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The Relationship Between Lean Six Sigma and Organizational Performance: An Empirical Investigation

A thesis
submitted in partial fulfilment
of the requirements for the Degree of
Master of Commerce and Management

at
Lincoln University
by
Sophie Thi Quynh Nga Ngo

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The practices of organizing and managing operations has experienced an increased application of universal, systematic patterns of Lean Six Sigma joint implementation in many corporations currently (Shah et al., 2008). Despite this the relationship between firm performance improvement outcomes and Lean Six Sigma is not yet well researched or understood. Though much anecdotal evidence suggests a strong positive association of Lean Six Sigma with firm performance, a closer inspection of the literature reveals there has been no empirical research that confirms this relationship. Regardless, the current belief in the field that Lean Six Sigma can be associated with improved organizational performance is popular and widely accepted.

Given the motivation to fill a perceived gap in our knowledge, as well as the need to meet the existing demand for greater insights into Lean Six Sigma from practitioners, the aim of the research is to develop insights into the relationship between Lean Six Sigma implementation and its organizational performance improvement outcomes. The value of this research is that it is the first survey-based research on this relationship. This is also the first attempt to compare the levels of performance outcomes between a Lean standalone model and a combined Lean Six Sigma program.

Utilizing a survey research methodology, an instrument has been developed to survey and interview multiple manufacturing firms in the New Zealand context which have been identified as implementing Lean and/or a Six Sigma program. An excellent response rate of 75% was achieved and the study has received strong interest and support from businesses and consultancies in the New Zealand market. Multivariate data analysis technique, specifically, an independent sample t-test is used to investigate the differences in organizational performance between the two groups of firms; the Lean implementer group and the combined
Lean Six Sigma implementer group. The research suggests that for SMEs Lean is a better choice than Lean Six Sigma as implementing Lean by itself is likely to lead to better business performance than implementing Lean Six Sigma.

**Keywords**: Six Sigma, Lean, Lean Six Sigma, Organizational performance, Empirical research
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Chapter 1
Introduction

Six Sigma has been implemented by many large, multinational companies, has gained considerable popularity world-wide, and is now accepted as one of the most successful process improvement systems available to businesses.

“Six Sigma is an organized, parallel-meso structure to reduce variation in organizational processes by using improvement specialists, a structured method, and performance metrics with the aim of achieving strategic objectives” (Schroeder et al., 2008, p.540).

Academics agree that Six Sigma is a distinct management methodology (Schroeder et al. 2008 and Zu et al. 2008), and it holds an important role in management theory as the practices of Six Sigma complement traditional quality management to enhance business performance. Lean is a very successful system focused on problem solving, waste elimination, efficiency, and making changes.

“Lean Production is an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability.” (Shah and Ward, 2007, p.791).

Lean has become increasingly popular with businesses of all sizes and markets. It promises significantly improved performance. One of its advantages is that it has a less formal structure than other programs such as Six Sigma.

Six Sigma and Lean were regarded as separate and distinct quality improvement programs in the mid to late 1990s. Presently there is a high degree of integration, which began in earnest in the early part of the new millennium. While consultants and practitioners have continued to directly influence the evolution of the integrated form, academics are researching the common holistic model. Practice has observed a trend of adapting Lean Six Sigma universally. Given this, some authors optimistically claim that the integration of Six-Sigma and Lean system represents an evolution of the Six Sigma methodology (Hoerl, 2004) and Lean Six Sigma is becoming a new continuous improvement approach in industry (Devane, 2004; George, 2003).

Despite this recent success, literature on the topic is scarce and particularly thin, especially in the narrow field of the model’s outcome. Academics are still in the exploratory stage of uncovering the definitional and methodological issues related to the integration of Lean and
Six Sigma program. Published articles provide much anecdotal evidence in the form of success stories regarding the positive linkage of the implementation of a combined Lean Six Sigma approach and higher performance benefits (Hahn et al., 2000; Basu, 2001; Antony et al., 2003; Fielder, 2004; George et al., 2003; McClenahen, 2004).

A review of literature reveals that there is little, if any, validated evidence proving this positive relationship. Given the growing importance and the increasing prevalence of the joint application of Lean and Six Sigma in the field, a survey based research supported by a specific-quantitative investigation is imperative.

Few recent papers have attempted to explore the relationship empirically. Shah, R., Chandrasekaran, A. and Linderman, K. (2008) conducted survey based research. However, the findings focused on outcomes of each model in isolation. The hypothesis concerned Lean Six Sigma but their findings were specific to Six Sigma only, concluding that it leads to superior performance (Shah et al., 2008). Other recent papers have similarly aimed to investigate Lean Six Sigma, yet presented conclusions that promote either Six Sigma or Lean independently. Therefore, the current research leaves the following questions largely unanswered: Do firms adopting Lean Six Sigma experience superior performance improvement over non-implementers and can Lean Six Sigma be empirically tied to superior operating performance?

Another primary unanswered question is whether the combination of Lean and Six Sigma generates a better result than when either model stands on its own. Many practitioners and consultants believe that it does, although sufficient research is needed to lend credence to this belief. Researchers and practitioners question whether Lean-Six Sigma is simply the latest management fad. Again, this is an assertion that is waiting for an empirically based answer. A comparison of performance improvement outcomes between Lean Six Sigma and the standalone models should be able the address this question.

Finally, the literature indicates that studies on business improvement programs such as Six Sigma and Lean regarding SMEs are scarce and methodologically weak. Key findings on the relationships of Six Sigma, Lean and performance are primarily attributed to large size firms. Given this, practitioners must question whether programs like Six Sigma, Lean, and Lean Six Sigma can help SMEs effectively enhance their operating performance as they do for larger size firms. Furthermore, it is argued that contexts in which firms operate possibly affect the effectiveness of manufacturing improvement programs (Cua et al., 2001; Zu et. al, 2008; Parasr, 2010). Benefits resulting from these programs may vary considerably across different
contexts, such as firm size. As a result, questions must be asked concerning whether what has been believed and found to be true for large size firms is true for smaller settings and whether either Lean or Six Sigma, or Lean Six Sigma is better for SMEs. Whilst these questions have been put forward, there is a need to verify these issues empirically.

Definitions of SMEs vary considerably across different nations. In New Zealand SMEs are defined as enterprises employing 19 or fewer staff (Statistics New Zealand, 2010). The Australian Bureau of Statistics defines SMEs as businesses employing less than 200 people (Department of Public Work, 2010). The European Commission defines SMEs as enterprises that have fewer than 250 employees (European Commission, 2010). While in New Zealand a business with more than 100 employees would be considered large, in the US small firms are often regarded as those with fewer than 100 employees and medium-sized business are those with fewer than 500 employees (OECD, 2010). Both the US and the EU consider businesses with fewer than ten employees small offices (SOHO) or Micro-SMEs. Although the research site is New Zealand market, in order to enable the findings of the study to be internationally applicable this study defines SMEs as those with fewer than 500 employees.

In summary, given Lean Six Sigma’s growing prevalence and importance in industry, there is a need to understand the relationship between firm performance improvement and Lean Six Sigma which is presently not well researched or understood. Establishing an empirical relationship between Lean Six Sigma implementation and firm performance is therefore identified as a key research problem that can contribute towards filling the current gap in the literature.

The aim of the research is to develop insights into the relationship between Lean, Six Sigma, Lean Six Sigma implementation, and organizational performance improvement outcomes. A survey methodology was chosen for the primary data collection. A review of literature indicates that prior studies have been focused mainly on anecdotal evidence based on untested assumptions and single case success stories. Therefore, survey based research is justified to address methodological shortcomings of previous research. An instrument was developed from an extensive review of the relevant literature. The researcher then surveyed and interviewed various firms which were identified as adopting Lean system and/or a Six Sigma program in the New Zealand context. The study focused solely on the manufacturing segment given that this is where most Lean and Six Sigma implementations happen and has the longest history in term of the development of both programs. An excellent response rate of 75% was achieved and the study has received strong interest and support from businesses and consultancies in the New Zealand market.
The performance levels of two groups of firms; those adopting Lean practices and those adopting a combined Lean/Six Sigma program were empirically compared. Research questions were tested as they are applied in SMEs. The multivariate data analysis technique was used to discover the difference between the two groups of implementers (Hair et al., 2010). Specifically, an independent samples t-test was employed to assess whether or not there is a significant difference in the performance levels of the combined Lean Six Sigma implementer group, and the standalone Lean implementer group, and to examine if the combination of Lean and Six Sigma result in superior performance compare to when either model stands on its own.

The study is believed to be value adding as it addresses a research gap in the literature on the topic of Lean and Six Sigma and firm performance. It also provides new insights into the body of knowledge regarding the SMEs setting. From a practical standpoint, the outcomes of this study may assist practitioners in deciding whether they should include Lean practices into a Six Sigma structure as well as providing practitioners with a better understanding of how their peer organizations utilize Lean Six Sigma and the level of performance improvement benefits that are achieved.

Specifically, the thesis is structured in six chapters.

Chapter 1: Introduction

Chapter 2: Literature Review

Chapter 3: Methodology

Chapter 4: Data and Analysis

Chapter 5: Discussions and Results

Chapter 6: Conclusion
Chapter 2
Literature review

2.1 Introduction

The overarching objective of the research is to develop insights into the relationship between Lean Six Sigma implementation and organizational performance improvement outcomes.

Specifically, the goals of the research are divided into three themes:

- To investigate the incremental difference in performance improvement between firms adopting either Lean or Six Sigma by themselves and those adopting a combined Lean Six Sigma approach.
- To assess whether the combination of Lean and Six Sigma results in superior performance in comparison to standalone implementation of either.
- To explore and measure the nature and extent of changes in organizational performance improvement that can be attributed to the impact of the implementation of Lean Six Sigma and Lean.

In alignment with these research objectives an extensive review of the literature has been conducted which proposes to:

- Provide enough background information for readers to gain an overview of the field specifically Six Sigma, Lean, and combined Lean Six Sigma and their outcomes.
- Provide a summary of the currently existing body of knowledge relevant to the chosen research topic area, particularly that which is supporting research arguments, questions, and discussion.
- Provide a detailed discussion of what researchers in the field already know about the topic and what is currently unknown, as well as prominent questions.

Therefore, this review of literature will help to:

- Provide a context for the research.
- Identify existing gaps in the literature, which the proposed research intends to address.
- Establish that the proposed research is value adding.
• Be aware of appropriate research methodologies for this topic area and include articles that utilize the methodology the research intends to use.

• Reinforce research findings.

These objectives can be achieved by investigating the broad body of knowledge related to Six Sigma, Lean and Lean Six Sigma on the theme: methodology – outcome. This review is, therefore, structured in two streams: Methodologies and Organizational Performance Improvement Outcomes.
2.2 Stream 1: Methodologies

2.2.1 Six Sigma Methodology

2.2.1.1 Overview
Six Sigma is a quality improvement initiative that has evolved over 25 years. It was developed by Bill Smith and first applied by Motorola Corporation in 1986 (Tennant, 2001). Six Sigma has been implemented by many large, multinational companies world-wide, and has gained considerable popularity over the years.

The Six Sigma program has been widely accepted to be one of the most successful process improvement systems available to businesses (Snee and Hoerl, 2003). It has been applied in a wide range of business areas, including manufacturing and service settings, and expanded recently to financial institutions, education, hospitality, and health care organizations. Moreover, Six Sigma has been successfully introduced into many other special business functions such as human resources management, research and development (R&D), supply chain management (SCM) and e-business (Snee and Hoerl, 2003).

Firms adopting Six Sigma have reported significant financial gains from their deployment efforts. For example, in 1999 General Electric reported $2 billion of net income benefits from Six Sigma initiatives (Pande et al., 2000). The program at American Express, which cost $2 million and employed 300 Black Belts and involved 66 funded projects, achieved a net saving of $100 million in 2001 (Aubrey, 2003).

2.2.1.2 Definition
Literally, Sigma is a statistical term used to describe and measure process variability in organizations. Sigma might create a perception that the main theme of Six Sigma methodology is focusing on reducing the number of defects (McAdam and Lafferty, 2004). Six Sigma expresses a quality goal of 3.4 DPMO (defects per million opportunities). Six Sigma is characterized as a quality control concept that requires processes to operate at a variation of ± 6 SD/sigma from the mean (Breyfogle et al., 2001). It is also further assumed that processes operating with a variation of ± 6 SD/sigma from the mean allow a mean to shift by as much as ±1.5 SD/sigma off the target (Montgomery, 2001). Thus, a shift of 1.5 S.D in the process mean will still result in a 3.4 DPMO (Montgomery, 2001 and Breyfogle et al., 2001). This goal is far beyond normal quality levels and requires an extensive improvement effort (Linderman et al., 2003). For example, a three sigma process results in 66,880 DPMO or 93.3% process yield, while a six sigma results in 3.4 DPMO and a 99.99966% process yield. Linderman, K., Schroeder, R.G., Zaheer, S. and Choo, A.S. (2003) believe that not all
processes should operate at a six sigma level. These authors suggest that an appropriate level depends on the strategic importance of the process and the cost of the improvement relative to the benefit. In this regard, Linderman et al. (2003) also state that the effort and difficulty/sophistication of statistical tools exponentially increases as the target sigma level increases.

Figure 2.1 shows the relationship between DPMO and Process Sigma assuming the normal distribution.

![Figure 2.1: Defect rate (DPMO) versus Process Sigma Level](source)


It can be seen that the Six Sigma program maintains a strong focus on specifying measurable and quantifiable goals (Linderman et al. 2003). This characteristic distinguishes Six Sigma from other business improvement initiatives.

Six Sigma works under two data-driven methodologies and one deployment approach (Nonthaleerak and Hendry, 2006). The Six Sigma methodologies are DMAIC and DFSS. DMAIC is an acronym covering five phases of the implementation process: Define, Measure, Analyze, Improve, and Control, and is applied for a current process or an existing product/service performance. Meanwhile, Design for Six Sigma (DFSS) is used to develop a new product or process. These methods rely on the use of approximately 140 statistical tools and concepts to achieve particular tasks/targets in each phase of a Six Sigma project (Bendell, 2006).

Six Sigma is deployed through a project-by-project basis by the introduction of a structured/hierarchical system of improvement specialists with various roles (Bendell, 2006). For example, the title of “Champion” is given to the top senior leader who is responsible for
success of whole Six Sigma projects. Each Six Sigma project is led by full-time improvement engineers or managers titled “Master Black Belts”, “Black Belts” or part-time improvers who often work as technical analysts and supervisors referred to as “Green Belts”. Each belt level is given appropriate training that provides a level of knowledge and skills, given the scope of that belt’s level or responsibility, scope of work, and specific targets.

