B$ of GDP to Canadian economy. Based on available data on Statistics Canada website, Canada is the fifth country in terms of contribution of aerospace industry revenue in the country's gross revenue. Based on the importance and the influence of the aerospace industry in Canadian revenue and employment, there is a need to improve the performance of the production and try to consider the most important lean and green management strategies. In the following section statistical graphs are presented in order to provide some descriptive insight of the survey performed in Canadian aerospace industry.

5.2.1. Aerospace Supply Chain and Tiers

Aerospace supply chain consists of different segments, each of which playing important role in the supply chain. The implementation of lean and green strategies is dependent on the position of the company in the supply chain. The concept of lean and green implementation is different for a company which is a manufacturer and a one which provides logistics services. In order to start evaluating the performance of lean and green management strategies the position of the company in the supply chain should be determined. Figure 13 shows a schematic demonstration of the aerospace supply chain segments.

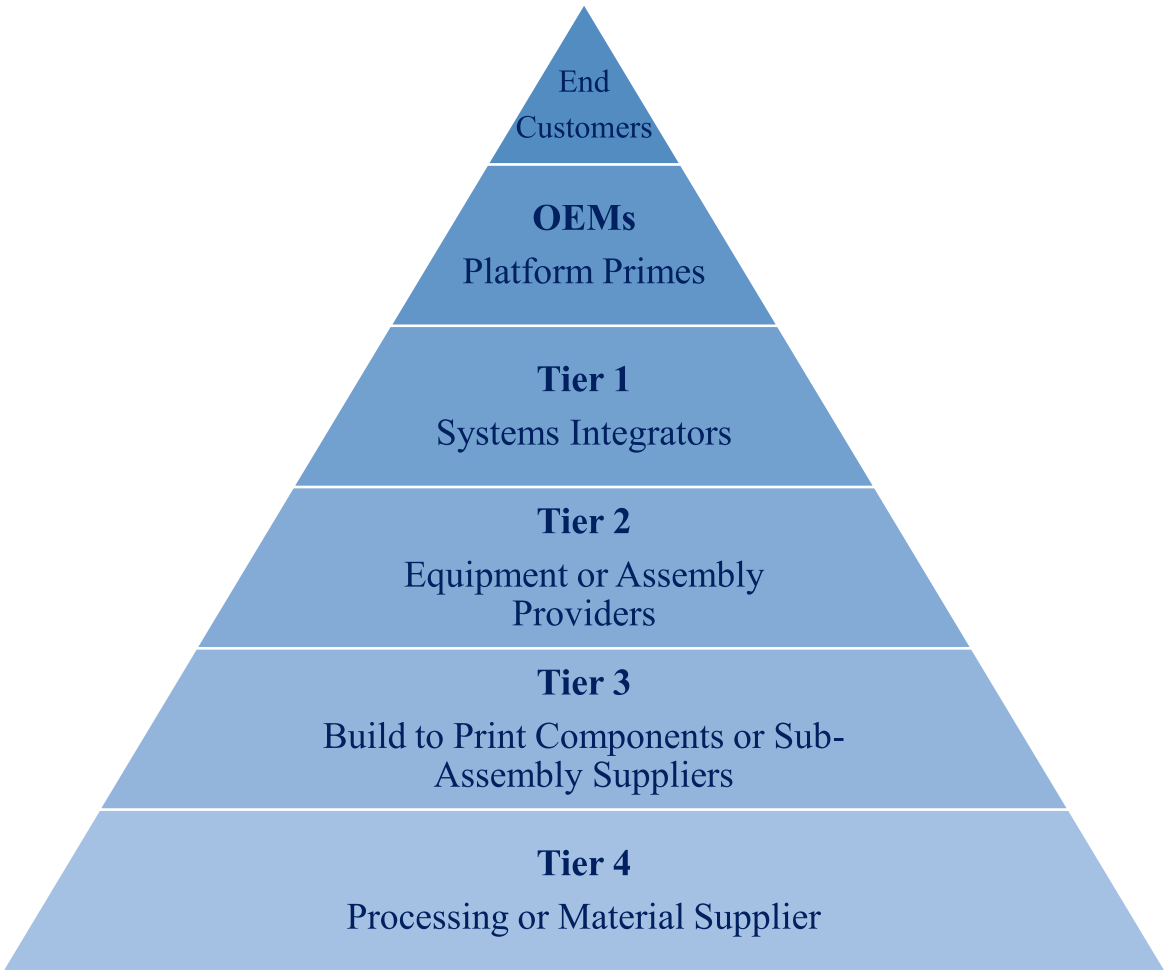

Figure 13 - Tiers of Aerospace Supply Chain

As it can be seen in Figure 14, aerospace supply chain can be segmented into different sections. The OEMs in the aerospace supply chain finalize the aircraft production, perform marketing activities and sell it to the end customers. In Canada, Bombardier and Bell Helicopter are among the top OEMs which provide the customers such as airlines or the military and defense organizations with the finalized manufactured aero vehicles.

The Tier 1 system integrators in the supply chain, are the companies which provide the OEMs with the major aircraft systems and structures such as landing gear, fuselage and wing and the propulsion systems. As an example in Canadian aerospace industry, Pratt & Whitney is a company which manufactures the aircraft engines and can be classified in the Tier 1 system integrators. Tier 2 consists of equipment providers which contribute in design and manufacturing of subsystem such as small sensors and cockpit displays. Mecachrome is well known structures manufacturing company which can be considered in the Tier 2 segment.

Tier 3 companies are mostly involved in manufacturing and machining the minor assemblies. They are mainly providing their service to the Tier 1 and Tier 2 segments. They rarely supply to the OEMs directly. Tier 4 are the companies which provide the Tier 3 and Tier 2 segments with minor services such as coating and heat treatment services. Dishon and Vac Aero are examples of Tier 3 and Tier 4 respectively.

The following pie chart (Figure 14) shows the distribution of the investigated companies in the Canadian aerospace supply chain which responded to the performed survey.

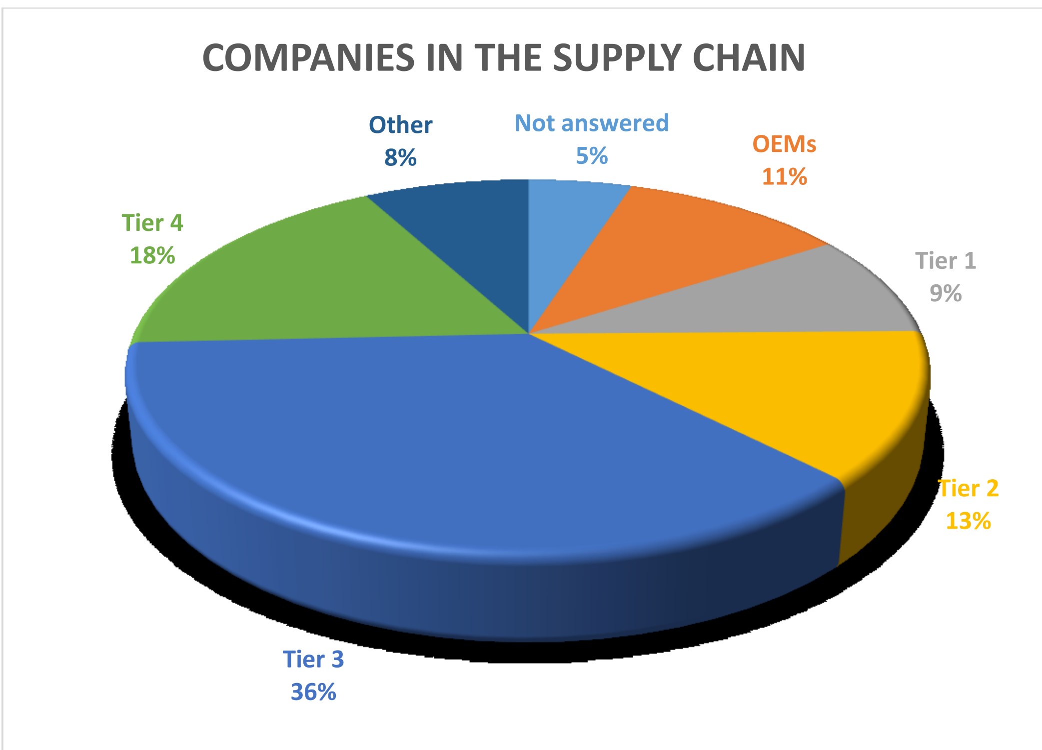

Figure 14 - Aerospace Supply Chain Distribution

As it be can be seen in Figure 14, the major portion of the survey respondents were placed in Tier 3 with 23% of total survey respondents. Moving from the higher tiers to lower ones, the competition is more focused on the cost of the production. One of the concerns related to the obtained data, is that the population in the lower tiers is high and it is necessary for the lower tiers to progress and move up in the tiers in order to match with the large OEMs such as Bombardier or Boeing in the Canadian aerospace industry. It is thus necessary to apply approprtiate supply chain management strategies such as lean and green in order to compete with the world class aerospace industry. These strategies will increase the capability of the Canadian companies in the different tiers, specifically Tier 1 and 2, to win new business markets in the globe.

5.2.2. Lean Practices Statistics

In the previous chapter, lean definition and its most important practices have been discussed. These practices were selected according to their importance in the aerospace supply chain. Previous works in this field have been investigated and the findings were verified and discussed with an aerospace professional. Based on these practices the conceptual framework was developed and the questionnaire was designed accordingly. The most important practices which were chosen for the purpose of this work were value stream mapping, continuous flow, and just in time (JIT). These lean practices were included in the questionnaire to see if the aerospace companies are interested in implementing them in their production system and also to see if their impact on the outcomes of the supply chain is significant.

