



Evaluation of the performance of organizations that implemented Lean Manufacturing and Six Sigma methods: application to French industries

Ibrahim Alhuraish

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Ibrahim Alhuraish

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L'évaluation des performances des organisations implémentant les méthodes Lean Manufacturing et Six Sigma : Application aux industries Françaises

JURY

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Abbreviation

PDCA	Plan-Do-Check-Act
TPS	Toyota Production System
VSM	Value Stream Map
FEMA	Failure Mode Effects Analysis
TQM	Total Quality Management
DMAIC	Define Measure analysis Improve Control
DPMO	Defect Per Million Opportunities
VOC	Voice of Customer
SMED	Single Minute Exchange of Die
TPM	Total Productivity Maintenance
CTQ	Critical to Quality
Poka-yoke	Mistake Proofing & Prevention
MBB	Master Black Belt
BB	Black Belt
GB	Green Belt
YB	Yellow Belt
AHP	Analytical Hierarchy Process
CR	Consistency Ratio
RI	Random consistency index
STD	Stander deviation

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Résumé

Dans un marché international, de plus en plus globalisé et caractérisé par une concurrence féroce, les entreprises cherchent à améliorer l'efficacité de leurs processus et ainsi niveler les performances opérationnelles et financières. Pour atteindre ces objectifs, les entreprises font appel à des méthodes de management comme le Lean Manufacturing et Six Sigma afin de parvenir à une amélioration continue des indicateurs opérationnels, financiers et d'innovation.

De nos jours, le Lean Manufacturing et Six Sigma sont devenus des méthodologies indispensables pour soutenir l'amélioration de la performance avec des résultats palpables et forts. Cette thèse porte sur l'évaluation de la mise en œuvre de Lean Manufacturing et Six Sigma au sein des entreprises françaises. Les questions auxquelles nous avons essayé de répondre sont donc :

- Est-ce que les entreprises françaises bénéficient-elles des résultats de performance lors de la mise en œuvre de Lean Manufacturing et Six Sigma ?
- Y-a-t-il une manière spécifique aux entreprises françaises pour la mise en œuvre de Lean Manufacturing et Six Sigma ?
- Quelles sont les améliorations obtenues, au sein des entreprises françaises, via la mise en œuvre de Lean Manufacturing et Six Sigma (la qualité, la réduction des coûts et la productivité) ?

L'objectif de ce mémoire est d'évaluer les résultats de performance pour les entreprises françaises via l'implémentation des méthodologies Lean Manufacturing et Six Sigma. En outre, nous avons tenté de distinguer les outils qui ont permis aux entreprises étudiées une implémentation réussie de Lean Manufacturing et Six Sigma. Nous avons également visé à identifier les facteurs clés de succès de leur mise en œuvre. L'étude vise aussi à identifier s'il existe des différences et des similitudes importantes entre les facteurs de succès de Lean Manufacturing et Six Sigma. En conséquence, une comparaison des facteurs clés de succès de Lean Manufacturing et Six Sigma a été réalisée. La littérature scientifique et les pratiques dans ce domaine révèlent que la mise en œuvre « réussie » de Lean Manufacturing et Six Sigma aboutit à des meilleurs résultats en termes de performance globale des entreprises. En outre, nous avons examiné les caractéristiques des entreprises ayant mis en œuvre le Lean Manufacturing et Six Sigma simultanément ou séparément, en prenant en compte les entreprises qui ont adapté des normes telles que ISO 9001 et ISO 14001.

Une analyse AHP « Analytic Hierarchy Process » a été également réalisée pour évaluer la performance de trois catégories d'entreprises (Sociétés A = mise en œuvre de Lean Manufacturing et Six Sigma, B = entreprises mettant en œuvre la production Lean, C = les entreprises utilisant des outils limités de qualité) en termes des méthodes les plus efficaces qui ont été appliquées. Cette évaluation a été basée sur trois critères : la performance financière, la performance opérationnelle et la performance de l'innovation

Dans cette thèse, nous avons établi une enquête sous forme de questionnaire qui a été distribué au plus de 100 entreprises en France. De ce fait, nos résultats sont basés sur les données collectées des 33 entreprises qui ont répondu.

De manière globale, les résultats montrent que les entreprises appliquant Lean Manufacturing et Six Sigma sont plus efficaces en termes de l'amélioration des performances financières et opérationnelles. Par ailleurs, les entreprises qui utilisent juste une partie des pratiques de Lean Manufacturing et/ou de Six Sigma ont montré des améliorations limitées. En ce qui concerne le volet innovation, nous avons montré que l'implémentation de Lean Manufacturing est suffisante pour avoir une amélioration des performances. Cette étude a aussi révélé que le Lean Manufacturing et/ou Six Sigma supportent de manière significative une amélioration de la performance de l'entreprise, et montré que de nombreuses entreprises dans l'industrie française ont récemment mis en œuvre le Lean Manufacturing et/ou Six Sigma. L'enquête montre que la plupart des industries françaises appliquent des outils comme le Brainstorming, le travail standardisé, le contrôle visuel, le PDCA, et 5S, d'une part. D'autre part, peu d'entreprises ont reconnu l'importance des outils statistiques tels que les plans d'expériences, DPMO, DMAIC, et l'analyse de régression.

Cette recherche a également révélé qu'il existe des différences significatives entre les petites-moyennes entreprises et les grandes entreprises en termes d'utilisation des outils tels que DMAIC, DPMO et One Piece Flow. En ce qui concerne les facteurs du succès pour le Lean Manufacturing et Six Sigma, nous avons mis en lumière des différences statistiquement significatives dans le niveau d'importance d'adaptation de certains facteurs dans la mise en œuvre de Lean Manufacturing ou Six Sigma, par exemple les facteurs « changement de la culture », « la communication » et « la participation des employés ». En outre, le résultat indique que les certifications, telles que ISO 9001 ont aucune influence sur la mise en œuvre de Lean Manufacturing et Six Sigma en même temps. Certains secteurs d'industries comme l'automobile, les services, et l'électronique ont montré une efficacité excellente en matière d'innovation, d'exploitation et financière. De plus, cette étude montre l'absence de Lean Manufacturing et/ou Six Sigma dans le secteur de la santé en France.

Au travers cette thèse, nous avons montré pour la première fois que les entreprises françaises bénéficient, comme ses semblables internationales (ex. japonaises, Etats Unis), de la mise en œuvre des méthodes de Lean Manufacturing et Six Sigma afin d'augmenter le rendement financier, la performance opérationnelle et la performance de l'innovation. Ce travail réaffirme l'importance de ces méthodes encore une fois comme il a été démontré dans d'autres pays.

CHAPTER 1.

GENERAL INTRODUCTION

1. General introduction

In today's increasingly globalized market, companies are seeking to improve competitiveness through the use of quality approach to increase efficiency in operational and financial performance. They are no longer satisfied with merely improving operations and finances in general, but also want to achieve continuous improvements in key operational and financial indicators, such as better quality of services and products, waste and cost reduction, improved customer and job satisfaction, and greater innovation. Companies are now considering improvements in quality and efficiency as the most productive route to greater competitiveness (**Favaro, 2015**). Quality here refers to the management of processes such that both input and output comply with best practice in terms of minimizing waste and cost and putting all resources into productive use, while efficiency refers to reducing costs and waste to achieve optimal production (**Favaro, 2015**). According to **Romaniello et al. (2011)**, when companies fail to take advantage of methods designed to help improve quality, such as total quality management (TQM), lean, six sigma, agile manufacturing, and the theory of constraints, manufacturing output is poor. The recent developments of highly competitive global markets have put further pressure on companies to meet the demand for high quality in terms of production and of efficiency in customer services. In other words, any company wishing to be competitive and serviceable must implement quality management as a means of satisfying both customer and market demands.

Many companies have succeeded in achieving quality goals at low cost through the use of a number of approaches to improving quality, including total quality management (TQM), lean manufacturing, six sigma, and a number of other methods that evaluate problems and solutions utilizing various quality control philosophies. In order to achieve quality and efficiency to gain a competitive advantage, many companies today use lean and six sigma methodologies (**Favaro, 2015**). These two particular approaches have proven to be powerful and effective in improving quality, speed, and efficiency through lowering cost and waste while achieving customer satisfaction, and have grown in popularity during recent decades. Lean, six sigma, or the combined approach, lean six sigma, can be applied to any industry, including hospitals, electronics, and automobile manufacture, for example (**George, 2002**). Lean manufacturing refers to an approach designed to lower the cost and waste involved in production, with a view to maximizing output (**Meade et al., 2010**). Research has shown that companies that implement and practice lean manufacturing or lean production see significant improvements in operational performance (**Shah and Ward, 2003**). According to **Montgomery and Woodall (2008)**, six sigma is a statistical technique that allows a scientific evaluation of processes and transactions, with the aims of reducing variability and of removing defects in operation. Lean originated from the Toyota Production System, with a focus on the elimination of waste in production, starting from the time an order is placed and ending when the order is delivered (**Pojasek, 2003**). Six sigma was introduced by the Motorola Corporation and is designed to eliminate variations in production and services and the processes involved so that defects are reduced and customer satisfaction is improved (**Andersson et al., 2006 and Desai, 2006**). Many industries have been motivated to implement both lean manufacturing and six sigma because of the great success of these approaches in improving performance by reducing costs, improving productivity, and

reducing the cycle time of an organization. However, their successful implementation depends on a company's ability to identify opportunities for reducing costs and waste (**Guarraia et al., 2008**). A review of the literature reveals that the successful implementation of lean six sigma yields greater improvements in performance outcomes than lean manufacturing or six sigma alone. Lean manufacturing, which focuses on reducing waste, is not on its own sufficient to increase a company's performance in terms of increased profit and reduced cost. Where six sigma focuses on reducing defects. However, a combination of the two methods should allow an organization to benefit from significant improvements in a short period of time at a significantly reduced cost (**Mousa, 2013, George, 2002**). It therefore follows that, for optimal results, organizations could consider integrating lean manufacturing and six sigma methodologies to achieve waste reduction, improvements in value, and greater customer satisfaction. The work described in this thesis focuses on both lean manufacturing and six sigma, with the aim of demonstrating their compatibility, as well as their differences, in the context of achieving continuous improvement in French industries.

This first, introductory chapter contains the research problem, the research investigation and the research objective. The second chapter provides a review of the literature on lean manufacturing and six sigma, including their history and definition, as well as the tools and key success factors involved. The third chapter describes the research methodology applied in this investigation: the research design, the sampling technique, and the tests of reliability and normality. It also discusses the implications for practical implementation and analysis of the results obtained. The fourth chapter discusses how lean manufacturing and/or six sigma can be applied in practice, including their combined implementation, as well as the key success factors involved and the variables that help to increase company performance. The fifth chapter presents and discusses the results obtained with lean manufacturing and/or six sigma tools in practice. The sixth chapter describes the integration of the analytic hierarchy process (AHP) model with lean manufacturing and/or six sigma implementation, together with the results of a statistical investigation of different categories aimed at determining effective methodologies for increasing companies' performance outcomes. Finally, concluding remarks are given, with a summary of the research findings as well as prospects for future research.

1.1. Research problem

Many companies today seek to improve quality management as a route to better competitiveness in a globalized market where consumer demands are changing more rapidly and are more complex than ever before. Literature review has shown that in order to improve quality management, several quality methodologies are available, including lean manufacturing, and six sigma, among others. Therefore a number of problems arise for consideration in this context: Do French companies benefit in terms of performance outcomes when they implement lean manufacturing and six sigma? Is there a specific way in which French companies have implemented lean manufacturing and six sigma that accounts for their performance outcomes? Thus, do French companies implementing and extending the practice of lean and six sigma achieve improvements in quality, reduced cost, and productivity as reported in the literature? Additionally, there has been

a lack of consideration in the literature of differences in key success factors for lean manufacturing compared with six sigma. Therefore, the question arises as to the nature of the factors that are relevant for companies in achieving successful implementation of lean manufacturing and six sigma.