2.2.1.3 Six Sigma – A Structured Method

Schroeder, R. G., Linderman, K., Liedtke, C. and Choo, A. S. (2008) and Zu, X., Fredendall, L.D. and Douglas, T.J. (2008) support the contention that Six Sigma uses a structured method. Schroeder et al. (2008) suggest this approach is one of the four elements of the Six Sigma definition. Zu et al. (2008) identify and empirically verify that Six Sigma’s structured improvement procedure is one of the key three practices which are critical for implementing Six Sigma in organizations. The structured method, DMAIC, provides companies a meta-routine to follow in order to solve problems and improve processes (Schroeder et al., 2008).

In alignment with these ideas, Zu et al. (2008) argue that the Six Sigma structured improvement procedures provide teams a methodological framework to guide them in the conduct of improvement projects. Specifically, Six Sigma applies an approach to managing improvement activities, which is represented by Define–Measure–Analyze–Improve–Control (DMAIC) (see figure 2.2). In this regard, Linderman et al. (2003) suggest that although the DMAIC method is similar to the problem-solving steps of the classic Plan–Do–Check–Act cycle (PDCA model) and that the tools used in Six Sigma are not new, the novelty of Six Sigma is that it specifies quality management tools and techniques to use within each step. Six Sigma places emphasis on integrating specific tools into each step of the method, which makes Six Sigma unique (Schroeder et al., 2008). Further, DMAIC involves different specialists and organizational members at different steps in the method. Schroeder et al., (2008) highlight that there is greater clarity regarding the role and scope of work in each step with DMAIC than within the structures of other quality management methods.

Schroeder et al. (2008) captures the characteristics of the DMAIC structure and three theoretical aspects of Six Sigma in the following definition:

“Six Sigma is an organized, parallel-meso structure to reduce variation in organizational processes by using improvement specialists, a structured method, and performance metrics with the aim of achieving strategic objectives” (p.540).
2.2.1.4 Six Sigma – A Distinct Management Philosophy

While Six Sigma has been developed over 25 years by a large range of companies, academics are continuing to strive to reach a consensus on a holistic definition. To date there have been no shortage of definitions offered, however most tend to focus on one particular aspect of the Six Sigma model such as customer driven approach, decision-making based on quantitative data, and the bottom line results (Harry, 1998; Breyfogle, 1999; Pyzdek, 2003).

Further, the issue of whether Six Sigma is a distinct management philosophy continues to be debated (Hahn et al., 2000; Sanders and Hild, 2000; Wiklund and Wiklund, 2002; Dedhia, 2005; Hekmatpanah et al., 2008). Six Sigma has been criticized as the latest management fad to repackage old quality management principles, practices, and tools/techniques (Clifford, 2001), or an old wine in the new bottle (Hahn et al., 2000). Meanwhile, others are convinced that Six Sigma is an evolution of the TQM approach (Dedhia, 2005), and that Six sigma is a toolset, not a management system which is best used in conjunction with other more comprehensive quality standards (Raisinghani et al., 2005).

Academics who argue that Six Sigma is a quality improvement philosophy or management system include Schroeder, R. G., Linderman, K., Liedtke, C. and Choo, A. S. (2008) and Zu, X., Fredendall, L.D. and Douglas, T.J. (2008). Schroeder et al. (2008) propose a conceptual definition and underlying theory of Six Sigma. Their research argues that although the tools and techniques in Six Sigma are strikingly similar to prior approaches to quality management,
Six Sigma provides an organizational structure not previously seen. The authors propose a definition constructed by four main elements of Six Sigma, *parallel-meso structure, improvement specialists, structured method, and performance metrics*. The authors also contribute to the body of Six Sigma research through the discussion of the concepts of ambidextrous organizations, parallel-meso organization, structural control and structural exploration. Their research claims that higher levels of simultaneous structural control and structural exploration in Six Sigma tends to result in higher organizational performance. The work by Schroeder et al. (2008) adds considerable value as the rigorous conceptual definition and underlying theory proposed by the study provide a scientific identification for the Six Sigma phenomenon.

Zu et al. (2008) concentrate on the role of Six Sigma in the theory of quality management. Their study suggests that Six Sigma is a distinct quality management philosophy. Zu et al. (2008) studied the influence and contribution of Six Sigma to quality management theory. The authors identified three new practices that are critical for Six Sigma implementation: Six Sigma role structure, Six Sigma structured improvement procedure, and Six Sigma focus on metrics. A large-scale survey on 878 manufacturing plants was used to investigate the relationships between these three practices, traditional practices, and the impact that the integration of Six Sigma practices and seven traditional quality management practices has on quality and business performance. The research found that the three Six Sigma practices are distinct from others, and that they complement the traditional quality management practices in improving performance.

It can be seen that the three Six Sigma practices identified by Zu et al. (2008) are consistent with three of the four elements suggested by Schroeder et al. (2008). This consensus between the works of two separate/independent groups of researchers strongly supports the presumption that Six Sigma is a management methodology distinct from traditional approaches. This greatly contributes to existing knowledge as the studies go towards confirming that Six Sigma is a fact, as opposed to fiction. Further, it reinforces the idea that the new and unique practices offered by the Six Sigma methodology deliver a superior performance improvement outcome. In conclusion, Six Sigma holds an important role in management theory and the three critical practices of Six Sigma complement traditional methods to enhance business performance.
2.2.1.5 The issue of Six Sigma’s applicability

While the development of Six Sigma programs has been deeply embraced in manufacturing organizations, the programs have also been widely applied in non-manufacturing settings such as banking, education, hospitality, and healthcare service (Snee and Hoerl, 2003). The literature on Six Sigma reveals that methodology focused studies set in non-manufacturing contexts are numerous but methodological weak, mostly in the form of either descriptive single case studies or grounding literature research/conceptual papers. Most of the key findings regarding the Six Sigma’s methodology and theory are provided from large scale survey based studies on manufacturing firms (Linderman, et al., 2006; Zu et al, 2008) or from rigorously conceptual works in a manufacturing context (Linderman, et al., 2003). Therefore, it can be reasonably claimed that what has been understood and developed regarding the philosophical issues of Six Sigma are attributed to solely the manufacturing area. There is only little development regarding the issues for non-manufacturing businesses.

Further, Six Sigma methodology has also found to be applicable in particular business processes and areas such as financial system (Faltin and Faltin, 2003), supply chain management (Tirthankar, 2003), research and development (Mader, 2003; Koch et al., 2004), human resources (Harrison, 2006), and organizational learning (Wiklund, 2002). While a number of papers have been published describing the successful implementation of Six Sigma in these areas, few papers investigate and explain the Six Sigma methodology empirically as an attempt to identify and develop a solid methodological foundation for the adoptions.

In addition to the highlighted areas, the applicability of Six Sigma has been also widening as the programs have been combined and integrated with other business improvement initiatives. The literature indicates there are many attempts to integrate and combine Six Sigma with various management initiative programmes such as TQM, ISO9000, and Lean (Nonthaleerak and Hendry, 2006). Particularly, the integration of Lean and Six Sigma is becoming prevalent and the improvement methodology in Lean Six Sigma is emerging as important to the business improvement areas and industry (Devane, 2004 and George, 2003). The existing literature mainly focuses on the advantage and detail description of integrating Six Sigma methodology with Lean practices (Sharma, 2003; Laureani et al., 2010; Salah et al., 2010). A review of the literature reveals that little research examines the compatibility and develops a conceptual model in which Six Sigma and Lean combine and interact. The literature on the topic is still thin and scarce across all areas.
2.2.1.6 Knowledge Gaps and Future Research Suggestions

Linderman, K., Schroeder, R.G., Zaheer, S. and Choo, A.S. (2003) remark that: “While Six-Sigma has made a big impact on industry, the academic community lags behind in understanding of Six-Sigma” (p.193). More recently, according to Shah, R., Chandrasekaran, A. and Linderman, K. (2008), Six Sigma is still an emerging concept, and our understanding of Six Sigma remains exploratory in nature. This is evidenced by many of the recent published articles that simply focus on developing a definition that establishes its boundaries and distinguishes it from other quality management concepts (Hahn and Hill, 1999; McClenahen, 2004; and Schroeder et al., 2008).

A review of Six Sigma literature reveals an absence of a consistent and consolidated explanation of its methodology and philosophy, which can serve as a basis for scientific research. Given the prominent role that Six-Sigma plays in quality improvement in contemporary business and industry, there is a definite need for a more scientific research on enhancing Six Sigma methodologies by:

- Developing a scientific or theoretical foundation for Six Sigma (Nonthaleerak and Hendry, 2006);
- Proposing additional Six Sigma features, which have not yet been identified and identifying new practices for Six Sigma;
- Exploring theories of Six Sigma, which are important in providing insights into the success of the Six Sigma philosophy from an academic/theoretical perspective. These theories could provide scientific explanations for the phenomenon occurring and help to predict outcomes of Six Sigma implementation in practice. These suggestions combined could help build up a better understanding of Six Sigma, adding value to the quality business improvement literature. Testing of such theories using empirical evidence is also an interesting area for future study.

The second significant issue identified by this review of the literature is the need to explore and widen the applicability of Six Sigma in business.

Instead of conducting further research on the definition and concept of Six Sigma, scholars should investigate the adoption of Six Sigma practices in different organizational contexts, given that different settings have quality management programs at various levels of advancement (Zu et al., 2008). Therefore, future research should explore the critical contextual factors influencing the integration of Six Sigma practices into an organization’s existing quality management system.
The literature review has identified that there is scant research investigating how Six Sigma works with other improvement methods such as Lean. Future research should explore how Six Sigma practices interact with Lean practices in providing a novel approach to organizational excellence. Further investigation should seek to identify whether the inclusion of Lean in Six Sigma methodology is tied to a superior performance improvement and whether the combination of Lean and Six Sigma could result in a better performance outcome than when either model exists on its own.

2.2.2 Lean Methodology

2.2.2.1 Overview

Lean is a very successful system focused on solving problems and making changes. Lean is gaining in popularity with businesses of all sizes and markets as it promises significantly improved performance with a less formal structure than programs like Six Sigma. Lean’s applicability has expanded to wide range of business areas including manufacturing, and non-manufacturing settings such as banking, education, hospitality, health care services, and special business functions such as accounting.

The evolution of Lean has its roots in the development of the Toyota Production System (TPS) in Japan during the seventies and eighties. The term “Lean” was introduced in 1988 by John Krafcik to describe the new manufacturing system used at Toyota. He was studying developments in the automobile industry as part of the MIT International Motor Vehicle Program lead by Daniel Roos, James Womack and Daniel Jones. Their work was published in “The Machine That Changed the World” (Womack et al., 1990). They referred to the group of techniques pioneered by Toyota which they extended into their ideas of Lean Thinking (Womack and Jones, 1996). The book extends the philosophy and the guiding principles underlying Lean to an enterprise level.

2.2.2.2 Definition

Despite the long period of time in which the Lean concept has been developed, as well as the extensive and intensive application of Lean in industries worldwide, there is still no consensus among academics and practitioners on what Lean actually means.

The book “The Machine That Changed The World”, published in 1990 by Womack, Jones and Roos, establishes the Lean concept, codifies much of the thinking regarding Lean and describes Lean System in detail. However, it does not offer a specific/precise definition of the paradigm.
Meanwhile, some researchers claim that Lean is simply JIT philosophy repackaged. Gaither and Frazier (2002) define Lean management as implementing “the approaches embodied in JIT” while others believe Lean and JIT are indistinguishable and use the two concepts interchangeably (Heizer and Render, 2001). Recently, Lean is still characterized as a concept which is broader than JIT (Chase et al., 2004). Some scholars view Lean and broader forms of JIT manufacturing as being related (McLachlin, 1997; Krafick, 1988).

Despite the variation, the most widely held consensus among academics is that Lean systems are designed to eliminate waste (Womack and Jones, 1996; Shah and Ward, 2003; Hopp and Spearman, 2004; de Treville and Antonakis, 2006; and Narasimhan et al., 2006). Shah and Ward (2003) describe Lean as a philosophy of identifying and removing inefficiencies like the non value-added (waste) cost or unneeded wait time within the process caused by defects and excess production. Similarly, Narasimhan, R., Swink, M. and Kim S.W., (2006) suggest the essential aspect of Lean is the efficient use of resources through the minimization of waste. Lean manufacturing focuses on reducing wastes and non-value adding activities. These authors propose that “Production is Lean if it is accomplished with minimal waste due to unneeded operation, inefficient operations, or excessive buffering in operation” (p.443).

A few recently published articles have focused on conceptual definitions of Lean as well as exploring and highlighting the overarching nature of Lean (McLachlin, 1997; Shah and Ward, 2003; Hopp and Spearman, 2004; de Treville and Antonakis, 2006). While definitions proposed vary among these authors, they generally agree on key points of Lean. Shah and Ward (2003) characterize Lean as a collection of practices that work together synergistically to create a streamlined, high quality system that produces finished products at the pace of customer demand with little or no waste. The authors identify practices included in Lean systems, such as JIT, human resource development and empowerment practices, equipment management and preventive maintenance, and various quality control practices (Shah and Ward, 2003).

2.2.2.3 Conceptual Definition Proposed by Shah, R and Ward, P.T. (2007)

Shah, R and Ward, P.T. (2007) highlight a confusion and inconsistency associated with Lean concept. From a practical point of view, Lean is implemented in different scales and dimensions. Additionally, there is no consensus among practitioners on underlying components of Lean systems as well as on its implementation manifestations. A review of related literature reveals that while there exist many descriptions of Lean and its underlying components, there are a few conceptual definitions. Shah and Ward (2007) claim that the definitions are very general and are becoming more expansive over time. The authors identify
a considerable overlap over this issue and believe that Lean’s concept is insufficiently well
developed theoretically and operationally.

Shah and Ward (2007) suggest that Lean is not simply just these concepts: waste elimination,
continuous improvement, JIT, pull production, Kanban, TQM and employee involvement, but
more than this. The authors state that “Lean Production is an integrated system composed of
highly inter-related elements” (Shah and Ward, 2007, p.800). In addition to this argument, the
authors also highlight that implementation of Lean represents itself in multiple facets.