In the survey instrument (questionnaire), the respondents were asked about the frequency of performing each of the determined lean practices. They were provided with four options including always, occasionally, rarely, and they had also the not applicable (N/A) option in case they are not considering any of the practices. The respondents are considered practitioners for each practice if they have shown that at least occasionally they implement each of the practices in their system. The results of the survey contain valuable information about the rate of implementation of these major lean practices among the survey respondents in Canadian aerospace supply chain. Among 207 respondents in the sample community of the survey, 69% of the respondents are considering just in time (JIT) in their production system which shows higher rate of focus on this practice in the aerospace industry. However the rate of implementation for value stream mapping and continuous flow are quite close to just in time practice.

Since in manufacturing process of an aircraft or an aerospace vehicle, millions of parts have to be used, the inventory operations and cost are of high importance in the aerospace industry. Therefore reducing the parts' storage time in the warehouses (both as a raw material and/or working process) and using them in the right time would significantly reduce the inventory costs and smoothens the material flow in the production. Consequently, it was expected to find the higher rate of just in time implementation in the aerospace industry. Table 8 includes the data about the number of practitioners for each of considered lean manufacturing practices.

Table 7 - Number of Lean Practices Performers

Lean Practices	Number of Practitioners (Out of 207)	Percentage
Value Stream Mapping	123	59%
Continuous flow	99	48%
Just in Time	143	69%

The above table shows the higher interest which companies demonstrate for implementing the just in time and value stream mapping strategies. The same as just in time, the rate of value stream mapping implementation is a result which seems to be expected considering the requirements of aerospace supply chain. Most of the aerospace companies are currently trying to have precise prediction of their future productions and to reduce their production waste accordingly. Considering the fact that production of aerospace vehicles from initial design operations until the final production is pretty expensive, prediction of production losses and wastes based on the evaluation and analysis on the customer demands and the market is quite necessary for the aerospace manufacturing companies in different tiers of the supply chain.

Figure 15 is a graphical demonstration of the percentages of implementation of each lean practice.

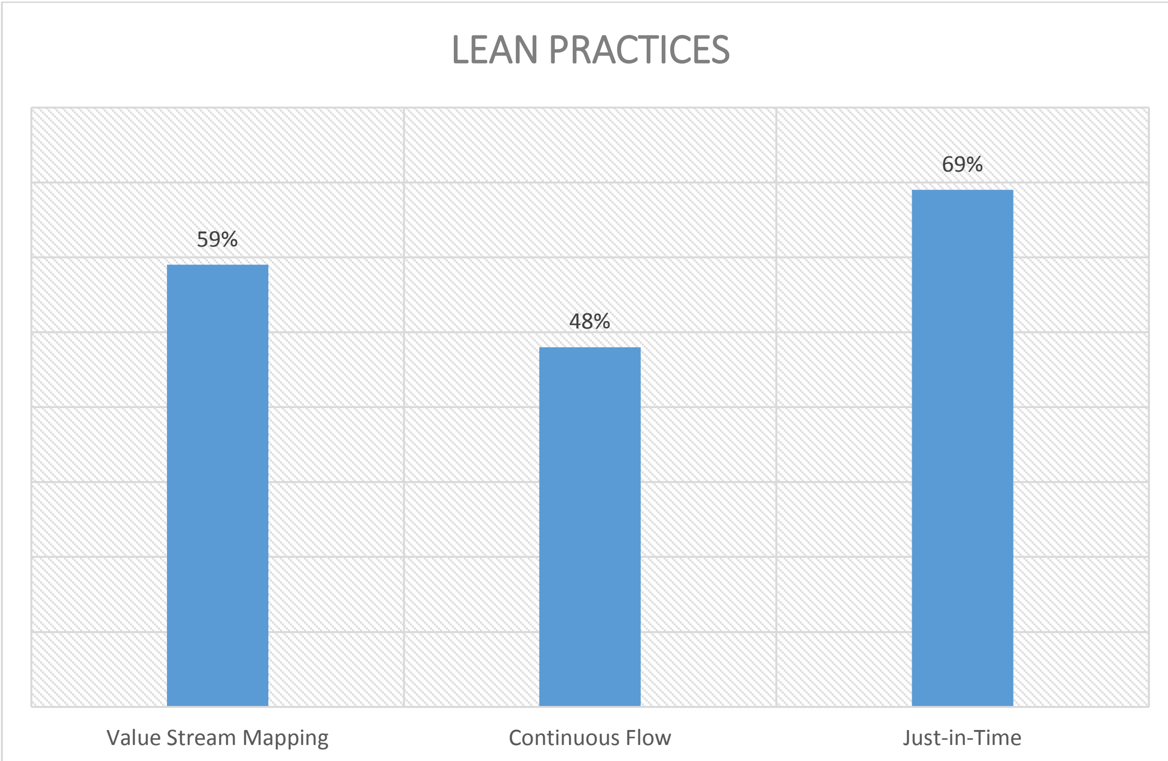

Figure 15 - Percentage of Implementation of each major Lean Practice

5.1.3. Green Practices Statistics

Green practices have been discussed in detail in the previous material. The goal of green activities is more than the internal production improvement in the company. Companies generally think beyond the internal performance and try to improve the environmental aspects of their production activities and contribute in green manufacturing. The major practices in the green management strategies were discussed and listed in the previous chapter. Environmental standards, energy reduction, and recycling/reuse were determined to be the major green practices applicable for the aerospace supply chain.

By preparing the survey questionnaire and analyzing the obtained data from Canadian aerospace industry, useful information has been derived and the results are presented in Table 9. Among the respondents to the survey instrument, 67% of them have declared that they perform Recycle/reuse practices in their system. This number shows the highest percentage among the three green practices under observation. This result was predictable because recycling and reuse activities have major effects not only on the environmental aspects but on the outcomes of the company. This practice would decrease the waste in the production by reusing the wasted material and parts in the system and bringing them to the production cycle. It would also reduce the amount of required raw material according to recycling capability of that company. Energy reduction practice rate is quite close to recycling rate among the respondents. This practice has also not only environmental advantages but cost advantages for the companies so the high rate of implementation is reasonable for this practice as well. Performing environmental standards has the lowest rate among the three practices but still quite acceptable number of respondents have declared they perform it.

Table 8- Number of Green Practices Performers

Green Practices	Number of Practitioners (Out of 207)	Percentage
Environmental Standards	109	53%
Energy Reduction	116	56%
Recycle/Reuse	139	67%

Figure 16 is a graphical demonstration of the percentages of implementation of each green practice.

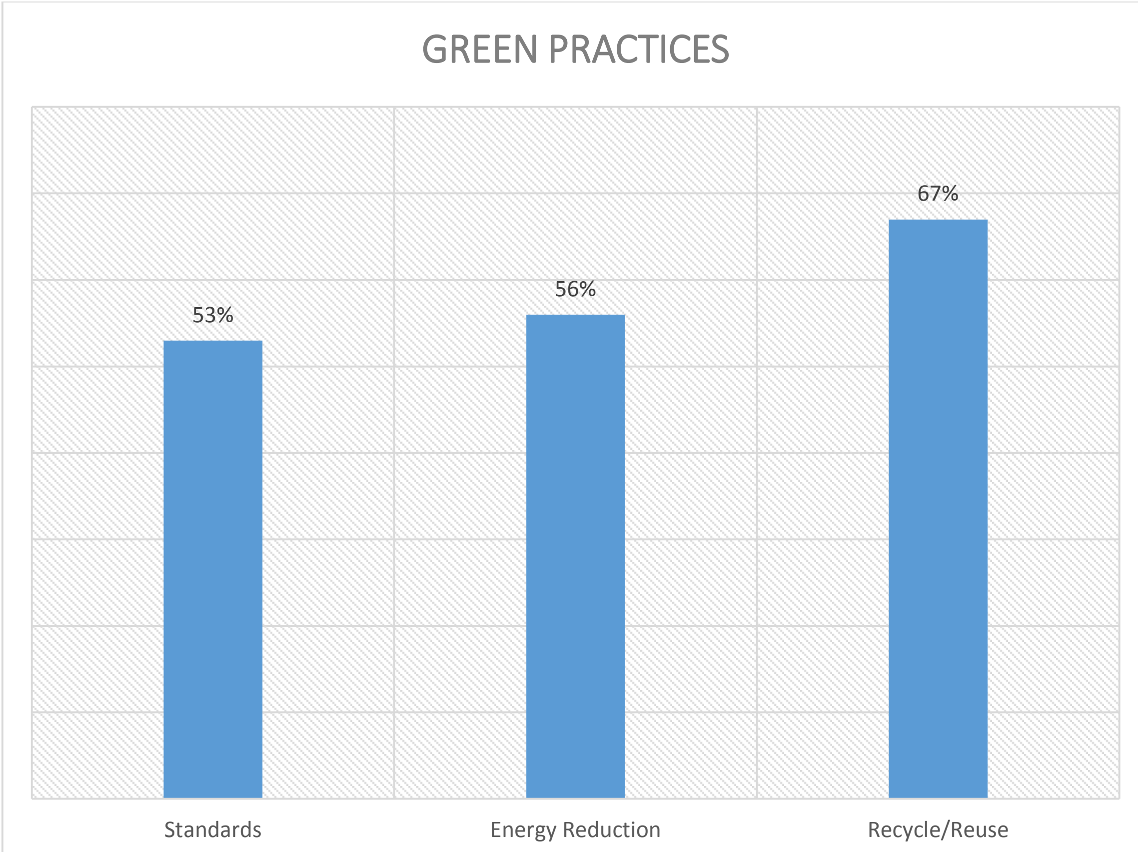

Figure 16- Percentage of Implementation of each major Green Practice

5.2. Inferential Analysis

In the previous section, a preliminary descriptive study was performed on the survey data in order to acquire an overall understanding of different categories of aerospace companies, their distribution, and the rate of tendency to perform lean and green practices in the aerospace industry in Canada. Having gained the valuable insight to the Canadian aerospace industry through descriptive statistics, the inferential analysis (considered as the most important and conclusive analysis of the current research) will be presented in this section. The aim of this section would be to validate the conceptual framework developed in the previous chapter and verify its hypotheses. By the end of this section, the conclusions will be made on the effect of implementing both lean and green practices on the outcomes of the supply chain. The conclusions are mostly focused on how the parallel implementation of lean and green practices makes difference in the outcomes of the supply chain in comparison to implementing only lean or only green or none of these strategies.