1.2. Research Investigation and Question

This study examines the implementation of lean manufacturing and six sigma, alone and in combination, and estimates the impact of such implementation on French industries with regard to performance outcomes. It also identifies the current status of lean manufacturing and six sigma in these industries, considering, for example, the range of implementation of these techniques. The aim is to identify the potential benefits and the relationship between performance outcomes and the extent to which lean manufacturing and six sigma are employed. Additionally, a number of important points are illustrated, among which is the controversy regarding whether the two methodologies should be applied simultaneously or separately. In addition, there is the question of comparing companies that have implemented lean manufacturing and six sigma, either simultaneously or separately, with those that are accredited with regard to standards such as ISO 9001 and ISO 14001.

The number of years over which lean manufacturing and/or six sigma have been implemented are considered, and the impact of this factor on financial and operational performance is examined. The tools and practices that are relevant to the implementation of lean manufacturing or six sigma, such as the Kaizen team, Kanban, DPMO, Visual Control, SMED, and 5S, are investigated, with the aim of identifying which are able to increase company performance. This research also seeks to identify the key success factors for implementing lean manufacturing and six sigma within French industry. The aim is to discover whether there are significant differences and similarities among the common success factors for lean manufacturing and six sigma and whether there are differences in priority among these. The respective factors that have turned out to be most critical for those companies that have successfully implemented either lean manufacturing or six sigma are investigated. Finally, the levels of success of implementation of lean manufacturing, six sigma, or both, are investigated. In summary, this research investigates the implementation of lean manufacturing and six sigma within French industry by focusing on the following questions:

- What are the impacts of implementing lean manufacturing and six sigma?
- What are the impacts of implementing lean manufacturing only?
- What are the differences in terms of benefits obtained between companies implementing both lean manufacturing and six sigma, those implementing lean manufacturing only, and those that use just a limited range of tools from lean manufacturing and six sigma?
- How has lean manufacturing extended through French industry?
- How has six sigma extended through French industry?
- Which tools and practices associated with either lean manufacturing or six sigma support reductions in cost and inventory, improvements in quality, reductions in turnover rate, improvements in profit, etc.?

- How is the success of lean manufacturing defined in French industry?
- How is the success of six sigma defined in French industry?
- Do six sigma initiatives share a similar success rate with lean manufacturing initiatives?
- What are the difference between small and medium enterprises (SMEs) and large companies in terms of performance outcome, tools, and technique?
- What are the key successes factors in lean manufacturing initiatives?
- What are the key successes factors in six sigma initiatives?
- What are the differences in implementation between lean manufacturing and six sigma for identical common success factors?
- What are the reasons for not implementing lean manufacturing and six sigma simultaneously?
- What are the reasons for implementing lean manufacturing and six sigma simultaneously?
- Do ISOs adopted by companies support simultaneous implementation of lean manufacturing and six sigma?

1.3. Research Objective

The objective of this research is to evaluate performance outcomes for French companies implementing lean manufacturing and six sigma. Therefore, there are a number of objectives involved. Firstly, this research seeks to estimate the impact of lean manufacturing and six sigma on financial performance, operational performance and on innovation performance. Additionally, it aims to evaluate what the impacts are of implementing lean manufacturing and six sigma either simultaneously or separately. Secondly, this research seeks to identify tools and techniques required to help companies improve their financial and operational performance and to determine to what degree the implementation of lean manufacturing and six sigma has been successful. Moreover, this research seeks to identify the key success factors for implementing lean manufacturing and six-sigma separately. The scenario adopted for this research is shown in Figure 1.

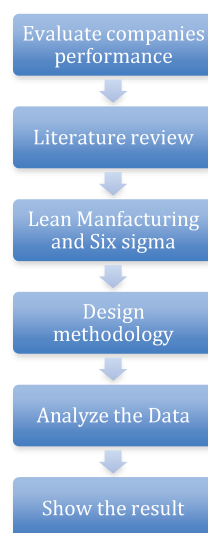


Figure 1.1: Scenario adopted for this research

As demonstrated in Figure 1, the research scenario begins with the objective of the research, namely, to evaluate the performance of these methods within French industry in terms of performance outcome, tool, success factors, etc. An extensive literature review is then conducted, selecting appropriate variables from the literature and examining the views of experts with regard to lean manufacturing and six sigma implementation. Next, appropriate research methodologies are applied to obtain empirical data, through visiting various enterprises and through the use of questionnaires. Then, results are subjected to statistical analysis such as the multicriteria decision-making method and a nonparametric test. Finally, the overall results obtained from this research are discussed in comparison with those from the literature review.

CHAPTER 2.

LITERATURE REVIEW

2. Literature Review

2.1. Introduction

The literature review showed that several industries have achieved significantly increased incomes by implementing lean manufacturing and six sigma. The companies in France that have done so include Alstom, 3M, Essilor, Technip and Safran, Oréal, and STMicroelectronics (**USINE NOUVELLE**). To deploy lean manufacturing or six sigma successfully, there are various requirements, such as the use of appropriate tools and techniques and consideration of a number of key factors. Therefore, this chapter discusses the history and principles of lean manufacturing and six sigma, as well as tools, techniques, and success factors.

2.2. History of Lean Manufacturing

The origin of the lean manufacturing approach is attributed to the Toyota Motor Company (**Womack, 1990**). At the end of the Second World War, Japanese manufacturers faced challenges of shortages of both materials and financial and human resources (**Khalil and Abu Shaaban, 2013**). Toyota developed lean manufacturing with the aim of addressing their specific needs in a market that was restricted during economically troubled times. Through the use of a set of integrated practices and tools such as interchangeable parts, standard work methods, and assembly flow lines, Toyota was able to manufacture products at high speed (**Manotas Duque and Rivera Cadavid, 2007**). They adopted a lean production system during the 1940s to improve efficiency and gain a competitive advantage in the motor industry, which was characterized by stiff competition. They were also able to provide more value to customers. Toyota adopted lean manufacturing so that it could avoid the need to push products to its clients. Instead, the company allowed its customers to pull the products (**Dora et al., 2013**). Thus, customers could provide specific details about the type of cars they wanted and when they wanted them. Toyota then sourced raw materials and applied processes to ensure that cars fitting the customer specifications were manufactured and delivered in a timely manner. The roots of lean manufacturing can also be traced back to Henry Ford's invention in 1913 of a production system for the Highland Park automobile plant, which was integrated in such a way as to facilitate the rapid manufacture of products (**Manotas Duque and Rivera Cadavid, 2007**). According to **Mostafa et al., (2013)**, lean manufacturing can be considered as an important socio-technical mechanism, encompassing a number of management tools. Krafcik initially introduced the concept of lean in 1988; however, it was Womack, Jones, and Roos, with their incorporation of lean manufacturing in the Toyota Production System (TPS) in 1991, who explicitly implemented the principle of lean manufacturing in a practical context (**Womack, 1990**).

2.3. Lean Manufacturing

Lean manufacturing operates on a philosophy that production is maximized through the elimination or reduction of waste and cost in production. Lean manufacturing was introduced

with the aim of eliminating all the non-valued activities encountered by an organization, with lower resources and work force, in order to generate higher returns and value for the organization (**Womack et al., 1990**). Besides providing services, lean manufacturing enables an organization to diminish wastes associated with production of products and services, in order to manage the value chain associated with production, which consequently reduces the overall costs. Lean Manufacturing enables the organization to reduce a number of wastes, such as waiting time, quality defects, production wastes, excessive stock and wastes in the existing process (**Wilson, 2010 and Womack et al., 1990**). The goal of lean management is to eliminate waste. Thus the overarching philosophy of lean manufacturing is “more value with less work” because it involves producing goods and services by operating less of everything (**Anvari, et al., 2011**).

2.3.1. Waste

Many organizations have sought to remain competitive in the global market by adopting lean manufacturing, which reduces costs by eliminating non value added activities (**Rahani and al-Ashraf, 2012**). In lean manufacturing, the main aim is to reduce the costs that an organization incurs in the process of manufacturing by ensuring that the company eliminates waste. However, several types of waste throughout a company ought to be continuously eliminated. Below, the seven types of waste attack by the lean manufacturing method are listed, as identified by Toyota: Over-Production, Waiting Time, Over Processing, Transportation, Inventory, Motion and Defects (**Dailey, 2003**).

- Over-Production means that the quantity of material produced is greater or faster than required. Material should be produced based on customer demand.
- Waiting Time is the idle time that happens during the process, such as operators stood waiting to receive his or her order in the assembly line or waiting for responses from other departments etc.
- Over Processing is a surplus of work that doesn't add value to a product or service.
- Transportation waste is any of the material movement that does not add value to or support immediate production.
- Inventory waste is any material or work in progress or finished material that exists in the factory which is not being processed, such as waiting to deliver parts or products that have already been prepared for transport.
- Motion waste is any effort or movement of people that does not contribute to added value to the product or service.
- Defect waste represents the efforts needed to repair or inspect the defective items or service that led to the rework.

Through lean manufacturing, attempts to exclude the seven categories of waste are made, in a bid to minimize costs. This involves all organizational aspects including over-production, motion, transportation, waiting, inventory surplus, and defects and over-processing. All-round value takes preference in lean manufacturing. The main objective is to reduce costs, improve quality, and achieve appropriate delivery times by total elimination of waste (**Wilson, 2010**,

Womack et al., 1990). Efficiency and attention to detail are very important towards the achievement of productivity in such industries, and improvements in system efficiency can lead to elimination of significant waste in terms of material usage, time and labor. Lean manufacturing is a philosophical approach to managing production and consists of facilitating a system for eliminating or reducing waste and any activity that does not add value for the end customer (**Dora et al., 2013**). At its core, lean manufacturing is a continuous improvement technique focused on just-in-time (JIT), quality systems and team works (**Wong et al., 2009**). The lean philosophy is based on the concept that a resource committed to any faction that is not of value to the customer is a wasted resource. Therefore, the goal of lean manufacturing is to eliminate waste. The core schemes or principles of the lean system are presented next.

2.3.2. Lean principle

There are five steps involved in the implementation of the lean principle (See Figure 2.1) and they are summarized as follows (**Taghizadegan, 2006**).

1. **Value**, which describes customer value from the perspective of the customer.
2. **Value Stream Map**, which includes identifying all products or service activities and the resources used for producing them.
3. **Flow**, which involves creating a system in which value is added on a continuous basis, and anything that does not add value or merely creates obstacles to value is removed.
4. **Pull system**, which involves input that is consistent only with customer demand and expectations.
5. **Perfection**, which involves persistently refining processes for improving efficient operations, reducing production times, improving quality and reducing costs.

According to **Åhlstrom (1998)**, lean manufacturing is about elimination of waste, ensuring that there are no defects, scheduling processes as per customer requirements, having excellent team leaders, continuous improvement, multifunctional teams and flexible information systems. In lean manufacturing, value is determined by the customer, and the process involves continuous identification and removal of waste in the manufacturing process (**Erfan, 2010**). Employees should be included in the program as well because they are the ones responsible for performing tasks (**Marin-Garcia and Bonavia, 2011**). Employees perform maintenance tasks of the lean manufacturing program. Success of lean manufacturing implementation is influenced by numerous factors and approaches. However, the most critical factors that contribute to success are leadership and management skills, employee skills and expertise, financial factors and an organizational culture that is supportive (**Achanga et al., 2006**). In lean manufacturing, the main aim is to reduce the costs that an organization incurs in the process of manufacturing by ensuring that the company manufactures the right quantity of products and delivers them to clients in time. Consequently, warehouse requirements, labor, and time are reduced (**Goriwondo and Maunga, 2012**). Generally, a company should be able to specify customer wants and timelines and all the processes and activities that are required to bring the product to the customer. The essential steps in lean are identification of features that create value including identification of a value stream

sequence of activities, making the activities flow, letting the customer pull the product or service through the process and making the process perfect (Nave, 2002).