In an attempt to clarify the confusion surrounding the complicated concept of Lean, Shah, R.

“Lean Production is an integrated socio-technical system whose main
objective is to eliminate waste by concurrently reducing or minimizing
supplier, customer, and internal variability.” (Shah and Ward, 2007, p.791)

While the proposed definition is believed to capture the integrated nature of Lean systems and
identify the underlying multidimensional structure, it does not specifically explain Lean.

The research empirically identifies a set of ten main components, which characterize ten
distinct, essential dimensions of a Lean system, including Supplier Feedback, JIT Delivery,
Developing Supplier, Involved Customers, Pull, Flow, Low Setup, Controlled Processes,
Productive Maintenance, and Involved Employees. The authors also developed a framework
(see figure 2.3) to describe the interrelatedness of these ten factors. The components are
classified into three main underlying streams of Lean philosophy, supplier, customer related,
and internally related construct. The definition involves well-rounded perspectives of Lean
systems as including both people and process, both internal and external operational elements.

Figure 2.3: Conceptual and empirical mapping as proposed and validated in
Shah and Ward (2007)
2.2.2.4 Operational Instrument Developed by Shad, R and Ward, P.T. (2007)

A review of the literature indicates that there are well-developed instruments which are used to measure the components of Lean separately, however not for Lean itself. Further, the literature also identifies an overlap and confusion surrounding Lean’s instruments of measurement. Prior instruments developed by Shah and Ward (2003) are criticized as only reflecting internal facets of Lean systems as it measures Lean under four dimensions, just in time, total quality management, total preventive maintenance, and human resource management. Meanwhile, levels/states of Lean implementation vary considerably across various companies. Lean systems manifest themselves across companies in many dimensions and facets. Shah and Ward (2007) attribute this to the multiple component nature of Lean constitution and suggest that the practices/tools used to measure Lean must support the multiple components.

In order to address the observed demand for a precise, operational measurement of Lean from practitioners and academics, Shah and Ward (2007) developed a set of forty-eight items included in ten scales. These scales and items are believed more comprehensive and empirically validated than other measures observed in the existing literature in the topic. The instrument makes some important contributions.

From an academic perspective, the empirically validated measurement instrument provided by this study is useful for researchers who are interested in conducting survey research related to Lean systems. The instrument is believed to allow the researchers an operational measurement of the implementation of Lean, to assist a precisely assessment of the status of Lean implementation, and consequently, assist researching the association of Lean with firm performance outcomes. Therefore, the instrument provided by this study is expected to guide empirical research seeking parsimony in data collection.

From a practical standpoint, the study provides a tool for managers to assess the state of Lean in their specific operations. Managers can rely on the scales provided in this study to benchmark their Lean implementation. These can be used by practitioners either to self-evaluate their progress in implementing Lean, or to assist them to achieve a proper implementation of a “truly” Lean. Shah and Ward (2007) suggest that every one of the ten dimensions of Lean is an important contributor. Therefore, none of the ten scales should be eliminated or missed.

In conclusion, the work by Shah and Ward (2007) has accomplished more than just the research objectives themselves, such as propose a definition, identify the dimensional
structure underlying Lean and construct of reliable and valid scales to measure it. What the study has critically contributed is to provide a seminal guideline and direction for future study and to orientate academics in a right path of researching. The study is greatly value adding to existing knowledge as it goes towards providing clarity on a consistent conceptual definition of Lean and identifying boundaries between Lean and its predecessors. A holistic, synthesized, well-rounded understanding of Lean, which provided by the study, is important and needed for further scientific research on the Lean phenomenon. The study also identifies key research problems, which need to be addressed. Additional to the theoretical value, the study provides managers scales to assist a delivery of a uniform, real Lean given its multi-dimensional nature.

2.2.3 A Combined Lean Six Sigma Approach

2.2.3.1 Overview
The prominence of Lean Six Sigma in the field is undeniable as many corporations are currently jointly implementing Lean and Six Sigma approaches (Shah et al., 2008). However, disappointingly, the growing importance of Lean Six Sigma is not yet reflected in the academic literature, which can generally be described as scarce and particularly thin in certain areas. Perhaps most notably, there has been little or no development of an academically rigorous theoretical model. This would reduce the existing confusion and uncertainty with respect to achieving uniformity across corporations with respect to implementation and deployment.

2.2.3.2 Definition
Mader, D.P. (2008) is the first peer reviewed article that describes the evolution of Lean Six Sigma in detail, demonstrating and analysing how the separate bodies of knowledge from Six Sigma and Lean integrated to form Lean Six Sigma. The author believes that the combination of Lean practices and Six Sigma methodology can lead to superior benefits, including process variation reduction and dramatic business improvement (Mader, 2008).

While definitions of Lean and Six Sigma as separate systems are prevalent in academic literature, there is currently a noticeable absence of any theoretically supported definitions of Lean Six Sigma as a distinct approach. Mader (2008) points out that while academics still describe Lean Six Sigma as the underlying key attributes of its two separate components, practitioners perceive Lean Six Sigma as existing in its own right, an integration of the two distinct models (Mader, 2008).
Brett, C and Queen, P. (2005) favour an analysis of Lean Six Sigma that emphasizes the application of Lean techniques to an existing Six Sigma environment, and an implication that Lean is subordinate to Six Sigma in terms of importance when the two are combined.

“Lean Six Sigma is the application of Lean techniques to increase speed and reduce waste and process complexity, while employing processes to improve quality and focus on the voice of the customer” (Brett and Queen, 2005, p.10).

Byrne, G., Lubowe, D. and Blitz, A. (2007) provide a definition and suggest that both methodologies are more or less equivalent in importance. However, their definition arguably places too much emphasis on the individual characteristics of the two methodologies rather than defining Lean Six Sigma as a synthesis of something that is new.

“Lean Six Sigma builds on the knowledge, methods and tools derived from decades of operational improvement research and implementation. Lean approaches focus on reducing cost through process optimization. Six Sigma is about meeting customer requirements and stakeholder expectations, and improving quality by measuring and eliminating defects. The Lean Six Sigma approach draws on the philosophies, principles and tools of both. However, Lean Six Sigma’s goal is growth, not just cost-cutting. Its aim is effectiveness, not just efficiency.” (Byrne et al., 2007, p.11).

While Brett and Queen (2005) and Proudlove, N., Moxham, C. and Boaden, R. (2008) favour the description about Lean Six Sigma that Lean practices embed within Six Sigma method, Hoerl, R. (2004) prefers describing Lean Six Sigma as an inclusion of Six-Sigma projects into a Lean context. However, Hoerl (2004) suggests that since it is providing an overall deployment and problem solving methodology, Six Sigma is an overarching/main major program containing Lean existing in subordination. Similarly, Bendell, T. (2006) supports that Lean is implemented in a subordinate role to a Six Sigma dominated organisational structure. Given the growing importance of Lean Six Sigma concept, Hoerl (2004) highlights a need for developing an integrated approach over identifying the significance of either initiative individually.

2.2.3.3 Combination and Compatibility

A review of literature related to the philosophy, practices, and techniques of Lean and Six Sigma suggest many similarities and important differences between the two approaches.

There are common characteristics between Lean system and Six Sigma program in reducing waste and improving process (Breyfogle et al., 2001 and Bendell, 2006). Firstly, both Six Sigma and Lean focus on use of statistical techniques and tools. Secondly, Lean practices focus on streamlining process, while Six Sigma targets focus on the identification and
elimination of root causes of problems. Lean emphasizes process flow and Six Sigma concentrates on process defects (George, 2002). Last but not least, Six Sigma and Lean both focus on performing improvements, mainly through projects. In summary, many researchers agree on the contention that there are more commonalities between Lean and Six Sigma tools and practices than differences.

However, it is important to note that academics also observe many differences in the two Lean and Six Sigma methodologies. Specifically, improvement projects in a Six Sigma program are conducted in a wide range of areas and at different levels of complexity in order to control and reduce variability of operational processes. Six Sigma is process focused. Lean, on the other hand, is a philosophy which is a lot about solving problems and making change. Lean is value stream focused with daily problem solving. It is a discipline that focuses on process speed and efficiency, or the flow, in order to increase customer value.

Second, both Six Sigma and Lean focus on the use of statistical techniques and tools but Lean only requires “good enough data” (McNaughton, 2010), in contrast to Six Sigma, which requires intensive validated data and use of sophisticated statistical analysis.

The most critical difference between Six Sigma and Lean is the nature of people involvement. To support Six Sigma activities an intensive employment of improvement specialists are trained and introduced into a Six Sigma management structure with various role titles often referred to as Black Belts, Master Black Belts, Green Belts and Project Champions. “Expert driven” is the key factor of Six Sigma implementation. Lean is “shop floor driven” and directly engages all workers involved in the process in contrast to a group of elite personnel organized under a belt system in Six Sigma. Lean is an employee centred methodology.

Table 2.1 summarises the differences between the two structures as exhibited in the Practical Problem Solving presentation by McNaughton (2010).
Table 2.1: A comparison between Lean and Six Sigma methodologies

<table>
<thead>
<tr>
<th>Lean</th>
<th>Six Sigma</th>
</tr>
</thead>
<tbody>
<tr>
<td>Go and See</td>
<td>Collect data</td>
</tr>
<tr>
<td>Good enough data</td>
<td>Intensive use of validated data</td>
</tr>
<tr>
<td>Visual data display</td>
<td>Sophisticated and statistical analysis</td>
</tr>
<tr>
<td>Shop floor driven</td>
<td>Expert driven</td>
</tr>
<tr>
<td>Daily Kaizen</td>
<td>Project focus</td>
</tr>
<tr>
<td>Value stream focus</td>
<td>Process focus</td>
</tr>
<tr>
<td>Action bias</td>
<td>Analysis bias</td>
</tr>
</tbody>
</table>

In short, Brett and Queen (2005) indicate the complementary nature of both disciplines. The authors argue that each methodology’s strengths help to address the other's weakness, thereby, creating a superior overall approach. For example, Lean, while enabling fast, accurate process flows, lacks the discipline for firms to managing improvement activities. Six Sigma addresses this weakness by providing a methodological framework DMAIC to guide improvers in the conduct of improvement projects. However, the study was conducted in the form of a single case. Findings are based on experience and not supported by validated evidence.

2.2.3.4 To What Extent Are the Two Approaches Compatible and How Can They Be Effectively Combined In One System?

Bendell, T. (2006) attempts to assess the compatibility of Lean and Six Sigma and proposes a holistic approach towards their combination. He highlights the fact that the idea of Lean Six Sigma as a distinct model is presently more of a philosophical concept than one that is derived in sound theory. He questions the compatibility of the two models and the effectiveness of the combination. The author also identifies the scarceness of current literature on a common model as well as a mutual method for Lean Six Sigma. Given this, he suggests that academics need to develop a holistic model and definition which builds in the excellences of both methodologies. Bendell, T. (2006) comments on the issue of assessing Lean Six Sigma compatibility and on the construction of an integrated model. The author does not solve this issue since his work is experience-based and is unsupported by a specific-quantitative investigation. The question of to what extent the two approaches are compatible and how they can be effectively combined into one system remains largely unanswered. This is a key area that requires further attention from researchers in the future.
2.2.3.5 Knowledge Gaps and Future Research Recommendations

The literature addressing the topic of Lean Six Sigma is thin across all areas. This is attributed to its contemporary nature. Most descriptive papers provided examples of significant results achieved either in the form of cost savings, process and product innovations, or as a direct result of the implementation of Lean Six Sigma. The literature suggests that Lean Six Sigma can produce results across a wide range of differing settings such as healthcare, financial services, and manufacturing. Given the growing importance of combining Lean and Six Sigma in practice, further research should investigate the performance improvement outcome of the combined approach.

Furthermore, academics should develop a holistic, conceptual model in which Six Sigma and Lean are combined and interact in creating a unique approach to organizational excellence, (Bendell, 2006; Zu et al., 2008). Such a model/framework can provide a guide in applying Lean Six Sigma as well as can provide scientific explanations for the phenomena in Lean Six Sigma implementation. Should there be many types of combinations depending on organizational context or can a universal model be developed? Future research should investigate how Lean and Six Sigma are integrated by organizations in the future; this would include the building and testing of new/proposed ways of applying the two (Hoerl, 2004). All of those issues are needed to be investigated and clarified in the future.

2.3 Stream 2: Organizational Performance Improvement Outcomes

2.3.1 Six Sigma and Performance Improvement Outcome

The academic literature and practitioners’ articles report massive financial savings and increased customer satisfaction as a result of Six Sigma projects. For example, Blakeslee, J. A. (1999) called Six Sigma a “high-performance, data-driven approach to analysing the root causes of business problems and solving them”. Harry, M.J. and Schroeder, R. (2000) described it as a “business process that allows companies to drastically improve their bottom line by designing and monitoring everyday business activities in ways that minimize waste and resources while increasing customer satisfaction” (p. vii). Though anecdotal evidence suggests a strong positive association of Six Sigma with firm performance, there has been no empirical research to confirm this relationship except for the recent articles published by Zu, X., Fredendall, L.D. and Douglas, T.J. (2008) and Shah, R., Chandrasekaran, A. and Linderman, K. (2008).

The authors established that Six Sigma practices complement the traditional quality management practices in improving performance. The research provided further evidence that an adoption of Quality Management practices and Six Sigma results in significant bottom-line benefits and improves product and service quality.

The work in Zu, et al. (2008) provides a basis for further research on Six Sigma in terms of many perspectives included in the survey instrument. In order to measure Six Sigma, Zu, X., Fredendall, L.D. and Douglas, T.J. (2008) developed a survey instrument to investigate how Six Sigma practices integrate with seven traditional quality management practices to generate firm performance improvement. While measures for traditional quality management practices and performance were obtained/selected from the relevant literature, new measures were developed to evaluate the three new Six Sigma practices. All of these scales and items were statistically tested for uni-dimensionality, reliability and validity in a large scale survey in the US. For measuring Six Sigma, seventy four items are included in ten scales (bundles), such as: Top management Support, Customer Relationship, Supplier Relationship, Workforce Management, Quality Information, Product/Service Design, Process Management, Six Sigma Role Structure, Six Sigma Structure Improvement Procedure, and Six Sigma Focus on Metrics. Zu et al. (2008) measures a firm performance outcome on two broad scales, quality performance and business performance. Quality performance includes seven items such as quality of product, process variability, delivery, cost of scrap and reworks, cycle time, customer satisfaction, equipment downtime. Business performance consists of sale, market share, unit cost of manufacturing, operating income, profit, return on assets. The scale and items developed in this study are more comprehensive than other measures observed in literature. These measurements are, therefore, believed to be able to greatly assist researchers to assess Six Sigma implementation in firms as well as to investigate how Six Sigma works with other improvement methods such as Lean.