In this section, first, the number of lean or green or lean-green (parallel) practitioners are obtained from the survey data by employing factor analysis. Then Kruskal-Wallis test was used to perform the hypothesis testing.

5.2.1. Factor Analysis

In the previous sections, three lean practices and three green practices were discussed and the number of their practitioners among the survey sample in the Canadian aerospace industry was obtained. In this step of the survey analysis, it is desired to determine whether a company in the aerospace supply chain can be considered a lean practitioner or green practitioner or both or none of them according to their use of the lean and green practices. Having categorized the companies in these four categories, the effect of implementing the lean strategies, green strategies, or both of them at the same time on the outcomes of the supply chain can be evaluated.

In order to determine which companies fit in each of the above mentioned categories, factor analysis was performed. The objective of factor analysis is to combine the variables which measure a single factor. Factor analysis is a well-known method for investigating the concepts which are not easy to be directly measured and are needed to be divided in different underlying variables. For example, in the current study, the single factor is either leanness or greenness of the company because it is desired to put each company in the different categories. Throughout this research we have split the lean and green concepts into three variables and evaluated the resulted variables. These variables are then considered in the questionnaire and the required data obtained. Afterwards, these variables will be combined. It is necessary to combine the results of these practices in order to determine whether a company can be allocated to either lean, green, both or none categories. The factor analysis can be performed among the practices and then based on the results of factor analysis, a single score will be obtained for each respondent. According to this number, the respondents will be allocated to lean, green, lean-green or none categories.

In order to verify if the factor analysis can be employed and is appropriate for the set of variables, KMO measure (Kaiser-Meyer-Olkin measure) is used in this research. The value of KMO ranges from 0 to 1 and for the values above the 0.5, the set of variables is considered appropriate for performing factor analysis and they can be combined in order to decide about their underlying factor. Table 9 and then table 10 includes KMO measure for each of lean or green strategies. For the lean variables it can be seen that KMO is more than 0.5 and so the factor analysis is appropriate for the considered variables. The same as lean concept, the factor analysis for the considered variables for green concept are also appropriate. This is evident by calculation of KMO for these variables which shows a value of 0.575.

Table 9 - KMO test results for Lean Variables

KMO Measure of Sampling Adequacy for Lean Practices	0.579

Table 10- KMO test results for Green variables

KMO Measure of Sampling Adequacy for Green Practices	0.575

In the above discussions, it was concluded that the factor analysis can be performed in order to combine the results of each lean or green practice and consequently investigate the underlying concepts (which are lean and green).

The factor analysis has been performed using the SPSS software. As the first step, the answers of the respondents to the questions of survey were coded with values between 0 and 3 using Likert scale. In that scale 0 was representative of a company which does not apply that practice and 3 was demonstrating a company which frequently performs the practices. These scaled results were used as the input for the SPSS software to perform the factor analysis. In the course of this analysis, each of the practices will be given a weight factor. For each specific respondent, combining the results for each practice considering the weight factor of that practice, generated a unique number for that respondent and for that specific strategy (lean or green).

Among several possible methods available for the users in the SPSS software, the principal component analysis method (PCA) was selected. This method is one of the most popular methods of factor analysis employed for assigning weights to each variable. The following tables are the component matrixes which are one of the outcomes of the factor analysis obtained from SPSS software.

Table 11- Component Matrix for Lean Practices

Practice	Weight
Value Stream Mapping	0.651
Continuous Flow	0.737
Just-in-Time	0.661

Table 12- Component Matrix for Green Practices

Practice	Weight
Green Standards	0.574
Energy Reduction	0.802
Recycle/Reuse	0.829

The above calculated weights for each practice will be used to combine the scaled numbers of each practice to achieve a unique number. That unique number will represent the main strategies which are the lean management and green management strategies. Since it is desired to obtain a unique value between 0 and 3, the above weights are normalized such that their summation is equal to 1. In the below tables these normalized weights are presented.

Table 13- Normalized Weight Factors for Lean Manufacturing Practices

Practice	Normalized Weight Factor
Value Stream Mapping	0.318
Continuous Flow	0.360
Just-in-Time	0.323

Table 14- Normalized Weight Factors for Green Manufacturing Practices

Practice	Normalized Weight Factor
Green Standards	0.260
Energy Reduction	0.364
Recycle/Reuse	0.376

After obtaining the above normalized weight factors for each of the main strategies, the following formulas have been used to obtain the unique number for each of the main strategies for each of the respondents.

$$Lean = (VSM \times W_{VSM}) + (CF \times W_{CF}) + (JIT \times W_{JIT}) \qquad \text{(Eq. No.3)}$$

$$Green = (Green\ Std \times W_{Gstd}) + (Energy\ Rdc \times W_{Erdc}) + (Recycle \times W_{Rcyl}) \qquad \text{(Eq. No.4)}$$

Based on the above formulas a unique value for green and lean strategies will be obtained. This value would be a real number between 0 and 3. At this stage it is desired to round these numbers to their next or previous integers. In this case a code either 0, 1, 2, or 3 would be obtained for that specific main strategy. The meanings of codes are presented in the following table.

Table 15 – Lean/Green Status Code Definitions

Lean/Green Status	Code
Not Applicable	0
Rarely	1
Occasionally	2
Always	3

In Table 15, different meanings for each of the codes are described. "Not applicable" status means that the respondents either never consider lean or green in their system, or these strategies are not applicable for their companies. The "Rarely" status means that the company rarely performs either of lean or green strategies, while "Occasionally" shows higher rate of performing the lean and green strategies in the company. "Always" status demonstrates highest rate of implementation and interest of the company in lean and green strategies, and means they always perform these strategies to improve the outcome of their corporation. These codes can be achieved for each of lean or green main strategies so for each of lean and green strategies four status can be obtained. After obtaining these codes, it is desired to combine the results to determine if a company is solely lean or solely green or both or none of them. In order to do so we need to consider sixteen possible status obtained by product of $4 \times 4 = 16$. These 16 possibilities are presented in the following table.

Table 16 - Description and Categories of Lean and Green Status

Groups	Description	Code Combinations
None (0)	The respondents who rarely practice both Lean and Green, or replied Not Applicable	00 01 10 11
Lean (1)	The respondents who occasionally or always practice Lean, but not a Green practitioner.	20 21 30 31
Green (2)	The respondents who occasionally or always practice Green, but not a Lean practitioner.	02 03 12 13
Lean-Green (3)	The respondents who practice both Lean and Green.	22 23 32 33

In the above table the results of the survey are finalized and categorized in four separate groups. Table 17 shows the number of companies which fit in each of the above described categories obtained from the survey.

Table 17 - Different groups of companies and the number of members

Groups	Number of Members
None (0)	14
Lean (1)	45
Green (2)	32
Lean-Green (3)	116

In the above sections, the method based on which the survey data has been categorized and coded was described. The overall procedure ended up with a coding method which enables us to determine whether a company can be considered lean or green or both at the same time. Then the companies were allocated in either of these four categories so that the outcomes of each group can be analyzed conveniently. At this stage for each company, first the category of that company would be determined and then the outcome would be evaluated. Then the outcomes of each group can be compared to the other groups to see the effect of parallel implementation of lean and green strategies in comparison to the implementing only one of the strategies at the time. In the next section the hypothesis verification test (Kruskal-Wallis) will be described in detail. This test enables us to verify the developed conceptual framework and its hypothesis for the lean-green supply chain management.

5.3. Hypothesis Testing

In the final section of the inferential statistics, the hypothesis testing will be performed to validate the developed conceptual framework in the previous chapters and its corresponding hypothesis. The conceptual framework was developed to evaluate the effect of lean and green strategies on the supply chain outcomes. For this purpose the hypotheses are validated in two consecutive steps. First, the existence of a relation between the parallel implementation of the lean and green strategies will be analyzed by performing the hypothesis testing. Then the direction of the relation (either positive or negative) will be studied by performing correlation testing. By going through these steps on the gathered data, one can realize if the sample data can provide demonstrative results of the total population and the hypotheses which are developed in accordance with research objectives are valid. Hypothesis testing is one of the most important procedures in the inferential statistics.

Using the probability value (P-Value) the hypothesis will be tested to see whether the results of the survey support the initial ideas or not. For the first step of the hypothesis validation, the hypothesis test will be performed in order to validate the existence of a difference between the outcomes of a supply chain which practices both lean and green strategies at the same time and the outcomes of a supply chain which implements between the parallel implementation of lean and green strategies and each of the supply chain outcomes including production quality, overall performance and the customer satisfaction.