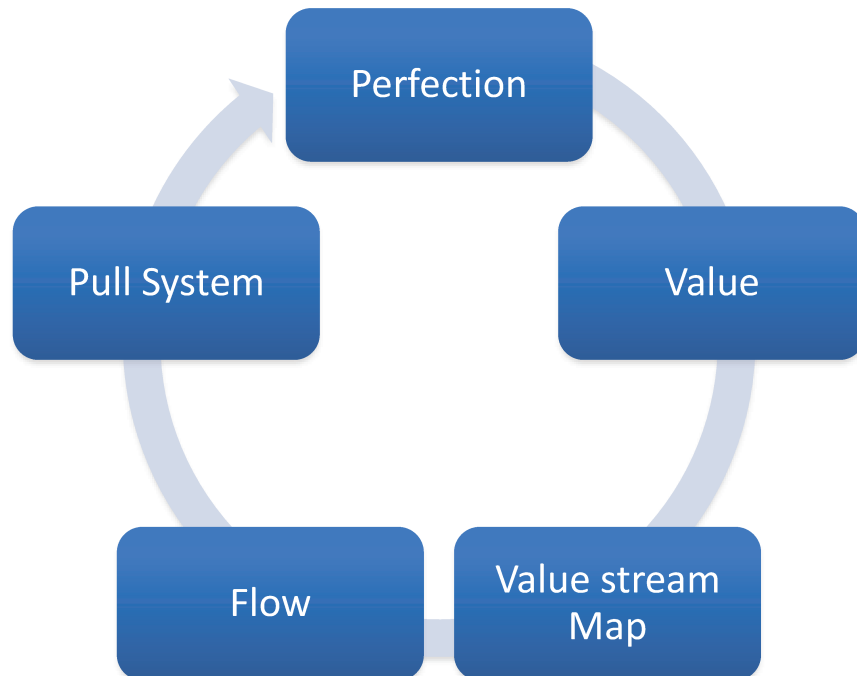


Figure 2.1: Lean manufacturing principles

The process of value identification involves workers, experts and customers identifying product aspects that are of extreme significance. This process of lean implementation begins with analysis of the current situation of the company by Value Stream Map in terms of problems, opportunities and strategies and how lean manufacturing can be implemented effectively. The process of identification of the value stream involves distinguishing activities that add value and should be retained, activities that do not add value but cannot be avoided by a company and those activities that do not add value and the company should eliminate (Čiarnienė and Vienažindienė, 2012). The Value Stream Map displays whole processes from supplier to customer to attack the seven types of waste such as waiting, transportation, and machine time etc. Eliminating this waste ensures that your product or service creates continuous flows. Implementation of lean manufacturing leads to the elimination of defects within the production system, which leads to minimization of lead time and on-time delivery, reduction in the amount of inventory used, as well as customer satisfaction (Khalil and AbuShaaban, 2013). In order to achieve perfection, there should be also continuous improvement of the manufacturing processes to attain customer demand with zero defects (Manotas Duque and Rivera Cadavid, 2007).

2.4. History of Six Sigma

William Smith, an engineering scientist at Motorola, can be considered the father of six sigma, with his development of the concept in the 1980s (Bryefogle, 1999 and Taghizadegan, 2006).

Together with other pioneering scientists and engineers, Smith sought to develop the six sigma concept in order to reduce variation, maximize productivity, and improve quality (**Taghizadegan, 2006 and Brun, 2011**). Six sigma helped Motorola realize powerful bottom-line results in their organization. They documented more than \$16 billion in savings as the result of six sigma efforts. Since then, hundreds of companies around the world have adopted six sigma as a way of doing business. Owing to its numerous advantages, many successful organizations around the globe have implemented six sigma in order to facilitate corporate management, reduce the costs associated with their products, enhance customer loyalty, augment sales, and boost their competency at an organizational level (**Chen, 2008**). Six sigma can be considered a high-performance approach, enabling an organization to analyze the core reasons behind problems that arise and the ways in which such problems can be eliminated in organizational scenarios.

2.5. Six Sigma method

The six sigma method is related to 3.4 defects per million opportunities (DPMO) approach, with the intention of identifying and eliminating defects, so that an organization can significantly improve its quality of production (**Bryefogle, 1999**). Six sigma is applied in an organization as a means of solving quality problems and designing new and improved processes. The philosophical premise of six sigma is the reduction of variations in the production process (**Nave, 2002**). Six sigma looks to do this through continuous statistical evaluation and the removal of such variations (**Bryefogle, 1999**). Furthermore, six sigma can be regarded as a business mechanism that enables organizations to develop their bottom lines through evaluation of business tasks and thereby to facilitate reductions in waste as well as an enhanced level of customer satisfaction (**Hekmatpanah et al., 2008**). The focus of six sigma is on problem-solving, on the basis that problems cannot be solved unless they are fully understood. Therefore, six sigma is project-driven and operates on a statistical basis centered around a five-phase approach to reducing variations and thereby solving business and operational problems: define, measure, analyze, implement, and control (DMAIC) (**Bryefogle, 1999 and Kwak and Anbari, 2006**).

2.5.1. DMAIC

The framework steps for implementing six sigma are Define, Measure, Analysis, Improve and Control and are provided in the below Table 2.1 (**McClusky, 2000**). DMAIC is the most commonly used framework for problem identification and resolution in six sigma. DMAIC structures a continuous process for improvement via directing a sharp focus on the detection, analysis and resolution of root causes of process failure (**Bryefogle, 1999**). Six sigma can be defined as a statistical measure of the performance of a process, as an aim that reaches near perfection for performance improvements to achieve world-class performance (**Pande et al., 2000**). In general six sigma is a methodical and philosophical approach to problems for improving the quality of production through statistically defining and analyzing problems as a means of discovering defects per unit and the probability of a failure for implementing solutions and controls on a continuous level (**Desai, 2006**). It is thought that by taking this approach, six sigma that produces zero defects and the risk of defects occurring once the control phase of the DMAIC is implemented (**Goriwondo and Maunga, 2012**).

Table 2.1 Five phases for Six Sigma

Six sigma step	Key Process
Define	Define the requirement and expectations of the customer Define the project boundaries Define the process by mapping the business flow
Measure	Measure the process to satisfy customer's need Develop a data collection plan Collect and compare data to determine issue and shortfalls
Analyze	Analyze the causes of defects and sources of variation Determine the variation in the process Prioritize opportunities for future improvement
Improve	Improve the process to eliminate variation Develop creative alternatives and implement enhance plan
Control	Control process variation to meet customer requirement Develop strategy to monitor and control the improved process Implement the improvement of systems and structures

Six-sigma methodologies are applied in an organization as processes of solving quality problems and designing new and improved processes. As a statistical measure, it defines how much variation exists in a set of data, a group of items and looks at how well you are meeting customer requirements. The sigma measure was settled to aid focus measures on the paying customers of a business, and provides a consistent way to measure and compare different processes (**Pande et al., 2000**). Six sigma implies 3.4 defects per million opportunities (see Table 2.2). The six sigma methodology deals with the intention that identifying and responding to 3.4 defects, the organization can significantly improve quality of production (**Klefsjo et al., 2001**). Six sigma requires the use of several statistical tools that focuses on the reduction of variation. These statistical tools measure each of the stages of the process evaluation, design and re-design (**Zare Mehrjerdi, 2011**).

Table 2.2 Sigma level

Sigma Level	Defect per Million Opportunity (DPMO)
6	3.4
5	233
4	6.210
3	66.807
2	308.537
1	690.000

The objective of applying six sigma is to solve identification problems or reduce variation by implementing the DMAIC framework. The processes involved in DMAIC include several tools and techniques. **Pyzdek and Keller (2003)** reviewed the tools and techniques shown in Table 2.3, which require integration with each phase of the DMAIC framework.

Table 2.3 DMAIC Process and Tools

Six sigma phase	Key process	Tools and technique
Define	Define the goals of the improvement activity, and incorporate into a Project Charter. Obtain sponsorship and assemble team	Project Charter, collecting Voice of customer such as surveys, focus group Process Map, Quality Function deployment, Supplier Input Process Output Customer, Benchmarking, Project planning and management tools, Pareto Analysis.
Measure	Measure the existing system. Establish valid and reliable metrics to help monitor progress toward the goal(s) defined at the previous step. Establish current process baseline performance using metric	Exploratory data analysis, Descriptive statistics, Run chart, Pareto analysis
Analyze	Analyze the system to identify ways to eliminate the gap between the current performance of the system or process and the desired goal. Use exploratory and descriptive data analysis to help you understand the data. Use statistical Tools to guide the analysis	Cause-effect diagrams, Tree diagram, Brainstorming, Process behavior charts, Process maps, Design of Experiments, Enumerative statistics, Inferential Statistic, Simulation
Improve	Improve the system. Be creative in finding new ways to do things better, cheaper, or faster. Use Project Management and other planning and management tools to implement the new approach. Use statistical methods to validate the improvement	Force field diagrams, FMEA, 7M tools, Project planning and management tools, Prototype and pilot studies, Simulations
Control	Control the new system. Institutionalize the improved system by modifying compensation and incentive systems, policies, and procedures, MRP, budgets, operating instructions and other management systems. You may wish to utilize standardization such as ISO 9000 to ensure that documentation is correct. Use statistical tools to monitor stability of the new systems	SPC, FMEA, ISO 900x Change budgets, bid models, cost estimating models, Reporting system

Source: Pyzdek and Keller, 2003

2.5.2. Benefits of Six Sigma

According to **Pande et al. (2000)**, six sigma has a number of beneficial effects, such as enhanced success, increased company performance, and enhanced value to customers. Table 2.4 presents a summary of the general benefits to companies of implementing six sigma.

Table 2.4 Illustrations the benefits and savings from Six Sigma implementation

Company/project	Metric/measures	Benefit/savings
Motorola (1992)	In-process defect levels	150 times reduction
Raytheon/aircraft integration systems	Depot maintenance inspection time	Reduced 88% as measured in days
GE/Railcar leasing business	Turnaround time at repair shops	62% reduction
Allied Signal (Honeywell)/ laminates. plant in South Carolina	Capacity Cycle time Inventory On-time delivery	Up 30% Down 50% Down 50% Increased to near 100%
Allied Signal (Honeywell) bendix IQ brake pads	Concept-to-shipment cycle time	Reduced from 8 months to 8 months
Hughes aircraft's missiles systems group/wave	Quality/productivity	Improved 1.000%/improved 500%
General electric	Financial	\$2 billion in 1999
Motorola (1999)	Financial	\$15 billion over 11 years
Dow chemical/rail delivery project	Financial	Savings of \$2.45 million in capital expenditures
DuPont/Yerkces plant in New York (2000)	Financial	Savings of more than \$25 million
Telefonica de espana (2001)	Financial	Savings and increases in revenue 30 million euro in the first 10 months
Texas instruments	Financial	\$600 million
Johnson and Johnson	Financial	\$ 500 million
Honey well	Financial	\$1.2 billion

Source: Kwak and Anbari, 2006

2.6. Lean Manufacturing and Six Sigma Tools

This section discusses some of the popular tools and techniques applied in quality improvement methodologies such as those used in six sigma and lean manufacturing. Those widely used in lean manufacturing include such as Kaizen, Kanban, Brainstorming, Value stream Map (VSM), 5S, Total productivity Maintenance (TPM), Kaizen team, Work cell optimization, Mistake proofing & prevention (Poka-yoke), Gemb, PDCA, Standardized Work, Takt time, Visual Control, Once Piece Flow, Single Minute Exchange of Die (SMED). Whereas six sigma more commonly uses statistical tools such as Voice of customer (VOC), Cause and Effect Diagram, Check Sheet, Design of Experiment (DOE), Defect Per Million Opportunities (DPMO), Failure Mode and effects analysis (FMEA), Pareto Diagram, Process Flow Chart, DPMO, Control Chart.