Shah, R., Chandrasekaran, A. and Linderman, K. (2008) also carried out a large scale survey-based research on the implementation pattern of Lean and Six Sigma. While a comprehensive amount of data was collected from a sample of 2,511 plants, the study does not develop its own instrument, instead using data from the annual survey conducted by Penton Media Inc., publishers of Industry Week and other manufacturing related publications. The research fails to prove any linkage between a combined Lean Six Sigma approach and organizational performance outcomes. This can be attributed to the shortcoming of the research method, especially the lack of a proper survey instrument. However, the study does provide empirically validated evidence supporting that the group of plants implementing Six Sigma
had a higher performance than non-implementers. Their research ideas build upon prior research conducted by Schroeder, R. G., Linderman, K., Liedtke, C. and Choo, A. S. (2008). These authors hypothesized that firm performance will improve if the specific practices and parallel-meso organizational structure associated with Six Sigma are implemented. Shah et al. (2008) test the hypothesis and established that Six Sigma results in superior performance.

It can be seen that the two works by Zu, X., Fredendall, L.D. and Douglas, T.J. (2008) and Shah, R., Chandrasekaran, A. and Linderman, K. (2008) are both based on data gathered from firms located in the US with thousands of employees. However, the contexts in which firms operate can exert a certain level of impact on the performance improvement power of manufacturing improvement programs (Cua, et al., 2001). Given this, further investigation of the association of the programs with performance improvement in different organizational contexts is highly recommended for future studies.

Further, many quality-mature organizations with a quality track record, such as Ford, Honeywell, and American Express, have adopted Six Sigma and have reported enhanced business performance. According to Schroeder et al. (2008), Six Sigma performance benefits have an impact on multiple levels of the organization and can be categorized as customer-oriented metrics or financial metrics. Literature in this area has focused on studying the relationship between Six Sigma and company financial performance (Bisgaard and Freiesleben, 2004; Goh et al., 2003; Motwani et al. 2004). Goh et al. (2003) conducted an exploratory study on the impact of Six Sigma implementation on stock price performance. Motwani et al. (2004) propose a framework for evaluating the impact of the implementation on a firm performance in a case study at Dow Chemical. Bisgaard and Freiesleben (2004) propose a managerial accounting framework that can be modified to a quality context to evaluate the financial effects of Six Sigma. Meanwhile, Watson, G.H. (2000) describes how Six Sigma could lead to improvements in both shareholder value and customer satisfaction. Rucker, R. (2000) presents a business case of Citibank using Six Sigma to improve total customer satisfaction through defect and cycle time reduction.

In terms of measuring Six Sigma’s impact on organizational performance, most advanced Six Sigma organizations employ financial and accounting personnel that explicitly track the financial benefits of Six Sigma projects (Pyzdek, 2003). According to Schroeder et al. (2008), an extensive use of metrics and measurements in Six Sigma help ensure that outcomes are measurable. These include customer requirements, DPMOs, and process sigma measures.
Academics have also researched the other outcomes of Six Sigma implementation. It is claimed that Six Sigma brings competitive advantages to implementers (Harry, 1998 and De Mast, 2006). A positive association of Six Sigma with firm productivity has been investigated by Hekmatpanah et al. (2008). Tirthankar, D. (2003) uncovers a positive relationship between Six Sigma implementation and performance of supply chain management performance. At that time no other research had explored this issue. This research initiated an interesting topic for future study.

In summary, though these studies have greatly contributed to the existing knowledge as verifying the positive linkage of Six Sigma application and many facets of organizational performance improvement outcomes, the majority of the research claims results by either grounding in theory or exploring conceptually. Findings are based on anecdotal, un-tested assumption and single case study. These works still need to be tested empirically.

2.3.2 Lean and Performance Improvement Outcome

A review of literature reveals an abundance of evidence regarding the positive association of Lean practice implementation with performance outcomes. Not only anecdotal evidence provided by multiple opinion-based studies or single case research, but also empirical evidence given by plenty of survey-based studies, econometric studies on Lean, and performance. The literature confirms a consistent, widely held consensus among researchers that the implementation of a broad set of Lean practices is tied to a superior performance improvement.

The association of Lean practices with better organizational performance has been proven by Im and Lee (1989); Norris et al. (1994); Samson and Terziovski (1994); Flynn et al. (1995); White et al. (1999); McKone et al. (2001); Cua et al. (2001); Shah and Ward (2003); Wood et al. (2004); Li et al. (2005); Narasimhan et al. (2006) and Eroglu and Hofer (2010). Furthermore, many studies also suggest that financial performance is positively related to the implementation of Lean practices (Eroglu and Hofer, 2010).

The literature confirms that Lean enhances organizational performance in multiple facets, including manufacturing productivity, customer satisfaction, market performance, financial performance, competitiveness, and environmental performance. Lean enhances manufacturing productivity by reducing setup times and inventory (Eroglu and Hofer, 2010). Lean achieves customer satisfaction by increasing customer responsiveness and reducing customer lead time (Shah and Ward, 2003). Lower prices and quality products resulted by Lean implementation help to improve customer value and thus enhance market performance. Lean impacts to
financial performance by improving organizational processes, cost efficiencies (Fullerton et al., 2003) and labour and asset productivity increase (Kinney and Wempe, 2002). Lean is also believed to have a great impact on competitiveness (Womack et al., 1990). Environmental performance, a component of an organization’s corporate social performances is currently one of the research interests of Lean outcomes (Yang, Hong, and Modi, 2010).

Organizational performance is multifaceted. When researching performance outcomes of Lean, researchers view this under various aspects depending on their own research interest. The following is a further discussion on a number of papers on particular aspects of these performance outcomes.

Cua, K.O., McKone, K.E. and Schroeder, R.G. (2001) investigate the joint implementation of Total Quality Management (TQM), Just-in-Time (JIT) and Total Productive Maintenance (TPM) and the integrated effects of these programs on firm performance. A large body of previous empirical papers have looked at these in isolation. For example, studies on JIT practices by themselves have supported the positive association with higher performance improvement (Fullerton and McWatters, 2001). However, a few articles have tried to examine the joint implementation of TQM and JIT (Sriparavastu and Gupta, 1997). The study by McKone, K.E., Schroeder, R.G. and Cua, K.O., (2001) has tried to consider the three programs together but the findings focus on only TPM. The study by Cua et al. (2001) is based on a survey-based method with data gathered from 243 world class manufacturing (WCM) plants with more than 100 employees. The research provides empirical evidence successfully proving that the integration of TQM, JIT and TPM results in higher performance than either program by itself.

Recent papers research the impact of Lean practices on inventory outcome/turnover such as supplied by Mackelprang, A.W. and Nair, A. (2009); Demeter, K. and Matyusz, Z. (2010); and Eroglu and Hofer, (2010). The study by Eroglu, C. and Hofer, C. (2010) is believed to be the most interesting. While the research question is not new, the innovative is the attempt to investigate whether the continuous increase in inventory leanness could always lead to superior firm performance. This is a five-year long, massively large scale-survey based study with data consisting of 7,804 firm-year observations from 1,600 firms in 54 industries in the US. A post-hoc analysis was used to reveal that while the significance and shape of the relationship varies across industries, in most of cases this relationship of inventory leanness and performance is concave. This finding suggests that there is an optimum level of inventory leanness beyond which firm performance deteriorates, which means in particular industries, leaner inventory is not always better.
Yang, M., Hong, P. and Modi, S.B. (2010) research the financial performance outcomes of Lean by investigating the integrated impact of Lean adoption and environmental management practices on business performance outcomes. The study suggests that while environmental management practices alone negatively impact financial performance, improved environmental performance reduces the negative impact of environmental management practices on market and financial performance.

In summary, the positive association of Lean practices with organizational improvement performance in multiple facets has been largely proven by the literature. The studies are mainly focused on large firm. However, the level of benefit resulting from the practices can vary across different contexts, such as firm size (Cua, et al. 2001; Zu, et al, 2008). Given this point, a closer investigation of the issue in different contexts is recommended for future research.

2.3.3 Lean Six Sigma and Performance Improvement Outcome

While academics are still in the exploratory stage of uncovering the definitional and methodological issues related to the integration of Lean system and Six Sigma program, published articles provide many stories regarding the positive linkage of the implementation of a combined Lean-Six Sigma approach and enhanced performance outcomes (Hahn et al., 2000; Basu, 2001; Antony et al., 2003; McClenahen, 2004). Several papers discuss some of the advanced features of Lean Six Sigma in a practical sense by describing several corporate examples of success (Byrne et al., 2007). Brett and Queen (2005) and Alukal (2006) believe that the combination that comprises Lean Six Sigma can lead to superior results rather than the utilization of either on its own given the complementary nature of the two models. Gordon, D.K. (2007) supports this proposition and suggests organizations should implement both to achieve organizational excellence. While these are all anecdotal, based on experience and not supported by a specific quantitative investigation, the idea that Lean Six Sigma can be associated with improved organizational performance is popular and widely accepted in the field.

A closer inspection of the literature reveals there has been no empirical research to confirm this relationship. The recent article published by Shah, R., Chandrasekaran, A. and Linderman, K. (2008) tried to examine the relationship by a large scale survey research with a data sample of 2511 plants. This study is also viewed as a first empirical research attempting to empirically investigate the systematic patterns of Lean practice implementation with Six Sigma implementation. The research findings reveal that implementation of any practice from
a broad set of Lean practices improves the likelihood of implementing Six Sigma. It indicates that there is an association between the implementation of Six Sigma and an individual Lean practice. Given this, the authors deductively suggest that Lean and Six Sigma should be viewed as complementary to one another.

With regards to the issue of the performance outcome, the study suggests that Lean has a greater impact on performance improvement under a Six Sigma basis. The authors argue that Lean benefits from the structured deployment effort resulting from Six Sigma implementation. Six Sigma provides a conducive environment for Lean deployment through the existing resources given by Six Sigma deployment such as improvement specialists, training, improvement method, hierarchical management structure and strategy. The study tried to investigate whether or not Lean practices result in a superior performance improvement in Six Sigma implementers than in non-implmenter firms. While the research does not successfully prove this, it establishes that Six Sigma implementation is significantly tied to a superior performance as verifying that group of plants implementing Six Sigma has a higher performance than non-implementers.

In summary, along with prevailing implementation of Lean Six Sigma in large corporations today, there is abundance of anecdotal evidence supporting the joint implementation of Lean and Six Sigma. Despite this, the academic literature is still lacking an empirical investigation of the association of Lean Six Sigma with firm performance outcome. There are still questions as the exact extent and nature of the organizational performance improvement benefits that can be achieved. Whether combined Lean-Six Sigma approach results in a superior performance outcome, or leads to significant performance benefits that exceed isolated implementation is not yet apparent. Given the growing importance of combining Lean and Six Sigma in practice and the existing research gap on this topic in the literature, providing an insight into the relationship between Lean Six Sigma implementation and firm performance improvement has been put forward as a key issue that needs to be addressed.
2.4 Conclusion

The review presented in this chapter has covered a large body of the existing literature related to the topic of Lean and Six Sigma. This extensive review has been conducted by tracking two broad streams of knowledge: Methodology – Outcome. While plenty of salient points as well as research gaps have been found and recommended, this section simply re-states some relevant striking points which help establish a research foundation given the proposed research interest – combined Lean Six Sigma program and its outcome.

First, the review of literature firmly supports the positive associations of either Six Sigma or Lean standing by itself with superior performance improvement.

Second, despite the growing importance and the increasing prevalence of the joint application of Lean and Six Sigma in the field, related literature is still scarce and particularly thin on the narrow field about the model's outcome. In terms of definitional and methodological issues, there has been a little development of an academically rigorous theoretical model for the integration. Similarly, studies on the linkage of Lean Six Sigma joint implementation and performance outcomes have just focused majorly on anecdotal evidence, opinion, experience-based papers and single case research. The review of literature reveals no empirical evidence proving this positive relationship so far. To address the shortcoming of the method used by prior research, a conducting of survey-based study is justified and imperative.

Third, there are relatively few papers that have recently tried to examine the joint implementation of Lean and Six Sigma. While measuring the combined approaches outcomes, the finding focuses only on outcome of either model by itself, for instance the work by Shah et al. (2008). Researchers have just explored only part of the relationship. Do firms adopting Lean Six Sigma have a better performance improvement than those firms who are non-implementers? Does the combined Lean Six Sigma result in superior performance improvement? These questions are still largely unanswered.

Furthermore, a closer inspection into the relationship indicates that the question of whether a combined Lean-Six Sigma approach can generate superior results than the utilization of either on a standalone basis has yet to be properly investigated. While this idea has been put forward there is a need for verifying this issue empirically in the future. A comparison of performance improvement outcomes between the combined approach and the standalone models should be able the address this gap.
Last but not least, the review of literature on manufacturing programs indicates that a large body of existing empirical papers have mainly focused on large size, multinational corporations. Key findings regarding Lean and Six Sigma are majorly derived from studies based on data gathered from firms in the US with thousands of employees (Cua et al., 2001; Shah and Ward, 2003; Zu et. al, 2008; Eroglu and Hofer, 2010). The literature provides little insight on the phenomenon of business improvement programs, particularly Six Sigma, when they are implemented in the SME context. On another hand, it is argued that contexts in which firms operate possibly affect the effectiveness of manufacturing improvement programs (Cua et al., 2001; Zu et. al, 2008; Parast, 2010). Given this, practitioners may question whether what has been found to be true for large firms can be true for smaller settings, specifically whether Lean, Six Sigma and the combined Lean Six Sigma can generate results analogously across organizational cultures and contexts. In short, with respect to SMEs, the implementation of either Lean or Six Sigma by themselves or Lean Six Sigma as a combination, regarding firm performance improvement, is still largely unexamined.

In summary, given the research gaps/problems that have been identified, two research question are derived and put forward below and were addressed by this research:

**Research question 1**: Does the combination of Lean and Six Sigma result in superior performance than when Six Sigma model stands on its own?