For this purpose a null hypothesis (H_0) and an alternative hypothesis (H_1) will be defined. Using the hypothesis testing one of these two hypotheses will be rejected and the other one would be validated to be true. By evaluating the survey data, the estimated probability (p-value) will be calculated considering that the null hypothesis is true. If the estimated probability value is smaller than the significance value, then it would be concluded that the null hypothesis is rejected and alternative hypothesis is accepted. Below are the steps of the hypothesis testing (McDonald, 2009):

- Defining the null hypothesis (H_0)
- Defining the alternative hypothesis (H_1)
- Consider a value for the desired significance level (usually between 5% and 10%)
- Decide on the suitable test statistics based on the sample characteristics
- Calculate the P-Value and compare it to significance level
- Conclude on the null hypothesis either it is rejected or accepted

In this research the considered significance level is equal to 5%. It means that for the P-values of less than 5% the null hypothesis would be rejected otherwise there is not enough evidence to reject the null hypothesis. The SPSS software would provide the researchers with P-value based on the selected test statistics for the given data. This software receives the survey data from the user and then the user will perform the non-parametric test which by having the option to select the Kruskal-Wallis test. The P-value would be obtained among the outputs of this software which facilitates the process of comparing the P-value and the considered significance level. The most common significance level that is used for statistical analysis, is 0.05. This means that the findings and the assumptions of the researcher have a 95% chance of being true.

Since the data for this research is gathered by means of questionnaire, and by data is coded using the Likert scale, the obtained data is ordinal and consequently non-parametric. In this type of data no specific distribution can be assumed for the data (Amir & Sonderpandian, 2002). The data for this study is categorical and non-parametric, which means the data does not come from a distribution that can be described by two parameters (mean and standard deviation).

For this type of the survey data the most common and widely used hypothesis testing is the Kruskal-Wallis test (McDonald, 2009) which is described in detail in the following the sections and the results for each of the desired supply chain outcomes is described.

5.3.1. Kruskal-Wallis Test

In this section, the hypothesis testing is performed. As it was mentioned the hypothesis testing in this research was performed in two consecutive steps. In the first step which is performed by the Kruskal-Wallis test the existence of a difference would be verified. Then the next step would be to evaluate the direction of that relation. The test is performed among 4 groups of none, Lean, Green, and Lean-Green which were defined and described in the previous sections. The hypotheses considered for this research were defined in Chapter 3 of this thesis.

5.3.1.1. Production Quality

As it was described in the previous sections of this research, production quality was one of the important outcomes of the supply chain, especially in the nowadays competitive market for the aerospace companies. Having a high production quality will result in the delivered quality to the customers and that is why the companies try to improve their production quality by performing variety of supply chain management strategies such as lean and green strategies. In order to verify the effect of the parallel implementation of lean and green strategies on the production quality as one of the important outcomes of the supply chain management strategies, the null hypothesis was defined and based on the results of the Kruskal-Wallis test the null hypothesis was proved to be rejected. Below the H_0 and H_1 demonstrate the null and alternative hypotheses respectively.

H_0: There is no difference in the production quality of those companies which applied lean and green practices at the same time and those which did not apply these strategies at the same time.

H_1: There is difference in the production quality of those companies which applied lean and green practices at the same time and those which did not apply these strategies at the same time.

The procedure to acquire the desired outputs from the software was previously described. The following table contains the results of Kruskal-Wallis test obtained from the SPSS software.

Table 18 - Kruskal-Wallis test on Production Quality for Lean-Green vs. Lean

Outcome	Lean-Green vs. Lean	Number of respondents	Mean Rank
Production Quality	Lean-Green	116	85.28
	Lean	45	69.97
	Total	161	
		Test Statistics	4.322
		df	1
		P-Value	0.038*

Table 19 - Kruskal-Wallis test on Production Quality for Lean-Green vs. Green

Outcome	Lean-Green vs. Green	Number of respondents	Mean Rank
Production Quality	Lean-Green	116	79.34
	Green	32	56.94
	Total	148	
		Test Statistics	8.407
		df	1
		P-Value	0.004*

Table 20 - Kruskal-Wallis test on Production Quality for Lean-Green vs. None

Outcome	Group None/ Lean-Green	Number of respondents	Mean Rank
Production Quality	None	14	32.43
	Lean-Green	116	69.49
	Total	130	
		Test Statistics	14.890
		df	1
		P-Value	0.000*

As far as the P-value is concerned, the above results shows that for this specific supply chain outcome the P-value is calculated to be 0.038 for lean-green versus lean, 0.004 for lean-green vs. green and 0 for lean-green vs. none which are all less than 0.05 significance level considered for the purpose of this research. The test is hence statistically significant and this justifies the rejection of the null hypothesis. This means that there is a significant difference among the production quality of those companies which implement both lean and green, and those which either perform none of them or only one of them at a time. This shows that parallel implementation of lean and green strategies is associated with the production quality of the supply chain, based on the results of the current survey.

5.2.2.2. Overall Performance

The overall performance is also one the important outcomes of the supply chain which was described in detail in Chapter 3. In this section the H_0 and H_1 (the null and the alternative hypotheses) are developed for this outcome parameter. The Kruskal-Wallis test demonstrated that the null hypothesis can be rejected. This means that as far as the overall performance of the supply chain is concerned there exists a difference between a company which performs the lean-green strategies and a company which either perform none of them or only one of them at a time. In the following table the results of the hypothesis testing is demonstrated for the overall performance of the supply chain.

H_0: There is no difference in the overall performance of those companies which applied lean and green practices at the same time and those which did not apply these strategies at the same time.

H_1: There is difference in the overall performance of those companies which applied lean and green practices at the same time and those which did not apply these strategies at the same time.

Table 21 - Kruskal-Wallis test on Overall Performance for Lean-Green vs. Lean

Outcome	Lean-Green vs. Lean	Number of Respondents	Mean Rank
Performance	Lean-Green	116	85.15
	Lean	45	70.30
	Total	161	
		Test Statistics	3.898
		df	1
		P-Value	0.048*

Table 22 - Kruskal-Wallis test on Overall Performance for Lean-Green vs. Green

Outcome	Lean-Green vs. Green	Number of Respondents	Mean Rank
Performance	Lean-Green	116	78.42
	Green	32	60.30
	Total	148	
		Test Statistics	5.324
		df	1
		P-Value	0.021*

Table 23 - Kruskal-Wallis Test on Overall Performance for Lean-Green vs. None

Outcome	Group None/ Lean-Green	Number of Respondents	Mean Rank
Performance	None	14	33.07
	Lean-Green	116	69.41
	Total	130	
		Test Statistics	13.716
		df	1
		P-Value	0.000*

In the above tables the results of the Kruskal-Wallis test are presented and again it can be seen that the P-value is calculated to be 0.048 for lean-green versus lean, 0.021 for lean-green vs. green and 0 for lean-green vs. none which is less than the considered significance level for this test. Therefore it can be concluded that the null hypothesis is rejected and the test is statistically significant. It can be concluded that there is a significant difference between the overall performance of the companies who perform the lean and green strategies and those who do not perform these strategies at the same time.

5.2.2.3. Customer Satisfaction

Customer satisfaction is one of the main factors which makes a company strong among the other competitors. Factors such as short response time to the customers' inquiries while maintaining the high quality of the product are important in evaluating the customer satisfaction. It is quite evident that implementing the supply chain improvement strategies such as lean and green practices will have considerable effects on the customer satisfaction. Specifically in the aerospace industry, timing of the production as well as the quality of the products which should meet variety of national and international standards and regulations is of high importance. In this section the hypothesis regarding the effect of lean and green strategies on the level of customer satisfaction is tested and verified by means of the Kruskal-Wallis test. The null and the alternative hypotheses are formulated as follows:

H_0: There is no difference in the customer satisfaction level of those companies which applied lean and green practices at the same time and those which did not apply these strategies at the same time.

H_1: There is difference in the customer satisfaction level of those companies which applied lean and green practices at the same time and those which did not apply these strategies at the same time.

Table 24 - Kruskal-Wallis test on Customer Satisfaction for Lean-Green vs. Lean

Outcome	Lean-Green vs. Lean	Number of Respondents	Mean Rank
Customer Satisfaction	Lean-Green	116	83.98
	Lean	45	73.31
	Total	161	
		Test Statistics	2.096
		df	1
		P-Value	0.148

Table 25 - Kruskal-Wallis test on Customer Satisfaction for Lean-Green vs. Green

Outcome	Lean-Green vs. Lean	Number of Respondents	Mean Rank
Customer Satisfaction	Lean-Green	116	74.34
	Green	32	75.08
	Total	148	
		Test Statistics	0.009
		df	1
		P-Value	0.923

Table 26 - Kruskal-Wallis test on Customer Satisfaction for Lean-Green vs. None

Outcome	Lean-Green vs. Lean	Number of Respondents	Mean Rank
Customer Satisfaction	Lean-Green	116	68.92
	None	14	37.18
	Total	130	
		Test Statistics	10.811
		df	1
		P-Value	0.001*

The above table shows the results of the Kruskal-Wallis test for the customer satisfaction as an outcome of the supply chain. The P-value is calculated by the SPSS software and the results obtained are 0.148 for lean-green versus lean, 0.923 for lean-green vs. green and 0.001 for lean-green vs. none. In this case the null cannot be rejected for the case of lean-green vs. lean and lean-green vs. green but for there is a significant difference in customer satisfaction of lean-green companies and those which do not perform any of lean or green strategies. At the end it can be concluded that there exists a significant difference in the customer satisfaction level for the companies who perform the lean and green strategies as opposed to the companies which implement none of these strategies.