2.6.1. Brainstorming

Brainstorming is a team concept and is applied for improving a team's ability to be creative and efficient. This is because brainstorming facilitates liberal thinking and an unrestrained exchange of ideas. While there are several brainstorming techniques, the most popular ones are round robin (Structured) and free Wheeling (unstructured) (Basu, 2004). These two techniques are presented as follows:

- Round Robin: This is a structured brainstorming process, and as such participants in a team are invited to share their individual ideas.

- **Free Wheeling:** This is an unstructured brainstorming process in which all team members are at liberty to produce and express ideas whenever they see fit.

Brainstorming is an appropriate tool when quantitative or logistic solutions to a problem are available. The brainstorming tool is designed to stimulate an interaction of ideas that function to produce an effective combined solution (**George et al., 2005**). One of the unique benefits of Brainstorming is its ability to facilitate whole group engagement and participation and therefore avoids a team environment where exclusion of some members occurs and others are the focal point (**Basu, 2004**).

2.6.2. Cause and Effect Diagram

The cause and effect diagram graphically depicts possible causes attributed to specific effects. Initially introduced by Ishikawa, this graphic depiction was frequently expressed in terms of the Ishikawa Diagram. More recently, the cause and effect diagram is more popularly referred to as a fishbone diagram (**Basu, 2004**). The cause and effect diagram goal is to aid in brainstorming through helping a team document and follow identified and graphically displayed ideas reflecting the root causes of a problem (**George et al., 2005**). The cause and affect diagram can be described as among the most popular quality improvement tools. The effect depicts a particular problem and is presented as the diagram (see Figure 2.2). The main structure of the cause and effect diagram contains six elements that are self-explanatory and are otherwise known as 6Ms. The 6Ms are Manpower, Material, Machine, Method, Measurement, and Environment (**Basu, 2004**). There are certain steps in the Cause and Effect process. These steps are described as follows (**George, 2005**):

- Choosing the appropriate format that allows for the identification and analysis of cause and effect.
- Clearly defining and documenting the primary effects arising out of the problem. A box situation at the right side of the diagram will frequently contain this.
- Once the primary classification of causes are agreed upon, the main fishbone branches are drawn and create basic diagram on flipchart
- Brainstorming occurs in the categorization of causes where sub-causes stemming from categorized causes are identified.
- At this point where the sub-causes have been identified, a list compiling the sub-causes are placed on a flipchart.
- After the team agrees on the top sub-causes and the top six sub-causes, the subcases are ranked in a way that corresponds with their level of importance.
- Review the diagram
- For each category of causes, the top sub-causes are listed on the diagram. The resulting sub-causes are known as the Root Causes.

- At this point a decision is made on whether to carry out further dispersion analysis or to collect more data necessary for confirming the Root Causes.
- Finally, solutions together with a plan for improvement are developed.

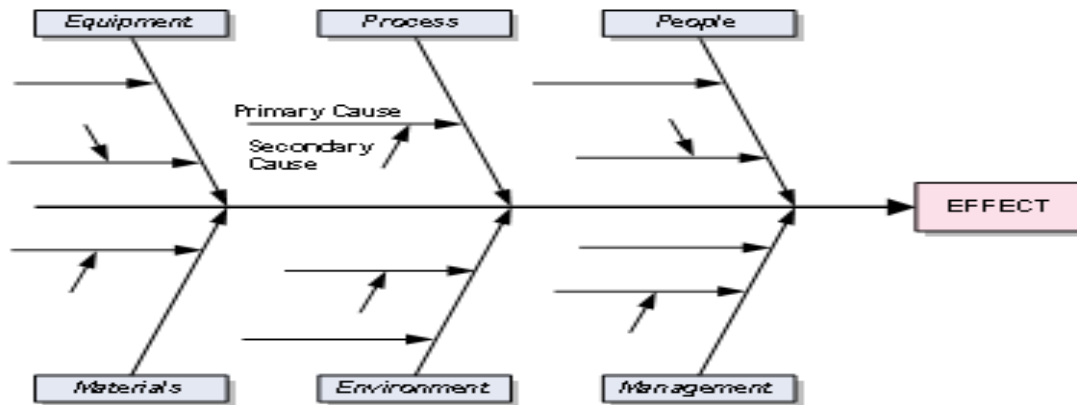


Figure 2.2: Illustration for Ishikawa Diagram (<http://www.vertex42.com>)

2.6.3. Check Sheet

The check sheet provides an easy and efficient method for documenting and identifying when transactions or activities take place. The check sheet is a form or a sheet that permits teams to document and harvest data that is observed so that patterns can be delineated (see Figure 2.3) (Basu, 2004). The simple check sheet is utilized for documenting data that does not conform and activities such as the below:

- I. Machine malfunctions,
- II. Activities that do not add value
- III. Defects or errors observed in a process or a problem.

The check sheet form is prepared in anticipation of the subsequent documenting of data by those who are involved in or impacted by the problem or process. By taking this approach, patterns in the data are clearer, factual, and are derived from an easy to uses process that is applicable to virtually all areas of performance (Basu, 2004).

Telephone interruption						
Reason	Day					
	Mon	Tues	Wed	Thurs	Frid	Total
Wrong number	III	II		III	III 11	20
Information request	II	II	II	II	II	10
Boss	III	II	III 11	I	III	19
Total	12	6	10	8	13	49

Figure 2.3: Illustration for check sheet (<http://www.asq.org>)

2.6.4. Control Charts

The control chart, which was initially, introduced by Shewhart and others at Bell Telephone can reveal the existence of specific causes that interfere with an efficient process (**Shewhart, 1925**). The control chart contains a graph, which consists of a horizontal axis for time and a vertical axis that measures items such as mean or variance/range. Usually, the control chart is a graph representing a behavior of the processes (see Figure 2.4). It monitors the quality characteristics variability, in order to assure process stability. We assume here the data follow normal distribution and the observations are independent.

There are three Control Limits:

- Central Line (CL)
- Lower Control Limit (LCL)
- Upper Control Limit (UCL).

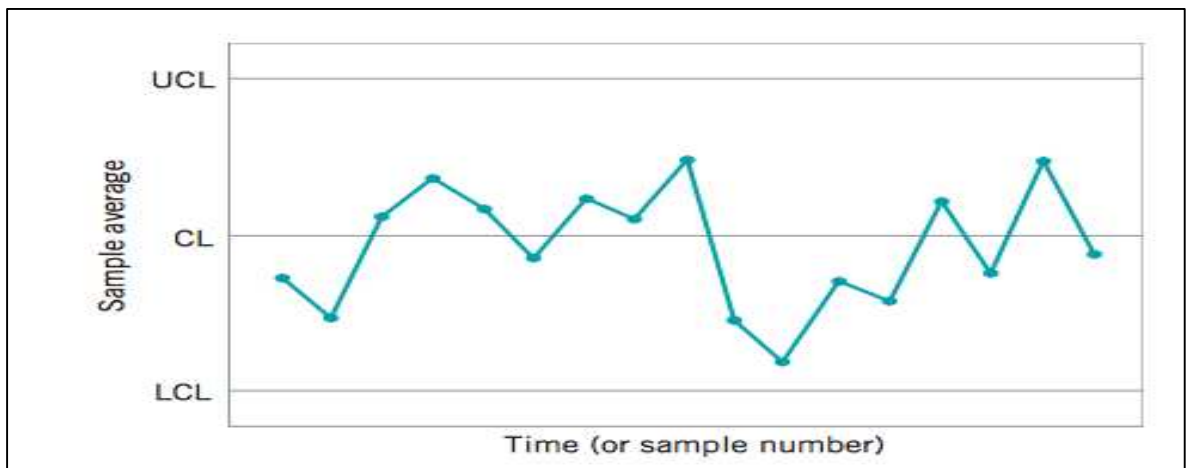


Figure 2.4: Typical control chart (Montgomery, 2009)

The observations above the UCL or below the LCL are signal of a special cause. Where signals are absent, it is presumed that the process is under control (**Montgomery, 2005**). The combination control chart is popularly used such as Xbar-R chart, Xbar-S chart for examining stability in a process that have developed by **Shewhart, (1925)**. However, there are many types of control chart: Xbar-R chart, Xbar-S chart, P chart. EWMA (**Roberts, 1959**), and CUSUM. The following is demonstrative of the mean and the control limits calculation (**Montgomery, 2005; Cohen et al., 2015**): The following is demonstrative of the mean and the control limits calculation:

$$\bar{\bar{X}} = \frac{\sum_{j=1}^m \bar{X}_j}{m}$$

Where,

j= 1, 2, 3 ...n

\bar{X}_j : Average subgroup

m: The number of samples

The 3 sigma control limits for \bar{X} bar chart is presented as:

$$UCL_{\bar{x}} = \bar{\bar{x}} + A_2 \bar{R}$$

$$LCL_{\bar{x}} = \bar{\bar{x}} - A_2 \bar{R}$$

$\bar{\bar{x}}$: The Estimate average

A_2 : only depends on the sample size

\bar{R} : Range

The R charts are define as following, the control limited is popularly used for examining the stability of processes in a wide range of industries. The calculation of the mean and control limits are:

The 3-sigma control limits for R chart is presented as

$$UCL_R = D_4 \bar{R}$$

$$LCL_R = D_3 \bar{R}$$

2.6.5. Design of Experiment

Design of experiment (DOE) is a series of techniques for identifying and controlling variables or boundaries that have the potential to affect the output of a process. The ultimate aim of DOE is to improve this output. DOE is an advanced technique that is applicable to new-product design, the manufacturing process of an existing product, or a re-design. This is accomplished via the following five steps (**Taghizadegan, 2006**):

- A. **Define** the project goal as well as customer demands both internally and externally.
- B. **Measure** and identify the needs and specifications of the customer (LSL and USL).
- C. **Analyze** the process or product option with the aim of satisfying customer needs.
- D. **Design** the process or product with the aim of satisfying customer needs.
- E. **Verify** the performance of the design and its ability to satisfy customer needs.

2.6.6. FMEA

Failure modes and effects analysis (FMEA) is a systematic and analytical quality planning technique applied at the product, process, and service stages to evaluate possible errors or missteps and thereby help to identify faulty processes. (**Taghizadegan, 2006**). The goal is to

categorize all potential flaws according to their impact and to measure them in terms of severity, occurrence, and detection rate, following which methods for their elimination or minimization can be developed. For identification of potential failures and their effects, FMEA is able to utilize subprocess activities and tree diagrams to reveal relevant correlations, as well as brainstorming techniques to reveal the existence of defects and to raise awareness of failures that cause such defects (George et al., 2006).

2.6.7. Pareto Chart

In the context of analyzing problems, a Pareto chart is a bar chart where the bars representing the problems are ranked from highest to lowest in order of the priorities of the problems. It is named after Vilfredo Pareto, a nineteenth century Italian economist who observed that 80% of effects were linked to 20% of causes. This is known as the 20/80 rule. Pareto charts are applied to the analysis of problems such as defects and accidents and the identification of their priorities. Areas for action are prioritized in order of their potential impact. For example, Pareto charts based on data applicable to identifying the principal cause of late delivery time (with the causes being denoted by A, B, C, and D) are illustrated in Figure 2.6.