**Research question 2**: Does the combination of Lean and Six Sigma result in superior performance than when Lean model stands on its own?
Chapter 3
Research Methodology

The aim of this study is to develop insights into the relationship between Lean, Six Sigma and Lean Six Sigma implementation and organizational performance improvement outcomes. Specifically, the two objectives of the research that have been established in the previous chapter are:

Research question 1: Does the combination of Lean and Six Sigma result in superior performance than when Six Sigma model stands on its own?

Research question 2: Does the combination of Lean and Six Sigma result in superior performance than when Lean model stands on its own?

![Figure 3.1: Research proposed framework](image-url)
The need identified by the review of the literature is to address the unanswered question of whether combining Lean and Six Sigma can lead to superior results than the utilization of either on a standalone basis. Research Questions 1 and 2 are designed to empirically test these issues. The study will measure the scale of Lean and Six Sigma implementation and the level of performance outcomes in various firms which have been identified as adopting Six Sigma, Lean, and Lean Six Sigma in the New Zealand context. Organizational performance is multifaceted. The literature has identified and validated a number of dimensions of organizational performance enhancement which are influenced by the implementation of Lean and Six Sigma. These include quality, business (including financial and market), inventory, environmental performance, working conditions, competitiveness, and customer satisfaction. Researchers investigate various aspects of the outcomes, based on their own research interests. The study is situated within the manufacturing context and focuses on the two dimensions: Quality and Business Performance (See Fig. 3.1). These adequately reflect performance outcomes of participating manufacturing firms as indicated by their use in Zu et al. (2008).

This chapter will:

Identify the research approach which is justified given the foundation and reasons established in the literature review.

Identify the methodology for data gathering including development of a research survey instrument and the approach used to collect data from the target sample.

Describe the data collection results.

In alignment with these objectives, this chapter is structured in four sections:

- Research Approach
- Development of Survey Instrument
- Data Collection Method
- Description of The Data Collection Result
3.1 Research approach

It can be argued that a multi-case study approach could also be viable as it overcomes shortcomings of previous papers which have focused on a single organization. It enables the researcher to gather rich data and affords a direct comparison and in-depth understanding about phenomenon associated with implementations of Lean and Six Sigma between different firms surveyed (Nonthaleerak and Hendry, 2008). The multi-case approach is better suited to studies dedicated to a qualitative analysis. Given that the objective of this study is to provide a quantitative investigation regarding the research questions, a survey methodology was chosen. Justification for this research approach rests on a number of factors, including the purpose of the study, the data requirements and the extent of research.

With respect to purpose of the study, a need for empirical research which can provide validated evidence clarifying the linkage of Lean Six Sigma programs and performance outcomes has been established by the review of literature. A review of literature indicates that prior studies on the relationship have been focused mainly on anecdotal evidence based on un-tested assumptions and single case success stories. Therefore, survey based research is justified to address the empirical and sample size shortcomings of the previous research.

With regards to the data requirements, there is a need to gather a considerable amount of specific, in-depth, in-orientation, comparable and computable data on the nature and extent of the key elements of the research - Lean, Six Sigma and the combined implementation. A survey methodology was chosen for the primary data collection.

In terms of the extent of the research, an adoption of a survey approach is possible given the reasonable amount of time for completion of a master’s thesis. However, the intent is not a large scale survey study with a sample of hundreds of firms, which requires a long time period of data collection. The target sample size is around thirty, which is believed to be comprehensive enough to adopt certain statistical analysis techniques and to provide a validated conclusion.

The steps of data development are shown in the table below.
Table 3.1: Steps of data development

<table>
<thead>
<tr>
<th>Steps</th>
<th>Description of steps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developing survey instrument</td>
<td>An extensive Literature review For Six Sigma - Zu et al. (2008) For Lean - Shah and Ward (2007) The instruments have been tested for validity and reliability by these authors.</td>
</tr>
<tr>
<td>Approaching consultants and Government initiatives</td>
<td>Identifying consulting firms as key players in the area of business performance improvement. Approaching these consulting firms and several Government initiatives to ask if they can recommend possible participants for the project.</td>
</tr>
<tr>
<td>Surveying, collecting data in firms</td>
<td>Using mail surveys, either surface mail or email, to the relevant, recommended personnel or responsible people for the implementations of Lean, Six Sigma or Lean Six Sigma in firms.</td>
</tr>
<tr>
<td>Describing data collection results</td>
<td>Describing the outcomes of data collection. Qualitatively describing the research data-base.</td>
</tr>
</tbody>
</table>

3.2 Development of the Survey Instrument

3.2.1 Measurement for Lean System and Six Sigma Program

A survey instrument was developed and employed to measure the extent of Lean and Six Sigma implementations in firms and to gauge the nature and extent of these implementations’ effects on organizational performance.

Given the need to obtain a well-validated questionnaire as well as insuring that the questions accomplish the research’s objectives, the survey instrument was adapted from instruments available in the literature. Measures for each construct, therefore, are obtained from an extensive review of the relevant literature. Specifically, for measuring Lean system, content was based on the instrument developed by Shah, R. and Ward, T.P. (2007). For Six Sigma implementation, the research follows the work in Zu, X., Fredendall, L.D. and Douglas, T.J. (2008).

The review of literature indicates that Lean systems consist of multiple underlying components and Lean systems manifest themselves in many dimensions and facets. Practical observation indicates that Lean implementation in industries is structured in in various states of progress depending on the level of application. Despite this, little research has been done related to measuring Lean. Shah, R. and Ward, T.P. (2007) conducted research to identify the
dimensional structure underlying Lean system and to develop scales to represent it. The study empirically develops an operational measurement in a set of forty-eight items included in ten scales, reflecting a comprehensive set of Lean practices. These scales cover the ten distinct dimensions of Lean system, including: Supplier Feedback, Just-in-Time Delivery by Suppliers, Supplier Development, Customer Involvement, Pull, Continuous Flow, Set up, Total Preventive Maintenance, Statistical Process Control, and Employee Involvement. The scales and items developed in this study have been rigorously validated by using a two-stage method and data collected by a large-scale survey in 280 manufacturing firms. Measures and items have been tested for model fit and uni-dimensionality and discriminant validity. Therefore, the instrument is believed reliable and valid.

The choice of the Shah, R. and Ward, T.P. (2007) instrument will allow the researcher to assess the state of Lean implementation in firms and to test hypotheses about relationships between Lean and other firm characteristics that affect firm performance.

With regards to measuring Six Sigma, Zu, X., Fredendall, L.D. and Douglas, T.J. (2008) developed a survey instrument to investigate how Six Sigma practices integrate with seven traditional quality management practices to generate firm performance improvement. While measures for traditional quality management practices and performance were obtained/selected from the relevant literature, new measures were developed to evaluate the three new Six Sigma practices. All of these scales and items were statistically tested for uni-dimensionality, reliability and validity in a large scale survey in the US. Seventy four items included in ten scales were identified: Top Management Support, Customer Relationship, Supplier Relationship, Workforce Management, Quality Information, Product/Service Design, Process Management, Six Sigma Role Structure, Six Sigma Structure Improvement Procedure, and Six Sigma Focus on Metrics. The scale and items developed in this study are more comprehensive and empirically validated than other measures observed in the existing literature in the topic. Further, they allow an accurate assessment of state of Six Sigma implementation in firms as well as greatly assist an investigation of how Six Sigma works with other improvement methods such as Lean. They are, therefore, believed to be a justified choice.
3.2.2 Measurement for Performance Outcome

As presented previously, the current research investigates firm performance outcomes under two dimensions, quality performance and business performance. Measures for performance were adapted from two scales included in thirteen items developed by Zu, X., Fredendall, L.D. and Douglas, T.J. (2008). There are several reasons for this choice. Perhaps most importantly, the scales and items provided by the study are more comprehensive and empirically validated than other measures observed in the existing literature on manufacturing performance.

While there are many approaches to quality performance, perhaps the most predominant approach that can be identified and validated in the literature is to use cost, quality, delivery and flexibility as the four basis indicators of manufacturing performance (Flynn et al., 1995; Samson and Terziovski, 1999; Cua et al., 2001; McKone et al., 2001; Kaynak, 2003; Narasimhan et al., 2006; Shah and Ward, 2007; Zu et al., 2008). Zu et al. (2008) measure quality performance using seven items, including quality of product, process variability, delivery, cost of scrap and rework, cycle time, customer satisfaction, and equipment downtime.

Business performance is measured by looking at firm market performance and financial performance. Specifically, for this measure Zu et al. (2008) employ six items, which are sale, market share, unit cost of manufacturing, operating income, profit, and return on assets.

Nine other items were employed to measuring contextual information about the firms interviewed, firm size, industry, duration of adoptions of Lean, Six Sigma, number of projects, and respondent’s details. The entire instrument consists of a total 144 items. Appendix A provides the survey instrument used in this study.

3.2.3 Likert Type Scales and Pilot Questionnaire

Items were measured on 7-point Likert's scales with end points of “strongly disagree” and “strongly agree”. When measuring Lean and Six Sigma, respondents were asked to rate the extent to which they agree or disagree with statements that present the current status of implementation in their firms. In terms of firm performance, respondents were asked to rate the extent to which they agree or disagree with statements that reflect the degree of change in performance in the firms over the preceding three years.

A pilot questionnaire was reviewed by a number of university lecturers and graduate students for comprehensibility and accuracy. Instruments were double checked to confirm that they
met certain requirements, including how well each scale captured the construct that it was intended to measure, whether the wording of each item was clear and understandable and whether the format was user friendly. Using the feedback, the instrument was further revised to ensure that the questionnaire was comprehensive, understandable and valid from these experts’ perspective.

3.3 Data Collection Method

3.3.1 Approach

The research unit is the individual firm. The target sample is of New Zealand manufacturing firms who have been identified as implementing Lean and/or Six Sigma. Firms with greater experience in Six Sigma and Lean are preferred candidates. As Lean Six Sigma is a relatively new method, the time-frames for performance measures was set to three years in the questionnaire. Given this short time frame it is possible that the outcomes of Lean Six Sigma implementation may not be fully revealed in the reported performance. This study examines the influence of Lean Six Sigma implementation on performance by obtaining as large a sample as possible of firms with experience with Lean/Six Sigma.

Target respondents include firm managers and persons who are responsible for the implementation of the programs in firms, project managers, operations managers, quality managers, Six Sigma Master Black Belts and Black Belts.

The intent was to mail surveys to possible participants using either surface mail or email.

3.3.2 How To Identify, Select and Get In Contact With Firms?

To identify Six Sigma/Lean and Lean Six Sigma implementers in the New Zealand market several consulting firms were identified as key players in the area of business performance improvement. These consulting firms were approached directly and asked for recommended research sites. The consultants either contacted the firm on behalf of the study or provided email addresses of key personnel.

Assistance was also provided by senior managers from New Zealand Government funded initiatives such as CMI Consortium (Competitive Manufacturing Initiative) and New Zealand Trade and Enterprise (NZTE). These initiatives provide funding to firms implementing quality management systems in the interests of improving the competitiveness of New Zealand business. They could provide information on implementers in the New Zealand market.
3.4 Expected and Unexpected Outcomes of Data Collection

During the data collection stage of the research relationships were established with a significant number of various consulting firms across the country such as Improve Group, INTENT Group, Productivity Solutions, Simply Lean, Improvement Direct, CBI International, Go Solutions, Lean 6 Sigma, and KAIZEN Institute,. Their support was invaluable in approaching potential respondents. Through the co-operation of these consulting firms, it was possible to considerably increase the number of participant firms involved in the research and therefore strengthen the quality and validity of research findings.

The total time spent on the data collection phase was six weeks. Forty four firms were asked to participate in the study. The response rate was 75%, which is very high in comparison to typical response rates for a mail survey. This unexpectedly high rate was attributed to the relevance of the research to the business community. Participants were made aware of the confidential and anonymous nature of the study, and that they would receive a report of research findings if they so wished. The fact that each firm was contacted personally may have also improved the response rate.

An even more remarkable outcome occurred when firms who had not been approached contacted the researcher and asked to be involved in the study. They had heard about this either from their consultant or through other contacts and thought the project had some potential value. They wished to be involved and were keen to hear the results.

The excellent response rate and the strong interest and willingness to support the study from the business community were unexpected outcomes of this research. This indicates that New Zealand businesses are very interested in the application of modern quality and business improvement initiatives to increase business competence and competitiveness. The interest expressed by the business community provides a justification for the effort in conducting this research.

3.5 Description of the Data Collection Results

The study involves thirty three manufacturing firms in New Zealand. This sample, while a modest size, is appropriately large enough for conducting certain statistical data analysis techniques. Participant firms were from a diverse range of industries. The sample covers seven out of the nine categories of the NZSIC codes. Distribution of the respondents according to the NZSIC codes is shown in Table 3.2 below.
Table 3.2: Distribution of the respondents according to the NZSIC codes

<table>
<thead>
<tr>
<th>Category of NZSIC classification</th>
<th>Distribution (n=33 firms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food, Beverage and Tobacco</td>
<td>27%</td>
</tr>
<tr>
<td>Textile, Clothing, Footwear and Leather</td>
<td>3%</td>
</tr>
<tr>
<td>Wood and Paper Products</td>
<td>18%</td>
</tr>
<tr>
<td>Printing, Publishing and Recorded Media</td>
<td>3%</td>
</tr>
<tr>
<td>Chemicals, petroleum, Rubber, Plastics and Associated Products</td>
<td>6%</td>
</tr>
<tr>
<td>Non-metallic Mineral Manufacturing e.g. Glass, Ceramics, Cement etc.</td>
<td>0%</td>
</tr>
<tr>
<td>Metal Product Manufacturing</td>
<td>27%</td>
</tr>
<tr>
<td>Machinery, Equipment and Electronics</td>
<td>0%</td>
</tr>
<tr>
<td>Other</td>
<td>16%</td>
</tr>
</tbody>
</table>

In this study SMEs are defined as those having up to 500 employees. Ordinarily New Zealand SMEs are defined as those firms with 19 employees or less. The international standard for an SME was applied to the New Zealand manufacturing firms surveyed so that the research results could be applied to the international context. Surveys indicated half of the companies involved into the study have more than 100 employees, and most of these firms (82%) are smaller than 500 staff. Distribution of the respondents according to firm size is provided in Figure 3.2 and 3.3 below.

![Figure 3.2: Distribution of the respondents according to firm size (n=33 firms)](image)
Most of the participant firms have less than three year experience in Six Sigma and Lean.