As it was mentioned in the Kruskal-Wallis testing section the existence of a relation between the hypotheses was verified and tested. As a next step the direction of these relations needs to be determined. It is necessary to find out which of the lean and green strategies has positive effect on each of the outcome parameters. These sets of inferential analysis would be described in the following section.

5.3.2. Correlation Analysis

Correlation analysis deals with the relationships between the variables. In this way the correlation coefficient demonstrates the association between the variables. The correlation coefficient value varies between -1 and 1 where the values close to +1 demonstrate a strong positive relation between the variables and the values close to -1 demonstrate a strong relation in a negative way. The value of zero for the correlation coefficient shows a weak relation between the parameters.

For the purpose of this research the correlation analysis was performed to determine the direction of the relationship between the supply chain strategies and the outcomes of the supply chain. Since the data in this research was non-parametric, the Spearman's Rank-Order correlation was used for the current study. There are two assumptions of this correlation method. First, the data set is ordinal and the second assumption is that the relationship between variables is monotonic. The monotonic relation means that by increasing one variable the other one either increase or decrease. These two assumptions are met in the gathered data from the large scale survey performed among aerospace supply chain companies in Canada.

In the following table the results of correlation analysis are demonstrated and the correlation coefficient for each pair of the outcomes and lean-green strategies is calculated.

Table 27 - Correlation Analysis Result

	Number of variables	*Lean Green Group*	*Overall Performance*	*Production Quality*	*Customer Satisfaction*
Lean Green Group	207	1			
Overall Performance	207	0.259*	1		
Production Quality	207	0.274*	0.148*	1	
Customer Satisfaction	207	0.181*	0.081	-0.013	1

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

As it can be seen in Table 21 the positive value for the correlation coefficients demonstrate the positive and significant relationship between the lean-green practitioners and the three outcome parameters of the supply chain.

Based on the above testing and analysis procedures the following hypotheses are verified to be true as the conclusion of this chapter.

- ✓ Parallel implementation of lean and green is positively associated with the production quality of the supply chain
- ✓ Parallel implementation of lean and green is positively associated with the overall performance of the supply chain
- ✓ Parallel implementation of lean and green is positively associated with the customer satisfaction of the supply chain

Chapter 6

Conclusion

6.1. Summary

A comprehensive survey study and statistical analysis have been performed in order to examine the effect of parallel implementation of lean and green supply chain management strategies in the aerospace industry in Canada. Aerospace industry is one of the major industrial sectors in Canada which contributes significantly in the annual revenue of the country. More than 700 companies were recognized to be involved in this sector which require careful investigation in their production process.

In this thesis, first, a comprehensive literature review has been performed to determine the gap in the previous research works in this field. During the course of literature review it was concluded that the lean and green strategies were subject of numerous research studies in the past but the parallel implementation of these strategies is quite neglected. It is an important phenomenon which requires much more effort from the researchers in the field of supply chain. These strategies were found to be quite important for the companies especially in the field of aerospace in order to compete in the current competitive market. The focus of these important strategies is on reducing the waste (waste is defined differently for each of these concepts) in the production process which is a great concern either from the environmental point of view or from the efficiency of the production point of view.

Knowing the importance of these strategies, variety of practices corresponding to these strategies as well as key supply chain outcomes have been studied and the most relevant and important ones for the aerospace industry have been selected. The selected practices and outcomes have been verified through meetings with experts in the field and conclusions have been made from studying the aerospace industry and their goals. In the next step, based on these practices and outcomes a conceptual framework has been developed demonstrating the practices, outcomes, and the relationships between them. The studied practices of each of the lean and green strategies are listed in the following table:

Table 28 - The strategies and practices

Strategies	Practices
Lean Production	• *Just-in-Time (JIT)* • *Value stream mapping* • *Continuous flow*
Green Production	• *Reducing energy consumption* • *Recycling/Reusing* • *Environmental standards*

The hypotheses of this research were:

- Parallel implementation of lean and green is positively associated with the production quality of the supply chain
- Parallel implementation of lean and green is positively associated with the overall performance of the supply chain
- Parallel implementation of lean and green is positively associated with the customer satisfaction of the supply chain

In order to gather the required data for making the required conclusions, survey has been selected as the research instrument and a questionnaire was carefully designed and verified by consulting with a knowledgeable expert in the field. The number of companies in target sample was determined based on population of companies in the field of aerospace and the questionnaire was distributed by means of online software (Qualtrics) and direct contact with the accessible companies. The required amount of data was gathered, processed and organized in order to perform statistical analysis.

Statistical analysis was performed in two sections. In the descriptive analysis sections valuable information was achieved which helped to understand the different Tiers and sectors in the aerospace supply chain. Inferential statistical analysis was performed in order to validate the hypotheses developed for this research. The results of the questionnaire were coded and then the usefulness of the factor analysis was verified by calculating and checking the KMO value. Factor analysis was then performed to determine the leanness or greenness of the companies by combining the results of each of lean and green practices. In order to test the hypotheses of the research, Kruskal-Wallis test was first performed in order to determine if there is a difference in outcome of the companies which practice lean and green practices and those which do not perform them. Then using correlation analysis, positive associations of performing lean and green strategies and each of the considered supply chain outcomes were verified.

In summary, it is concluded that parallel implementation of lean and green strategies and their associated practices would make a positive difference in the outcomes of the supply chain. This parallel implementation has positive effects on all the considered supply chain outcomes including overall performance, production quality and customer satisfaction. Furthermore, the research instrument, survey, was proved to produce acceptable results for the purpose of current research which can be used for the future research in the similar field.

6.2. Limitations and Future Work

Performing this study has some limitations. The population of Canadian aerospace industry was so much that reaching all companies was not possible. By performing survey as a methodology to gather the required data, an appropriate number of samples from the target population were reached to perform the survey. Although survey is an appropriate method of gathering data specially relating to performance and human opinions, it is difficult to assure that the respondents fully understood the concepts and questions, and answered without being biased.

Since there is only a few previous works on the parallel implementation of major supply chain strategies, this subject could be investigated for the combination of the other supply chain strategies such as agile and resilience.

- The framework of the current research can be modified and the other lean or green practices as well as other supply chain outcomes such as financial outcome can be considered.
- The effect of parallel implementation of lean and green practices can be investigated in other industrial sectors
- The research instrument which is survey in this research can be changed. Case study can be performed in order to analyze the effect of implementing lean and green strategies on a specific company.

Bibliography

2015 The State of Canadian Aerospace Industry. (2015, June). Industry Canada.

Aguado, S., Alvarez, R., & Domingo, R. (2013). Model of efficient and sustainable improvements in a lean production system through processes of environmental innovation. *Journal of Cleaner Production*, *47*, 141–148. http://doi.org/10.1016/j.jclepro.2012.11.048

Alvarez-Vargas, R., Dallery, Y., & David, R. (1994). A study of the continuous flow model of production lines with unreliable machines and finite buffers. *Journal of Manufacturing Systems*, *13*(3), 221–234. http://doi.org/10.1016/0278-6125(94)90006-X

Amir, A. D., & Sonderpandian, J. (2002). Complete Business Statistics. *New York: MeGraw-Hill*.

Andy Neely, Mike Gregory, and Ken Platts. (2005). Performance measurement system design. *International Journal of Operations & Production Management*, *25*(12), 1228–1263. http://doi.org/10.1108/01443570510633639

Aragon-Correa, J. A., & Sharma, S. (2003). A contingent resource-based view of proactive corporate environmental strategy. *Academy of Management Review*, *28*(1), 71–88.

Aref A. Hervani, Marilyn M. Helms, & Joseph Sarkis. (2005). Performance measurement for green supply chain management. *Benchmarking: An International Journal*, *12*(4), 330–353. http://doi.org/10.1108/14635770510609015

Azevedo, S. G., Carvalho, H., & Cruz Machado, V. (2011). The influence of green practices on supply chain performance: A case study approach. *Transportation Research Part E: Logistics and Transportation Review*, *47*(6), 850–871. http://doi.org/10.1016/j.tre.2011.05.017

Batista, G. E., & Monard, M. C. (2003). An analysis of four missing data treatment methods for supervised learning. *Applied Artificial Intelligence*, *17*(5-6), 519–533.

Beamon, B. M. (1999). Measuring supply chain performance. *International Journal of Operations & Production Management*, *19*(3), 275–292.

Behrouzi, F., & Wong, K. Y. (2011). Lean performance evaluation of manufacturing systems: A dynamic and innovative approach. *Procedia Computer Science*, *3*, 388–395. http://doi.org/10.1016/j.procs.2010.12.065

Bergmiller, G. G., & McCright, P. R. (2009a). Are Lean and Green programs synergistic. In *Proceedings of the 2009 Industrial Engineering Research Conference*. Retrieved from http://zworc.com/site/publications_assets/areleanandgreenprogramssynergistic.pdf

Bergmiller, G. G., & McCright, P. R. (2009b). Parallel models for lean and green operations. In *Proceedings of the 2009 Industrial Engineering Research Conference, Miami, FL*. Retrieved from http://zworc.com/site/publications_assets/ParallelModels.pdf

Bowers, J., George H. (1991). Continuous flow manufacturing (Vol. 1496, pp. 239–246). http://doi.org/10.1117/12.29746

Buck, S. F. (1960). A method of estimation of missing values in multivariate data suitable for use with an electronic computer. *Journal of the Royal Statistical Society. Series B (Methodological)*, 302–306.

Champagne, R., Furphy, S., Lee, J., & Vezina, M. (2013, November). A new reality of the aerospace supply chain. Deloitte LLP. Retrieved from www.ontaero.org

Chen, L., & Meng, B. (2010). The application of value stream mapping based lean production system. *International Journal of Business and Management*, *5*(6), p203.