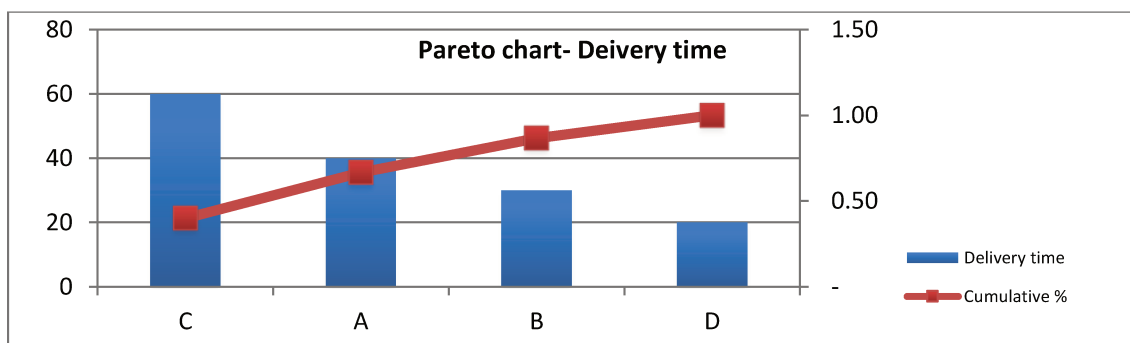


Figure 2.5: Illustration Pareto chart

2.6.8. Process Flow Chart

A flow diagram, also known as a flow chart, is a visual representation of all the important steps in a process as shown in Figure 2.7. Teams gain insight of the relevant process by the chart depiction of sequential transactions or activities in that process relative to specific products or services. The flow chart facilitates an agreement of what measures are required in a process and the identification of vital and difficult areas that need to be improved. Additionally, the flow chart supports training as it acts as a training guide for understanding the ins and outs of a process (Basu, 2004).

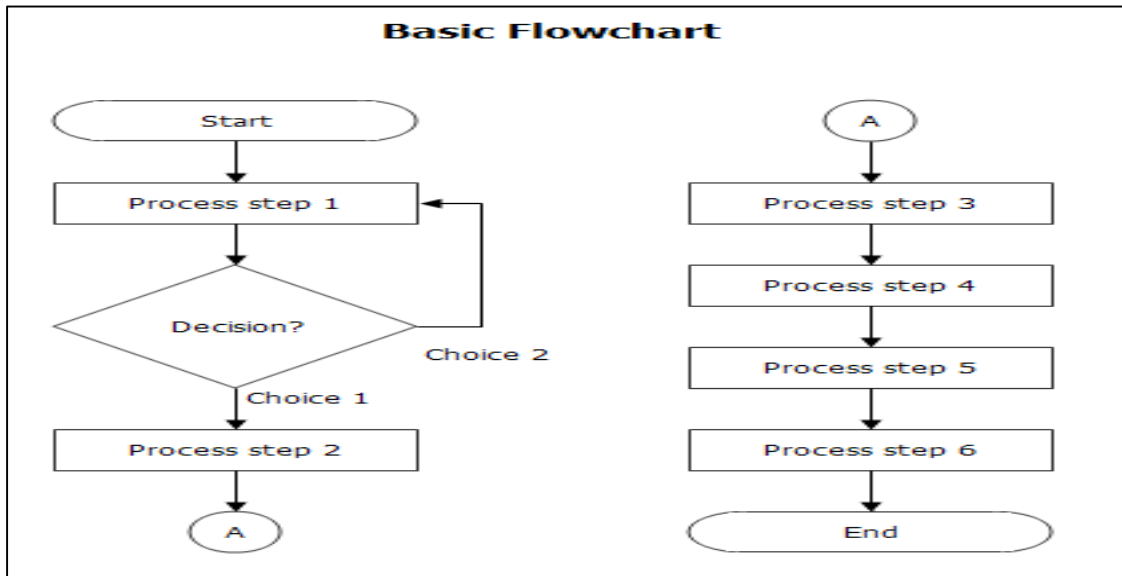


Figure 2.6: Illustration process flow chart (<http://www.breezetre.com/flow-charts/flowchart.htm>)

2.6.9. Value stream Map

The value stream map shows the necessary transactions and events that are involved in the process that takes a product from the supplier to the customer/end user via design, construction, assembly, and delivery, as shown in Figure 2.8. As the value stream map goes through this process, it is able to differentiate between value-added transactions and non-value-added transactions and activities (**Taghizadegan, 2006**). In this regard, a value-added activity is a part of the process that is necessary for satisfying customer demands; in other words, it is an activity in the process by which raw material or information is transformed for meeting customer requirements. A non-value-added activity or transaction is a part of the process that requires resources and time but does not add any value or improvement for the customer. The following are four essential steps in value-added analysis (**Taghizadegan, 2006**):

- I. Construct a process flowchart.
- II. Detect all the assignments that add value for the customer, such as reasonable prices, minimal or zero flaws, and punctual delivery.
- III. Detect all non-value-added activities such as inspection, moving, reworking inspection, moving, and reworking.
- IV. Select those activities that are vital for continuation of the process and exclude those that do not add value.

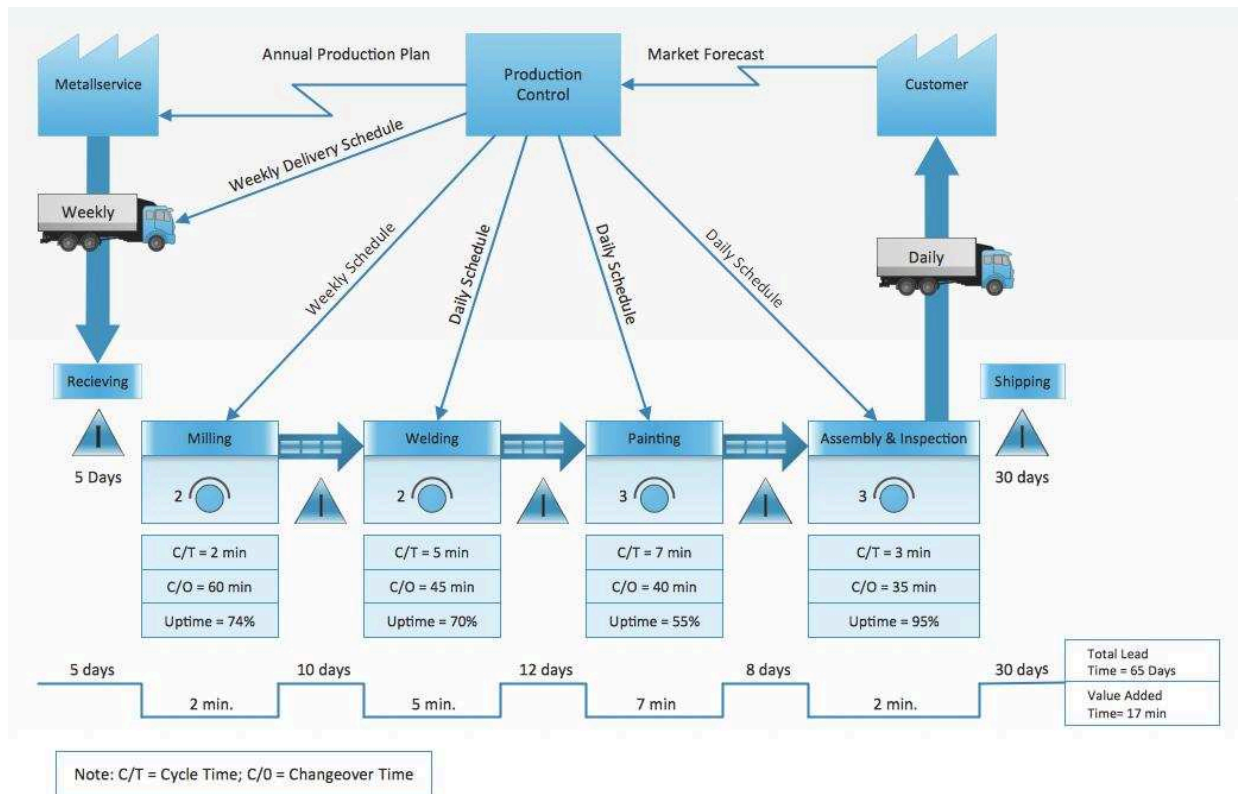


Figure 2.7: Illustration Value stream Mapping (<http://www.conceptdraw.com>)

2.6.10. 5S system

The 5S system is implemented within companies to enhance their efficiency and productivity (Taghizadegan, 2006).

A. S1= Sort (Seiri)

At the sort phase, items and activities are sorted out and only what is needed is retained and those that are not needed are eliminated.

B. S2: Set in order (Seiton)

Organize (what, where, and how).

At the organize phase, those items or activities that are retained once sorting has been accomplished are stored efficiently and effectively.

C. S3: Shine (Seiso)

Following the sort and organize phases, the cleaning up takes place.

What to clean

Those areas that are designated for cleaning are listed.

How to clean

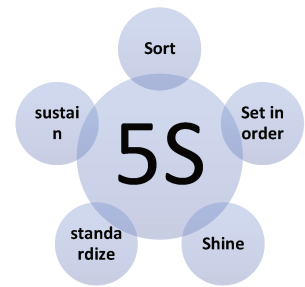
How cleaning takes place is identified.

Who will clean

Individual and overall duties are identified.

How much cleaning is necessary

This should take place on a daily basis.



D. S4: Standardize (Seiketsu)

The process that contributes most to improvement and the measures involved becomes a standard bearer for daily application.

E. S5: Sustain (Shitsuke)

The standardized process will be maintained and is incorporated into the organizational culture.

2.6.11. Total productivity Maintenance

Total productivity Maintenance is necessary for maximization of the lifecycle and productivity of the equipment. It is necessary to get all relevant staff involved and can include supervisors, maintenance crews, engineers, operators and so on, there are some highlight of TPM principle such as top management support to engage the employs on perform maintenance, training and education, evaluate the effectiveness of the machine, training and education (**Taghizadegan, 2006**).

2.6.12. Kaizen team

The Kaizen team is a technique that allows for the identification of opportunities for continuous improvement in a short period of time. The Kaizen team is an action-based strategy in lean manufacturing (**Taghizadegan, 2006**), Follow up standardizes the improvement and applies them to the ongoing process:

The Kaizen team process

- Measuring the existing performance
- Examine the process
- Develop new work combinations
- Redesign flowchart layout
- Apply implementation
- Measure results and communicate to participants
- Identify longer execution

2.6.13. Voice of customer

The objective of voice of customer (VOC) is to identify specific customer opinions or points of view on service issues, and performance indicators and expectations (**George et al., 2005**). The Table 2.5 shows the methods for collecting VOC.

Table 2.5 Voice of customer

Type of contact	Choose if the following is desired
Face-to-face interview	Unique perspective Senior-level participation Ability to pursue unexpected lines of questioning In-depth understanding of customers
Focus group	Information from customers with similar product and service needs Mid- to lower-level participation
Telephone interview	Information from customers who are widely dispersed geographically Information on basic or simple issues A large amount of data at a low cost
Survey	Quantifiable and statistically meaningful responses from many customers Confirmation of theories developed based on other forms of customer contact

Source: George et al., 2005

2.6.14. Work cell optimization

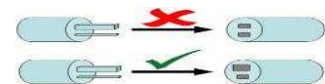
The work cell functions in reducing the time necessary for that completion of an activity or activities the removal of scenarios that is lying to errors. Thus the work cell identifies and removes or reduces inefficiencies including equipment and people, several benefit by performed cell layout designed such as easy moving, one piece flow processing (**George et al., 2005**).