The respondents were in upper-management positions in their firms. Respondent titles/expertise ranged from CEO and Managing Director to General Manager, Six Sigma Master Black Belt, Lean Champion, Six Sigma Deployment Manager, and Project Leader. Given the high profile of the participants, feedback provided by them is considered significant and further enhances the research validity.
Chapter 4
Data and Analysis

This chapter describes the data collected from surveying in the field, and presents in detail the approaches which were used to analyze the data in order to accomplish the research objectives. The content includes justification for performing the analysis as well as presentation of the results of the analysis. Each choice, decision, option made regarding the use of the data or technique employed during the analysis is justified given its purpose as well as its theoretical background. Technical results produced by the analysis are interpreted in an economic sense, and displayed in an accessible presentation.

The study aims to test the linkages between standalone Lean, Six Sigma, combined Lean Six Sigma program, and performance outcomes. The survey attempted to collect data from three types of implementers; standalone Lean, standalone Six Sigma, and combined Lean Six Sigma implementers. The research did not receive any feedback from firms adopting Six Sigma in isolation. Therefore, the available data for the analysis is obtained only from Lean and Lean Six Sigma implementers. The lack of data on the Six Sigma standalone model does not allow the study to conduct any analysis regarding the association of Six Sigma by itself with firm performance. Consequently, tests conducted in the analysis are only on Lean and Lean Six Sigma.

The primary goal of this research is to determine whether or not there is a significant difference in the performance levels of the combined Lean Six Sigma implementer group, and the standalone Lean implementer group. Given this, multivariate data analysis technique was used to discover the difference between the two groups of implementers (Hair et al., 2010). Specifically, an independent sample t-test was employed to assess whether there is a performance score difference between implementers.

Furthermore, the research aims to examine of the effects of quality management practices on firm performance and provide an understanding of the relative changes in organizational performance attributable to the implementation of these practices. To this end, a multiple regression method was employed to assess the strength and nature of the relationship between each of a set of quality management practices and performance.
This chapter is outlined as below:

- Data for Analysis
- Summaries of Data
- Independent Samples T-test
- T-test for Large Size Firms
- Multiple Regression Method
4.1 Data for Analysis

Data used for the analysis exists in the form of a score, either as an item score (rated for one item) or a scale score, being an average of multiple scores marked for items included in that scale.

Items were measured on 7-point Likert scales and the value of score ranges from one to seven. Item score is an integer ranging from one to seven while scale score is a real number ranging from one to seven.

To measure the level of performance in firms, respondents were asked to rate the extent to which they agree or disagree with statements that reflect the degree of change in performance in the firms. This measurement includes two scales; quality performance scale and business performance scale. The quality performance scale consists of seven items. The business performance scale consists of six items. Therefore, data used for assessing quality performance is a scale score which is an average of seven scores ranked for the seven items included in this scale. Similarly, data used for assessing business performance is an average of six scores marked for seven included items.

To measure Lean and Six Sigma, respondents were asked to rate the extent to which they agree or disagree with statements that present the current status of implementation of quality management practices in their firms. Each practice is evaluated by a scale which includes a number of items. Data used for examining the impact of each practice on performance is a scale score which is calculated by averaging all scores marked for items consisted in that scale.

As discussed previously, the study expected to obtain data from three types of implementers; standalone Lean, standalone Six Sigma, and combined Lean Six Sigma implementers. However, the research did not receive any feedback from firms adopting Six Sigma in isolation due to the current scarcity of firms adopting Six Sigma in the New Zealand market. The lack of data on the Six Sigma standalone model leaves the Research Question 1 of the study untested. The available data for the analysis is only from Lean and Lean Six Sigma implementers. Tests conducted in the analysis are only on Lean and Lean Six Sigma.

4.2 Summaries of Data

A number of summary statistics such as mean, minimum, maximum, and standard deviation are calculated and used to create informative graphical displays of data (histograms). These
serve to describe the general distributional properties of the data and to identify the patterns of observations that may affect the later analysis.

4.2.1 Data Summary for Quality Performance

As presented previously, quality performance is a scale measuring performance of firms in seven categories: quality of product, process variability, delivery, cost of scrap and rework, cycle time, customer satisfaction, and equipment downtime. Below are the descriptive statistics on quality performance for the two groups of firms.

Table 4.1: Descriptive Statistics of Quality Performance

<table>
<thead>
<tr>
<th>Implementer</th>
<th>Mean</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Std. deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lean</td>
<td>5.4379</td>
<td>4.00</td>
<td>6.86</td>
<td>.84635</td>
</tr>
<tr>
<td>Lean Six Sigma</td>
<td>5.1980</td>
<td>4.43</td>
<td>6.71</td>
<td>.92278</td>
</tr>
</tbody>
</table>

Note: Seven point Likert scale

The figures from Table 4.1 show several features of quality performance in these firms. Standalone Lean implementers have an average quality performance score of 5.44, while Lean Six Sigma implementers have an average of 5.20. The statistics suggest that Lean when used on its own yields a higher level of quality performance than Lean Six Sigma.

Figure 4.1: Histogram of Quality performance
A histogram is a graphical representation of the frequency of various data categories. The categories in Figure 4.1 are quality performance scores. Figure 4.1 shows that the data for quality performance is a symmetric distribution.

### 4.2.2 Data Summary for Business Performance

Business performance is a scale comprised of six items; sale, market share, unit cost of manufacturing, operating income, profit, and return on assets. Table 4.2 gives the descriptive statistics for the business performance of the two groups of firms; standalone Lean by itself and Lean Six Sigma implementers.

#### Table 4.2: Descriptive Statistics of Business Performance

<table>
<thead>
<tr>
<th>Implementer</th>
<th>Mean</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Std. deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lean</td>
<td>5.0836</td>
<td>3.17</td>
<td>7.00</td>
<td>1.0177</td>
</tr>
<tr>
<td>Lean Six Sigma</td>
<td>4.2340</td>
<td>3.17</td>
<td>6.00</td>
<td>1.0575</td>
</tr>
</tbody>
</table>

Note: Seven point Likert scale

Standalone Lean implementers have an average business performance score of 5.08, while Lean Six Sigma implementers average 4.23. The difference in averages suggests that standalone Lean implementers have a higher level of business performance than those firms adopting Lean Six Sigma.
Figure 4.2 shows that the data for business performance is a symmetric distribution.

### 4.2.3 Data Summary for the Overall Performance Score

Overall performance is a scale that combines business performance and quality performance and is intended to provide an overall assessment of firm performance. Therefore it includes the thirteen items in those scales; quality of product, process variability, delivery, cost of scrap and rework, cycle time, customer satisfaction, equipment downtime, sale, market share, unit cost of manufacturing, operating income, profit, and return on assets. Table 4.3 provides the descriptive statistics for overall performance for the two groups of firms.

#### Table 4.3: Descriptive Statistics of Overall Performance

<table>
<thead>
<tr>
<th>Implementer</th>
<th>Mean</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Std. deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lean</td>
<td>5.2746</td>
<td>3.69</td>
<td>6.62</td>
<td>.8071</td>
</tr>
<tr>
<td>Lean Six Sigma</td>
<td>4.7540</td>
<td>3.85</td>
<td>6.38</td>
<td>.9676</td>
</tr>
</tbody>
</table>

Note: Seven point Likert scale
The figures from Table 4.3 show that standalone Lean implementers have a mean score of 5.27 for overall performance, while Lean Six Sigma implementers have a mean of 4.23. These statistics suggest that Lean implementers enjoy greater overall performance than those who have adopted Lean Six Sigma.

![Figure 4.3: Histogram of Overall performance](image)

Figure 4.3 is a histogram suggests that the overall performance scale has a symmetric distribution.

### 4.3 Independent Samples T-test

Given the need to test whether there is a difference in the performance scores in the two different groups of implementers, an independent samples t-test was conducted (Hair, et al., 2010). A t-test is used to test the null hypothesis that the population mean in each of the two groups is equal.

The statistics in Table 4.4 show that while there is no evidence of a difference in quality performance and overall performance, a significant difference (90% of confidence) exists in business performance outcomes of the two groups. While there are a number of significance levels in statistics, such as 1%, 5%, 10%, and 15%, this research chooses the degree of 10%. Alternatively, if a p-value is less than 0.1 the test is considered statistically significant.

In summary, while the t-test shows that a combination of Six Sigma and Lean does not deliver superior quality performance over standalone Lean implementers it does suggest that
Lean yields a significantly higher level of business performance than the Lean-Six Sigma model.

Table 4.4: Independent Samples T-test Output for Whole Sample

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Overall means</th>
<th>Means</th>
<th>T-test</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lean</td>
<td>Lean Six Sigma</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quality performance</td>
<td>5.4015</td>
<td>5.4379</td>
<td>.577</td>
<td>.568</td>
</tr>
<tr>
<td>Business performance</td>
<td>4.9548</td>
<td>5.0836</td>
<td>1.711</td>
<td>.097</td>
</tr>
<tr>
<td>Overall performance</td>
<td>5.1958</td>
<td>5.2746</td>
<td>1.293</td>
<td>.206</td>
</tr>
</tbody>
</table>

Note: Seven point Likert scale
T-test significant (2-tail) level is 10 percent

4.4 Independent Samples T-test for Large Size Firms

A review of the literature shows a consensus among academics and practitioners that firms with large size are more likely to achieve greater success with a Lean Six Sigma model than in smaller firms. If this belief holds true in practice a t-test on the data for firm size may be used to assess the performance and quality impact of implementation patterns in large firms versus small firms.

The original data set was split into groups based on firm size. Large firms were classified as those with more than 100 employees and small firms were those with fewer than 100. Given that all the Lean Six Sigma implementers in the data set have over one hundred employees, a t-test cannot be conducted for smaller firms.

Table 4.5 presents the results for the t-test for large firm size. Large firms show greater differences in performance outcomes between the two groups, across all scales; quality, business and overall performance. The test shows there is a significant difference in business performance (97% of confidence). In terms of the overall performance outcome, Lean also generates a difference (97% of confidence).

In summary, the t-test for large firms shows greater differences in performance outcomes between Lean and Lean Six Sigma than when there is no filter for size and therefore indicates that the impact of these two programs on performance improvement are greater in large firms than in general. This result supports the consensus among academics and practitioners in the field.
### Table 4.5: Independent Samples T-test Output For Large Size Firms

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<th>Measurements</th>
<th>Overall means</th>
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<th>T-test</th>
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Note: Seven point Likert scale  
T-test significant (2-tail) level is 10 percent

#### 4.5 Multiple Linear Regression Analysis

One of the objectives of this research was to investigate the relative changes in the organizational performance that can be attributed to the implementation of Lean and/or Six Sigma. Given this, the study examined the impact of implementations of Lean and Six Sigma practices on performance outcomes. Multiple linear regression was employed to access the strength and nature of the relationship between each of a set of practices and performance outcomes.

#### 4.5.1 Lean Practices and Organizational Performance

The data set for this analysis is a set of scale scores marked for items measuring the implementation of ten Lean practices in firms. Each scale score represents an explanatory variable while each performance scale is a dependent variable in a regression model. Since there are three scale measuring performance, quality, business performance, three regression models are developed.

A matrix of correlations was computed to identify any correlation existing between the explanatory variables (Lean practices) and dependent variables (performance). The explanatory variables may be also correlated among themselves. The output in table 4.6 provides Pearson correlations between each pair of variables and associated significance tests.

Quality performance is strongly positively correlated with Supplier Feedback, JIT Delivery by Supplier, Customer Involvement, Set up time reduction, SPC, Employee Involvement, and TPM.

Business performance is strongly positively correlated with Supplier Feedback, JIT Delivery by Supplier, and TPM. A number of positive correlations are also found between Business performance and Supplier Development, Customer Involvement, and Employee Involvement.
Overall performance is strongly positively correlated with Supplier Feedback, JIT Delivery by Supplier, Customer Involvement, Employee Involvement, and TPM. The figures suggest that overall performance also has positive correlation with Supplier Development, Set up Time Reduction, and SPC.

It can be seen that the dependent variables are generally correlated with the explanatory variables. These correlations should result in useful regression models.

The multiple regression results in Table 4.7 indicate that quality performance model is significant at a level of 5 percent while the other two models for business and overall are significant at 10 percent level. Figures for $R^2$ are relatively high. These results indicate that the regression models can explain 63%, 48%, 60% of variance in quality, business and overall performance respectively.

In an attempt to identify which factor (variable) is the most important predictor on performance out of all considered factors, an automatic variable selection procedures was conducted. In this case, forward selection was used.

The results presented in Table 4.8 and 4.9 suggest that JIT Delivery by Supplier and Customer Involvement are the two important factors which affect quality performance in firms while Supplier Feedback is the greatest effect on business performance. The results in Table 4.10 indicate that Supplier Feedback and TPM are the two most important factors impacting on overall performance.
### Table 4.6: Pearson Correlation Matrix

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**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
Table 4.7: Summary of Multiple Regression Results

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### Table 4.8: Automatic Forward Variable Selection Output

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a. Predictors: (Constant), JIT delivery by supplier  
b. Predictors: (Constant), JIT delivery by supplier, Customer involvement  
c. Dependent Variable: Quality performance

### Table 4.9: Automatic Forward Variable Selection Output

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a. Predictors: (Constant), Supplier feedback  
b. Dependent Variable: Business performance

### Table 4.10: Automatic Forward Variable Selection Output

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a. Predictors: (Constant), Supplier feedback  
b. Predictors: (Constant), Supplier feedback, TPM  
c. Dependent Variable: Overall performance
4.5.2 Six Sigma Practices and Organizational Performance

The data set for this analysis is a set of scale scores marked for items measuring the implementation of ten Six Sigma practices in firms. Each scale score represents an explanatory variable while each performance scale is a dependent variable in a regression model. Since there are three scales measuring quality, business and overall performance, three regression models were developed.

A correlation matrix has been computed to identify any relationship between the explanatory variables and dependent variable. The results in Table 4.11 show there is a positive correlation between business performance and SS structure improvement procedure. The figures also show no correlation found between the dependent variables, quality performance, overall performance, and the explanatory variables.