Chiarini, A. (2014). Sustainable manufacturing-greening processes using specific Lean Production tools: an empirical observation from European motorcycle component manufacturers. *Journal of Cleaner Production*, *85*, 226–233. http://doi.org/10.1016/j.jclepro.2014.07.080

Christer Karlsson and Pär Åhlström. (1996). Assessing changes towards lean production. *International Journal of Operations & Production Management*, *16*(2), 24–41. http://doi.org/10.1108/01443579610109820

Clason, D. L., & Dormody, T. J. (1994). Analyzing Data Measured By Individual Likert-Type Items. *Journal of Agricultural Education*, *35*(4), 31–35. http://doi.org/10.5032/jae.1994.04031

Cooper, D. R., Schindler, P. S., & Sun, J. (2006). *Business research methods* (Vol. 9). McGraw-hill New York. Retrieved from http://sutlib2.sut.ac.th/sut_contents/H139963.pdf

Dhingra, R., Kress, R., & Upreti, G. (2014). Does lean mean green? *Journal of Cleaner Production*, *85*, 1–7.

Dowell, G., Hart, S., & Yeung, B. (2000). Do Corporate Global Environmental Standards Create or Destroy Market Value? *Management Science*, *46*(8), 1059–1074. http://doi.org/10.1287/mnsc.46.8.1059.12030

Duarte, S., Cabrita, R., & Machado, V. C. (2011a). Exploring lean and green supply chain performance using balanced scorecard perspective. In *Proceedings of the 2011 International Conference on Industrial Engineering and Operations Management, Kuala Lumpur, Malaysia*. Retrieved from http://www.iieom.org/ieom2011/pdfs/IEOM077.pdf

Duarte, S., Cabrita, R., & Machado, V. C. (2011b). Exploring lean and green supply chain performance using balanced scorecard perspective. In *Proceedings of the 2011 International Conference on Industrial Engineering and Operations Management* (pp. 520–525). Retrieved from http://www.iieom.org/ieom2011/pdfs/IEOM077.pdf

Dües, C. M., Tan, K. H., & Lim, M. (2013). Green as the new Lean: how to use Lean practices as a catalyst to greening your supply chain. *Journal of Cleaner Production*, *40*, 93–100. http://doi.org/10.1016/j.jclepro.2011.12.023

Faulkner, W., & Badurdeen, F. (2014). Sustainable Value Stream Mapping (Sus-VSM): methodology to visualize and assess manufacturing sustainability performance. *Journal of Cleaner Production*, *85*, 8–18. http://doi.org/10.1016/j.jclepro.2014.05.042

Florida, R. L. (1996). *Lean and green: the move to environmentally conscious manufacturing*. California Management Review. Retrieved from http://elibrary.ru/item.asp?id=2741751

Frazier, G. L., Spekman, R. E., & O'Neal, C. R. (1988). Just-In-Time Exchange Relationships in Industrial Markets. *Journal of Marketing*, *52*(4), 52–67. http://doi.org/10.2307/1251633

Galeazzo, A., Furlan, A., & Vinelli, A. (2014). Lean and green in action: interdependencies and performance of pollution prevention projects. *Journal of Cleaner Production*, *85*, 191–200. http://doi.org/10.1016/j.jclepro.2013.10.015

Govindan, K., Azevedo, S. G., Carvalho, H., & Cruz-Machado, V. (2015). Lean, green and resilient practices influence on supply chain performance: interpretive structural modeling approach. *International Journal of Environmental Science and Technology*, *12*(1), 15–34.

Gunasekaran, A., Patel, C., & McGaughey, R. E. (2004). A framework for supply chain performance measurement. *International Journal of Production Economics*, *87*(3), 333–347. http://doi.org/10.1016/j.ijpe.2003.08.003

Gunasekaran, A., Patel, C., & Tirtiroglu, E. (2001). Performance measures and metrics in a supply chain environment. *International Journal of Operations & Production Management*, *21*(1/2), 71–87.

Hajmohammad, S., Vachon, S., Klassen, R. D., & Gavronski, I. (2013a). Lean management and supply management: their role in green practices and performance. *Journal of Cleaner Production*, *39*, 312–320. http://doi.org/10.1016/j.jclepro.2012.07.028

Hajmohammad, S., Vachon, S., Klassen, R. D., & Gavronski, I. (2013b). Lean management and supply management: their role in green practices and performance. *Journal of Cleaner Production*, *39*, 312–320. http://doi.org/10.1016/j.jclepro.2012.07.028

Herrmann, C., Thiede, S., Stehr, J., & Bergmann, L. (2008). An environmental perspective on Lean Production. In M. Mitsuishi, K. Ueda, & F. Kimura (Eds.), *Manufacturing Systems and Technologies for the New Frontier* (pp. 83–88). Springer London. Retrieved from http://link.springer.com/chapter/10.1007/978-1-84800-267-8_16

Hines, P., & Rich, N. (1997). The seven value stream mapping tools. *International Journal of Operations & Production Management*, *17*(1), 46–64.

Holton, E. H., & Burnett, M. B. (1997). Qualitative research methods. *Human Resource Development Research Handbook: Linking Research and Practice. San Francisco: Berrett-Koehler Publishers*, 43–47.

Hopp, W. J., & Spearman, M. L. (2004). To pull or not to pull: what is the question? *Manufacturing & Service Operations Management*, *6*(2), 133–148.

Hulley, S. B., Cummings, S. R., Browner, W. S., Grady, D. G., & Newman, T. B. (2013). *Designing clinical research*. Lippincott Williams & Wilkins. Retrieved from http://books.google.ca/books?hl=en&lr=&id=_b62TBnoppYC&oi=fnd&pg=PT1&dq=Hulley,+Stephen+B.+&ots=A0pc2zJnRL&sig=pLEqS1IpdwxCY-OneOSx6ZlJaJM

Huson, M., & Nanda, D. (1995). The impact of just-in-time manufacturing on firm performance in the US. *Journal of Operations Management*, *12*(3–4), 297–310. http://doi.org/10.1016/0272-6963(95)00011-G

Jabbour, C. J. C., Jabbour, A. B. L. de S., Govindan, K., Teixeira, A. A., & Freitas, W. R. de S. (2013). Environmental management and operational performance in automotive companies in Brazil: the role of human resource management and lean manufacturing. *Journal of Cleaner Production*, *47*, 129–140. http://doi.org/10.1016/j.jclepro.2012.07.010

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

Johansson, G., & Winroth, M. (2009). Lean vs. Green manufacturing: Similarities and differences. In *Proceedings of the 16th International Annual EurOMA Conference, Implementation Realizing Operations Management Knowledge, Göteborg, Sweden*. Retrieved from http://www.researchgate.net/profile/Mats_Winroth/publication/257492917_Lean_vs._Green_manufacturing_Similarities_and_differences/links/547c92e80cf2cfe203c1add7.pdf

Kainuma, Y., & Tawara, N. (2006). A multiple attribute utility theory approach to lean and green supply chain management. *International Journal of Production Economics*, *101*(1), 99–108. http://doi.org/10.1016/j.ijpe.2005.05.010

Kalton, G. (1983). *Introduction to survey sampling* (Vol. 35). Sage. Retrieved from http://books.google.ca/books?hl=en&lr=&id=BTeUCazrOtAC&oi=fnd&pg=PA4&dq=Introduction+to+Survey+Sampling+and+Analysis+Procedures&ots=uLnF1gUDp6&sig=MZF3WXkg5Xw8B8mkI4Jh1SORu8Y

Kaplan, R. S., & Norton, D. P. (2005). *Creating the office of strategy management*. Division of Research, Harvard Business School. Retrieved from http://www.hbs.edu/faculty/Publication%20Files/05-071.pdf

Keyte, B., & Locher, D. A. (2004). *The complete lean enterprise: value stream mapping for administrative and office processes*. CRC Press. Retrieved from http://books.google.ca/books?hl=en&lr=&id=EUEqBgAAQBAJ&oi=fnd&pg=PP1&dq=value+stream+mapping+definition&ots=oOhooEmvFr&sig=JeVVtbymS0Woisfmq5qc6lCYChE

King, A. A., & Lenox, M. J. (2001). Lean and Green? An Empirical Examination of the Relationship Between Lean Production and Environmental Performance. *Production and Operations Management*, *10*(3), 244–256. http://doi.org/10.1111/j.1937-5956.2001.tb00373.x

Klassen, R. D., & Whybark, D. C. (1999). The impact of environmental technologies on manufacturing performance. *Academy of Management Journal*, *42*(6), 599–615.

Kleindorfer, P. R., Singhal, K., & Wassenhove, L. N. (2005). Sustainable operations management. *Production and Operations Management*, *14*(4), 482–492.

Kopicki, R., Berg, M. J., & Legg, L. (1993). Reuse and recycling - reverse logistics opportunities. Retrieved from http://www.osti.gov/scitech/biblio/133268

Kotrlik, J., & Higgins, C. (2001). Organizational research: Determining appropriate sample size in survey research appropriate sample size in survey research. *Information Technology, Learning, and Performance Journal*, *19*(1), 43.