2.6.15. Mistake proofing & prevention

Mistake prevention involves aborting errors so that they do not happen. Mistake proofing is designed to ensure that errors are not transferred from one phase to another; it doesn't need or require human assistance (**George et al., 2005**):

Two-step mistake-proofing system:

- “A caution system in which the process either shuts down or cautions when there is an error”.
- “Process stop when irregularity is detected”



2.6.16. Standardized Work

Standardized work involves identifying and implementing the best practices and activities for the same process each time. However, standardized work is reviewed and updated constantly through documentation and training. This takes place by observing operations and identifying sources of waste for continuous improvement. Standard work could be the first step for identifying waste sources by observing or analyzing how the operators are carrying out standard work in an

assembly line by noting any type of waste such as how many defective items, how many units are finished per shift or hour, motion etc. Attempt to create continuous improvement for standard work from time to time. Stander work consider one the tools that support continuous improvement (Åhlström, 1998 & Rahani and al-Ashraf, 2012).

2.6.17. Gemba

In lean manufacturing, the idea of Gemba (a Japanese term) is that problems should be made visible and that the best improvement ideas will come from performing Gemba. The advantage of following the Gemba approach is that it allows a visual identification of waste at its source, instead of from sitting in an office (Rahani and alAshraf, 2012).

2.6.18. PDCA

The PDCA cycle (plan—do—check—act) was developed in Dr. W. Edwards Deming’s lecture in1950 (Moen, 2006). The aim is to support improvements in the quality of services, to reduce waste, and to increase customer satisfaction (Powell et al., 2013). “Circle has no end, the PDCA cycle should be repeated again and again for continuous improvement” (www.ASQ.com)



2.6.19. Takt time

Takt time is the time that is needed for the production of one part, based on available time and customer requirements. It is helpful in determining the non-value-added components of the assembly line or the area of interest (Rahani and al-Ashraf, 2012). Takt time is calculated as follows:

$$\textit{Takt Time } (T) = \frac{\textit{Available time } (Ta)}{\textit{Customer demand } (Td)}$$

2.6.20. Kanban

A Kanban (Japanese for “signal” or “card”) can be interpreted in a number of ways, but it is generally considered to denote a card like that shown in Figure 2.9. The goal of Kanban is to facilitate flow and to accomplish a pull system while dealing with inventory limitations. Thus, Kanban is necessary for addressing problems caused by excessive production. Kanban is

essentially a pull system that calls upon the upstream workstation to only produce that which is necessary for downstream demands (Wilson, 2010).

Identification de la pièce : BZV 4216 Catégorie : BTR	
Origine : poste 17	Quantité : 6
Destination : poste 24	Minimum : 6 Maximum : 18
Temps de cycle : 25 minutes	

Figure 2.8: Illustrate Kanban card (<http://www.elcom.fr/lean>)

2.6.21. Visual Control

Visual control enable a process to manage itself, with clear indications being provided of opportunities available in the workplace. Visual control is achieved by simple signals providing immediate understanding of the situation in the factory (Gunasekaran and Lyu, 1997). The photograph illustrates visual control (see Figure 2.10).



Figure 2.9: Illustrate visual card (<http://torquemangement.org>)

2.6.22. Once Piece Flow

One piece flow is a sequence of products or activities considered one item at a time, as shown in Figure 2.11. The focus is on the product or the activity, as opposed to the actions of waiting, moving, and storing. Thus, one-piece flow techniques have a short turnover time and are consistent with pull systems (Li and Rong, 2009).



Figure 2.10: Illustrate of practicing one piece flow (<http://www.lean.org>)

2.6.23. Single Minute Exchange of Die (SMED)

SMED (single-minute exchange of die) is a lean manufacturing technique for reducing waste and cost. It relies on a rapid and efficient way of converting a manufacturing process from running

the current product to running the next one (Wang, 2011). Thus, SMED is also known as quick changeover (QCO), since it increases changeover times, thereby facilitating production at a lower cost. All changeovers and startups should take less than 10 minutes (Wang, 2011). Its conduct with more than one employee is as shown in Figure 2.12.



Figure 2.11: Illustrate SMED (<http://www.manufacturainteligente.com>)

2.7. Lean Manufacturing Vs. Six Sigma

A review of the literature reveals that from a philosophical perspective, lean and six sigma are different. Whereas six sigma focuses on identifying and removing variations and defects, lean manufacturing is focused on reducing waste. Both systems contemplate the creation of quality and value, respectively, while saving cost. Lean manufacturing and six sigma methodologies are aimed at continuously improving quality to the satisfaction of the end customer. An overview of the strengths of each of these methodologies is provided in Table 2.6. There are some fundamental differences in how six sigma and lean manufacturing are implemented and operated. In order to implement six sigma, the whole organization must be subjected to continuous adjustments as new problems are identified and new solutions implemented. This occurs on a project-by-project basis. An organization must create four different levels for a belt system to successfully implement six sigma (Taghizadegan, 2006). The infrastructures for the six sigma methodology are Champion, Master Black Belt (MBB), Black Belt (BB), and Green Belt (GB) or project leader (George, 2002). In contrast, lean manufacturing does not involve an organization's infrastructure. Instead, leadership is the most critical success factor for successful implementation of this methodology (Achanga et al., 2006). Moreover, lean manufacturing includes techniques of Kaizen, which are absent from the six sigma approach. Kaizen refers to the culture of whole-team involvement and thus employee empowerment (Mano et al., 2014). While six sigma can reduce variations and defects and improve efficiency, it does not by itself reduce waste or improve cost (Gamal Aboelmaged, 2010). Moreover, while six sigma uses a number of statistical tools, it does not provide a strategy for applying these to a system (Goerge, 2002).

Table 2.6 Differences between Lean and Six Sigma

Issue	Six sigma	Lean
Focus on customer value stream	No	Yes
Focus on creating a visual workplace	No	Yes
Creation of a standard work sheet	No	Yes
Attack on WIP-Inventory	No	Yes
Focus in good housing keeping	No	Yes
Process control and monitoring	Yes	No
Focus on reduction of variation and achieving uniform process output	Yes	No
Detailed focus on the application of statistical tools and techniques	Yes	No
Employment of a structured, rigorous and well planned problem-solving methodology	Yes	No
Attack on 7 wastes	No	Yes

Source: Antony, 2003

Lean manufacturing does not take account of the voice of the customer and design of experiment. On the other hand, six sigma does not speed up processes. In addition, whereas lean manufacturing focuses on the entire system, six sigma focuses too narrowly on one project at a time (**Sibley and Swanger, 2012**), which is counterproductive from the point of view of reducing waste. Then there is the obvious problem with lean manufacturing of focusing too narrowly on waste and ignoring the root cause of problems that arise, which is more suitably dealt with by six sigma. The overall effects of an integration of lean manufacturing and six sigma are captured by the model created by **Korde and Mishra (2003)** (see Figure 2.11).

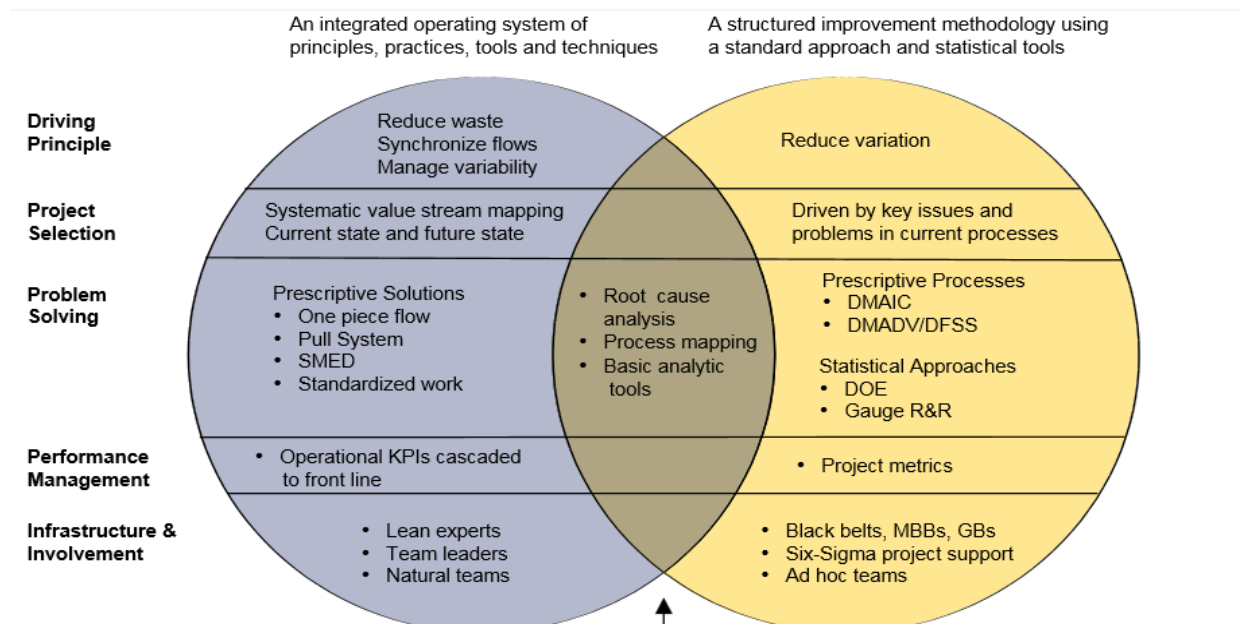


Figure 2.12: Diagram demonstrated the similarities between lean and six sigma

2.7.1. Implementation of Lean Manufacturing or Six Sigma in Isolation

There are definite concerns that implementing lean manufacturing without implementing six

sigma as well can lead to a number of problems. First, management might not select the best projects on which to focus, and this could result in either sub-optimizing the system or complicating it (Bryefogle, 1999). In addition, lean manufacturing does not put a process under statistical control (George, 2002). On the other hand, six sigma does not speed up a process. Therefore, firms that have implemented six sigma alone find that they have not made improvements in their lead time, but only slight improvements in work in progress (George, 2003). Moreover, George (2002) found that a number of companies that implemented lean manufacturing without six sigma enjoyed only partial improvements in quality of service and goods, and then only in some areas of the business. George (2002) also noted that implementing lean manufacturing without six sigma puts the organization in a position where a problem cannot be treated statistically to allow more efficient control.

Implementation of six sigma without lean manufacturing is also problematic. To begin with, six sigma does not specifically direct attention to lead time and does not have a technique for addressing flow, since its focus is on variations and defects (George, 2002). As Sibley and Swanger (2012) point out, while six sigma strives for perfection, this alone could lead to delays in production. However, lean manufacturing needs to be integrated with six sigma, and, at the same time, six sigma needs to be integrated with lean manufacturing, as explained in Table 2.7, in order to identify non-value-added waste, improve processing speed and cycle time, and provide rapid action. This allows six sigma to work well when waste has been eliminated. Combining lean manufacturing and six sigma allows both elimination of waste and the perfection philosophy of six sigma to be put into practice (Salah et al., 2010).

Table 2.7 Lean and Six Sigma needs each other

Six Sigma Needs lean	Lean Needs six sigma
<ul style="list-style-type: none"> Through lean manufacturing, wastes that are on no value addition are identified. Lean has tools that help to increase processing speed to improve cycle time such as 7 Muda, TPM, 5S etc. Lean embraces Kaizen, which is a method for rapid action. Lean enables Six Sigma to work efficiently by eliminating waste. 	<ul style="list-style-type: none"> Reduce variation Six Sigma has tools that identify critical aspects to quality such as capturing data through VOC and DMAIC. Six Sigma expresses, in details the culture and infrastructure system that is needed to achieve a sustainable result.

Source: George, 2003

In summary, it can be concluded that while lean manufacturing and six sigma have different theoretical bases, both aim to improve performance outcomes: improved value and reduced waste and costs. Lean theory is based on reducing waste, whereas six sigma focuses on reducing variations. In their application, lean manufacturing seeks to identifying value, whereas six sigma seeks to identify problems. Thus, whereas lean manufacturing focuses on flow, six sigma focuses on problems. Lean manufacturing proceeds on the assumption that if waste is reduced, value is created, whereas six sigma proceeds on the assumption that if variation is eliminated, the risk of problems is reduced. However, both philosophies expect to improve productivity and efficiency. This is demonstrated by a table of comparisons between the theories, methodologies and applications of lean manufacturing and six sigma as devised by Nave (2002) (see Table 2.8).