Statistical figures such as regression coefficients, t-statistics and the significance levels could not be computed. Therefore, the regression models of the relationships between firm performance outcomes and Six Sigma practices could not be established. This can be attributed to the fact that there were in the insufficient number of observations with respect to Six Sigma related firms.
Table 4.11: Pearson Correlation Matrix

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**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
Chapter 5
Discussion and Results

This chapter will discuss the findings of the current research. The results of the analysis presented in the previous chapter will be reviewed in the context of the research questions which have been stated previously. The discussion will focus on the extent to which the research has addressed the issues raised in the research questions. We are interested in what the data reveals and how these results relate to previous research findings and the existing theory and practices in the area. The discussion will also highlight how the research findings contribute to, extend, or confirm the body of knowledge on the topic. Suggestions or recommendations will be offered based on the specific context of the study. Finally, new insights into the research topic and future research questions will be identified.

Specifically, the chapter is structured in three sections. The first section discusses the finding that Lean by itself results in superior performance than a combination of Lean and Six Sigma. The second section discusses the impact of Lean on organizational performance improvement and the third section discusses the limitations of the research and future research recommendations.
5.1 Lean by Itself Results In Superior Performance than A Combination of Lean and Six Sigma

In general, there is a statistically significant difference in the business performance levels of the Lean-only implementers compared to the Lean Six Sigma implementers. The group of firms implementing standalone Lean have better results on the business performance scale than Lean Six Sigma implementers. This result suggests that implementing Lean by itself is likely to lead to better business performance than implementing Lean Six Sigma.

While the literature suggests there should be a difference between Lean-only and Lean Six Sigma implementation results, it uniformly presents the proposition that Lean Six Sigma will result in superior performance to Lean-only implementations. The current research reveals just the opposite. Firms adopting Lean practices by themselves have a superior business performance than those applying a combined Lean Six Sigma program.

In an attempt to better understand this result, an analysis was conducted separating large and small firms. For the purposes of this study in the New Zealand context, large was defined as firms with more than 100 employees. This analysis revealed that for these firms the difference in performance improvement was even more soundly supported with Lean-only firms achieving superior results to the Lean Six Sigma firms. These firms exhibited improved results in both business and overall performance.

This result is partially consistent with the literature. The greater differences shown by the larger firms suggest that the positive impact of these two programs on performance improvement is greater in large firms than in general. There is some consensus among academics and practitioners in the field that business improvement initiatives have a greater impact on performance enhancement in larger firms than in smaller (Cua et al., 2001; Shah and Ward, 2003). This may be most directly attributable to the larger resource base of the larger firms.

In summary, the result of this study provides a new insight into the relationship between Lean, Lean Six Sigma and organizational performance. The performance improvements attributable to the implementation of these two programs appear to be the opposite of what the literature suggests. From a theoretical perspective, there are some possible explanations for this finding.

Literature focussing on Lean and Lean Six Sigma in SMEs is still scarce and methodologically weak. The review of literature on manufacturing programs indicates that the large body of existing empirical papers have mainly focused on very large multinational
corporations. Key findings regarding Lean and Six Sigma are primarily derived from studies based on data gathered from firms in the US with thousands of employees (Cua et al., 2001; Zu et al., 2008; Eroglu and Hofer, 2010). It is reasonable to conclude that what has been presented about the relationship between these two programs in the literature is directly related to large firms. The literature provides little insight on the phenomenon of business improvement programs, particularly Six Sigma, when they are implemented in the SME context. The question must be asked whether programs like Six Sigma, Lean, and Lean Six Sigma can help SMEs effectively enhance their performance as they do for larger firms. Alternatively, the question is if what has been believed or found to be true for large firms can be true for smaller firms. This study suggests that this is not the case.

The literature indicates that Lean is a less formal approach than programs like Six Sigma and Lean Six Sigma. In addition, an application of Six Sigma requires a massive investment in human, finance, effort, and time resources which are more likely to be available in and affordable by large firms. It is believed the results of this study reveal that, lacking the resources of larger firms, SMEs find more success with Lean adoption rather than the combined Lean Six Sigma approach.

Furthermore, both t-tests in this study found no difference in quality performance between Lean and Six Sigma. This is evidence that Lean practices standing by themselves can result in a high level of quality improvement. This suggests that Lean practices are the smarter choice for SMEs. Lean system should be recommended as a first start with respect to quality targets rather than Six Sigma or Lean combined with Six Sigma.

The applicability of the research findings is strongly tied to the context from which they were derived. At the outset of this research the international standard for an SME was applied to the New Zealand manufacturing firms surveyed. Specifically, SMEs are those having up to 500 employees. New Zealand represents a relatively typical modern business economy. The implication is that the research results could be applied to the international context, given that the profile of the SME is standardized by definition. Surveys indicated that 82% of the participants in this study were from firms with fewer than 500 staff and a half of the companies have more than 100 employees. The sample is broken down with 33% having between 100 and 500 employees and 18% employing more 500 people. With respect to larger firms, the research results may not be applicable. The next section will provide further discussion on the issue of finding’s applicability to larger scale economies such as the US.
### 5.2 Contextual theory

The results of this study are contentious. In order to better understand how these findings fit into the existing theorized relationships or widely held beliefs/assumptions about the relationships that have been established by previous papers, they must be viewed in a connection to the theory of contextual factors.

Contextual theory states that context of the firm may exert a certain level of influence on manufacturing firm performance (Lawrence and Lorsch, 1967). It is also suggested by Cua et al., (2001); Zu et al. (2008) and Parast M.M. (2010) that the context in which firms operate possibly affects the performance improvement power of manufacturing improvement programs.

When exploring whether contextual factors help differentiate between low and high performers, Cua, K. O., McKone, K. E. and Schroeder, R. G. (2001) consider contextual variables such as the number of employee, capacity utilization, and process-type. The paper proposes that a higher level of manufacturing performance can be expected from manufacturing plants that are larger and have lower plant utilization and are more process oriented. Cua, et al. (2001) findings indicate that in fact organizational internal practices provide a better explanation of firm performance than the context in which a firm operates. Despite that the authors retain their suggestion to researchers to take into account the possible effects of contextual factors on performance and highly recommend future study to investigate the possible interaction effect of contextual factors and manufacturing practices on performance.

According to Zu, X., Fredendall, L.D. and Douglas, T.J. (2008) different organizations have quality management programs at various levels of advancement. The authors argue that the contextual factors are the maturity of existing quality management systems and firm size and may influence the integration of Six Sigma practices into an existing environment, such as Lean.

More recently, Parast, M.M. (2010) concluded that the literature lacks an understanding of the role of organizational and contextual variables with respect to the effectiveness of process improvement programs, particularly Six Sigma. Benefits resulting from these programs may vary considerably across different organizational contexts. The author suggests that rigorous empirical analysis may clarify the impact of firm context on the implementation of these programs.
The existing literature largely focuses on mature large-sized multinational firms in larger scale economies. In comparison, the result of this paper is derived solely from data provided by manufacturing SMEs. It is possible that the research findings of this study are inconsistent with the literature due to the size differential between SMEs and large multinationals. It is the opinion of this author that the theory of contextual factors provides an argument for why the expected direction in the relationship was not found.

In summary, the applicability of the findings should be limited to SMEs until validation on large firms has been completed. Further investigation of large firms in larger scale economies is strongly recommended to assess the finding.

5.3 Lean’s Impact on Organizational Performance Improvement

The regression analysis identifies a number of practices that largely affect firm performance in the field. In terms of quality, sets of practices including JIT Delivery by Supplier and Customer Involvement are the two important factors which influence performance. With respect to business performance, Supplier Feedback is the greatest impact on performance improvement. Meanwhile, the study suggests that majority of overall changes in organizational performance can be attributed to the implementation of Supplier Feedback and TPM. From a theoretical perspective, there are some explanations for these findings.

JIT Delivery by Supplier is identified as a basic practice included in a JIT manufacturing program (Cua et al., 2001). It ensures that suppliers deliver a sufficient quantity of right quality product at the right time in the right place (Shah and Ward, 2007). Supplier delivery is closely tied to the capacity for producing the order at the right quality, right quantity, and right time, which is controlled by the kanbans in a pull production system. Therefore, the practice typically has a causal impact on firm processing time. Meanwhile, Customer Involvement is a practice that focuses on developing the relationship with customers by being highly responsive to their needs in terms of quality and delivery performance by keeping close contact and surveying customers frequently (Cua et al., 2001). An accurate prediction of customer demand, resulting from Customer Involvement, allows firms to predict process output more exactly, to facilitate the continuous flows of product, and casually influence processing time.

As presented in the literature, Lean enhances performance by focusing on reducing and minimizing variability causing waste. In firms variability occurs from three sources, including supply, processing time, and demand (Shah and Ward, 2007). Further, there are inter-related effects among the three dimensions of improvement. Processing time variability is only
reduced by eliminating variability from supply and demand. The study is consistent with the literature as the results indicate that quality performance is critically influenced by the externally related practices *JIT Delivery by Supplier* and *Customer Involvement*. The study suggests that in order to enhance quality performance practitioners must prioritize implementing practices regarding improving supplier delivery and predicting demand rather than focusing on internally related improvement efforts.

*Supplier Feedback* includes providing regular feedback to suppliers about their performance, keeping close contact with suppliers and establishing long-term relationship with suppliers. The literature suggests that supplier feedback practice has a tight correlation to *Supplier Development* (Shah and Ward, 2007). The practice aims to make suppliers more closely involved in firm’s producing process, reduces the number of supplier, lets few key suppliers manage firm inventory and make suppliers committed to the cost reduction. It has been found in the literature that controlling the supply variance determines inventory of all types in the firms. Reducing supply related variability helps reduce excess inventory of supply. Reliable suppliers also result in a reduction of excess stock by securing a continuous process flow and reducing setup time. The literature states that a reduction of inventory, benefiting from the supplier related practices, is directly tied to cost reduction and financial performance gains (Eroglu and Hofer, 2010). Therefore, the supplier related practices generate business performance enhancement, which also has been confirmed by this research. The study suggests that *Supplier Feedback* is the key practice that largely affects business performance in firms.

*TPM* addresses equipment downtime through total productive maintenance and achieves a high level of equipment availability. This practice mainly focuses on controlling processing time related variability by facilitating a continuous flow. The study suggests that to achieve overall performance improvement (business and quality together) *TPM* and *Supplier Feedback*, are key solutions.
5.4 Research Limitations and Future Research Recommendations

Firstly, as discussed previously, the results of this study need to be validated in the context of large firms.

Second, this study was unable to answer the proposed research question regarding the effects of adopting Six Sigma by itself due to a lack of data for standalone Six Sigma implementation. This investigation is recommended for future studies.

Third, while this study made an attempt to investigate the problem empirically, the shortcomings of the research extent and scope did not allow testing the direct link of Lean Six Sigma to superior performance. Future studies should include longitudinal research and more detailed investigation of the relationships. Longitudinal studies could help to examine the casual linkage of Lean Six Sigma implementation and organizational performance and explore the exact nature and extent of performance improvement benefits that can be achieved.

Furthermore, this study only focuses on manufacturing firms. Lean and Six Sigma have been embraced in a wide range of business areas, including manufacturing and service settings such as financial institutions, education, hospitality, and health care organizations. Given this, examining the research problems in non-manufacturing settings is recommended for future research.

The literature of contextual theory calls for more studies on the possible interaction effect of contextual factors and manufacturing practices on performance. The unexpected findings of this study again stress an urgent need for a closer investigation of the organizational contexts that critically influence the implementation of manufacturing improvement programs. Given the currently growing integration Lean and Six Sigma, future researchers are recommended to explore the factors that affect the introduction of the combined Lean and Six Sigma in an approach to achieve organizational excellence (Zu et al., 2008).

Finally, the literature suggests two points of view regarding the joint implementation of Six Sigma and Lean, that is, the inclusion of Lean practices into Six Sigma methodology and inclusion of Six Sigma projects into Lean context. These two approaches not only indicate the order of the applications of the programs but demonstrate the method of combining the programs and managing improvement activities in firms. Specifically, the former approach suggests that Lean practices embed within Six Sigma structure and Six Sigma provides an overall deployment and problem solving methodology. Six Sigma is the main program
containing Lean in a subordinate role. Conversely, other authors argue that since the Lean concept emerged before Six Sigma, it created an overall improvement environment for Six Sigma to nest within. These authors contend that Lean should play a dominate role. The issue of which methodology is more or less important in creating an optimal joint model is in debate. While the current literature is still lacking a holistic, conceptual model in which Six Sigma and Lean are combined and interact, the questions that must be asked are which method can accurately reflect the combination of Lean and Six Sigma in the field, and whether there is a significant difference in organizational performance improvement benefits between the two approaches. These issues warrant further investigation.
Chapter 6
Conclusion

Lean Six Sigma is still an evolving concept in contemporary business and industry and the literature on Lean Six Sigma is exploratory in nature. This master’s thesis is one of few papers to empirically demonstrate the importance of the joint implementation of these two programs. The study presents a survey based approach that seeks to verify the positive relationship between the implementation of Lean Six Sigma and organizational performance. The validated results of the study indicate that Lean standing by itself can yield significantly better business performance improvement than a combined Lean Six Sigma approach. The research findings provided by this study were primarily derived from data gathered from firms which have fewer than 500 employees in the New Zealand market. They should be applicable to SMEs in the international context.

The study has brought academics and businesses a number of important implications.

6.1 From a theoretical perspective

This study contributes to filling the existing gap in the literature. While the joint application of Lean and Six Sigma is growing increasingly important in practice, the existing literature addressing this combination is thin across all areas. There is little development regarding definitional and methodological issues of the integration. In terms of the model’s outcome, there is scant research investigating the positive association of the joint implementation with firm performance improvement benefits. The outcome of this research helps shorten the perceived large gap between academic literature and perception of Lean Six Sigma in practice.

The literature abounds with anecdotal evidence in the form of either success stories or untested assumptions regarding the performance benefits of a Lean Six Sigma combination. The empirically validated evidence generated by this study is important in providing insights into the performance improvement capacity of a Lean Six Sigma combined model from a theoretical perspective. Interestingly, the study reveals that the performance improvements attributable to the implementation of these two programs are the opposite of what the literature suggests. These findings suggest that firms adopting Lean practices by themselves have a superior business performance than those applying a combined Lean Six Sigma program.
Furthermore, given the current lack of theoretical understandings regarding SMEs and the crucial role that they play in economies around the world this study makes an additional contribution by focusing on SME firms operating in a small but open economy. The validated result of the study also contributes toward extending the current scarcity of literature related to SMEs and providing a critical insight into the application of programs, Lean, Lean Six Sigma in the SME context. The study also represents a positive response to the call for further empirical research on SMEs in non-US settings however more investigations of the implementation of Lean, Six Sigma and Lean Six Sigma in the context of SMEs are needed. This is believed to be crucial not only to the development and growth of scientific knowledge of SMEs but also to a better understanding of programs like Six Sigma, Lean and Lean Six Sigma.