Kurdve, M., Zackrisson, M., Wiktorsson, M., & Harlin, U. (2014). Lean and green integration into production system models – experiences from Swedish industry. *Journal of Cleaner Production*, *85*, 180–190. http://doi.org/10.1016/j.jclepro.2014.04.013

Lakshminarayan, K., Harp, S. A., & Samad, T. (1999). Imputation of Missing Data in Industrial Databases. *Applied Intelligence*, *11*(3), 259–275. http://doi.org/10.1023/A:1008334909089

Lapinski, A., Horman, M., & Riley, D. (n.d.). Delivering Sustainability: Lean Principles for Green Projects. In *Construction Research Congress 2005* (pp. 1–10). American Society of Civil Engineers. Retrieved from http://ascelibrary.org/doi/abs/10.1061/40754%28183%296

Likert, R. (1932). A technique for the measurement of attitudes. *Archives of Psychology*. Retrieved from http://psycnet.apa.org/psycinfo/1933-01885-001

Li, S., Ragu-Nathan, B., Ragu-Nathan, T. S., & Subba Rao, S. (2006). The impact of supply chain management practices on competitive advantage and organizational performance. *Omega*, *34*(2), 107–124. http://doi.org/10.1016/j.omega.2004.08.002

MacDonald, J. P. (2005). Strategic sustainable development1 using the ISO 14001 Standard. *Journal of Cleaner Production*, *13*(6), 631–643. http://doi.org/10.1016/j.jclepro.2003.06.001

Martínez-Jurado, P. J., & Moyano-Fuentes, J. (2014). Lean Management, Supply Chain Management and Sustainability: A Literature Review. *Journal of Cleaner Production*, *85*, 134–150. http://doi.org/10.1016/j.jclepro.2013.09.042

Matos, S., & Hall, J. (2007). Integrating sustainable development in the supply chain: the case of life cycle assessment in oil and gas and agricultural biotechnology. *Journal of Operations Management*, *25*(6), 1083–1102.

McDonald, J. H. (2009). *Handbook of biological statistics* (Vol. 2). Sparky House Publishing Baltimore, MD. Retrieved from http://biolabstats.com/documents/HANDBOOK_OF_BIOLOGICAL_STATISTICS.pdf

Mellenbergh, G. J. (2008). Tests and Questionnaires: Construction and administration. *Advising on Research Methods: A Consultant's Companion. Adèr HJ, Mellenbergh GJ (Eds.) Johannes van Kessel Publishing: Huizen, The Netherlands 2008p*, 211–36.

Melnyk, S. A., Sroufe, R. P., & Calantone, R. (2003). Assessing the impact of environmental management systems on corporate and environmental performance. *Journal of Operations Management*, *21*(3), 329–351. http://doi.org/10.1016/S0272-6963(02)00109-2

Miettinen, P., & Hämäläinen, R. P. (1997). How to benefit from decision analysis in environmental life cycle assessment (LCA). *European Journal of Operational Research*, *102*(2), 279–294.

Monden, Y. (1981). Adaptable Kanban system helps Toyota maintain just-in-time production. *Industrial Engineering*, *13*(5), 29.

Monden, Y. (2011). *Toyota production system: an integrated approach to just-in-time*. CRC Press. Retrieved from http://books.google.ca/books?hl=en&lr=&id=DhZ4cWCI6MIC&oi=fnd&pg=PP1&dq=Monden+1983&ots=DaUra2YBT2&sig=aVa54pPtxRimA4K-v6cycXTkKw4

Montabon, F., Sroufe, R., & Narasimhan, R. (2007). An examination of corporate reporting, environmental management practices and firm performance. *Journal of Operations Management*, *25*(5), 998–1014.

Moullin, M. (2007). Performance measurement definitions: Linking performance measurement and organisational excellence. *International Journal of Health Care Quality Assurance*, *20*(3), 181–183.

Ōno, T. (1988). *Toyota production system: beyond large-scale production*. Productivity press. Retrieved from http://books.google.ca/books?hl=en&lr=&id=7_-

67SshOy8C&oi=fnd&pg=PR9&dq=oyota+Production+System:+Beyond+Large+Scale+Production&ots=YnSAAgElB_&sig=gs14qxOwBLeXhKeM05EG4-UaaD0

Pampanelli, A. B., Found, P., & Bernardes, A. M. (2014). A Lean & Green Model for a production cell. *Journal of Cleaner Production*, *85*, 19–30. http://doi.org/10.1016/j.jclepro.2013.06.014

Parveen, C. M., Kumar, A. R. P., & Narasimha Rao, T. V. V. L. (2011). Integration of lean and green supply chain - Impact on manufacturing firms in improving environmental efficiencies. In *2011 International Conference on Green Technology and Environmental Conservation (GTEC 2011)* (pp. 143–147). http://doi.org/10.1109/GTEC.2011.6167659

Purba Rao and Diane Holt. (2005). Do green supply chains lead to competitiveness and economic performance? *International Journal of Operations & Production Management*, *25*(9), 898–916. http://doi.org/10.1108/01443570510613956

Quayle, M. (2003). A study of supply chain management practice in UK industrial SMEs. *Supply Chain Management: An International Journal*, *8*(1), 79–86.

Robinson, C. J., & Malhotra, M. K. (2005). Defining the concept of supply chain quality management and its relevance to academic and industrial practice. *International Journal of Production Economics*, *96*(3), 315–337.

Rose, A. M. N., Deros, B. M., Rahman, M. A., & Nordin, N. (2011). Lean manufacturing best practices in SMEs. In *Proceedings of the 2011 International Conference on Industrial Engineering and Operations Management, Kuala Lumpur, Malaysia* (pp. 22–24). IEEE. Retrieved from http://www.iieom.org/ieom2011/pdfs/IEOM134.pdf

Rothenberg, S., Pil, F. K., & Maxwell, J. (2001). Lean, Green, and the Quest for Superior Environmental Performance. *Production and Operations Management*, *10*(3), 228–243. http://doi.org/10.1111/j.1937-5956.2001.tb00372.x

Rother, M., & Harris, R. (2001). Creating continuous flow. *The Lean Enterprise Institute*. Retrieved from http://www.lean.org/Library/Creating_Continuous_Flow_Introduction.pdf

Saeidi, S. P., Sofian, S., Saeidi, P., Saeidi, S. P., & Saaeidi, S. A. (2015). How does corporate social responsibility contribute to firm financial performance? The mediating role of competitive advantage, reputation, and customer satisfaction. *Journal of Business Research*, *68*(2), 341–350. http://doi.org/10.1016/j.jbusres.2014.06.024

Salvador, F., Forza, C., Rungtusanatham, M., & Choi, T. Y. (2001). Supply chain interactions and time-related performances: an operations management perspective. *International Journal of Operations & Production Management*, *21*(4), 461–475.

Sanjay Bhasin. (2008). Lean and performance measurement. *Journal of Manufacturing Technology Management*, *19*(5), 670–684. http://doi.org/10.1108/17410380810877311

Sarkis, J. (2003). A strategic decision framework for green supply chain management. *Journal of Cleaner Production*, *11*(4), 397–409. http://doi.org/10.1016/S0959-6526(02)00062-8

Sawhney, R., Teparakul, P., Bagchi, A., & Li, X. (2007). En-Lean: a framework to align lean and green manufacturing in the metal cutting supply chain. *International Journal of Enterprise Network Management*, *1*(3), 238–260.

Shah, R., & Ward, P. T. (2003). Lean manufacturing: context, practice bundles, and performance. *Journal of Operations Management*, *21*(2), 129–149. http://doi.org/10.1016/S0272-6963(02)00108-0

Shrivastava, P. (1995). The role of corporations in achieving ecological sustainability. *Academy of Management Review*, *20*(4), 936–960.

Slack, N. (1991). *The manufacturing advantage: achieving competitive manufacturing operations*. Mercury Books.

Spear, S., & Bowen, H. K. (1999). Decoding the DNA of the Toyota production system. *Harvard Business Review*, *77*, 96–108.

Srivastava, S. K. (2007). Green supply-chain management: a state-of-the-art literature review. *International Journal of Management Reviews*, *9*(1), 53–80.

SROUFE, R. (2003). Effects of environmental management systems on environmental management practices and operations. *Production and Operations Management*, *12*(3), 416–431.

Starik, M., & Rands, G. P. (1995). Weaving an integrated web: Multilevel and multisystem perspectives of ecologically sustainable organizations. *Academy of Management Review*, *20*(4), 908–935.

Stephan Vachon, & Robert D. Klassen. (2006). Extending green practices across the supply chain. *International Journal of Operations & Production Management*, *26*(7), 795–821. http://doi.org/10.1108/01443570610672248

SUGIMORI, Y., KUSUNOKI, K., CHO, F., & UCHIKAWA, S. (1977). Toyota production system and Kanban system Materialization of just-in-time and respect-for-human system. *International Journal of Production Research*, *15*(6), 553–564. http://doi.org/10.1080/00207547708943149

Sullivan, M. (2007). *Statistics: informed decisions using data 4th ed.* Pearson Education, Inc. Retrieved from http://iws2.collin.edu/sfoster/2014Fall/Orientation.pdf

Susana Duarte and V. Cruz-Machado. (2013). Modelling lean and green: a review from business models. *International Journal of Lean Six Sigma*, *4*(3), 228–250. http://doi.org/10.1108/IJLSS-05-2013-0030

Trochim, W. M., & Donnelly, J. P. (2001). Research methods knowledge base. Retrieved from http://www.anatomyfacts.com/research/researchmethodsknowledgebase.pdf

Tu, Q., Vonderembse, M. A., Ragu-Nathan, T. S., & Sharkey, T. W. (2006). Absorptive capacity: Enhancing the assimilation of time-based manufacturing practices. *Journal of Operations Management*, *24*(5), 692–710.