Table 2.8 Comparisons between lean and six-sigma methodology

Methodology	Lean	Six sigma
Theory	Reduce waste	Reduce variation
Application	Identify value Identify value stream Flow Pull Perfection	Define Measure Analysis Improve Control
Focus	Flow focused	Problem focused
Assumption	Waste removal will improve business performance. Many small improvement are better than system analysis	Problem exists system output improve if variation in all process is reduced
Primary effect	Reduce flow time	Uniform process flow
Secondary effect	Less variation Uniform output Less inventory Variation metric Improve quality	Less waste Fast throughput Less inventory New accounting system Flow metrics Improve quality

Source: Nave, 2002

Nave (2002), suggest that if an organization wants to rely on studies with analytical value, as well as the link between data and analysis, then six sigma is a good fit for the organization. If the organization is more determined to see immediate changes and results then a lean philosophy is best. However, a lean six sigma methodology is ideal for cutting cost, improving productivity and efficiency with improved quality (**George, 2002; Breyfogle, 1999; Sorqvist, 2009**).

2.7.2. Begin implementation of Lean Manufacturing or Six Sigma

According to (**Breyfogle, 1999; George, 2002 Sorqvist, 2009**) the emphasis in the implementation of lean manufacturing and six sigma is on obtaining simultaneously rapid and dramatic improvements. In integrating lean manufacturing with six sigma, some firms are unclear on how these should be implemented, because they put one methodology on top of the other. However, the structures and packages of lean manufacturing and six sigma are too different to make this approach successful in practice. On the other hand, there is proof that SMEs have successfully implemented lean manufacturing before six sigma (**Kumar and Antony, 2009**). Conversely, one company has implemented six sigma before lean, also with success (**Snee, 2010**).

SME may not be able to implement both methods simultaneously. Many authors have advocated such simultaneous implementation because of the complementary nature of the two methodologies, but they have not taken into consideration the capability of an organization to do this. SMEs have fewer resources in terms of expert knowledge and therefore may find it difficult to implement lean manufacturing and six sigma simultaneously. There are a few SMEs that have done so, but such integrated implementation is not widespread (**Antony, 2008**). Consequently, any organization that wishes to improve quality but does not have the capacity for simultaneous implementation and needs to choose between lean manufacturing or six sigma must decide which method is better suited to their particular enterprise. The choice of method depends on the capability of the enterprise to apply the appropriate success factors. Therefore, we shall try to

identify the appropriate method, depending on the capability of an organization to apply the success factors for lean manufacturing or six sigma or both (see Chapter 4, Section 6, Success factors for more details)

2.7.3. Integrating Lean Manufacturing and Six Sigma

The integration of six sigma with lean manufacturing allows six sigma to reduce variation and increases the ability of a process to identify critical quality factors so that data can be captured through the voice of the customer (VOC). Six sigma also deals with the culture and infrastructure required by a system to achieve and sustain better results. Thus, six sigma and lean manufacturing are complementary and both are important in improving shareholder value. The two methodologies enable an organization to achieve maximum improvement by addressing the root causes of poor process performance (**Snee, 2010**). Others have also suggested that both six sigma and lean manufacturing should be implemented simultaneously in SMEs (**Khurshid et al., 2012**). According to **George (2002)**, rapid and dramatic improvements have been achieved by implementing lean manufacturing and six sigma simultaneously. Such integrated methodologies result in a new way of working that is more effective than when either methodology is implemented on its own. If lean manufacture and six sigma are not implemented simultaneously, or one is superimposed on the other, there is less improvement in terms of process speed, value added, reduced cycle time, and inventory (**Sorqvist, 2009**). Lean six sigma, i.e., the combination of lean manufacturing and six sigma, seeks to increase shareholder value by ensuring high quality, speed, and customer satisfaction. The combined implementation can produce more efficient and effective outcomes when there is an emphasis on human beings or organizational culture as opposed to a single focus on training staff in techniques and tools (**Dahlgard and Dahlgard-Park, 2006**). Combining lean manufacturing and six sigma has resulted in improvements in product innovation, process reforms, and a significant increase in revenue (**Byrne et al., 2007; Snee, 2010; Delgado et al., 2013**). There is also a growing trend toward combining lean manufacturing and six sigma, as well as combining individual components of these two methodologies.

2.8. Key Success factors for lean manufacturing versus six sigma

Top management commitment and support is considered as the critical success factor of implementing either lean (**Näslund, 2008; Scherrer-Rathje et al., 2009**), or six sigma (**Antony and Banuelas, 2002; Näslund, 2008; Chakrabarty, 2009**). Cultural change in employees attitudes toward quality and the influencing as well as restructuring of organizations are among the importance of the involvement of top management in the implementation of the six sigma (**Henderson and Evans, 2000**). The commitment made by the managers helps the employees to gain an understanding of the projects associated with lean (**Scherrer-Rathje et al., 2009**).

Linking either six sigma or lean to suppliers. The core reason behind the successful incorporation of the suppliers within six sigma is the ability of the suppliers in six sigma to gather support from topmost managerial levels in the supplier firms. Under the philosophy of six sigma, the most

helpful way to lessen variability amongst the suppliers is to have lesser suppliers, who have high levels of sigma performance abilities (**Coronado and Antony, 2002**). Lean also applies along the company's supply chain network, consequently, there is waste reduction, as well as, increased organizational and supply chain communication (**Scherrer-Rathje et al., 2009**). There is an utmost need to correlate lean with the suppliers, since it is regarded as a critical success factor (**Keller et al., 1991**). It is necessary to decrease costs and wastages so as to ensure the success of lean manufacturing. This can be achieved by creating a relation amongst the suppliers and the manufacturers (**Wang, 2009**).

Linking either six sigma or lean to customers. During the process of implementing six sigma, there is an utmost need to consider the customers in the process, as they are regarded as one of the key players affecting the growth of organizations. Recognition of factor such as critical to quality (CTQ) is essential to link six sigma with the customers (**Antony and Banuelas, 2002; Coronado and Antony, 2002**). In the process of lean manufacturing, customers are the ones who determine the value stream. Hence, the company must be able to recognize the requirements of the customers and must arrange the activities that would make the products available to customers (**Wilson, 2010; Čiarnienė and Vienažindienė, 2012**).

Linking either six sigma (**Henderson and Evans, 2000; Coronado and Antony, 2002; Wyper and Harrison, 2000**), or lean (**Shah and Ward, 2003**), to human resources is necessary to ensure that the human resources employed in an organization work collectively towards the achievement of organizational goals. It is essential to link both methods to human resources in order to facilitate implementation, facilitate culture change, sustain the result, and achieve a respectable behavior from the employees and concerned human resources associated with the organization.

Education and training are considered as one of success factors within six sigma (**Henderson and Evans, 2000; Kwak and Anbari, 2006; Näslund, 2008; Brun, 2011**). Six sigma method own structure of training such as master black belt, black belts, and green belt that cooperative to make effective implementation of supporting to increase company performance (**George, 2003**). It is requiring training workers the principles of lean as well to facilitate the implementation of lean (**Pingyu and Yu, 2010**). Education and Training are also considered as one of the success factors for lean method (**Näslund, 2008, Rose et al., 2014**). In order to ensure that the employees are able to manage and implement either lean or six sigma, in an appropriate manner, it is necessary that they receive quality training, and possess essential education qualifications to carry out the process of implementation and to increase their expertise and learn to make decisions using their own understanding.

Skills and expertise possessed by the employees are considered critical success factors for lean manufacturing and six sigma (**Näslund, 2008**). The level of skills and competencies amongst the employees in an organization, determines the organizational ability to incorporate six sigma. Six sigma techniques have a wider application and required specific skills, creativity and training. There exists a wider scope and application of six sigma; hence, there it requires particular set of skills, training as well as creativity (**Antony, 2006; Gamal Aboelmaged, 2010**). The higher the level of skills and competencies possessed by employees concerned with implementation of six

sigma, the higher are the chances of success (George, 2003). Success of lean as well, is dependent upon the level of problem solving skills possessed by employees. In addition, skills and competencies acquired by the employees would help in generation of a plan regarding improvement in process and reduction of wastes (**Bhasin and Burcher, 2006; Scherrer-Rathje et al., 2009; Wilson, 2010**). Human skills and expertise are very important for the success of lean manufacturing (**Achanga et al., 2006**).

Understanding the tools and techniques is also considered as one of the success factors within six sigma (**Coronado and Antony 2002; Kwak and Anbari, 2006; Näslund, 2008**), or lean (**Näslund, 2008; Scherrer-Rathje et al., 2009; Wilson, 2010**). It is necessary to ensure that the tools and techniques associated with lean or six sigma are understood in a comprehensive manner. In addition, the techniques of six sigma are supported in the elimination of the defect related to quality and promote improvement of performance. Furthermore, six sigma is considered to be occupying a specific responsibility in the organization, which is based on a narrow approach (**Snee, 2010**). Six sigma incorporates a wider range of tools and techniques comprising DMAIC, SPC, process capability analysis and root cause analysis among others. On the other hand, lean aims to eliminate the wastage that include various tools such as value stream analysis, 5S, total productive maintenance and kaizen among others that support to add value. In our study, we made a modification to this factor to be “understand the tools and techniques within method to white-collar worker and blue collar worker” for lean manufacturing and six sigma methods, in order to identify whether there are a different levels of importance between lean manufacturing and six sigma across understanding the tools and technique.

The communication process can be improved by establishing a mechanism that can be employed in helping the top management to get feedback from their employees, to ensure that employees accept change and to overcome resistance. Communication among the team members concerned with implementation of either six sigma (**Coronado and Antony, 2002**), or lean (**Bhasin and Burcher, 2006; Manotas Duque and Rivera Cadavid, 2007; Scherrer-Rathje et al., 2009**) is vital as proper communication significantly contributes towards the achievement of organizational success. Studies by **Flynn et al., (1994)**, made it clear that open communication with customers help in monitoring the customers’ requirements as well as in helping to identify the necessary improvements if the customers’ requirements are not being met.

Cultural change plays a major role in determining the success rate of implementing six sigma (**Coronado and Antony, 2002; Antony et al., 2005, Kwak and Anbari, 2006**) or lean (**Achanga et al., 2006; Bhasin and Burcher, 2006; Wilson, 2010**). Culture change requires supporting from the upper level management for providing a guideline to employees. Employees working in an organization need to possess a positive attitude towards solving problems and reducing time to ensure that the defect and wastes are eliminated.

Linking either six sigma (**Coronado and Antony 2002; Brun, 2011**), or lean (**Bhasin and Burcher, 2006; Scherrer-Rathje et al., 2009**), to business strategy is potential reason why either lean or six sigma need to be incorporated into business strategy. It allows the organization to ensure that the business operations are efficiently conducted and are able to meet and surpass

customer requirements.

According to **Huq (2010)** there are various impacts of employee involvement such as decrease in ambiguity in the role of the worker, empowerment of the worker, as well as elimination of cultural resistance. Employee involvement is very important factors for effective implementation of six sigma (**Hahn et al., 2000; Arnheiter and Maleyeff, 2005**), as well as lean manufacturing (**Scherrer-Rathje et al., 2009; Hibadullah et al., 2014; Rose, 2014**), there is a need to involve the employees in the process of implementing lean, since it plays a crucial role in the determination of success.

There is an essential to reward the employees who are associated with implementation of lean as well as six sigma to ensure that the organization is able to effectively implement lean (**Åhlström, 1998; Scherrer-Rathje et al., 2009**), or six sigma (**Ho et al., 2008**). Reward may encourage the employees in the organization to participate in projects that lead to improve quality and sustain results.