6.2 From a practical standpoint

The current research provides a closer insight into the status of the applications of business improvement programs, Lean and the combined Lean Six Sigma in New Zealand market, and is therefore particularly relevant to New Zealand managers of similar firms.

The study provides practitioners with insights into how their peer organizations utilize Lean, Lean Six Sigma and the level of performance improvement benefits that have been achieved. The research suggests that for SMEs Lean is a better choice than Lean Six Sigma as implementing Lean by itself is likely to lead to better business performance than implementing Lean Six Sigma.

With respect to the impact of Lean practices on firm performance, this study provides detail on specific practices that lead to improved performance. Specifically, to achieve a greater quality performance, the research recommends that practitioners pay more attention to improving supplier delivery and predicting customer demand. Meanwhile, the supplier related practices regarding providing regular feedback to suppliers about their performance, developing long-term relationship with suppliers, letting few key suppliers manage firm inventory and achieving supplier buy in to cost reduction are important to business performance improvement. Together with externally related practices, total productive maintenance or equipment related practices are also relevant to achieving an enhanced overall performance outcome.
References


Watson, G.H. (2000). Toward a central tendency on Six Sigma: a reasonable middle ground is starting to emerge. *Quality Progress, 33*(7), 16, 17.


Appendix A
Survey Instrument
LINCOLN UNIVERSITY

Survey Instrument - 2010

For Research

“Relationship between implementation of Lean Six Sigma and organizational performance: An empirical investigation”

By: Sophie Ngo
Master researcher
Supervised by: Dr. Jeff Heyl

CONFIDENTIALITY

This interview is confidential and anonymous. All interview data will be processed and held at Lincoln University. No information will be passed to anyone that could allow for the possibility of identifying persons interviewed.

Please answer all the questions as best as you can and where a problem exists, please provide your best approximation.
Section 1: Firm’s information

Q1. How many employees work in your firm?
☐ Less than 100
☐ 100-500
☐ 501-1000
☐ More than 1000

Q2. How many years has it been since firm start-up?
☐ Less than 5 years
☐ 5-10 years
☐ 11-20 years
☐ More than 20 years

Q3. To which category of NZSIC classification does your firm belong? (tick one only)
☐ Food, Beverage and Tobacco
☐ Textile, Clothing, Footwear and Leather
☐ Wood and Paper Products
☐ Printing, Publishing and Recorded Media
☐ Chemicals, petroleum, Rubber, Plastics and Associated Products
☐ Non-metallic Mineral Manufacturing e.g. Glass, Ceramics, Cement etc.
☐ Metal Product Manufacturing
☐ Machinery, Equipment and Electronics
☐ Other

Q4. Please tick the boxes below to indicate which quality improvement methods your firm has implemented and the duration of the implementations.

<table>
<thead>
<tr>
<th>Quality improvement methods</th>
<th>Implementation</th>
<th>Duration of implementation</th>
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<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
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<tr>
<td>Lean production</td>
<td></td>
<td></td>
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<tr>
<td>Six Sigma</td>
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<tr>
<td>Other</td>
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</table>
Section 2: Respondent’s information

Q5. What is your role in the firm’s Six Sigma project?

☐ Senior Manager
☐ Financial Controller
☐ Six Sigma Leader
☐ Master Black Belt (MBB)
☐ Black Belt (BB)
☐ Green Belt (GB)
☐ Finance Team
☐ Other _____

Q6. How many years experience have you had with Six Sigma?

☐ Less than 2 years
☐ 2-5 years
☐ More than 5 years

Q7. How many years experience have you had with Lean?

☐ Less than 2 year
☐ 2-5 years
☐ More than 5 years

Q8. How many projects have you handled or been involved with so far, if any?

☐ None
☐ 1-3 projects
☐ More than 3 projects
Section 3: Six Sigma program’s information

Q9. Please tick on the box to indicate the number of Six Sigma projects in your firm that has completed, are on-going, or are opening.

<table>
<thead>
<tr>
<th>Status of Six Sigma projects</th>
<th>Number of projects</th>
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<tbody>
<tr>
<td></td>
<td>None</td>
</tr>
<tr>
<td>Completed</td>
<td></td>
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<tr>
<td>On-going</td>
<td></td>
</tr>
<tr>
<td>Opening</td>
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Q10. Please circle the number to indicate the extent to which you agree or disagree on statements that represent the current status of implementation in your firm.

Top management support

01 Our firm’s top management (i.e. top executives and major department heads) assumes responsibility for quality performance.  

02 Our firm’s top management provides personal leadership for quality products and quality improvement.

03 Our firm’s top management is evaluated for quality performance.

04 Major department heads within our firm participate in the quality improvement process.

05 Quality issues are reviewed in our firm’s management meetings.

06 Our firm’s top management has objectives for quality performance.

Customer relationship

07 We frequently are in close contact with our customers.

08 Our customers give us feedback on quality and delivery performance.

09 Our firm measures our external customers’ satisfaction.
10 We use customer requirements as the basis for quality.

11 Our employees know who our customers are.

12 Our customers visit our firm.

**Supplier relationship**

13 We strive to establish long-term relationships with suppliers.

14 We rely on a small number of high quality suppliers.

15 Our suppliers are actively involved in our product design/redesign process.

16 Our suppliers are evaluated according to quality, delivery performance, and price, in that order.

17 Our firm has a thorough supplier rating system.

18 Our suppliers are involved in our quality training.

19 We provide technical assistance to our suppliers.

**Workforce management**

20 Our firm forms teams to solve problems.

21 Our firm gives feedback to employees on their quality performance.

22 Our employees are recognized for superior quality improvement.

23 Hourly/non-supervisory employees are involved in quality decisions.

24 Supervisors encourage the persons who work for them to work as a team.

25 Quality-related training is given to hourly workers in our firm.

26 Quality-related training is given to managers and supervisors in our firm.

27 Training is given in the “total quality concept” (i.e., philosophy of company-wide responsibility for quality) in our firm.

28 Training is given in the basic statistical techniques (such as histogram and control charts) in our firm.


**Quality information**

29 Quality data (error rates, defect rates, scrap, defects, cost of quality, etc.) are available in our firm.  
30 Quality data are available to managers, supervisors, and engineers.  
31 Quality data are available to hourly/non-supervisory workers.  
32 Quality data are timely.  
33 Quality data are used as tools to manage quality.  
34 Quality data are used to evaluate supervisory and managerial performance.

**Product/service design**

35 Our firm conducts a thorough review of new product/service design before the product/service is produce.  
36 Multiple departments (such as marketing, manufacturing, and purchasing) coordinate in the product/service development process.  
37 Manufacturing and quality people are involved in the product/service development process.  
38 Quality of new products/services is emphasized in relation to cost or schedule objectives.  
39 We design for manufacturability.  
40 We make an effort, in the design process, to list only the specifications which are clearly needed.

**Process management**

41 Processes in our firm are designed to be “mistake-proof” to minimize the chances of errors.  
42 We dedicate a portion of everyday solely to maintenance.  
43 We usually meet the production schedule everyday.  
44 Production is stopped immediately for quality problems.  
45 Our firm conducts preventive equipment maintenance.
Clear work or process instructions are given to employees.  

Our firm’s shop floors are well organized and clean.  

A large number of the equipment or processes on the shop floor are currently under statistical process control.  

We make extensive use of statistical techniques to reduce variance in processes.  

**Six Sigma role structure**  

We employ a black/green belt role structure (or equivalent structure) for continuous improvement.  

We use a black/green belt role structure (or equivalent structure) to prepare and deploy individual employees for continuous improvement programs.  

In our firm, members of a quality improvement team have their roles and responsibilities specifically identified.  

The black/green belt role structure (or equivalent structure) helps our firm to recognize the depth of employees’ training and experience.  

In our firm, an employee’s role in the black/green structure (or equivalent structure) is considered when making compensation and promotion decisions.  

Our firm uses differentiated training so that employees who have different roles in the black/green belt role structure (or equivalent structure) can obtain the necessary knowledge and skills to fulfill their job responsibilities.  

**Six Sigma structured improvement procedure**  

In our firm, continuous improvement projects are conducted by following a formalized procedure (such as DMAIC—Define, Measure, Analyse, Improve and Control).  

We use a structured approach to manage quality improvement activities.  

We have a formal planning process to decide the major quality improvement projects.  

All improvement projects are reviewed regularly during the process.  

We keep records about how each continuous improvement project is conducted.
In our firm, the product design process follows a formalized procedure.

**Six Sigma focus on metrics**

Our firm sets strategic goals for quality improvement in order to improve firm financial performance.

Our firm has a comprehensive goal-setting process for quality.

Quality goals are clearly communicated to employees in our firm.

In our firm, quality goals are challenging.

In our firm, quality goals are clear and specific.

Our firm translates customers’ needs and expectation into quality goals.

We make an effort to determine the appropriate measures for each quality improvement project.

In our firm, measures for quality performance are connected with the firm’s strategic quality goals.

The expected financial benefits of a quality improvement project are identified during the project planning phase.

Financial performance (e.g., cost savings, sales) is part of the criteria for evaluating the outcomes of quality improvements in our firm.

We assess the performance of core processes against customers’ requirements.

The measures for quality performance are connected with critical-to-quality (CTQ) characteristics.

Our firm systematically uses a set of measures (such as defects per million opportunities, sigma level, process capability indices, defects per unit, and yield) to evaluate process improvements.
Q11. Please circle the number to indicate the extent to which you agree or disagree on statements that represent the current status of implementation in your firm.

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<tr>
<th>Supplier feedback</th>
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<tr>
<td>01 We frequently are in close contact with our suppliers.</td>
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<td>3</td>
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<td>5</td>
<td>6</td>
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<td>02 Our suppliers seldom visit our firm.</td>
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<td>03 We seldom visit our supplier’s firms.</td>
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<tr>
<td>04 We give our supplier feedback on quality and delivery performance.</td>
<td>1</td>
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<td>05 We strive to establish long-term relationship with our suppliers.</td>
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<th>JIT delivery by supplier</th>
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<tr>
<td>06 Suppliers are directly involved in the new product development process.</td>
<td>1</td>
<td>2</td>
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<tr>
<td>07 Our key suppliers deliver to firm on JIT basic.</td>
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<td>2</td>
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<td>08 We have a formal supplier certification program.</td>
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<tr>
<td>09 Our suppliers are contractually committed to annual cost reductions.</td>
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<tr>
<td>10 Our key suppliers are located in close proximity to our firm.</td>
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<tr>
<td>11 We have corporate level communication on important issues with key suppliers.</td>
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<td>6</td>
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<tr>
<td>12 We take active steps to reduce the number of suppliers in each category.</td>
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<td>2</td>
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<tr>
<td>13 Our key suppliers manage our inventory.</td>
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<tr>
<td>14 We evaluate suppliers on the basis of total cost and not per unit price.</td>
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<th>Customer involvement</th>
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<td>15 We frequently are in close contact with our customers.</td>
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<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>
16. Our customers seldom visit our firm.
17. Our customers give us feedback on quality and delivery performance.
18. Our customers are actively involved in current and future product offerings.
19. Our customers are directly involved in current and future product offerings.
20. Our customers frequently share current and future demand information with marketing department.
21. We regularly conduct customer satisfaction survey.

**Pull**

22. Production is “pulled” by the shipment of finished goods.
23. Production at stations in “pulled” by the current demand of the next station.
24. We use a “pull” production system.
25. We use Kanban, squares, or containers of signals for production control.

**Continuous flow**

26. Products are classified into groups with similar processing requirements.
27. Products are classified into groups with similar routing requirements.
28. Equipment is grouped to produce a continuous flow of families of products.
29. Families of products determine our factory layout.
30. Pace of production is directly linked with the rate of customer demand.

**Set up time reduction**

31. Our employees practice setups to reduce the time required.
32. We are working to lower setup times in our firm.
33. We have low set up times of equipment in our firm.
34. Long production cycle times prevent responding quickly to customer requests.
35. Long supply lead times prevent responding quickly to customer requests.
Statistical process control (SPC)
36  Large number of equipment/processes on shop
    floor is currently under SPC.
37  Extensive use of statistic techniques to reduce
    process variance.
38  Charts showing defect rates are used as tool on
    the shop floor.
39  We use fishbone type diagrams to identify
    causes of quality problems.
40  We conduct process capability studies before
    product launch.

Employee involvement
41  Shop-floor employees are key to problem
    solving teams.
42  Shop-floor employees drive suggestion
    programs.
43  Shop-floor employees lead product/process
    improvement efforts.
44  Shop-floor employees undergo cross functional
    training.

Total productive/preventive maintenance (TPM)
45  We dedicate a portion of everyday to planned
    equipment maintenance related activities.
46  We maintain all our equipment regularly.
47  We maintain excellent records of all equipment
    maintenance related activities.
48  We post equipment maintenance records on
    shop floor for active sharing with employees.
### Section 5: Quality performance and business performance

Q12. Please circle the number to indicate the extent to which you agree or disagree on statements that reflect the degree of change of performance in your firm over the past three years.

<table>
<thead>
<tr>
<th>Quality performance</th>
<th>Strongly disagree</th>
<th>Disagree</th>
<th>Somewhat disagree</th>
<th>Neither agree nor disagree</th>
<th>Somewhat agree</th>
<th>Agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>01 The quality of our firm’s products and services has been improved over the past three years.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>02 The process variability in our firm has decreased over the past three years.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>03 The delivery of our products and services has been improved over the past three years.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>04 The cost of scrap and rework as a % of sales has decreased over the past three years.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>05 The cycle time (from receipt of raw materials to shipment of finished products) has decreased over the past three years.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>06 Customer satisfaction with the quality of our products and services has increased over the past three years.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>07 The equipment downtime in our firm has decreased over the past three years</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Business performance</th>
<th>Strongly disagree</th>
<th>Disagree</th>
<th>Somewhat disagree</th>
<th>Neither agree nor disagree</th>
<th>Somewhat agree</th>
<th>Agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>08 Our firm’s sales have grown over the past three years.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>09 Our market share has grown over the past three years.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>10 The unit cost of manufacturing has decreased over the past three years</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>11 Our firm’s operating income has grown over the past three years.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>12 Our firm’s profits have grown over the past three years.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>13 Return on assets of our firm has increased over the past three years</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
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