Van den Broek, F., & Van den Broek-Serlé, N. (2010). Green Supply Chain Management, Marketing Tool or Revolution? *Breda/Zoetermeer, The Netherlands< Http://www. Logistiek. nl/PageFiles/12981/008_logistiek-Download-LOGNWS109613D01.*

Pdf>(accessed 02.02. 14). Retrieved from http://prod.logistiek.nl/PageFiles/12981/008_logistiek-download-LOGNWS109613D01.pdf

Van Teijlingen, E., & Hundley, V. (2002). The importance of pilot studies. *Nursing Standard*, *16*(40), 33–36.

Vaus, D. de. (2013). *Surveys In Social Research*. Routledge.

Vehovar, V., & Manfreda, K. L. (2008). Overview: Online Surveys. In *The SAGE Handbook of Online Research Methods* (pp. 176–194). 1 Oliver's Yard, 55 City Road, London England EC1Y 1SP United Kingdom: SAGE Publications, Ltd. Retrieved from http://srmo.sagepub.com/view/the-sage-handbook-of-online-research-methods/n10.xml

Venkat, K., & Wakeland, W. (2006). Is Lean Necessarily Green? *Proceedings of the 50th Annual Meeting of the ISSS - 2006, Sonoma, CA, USA*, *0*(0). Retrieved from http://journals.isss.org/index.php/proceedings50th/article/view/284

Verrier, B., Rose, B., Caillaud, E., & Remita, H. (2014). Combining organizational performance with sustainable development issues: the Lean and Green project benchmarking repository. *Journal of Cleaner Production*, *85*, 83–93. http://doi.org/10.1016/j.jclepro.2013.12.023

Welford, R., & Starkey, R. (1996). *Business and the Environment: A Reader*. Taylor & Francis.

White, R. E., Pearson, J. N., & Wilson, J. R. (1999). JIT manufacturing: a survey of implementations in small and large US manufacturers. *Management Science*, *45*(1), 1–15.

Womack, J. P., Jones, D. T., & Roos, D. (2008). *The machine that changed the world*. Simon and Schuster. Retrieved from http://books.google.ca/books?hl=en&lr=&id=dP_c3EZwUusC&oi=fnd&pg=PR7&dq=he++Machine++That+Changed+the+Wor&ots=SDR4VnVojt&sig=cgZIIfpGEmdDqB1nPo1BqU-cbac

Yang, M. G. (Mark), Hong, P., & Modi, S. B. (2011). Impact of lean manufacturing and environmental management on business performance: An empirical study of manufacturing firms. *International Journal of Production Economics*, *129*(2), 251–261. http://doi.org/10.1016/j.ijpe.2010.10.017

Zhu, Q., & Sarkis, J. (2004). Relationships between operational practices and performance among early adopters of green supply chain management practices in Chinese manufacturing enterprises. *Journal of Operations Management*, *22*(3), 265–289. http://doi.org/10.1016/j.jom.2004.01.005

Zhu, Q., Sarkis, J., & Lai, K. (2007). Green supply chain management: pressures, practices and performance within the Chinese automobile industry. *Journal of Cleaner Production*, *15*(11–12), 1041–1052. http://doi.org/10.1016/j.jclepro.2006.05.021

Appendix

Questionnaire

Lean-Green SC

SECTION 1: BUSINESS CONTEXT Please select the answers that best correspond to your company as a whole.

In which sector of the supply chain does your company operates:

- ❍ End Customer (1)
- ❍ OEMs – Aerospace Sector (Original Equipment Manufacturer) (2)
- ❍ Tier 1 – Systems Integrators (3)
- ❍ Tier 2 – Equipment or Assembly Providers (4)
- ❍ Tier 3 – Build to Print Components or sub-Assembly Suppliers (5)
- ❍ Tier 4 – Processing or Material Supplier (6)
- ❍ Other (please specify) (7) ____________________

Annual revenue of your company

- ❍ Less than $100 million (1)
- ❍ $100 million - $1billion (2)
- ❍ $1 billion - $10 billion (3)
- ❍ More than $10 billion (4)

Generally speaking, how would you rate the overall performance of company's supply chain, on a scale of 1 (much room for improvement) to 3 (excellent or we are the best practice company)?

❍ 1 (1)	❍ 2 (2)	❍ 3 (3)	❍ Don't Apply (4)

SECTION 2: A) Green Production Practices Green supply chain management integrates environmental thinking into supply chain management; this includes introducing technical and innovative processes into materials sourcing & selection, manufacturing & production, delivery of the final product to consumers, and end-of-life product management. Please indicate the level of frequency for each of the following statements regarding green supply chain practices within your company, on a scale of 1 (Rarely) to 3 (Always).

Our company has outlined a policy for green supply chain management.

❍ Rarely (1)	❍ Occasionally (2)	❍ Always (3)	❍ Don't Apply (4)

Our company practice the ISO and other Green standards.

❍ Rarely (1)	❍ Occasionally (2)	❍ Always (3)	❍ Don't Apply (4)

Our company is pursuing initiatives to reduce energy consumption.

❍ Rarely (1)	❍ Occasionally (2)	❍ Always (3)	❍ Don't Apply (4)

Our company re-uses or recycles materials and packaging.

❍ Rarely (1)	❍ Occasionally (2)	❍ Always (3)	❍ Don't Apply (4)

Green supply chain operations are integrated with all aspects of our supply chain.

❍ Rarely (1)	❍ Occasionally (2)	❍ Always (3)	❍ Don't Apply (4)

SECTION 2: B) Lean Production Practices

Lean Production is based on the Toyota Production System, a manufacturing process developed to remove waste, focus production flow and improve customer value. Please indicate the level of frequency of each of the following statements regarding lean supply chain practices within your company, on a scale of 1 (Rarely) to 3 (Always).

Our company has outlined a policy for practicing lean along the supply chain (waste reduction, value stream mapping...)

❍ Rarely (1)	❍ Occasionally (2)	❍ Always (3)	❍ Don't Apply (4)

Our company has a program of education and training for the employees in order to increase employee´s skills in lean production.

❍ Rarely (1)	❍ Occasionally (2)	❍ Always (3)	❍ Don't Apply (4)

Lean principle of value stream mapping is incorporated into our company's system

❍ Rarely (1)	❍ Occasionally (2)	❍ Always (3)	❍ Don't Apply (4)

Our company's system is based on Just-in-Time principles.

❍ Rarely (1)	❍ Occasionally (2)	❍ Always (3)	❍ Don't Apply (4)

Our company selects their suppliers through lean criteria.

❍ Rarely (1)	❍ Occasionally (2)	❍ Always (3)	❍ Don't Apply (4)

Our company practice continuous flow along the supply chain

❍ Rarely (1)	❍ Occasionally (2)	❍ Always (3)	❍ Don't Apply (4)

Our company shares lean strategy across the whole supply chain.

❍ Rarely (1)	❍ Occasionally (2)	❍ Always (3)	❍ Don't Apply (4)

SECTION 3: The effect of practices on Supply Chain Outcome

Please answer the following questions based on the previously mentioned practices.

In our company implementing Green practices leaded to higher overall performance of the supply chain

❍ Disagree (1)	❍ Neutral (2)	❍ Agree (3)	❍ Don't Apply (4)

In our company implementing Green practices leaded to higher production quality

❍ Disagree (1)	❍ Neutral (2)	❍ Agree (3)	❍ Don't Apply (4)

In our company implementing Green practices improved the customer satisfaction rate

❍ Disagree (1)	❍ Neutral (2)	❍ Agree (3)	❍ Don't Apply (4)

Please rank the following outcomes of Green practices in your company in the order of importance: (1- Most important to 6- Least important)

______ Lowest possible cost (1)
______ Higher production quality (2)
______ More customer satisfaction (3)
______ Less lead time (4)
______ more environmentally friendly (5)
______ more profit (6)

In our company implementing Green practices leaded to higher overall performance of the supply chain

❍ Disagree (1)	❍ Neutral (2)	❍ Agree (3)	❍ Don't Apply (4)

In our company implementing Lean practices improved the customer satisfaction rate

❍ Disagree (1)	❍ Neutral (2)	❍ Agree (3)	❍ Don't Apply (4)

In our company implementing Lean practices leaded to higher production quality

❍ Disagree (1)	❍ Neutral (2)	❍ Agree (3)	❍ Don't Apply (4)

Please rank the following outcomes of Lean practices in your company in the order of importance: (1- Most important to 6- Least important)

______ Lowest possible cost (1)
______ Higher production quality (2)
______ More customer satisfaction (3)
______ Less cycle time (4)
______ Being environmentally friendly (5)
______ More profit (6)

SECTION 4: Trade-off between Green and Lean which statement is true about Green and Lean importance:

- ❍ Green is more important than Lean (1)
- ❍ Lean is more important than Green (2)
- ❍ They are both at the same level of importance (3)
- ❍ Other (Please specify) (4) ____________________

Do you think a trade-off exist between these two paradigms?

- ❍ No (1)
- ❍ Yes (positively correlated) (2)
- ❍ Yes (negatively correlated) (Please explain more) (3) ____________________

SECTION 5: Demographics

Please select the function that best matches your current job:

- ❍ Supply chain management (1)
- ❍ Purchasing (2)
- ❍ Warehousing and logistics (3)
- ❍ New product development (4)
- ❍ Research and development (5)
- ❍ Other (please specify: marketing/sales management, accounting/finance management, operations management, other function not listed) (6) ____________________

How many years of total experience do you have in your company?

- ❍ 1-3 (1)
- ❍ 4-8 (2)
- ❍ 9-15 (3)
- ❍ 15+ (4)

Please indicate your comment or suggestion on performance measurement metrics and system regarding the Green-Lean paradigms.