Consultant participation is important factor that support to the development of organizational goals and facilitates the implementation of lean (**Scherrer-Rathje et al., 2009**). As well for six sigma (**Wiklund and Wiklund, 2002**). Consultant participation is known to support the activities, and aid the implementation lean and six sigma, which bring about continuous improvement.

Antony and Banuelas (2002), reported that six sigma, which is a project driven methodology, requires that each team member should be skilled in project management so as to meet deadlines as the project progress. Various studies had highlighted project management skills as success factors in the implementation of six sigma (**Coronado and Antony, 2002; Kwak and Anbari, 2006; Brun, 2011**). Project management skills among the employees concerned with the implementation of Lean is necessary in ensuring that wastages in the process of implementation are minimized. Therefore, project management skills has been added as a success factor for lean manufacturing, also due to the desire to compare between lean and six sigma in terms of success factors.

The factors that follow were not compared between lean manufacturing and six sigma due to the fact that each of the methods have characteristics unique to either lean or six sigma but not both. For instance, six sigma has belt system whereas lean manufacturing does not. Belt system may be considered as a key success factor for the six sigma implementation, and these include belt categories such as green belt, black belt, master black belt and champion. The belt mechanism enables the organization in the implementation of the six sigma for the achievement of success and all the belt mechanism have the responsibility of the development of six sigma within the organization (**George, 2003; Kwak and Anbari, 2006; Taghizadegan, 2006**). On the other hand, leadership is considered as a major success factor in the implementation of lean (**Dora et al., 2013**). Success of lean manufacturing largely depends upon the leadership qualities possessed who train the employees regarding implementation of lean by employees implementing lean. Leader works, as professionals in the organization must take necessary steps to ensure that lean

program is incorporated within an organization in achieve progress and success lean implementation (**Dombrowskia and Mielkea, 2013**).

Kaizen team is one of the lean technique which an important factor that assists in the enhancement of performance, which consequently affect the work in the improvement of lean projects rapidly with the organizations (**Radharamanan et al., 1996; Scherrer-Rathje et al., 2009, Rahani and al-Ashraf, 2012**).

Project prioritization and selection, reviews and tracking selection of an appropriate project with the purpose of implementing six sigma can be considered as an important factor that would ensure early success for the organization (**Antony, 2004**). Selection of appropriate six sigma project depends on a number of criteria. These can be considered as an assessment of the voice of customers (VOC), Defect per Million Opportunity (DPMO), and cost of poor quality, among others (**Coronado and Antony, 2002; Gamal Aboelmaged, 2010**).

By monitoring the progress and evaluation of the performance, an assessment of the lean progress would ensure that the implementation of lean is successful (**Scherrer-Rathje et al., 2009; Pingyu and Yu, 2010**). Furthermore, monitoring of the progress would enable the organization to ensure that the project is implemented on a timely basis and in a sequential manner to indicate progress as well as to assess the effectiveness of the different changes (**Åhlström, 1998; Manotas Duque and Rivera Cadavid, 2007; Pingyu and Yu, 2010**). Continuous monitoring and evaluation leads to understanding the current status and ensures that there is effective implementation of lean. Therefore, there should be evaluation of scheduling, material handling, employees, as well as, work processes.

There are some vital differences between lean manufacturing and six sigma. It therefore for optimal results, organization that desires to adopt either lean manufacturing or six sigma or both methods that need to set strategy and improve organizational culture, understanding the tools and train employees to increase their knowledge. Since lean manufacturing and six sigma includes various tools and techniques supportive of the elimination of waste and defect such as control chart, Value Stream Map, Regression analysis, 5S, Total Productive Maintenance and Kaizen, Kanban, however, methodologies such as lean manufacturing, six sigma or lean six sigma are among the most popularly used methodologies for facilitating a firm continuous improvement. These methodologies are implemented through a variety of techniques or tools (**Basu, 2009**). Therefore, tools and techniques are prescribed methods requiring the use of particular skills necessary for improving applicable transactions or processes in areas such as input, output and outcomes.

2.9. Conclusion

Lean manufacturing and six sigma are powerful methodologies, commonly used as quality improvement methods. There have been many publications describing the positive implementation of lean manufacturing in various industries. Based on the results in the literature,

it appears that the weaknesses of one approach are compensated by the strengths of the other. It therefore follows that, for optimal results, organizations could consider integrating lean manufacturing and six sigma to reduce waste and variation, improve value and achieve greater customer satisfaction and continuous improvement. In addition, the management of an organization that wants to adopt either lean manufacturing or six sigma should improve its organizational culture, allow workers to develop themselves, and encourage employees to increase their expertise and learn to make decisions through their own understanding. They should also prioritize customer focus and ensure that they align the organization on all levels. However, there is not much documented evidence about the implementation of lean manufacturing or six sigma in French industry. Therefore, this study investigates the status of implementation of lean manufacturing and six sigma. The results of the research are provided in the next chapter, which addresses the effectiveness of lean manufacturing and six sigma, the nature of the particular tools that are commonly used within French industry, and the success factors for implementing the two approaches.

CHAPTER 3.

RESEARCH METHODOLOGY

3. Research Methodology

In this chapter, we present the philosophical basis of the research methodology. The factors that allow assessment of companies' performance and their successful implementation of lean manufacturing and six sigma are described. This chapter also demonstrates that lean manufacturing and six sigma have been implemented in many ways. Bibliographic investigation shows there has been limited scientific research focusing on the implementation of lean manufacturing and six sigma within French industry. Therefore, this study aims to reveal which practices are relevant to such implementation. Many researchers have conducted survey questionnaires, which is an important technique for collecting data to provide a statistical validation of research results (Samson and Terziovski, 1999; Forza, 2002). The following sections describe the procedure according to which the study was performed, including research design, sampling technique, data collection, and reliability test analysis.

3.1. Research Design

The aims of this research is to evaluate the performance of lean manufacturing and six sigma implementation. This research has used the survey to collect the view of expertise in lean manufacturing and six sigma. We build 98 items to evaluate the situation of lean manufacturing and six sigma implementation (see Appendix). The research instrument used in this research was an online survey administered through Google survey. The first instrument contain general profile of the organization, including type of industry (service industry, electronics industry, automobile industry, health industry, transportation, and other industry), Age of companies (less than 5 years, between 5 and 10 years, between 10 and 15 years and more), respondent's positions (project leader, quality manager, operation manager, general management, consultant, CEO), numbers of employees (from 0 to 9 employees, from 10 to 49, from 50 to 249, and from 250 and more), duration for implementing the method (less than 3 years, between 3 and 6 years, Between 6 and 9 years, and 9 years and more). Additionally, this involved the investigation of the implementation of either lean manufacturing or six sigma, and whether methodologies lean manufacturing, six sigma implemented at the same time with the reasons for doing so. Moreover, the belts systems were investigated. The second instrument of the data collection aim to identify the impacts of lean manufacturing and six sigma implementation by 12. Table 3.1 shows the character questionnaire of each variable related to main variable. The questionnaire was designed as a Likert scale as follows: 1 representing strongly disagree; 2 representing disagree; 3 representing neutral; 4 representing agree; and five representing strongly agree. A higher score for benefit was 5, and therefore implied stronger agreement of the respondents, and a lower score for benefit was 1 implying stronger disagreement. The third instrument demonstrate the tools and techniques, each item was measured using a five point Likert scale. Relative scales ranged from 1= no implementation, 2= few implementation, 3=some implementation, 4= wide implementation, 5 = complete implementation. The fourth instrument shows the situation of the practices levels of lean manufacturing and six sigma implementation. The questionnaire was designed as a Likert-type as follows: 1=Not implemented to any department, 2= Implemented in few department, 3= Implemented in some department, 4= Implemented all departments, 5= implemented in all departments including supplier.

Table 3.1 Measure companies performance

objective	Dimension taken into account	The items presented in the questionnaire
Evaluate the performance	Financial performance	Increase profit Reduce cost
	Operation performance	Improve quality, improve productivity, Reduces Lead-time, Reduces variation, Customer satisfaction, Decreases Inventory, Creates safety environment
	Innovation performance	Reduces turnover rate, Involves employees, Suggestions from the employees

The fifth instrument shows the situation of the success levels of implementation lean manufacturing and six sigma are investigated. The questionnaire was designed as follows: 1=Not successful, 2= A slight successful, 3= Successful, 4= Very successful, 5= Totally successful. The final instrument was designed to determine success factors of lean manufacturing and six sigma separately. The sixth of the data collection was the comparison of implementing lean manufacturing and six sigma methods across success factors. Each of these factors were measured within a five-point Likert scale to indicate the important factors of implementing each method lean manufacturing and six sigma. Respondents had the following five choices for answering of each success factors follows; 1=Unimportant, 2=Slightly important, 3=Important, 4=Very important, 5=Critical. Critical was coded to be equal to 5 points, whereas unimportant was coded to 1 point. Participants were asked additional open question to add any other success factors that they believe is (are) very important to the successful implementation either for lean manufacturing or six sigma.

3.2. Reliability test

Pilot studies were conducted involving two academics and two experts in lean manufacturing and six sigma in order to test the validity of the research model. The two experts are working as a continuous improvement manager and an expert manager. Based on the experts' feedbacks from the pilot study, one question was added to find out whether lean manufacturing and six sigma were implemented simultaneously or not, and another item was added with regard to certification such as OHSAS 1800. A total of 33 valid questionnaires were received from companies between July 2014 and February 2015, a response rate of 19%.

3.3. Sampling Technique

By using survey, it means that data will be collected from informants who represent a significant portion of a certain population, whereby survey forms distributed to expert of lean manufacturing and six sigma. The respondents were also informed of the form in the first page where is explained the purpose of the study and asked the respondents to complete to questionnaire via the linked online survey. Contact was initially made via email through which the survey was sent

to 173 enterprises engaged in different types of industries in France. A total of 173 experts were identified from the list provided by the department of engineering (ISTIA¹) that specialist on quality and excellence industrial. The survey was released online and was written in two languages, English and French. The researcher selected expertise that they familiar and have a good knowledge for lean manufacturing and six sigma. The form explained the purpose of the study and asked the respondents that should have knowledge on lean manufacturing and six sigma. The initial email was sent to 173 enterprises engaged in different type of industries in France. From the emails, twenty emails were not delivered successfully because the email addresses were not valid. Five companies did not participate in answering the questionnaire because they had not implemented either lean manufacturing or six sigma methodologies within their organization. Other experts were in vacation. Follow-up email was sent one month and half later to remind the respondents who had not responded yet. Additionally, we attend a seminar that was organized by an organization, in order to meet experts in domain lean manufacturing and six sigma methodologies. However, an overall thirty-three valid questionnaires had been received from companies between July, 2014 to February, 2015 and the response rate was 19%.

3.3.1 Data Analysis

Descriptive statistics were used in analyzing and interpreting the survey results. Descriptive statistics are referred to as a set of procedures used to summarize and describe the important characteristics of a set of measurement (Mendenhall et al., 2011). Several types of statistical analysis were conducted in this research to determine the results collected from the French industries. Cronbach's alpha coefficient to test the internal reliability, test the normality, Binomial test, Spearman correlation coefficients, Mann-Whitney test, Chi-Square test were used for ordinal and categorical analyses (contingency), Kruskal Wallis One Way ANOVA test, and a regression analysis, Wilcoxon signed ranks tes and Analytic Hierarchy Process. Statistical package for the social sciences version 20, and super decision software were used to calculate and analyze the results.

3.4. Testing the reliability

The internal consistency and reliability for all variables in the survey (performance outcome variables, tools and techniques, and success factors for implementing lean manufacturing and six sigma) were tested using Cronbach's alpha coefficient. This coefficient tests the internal reliability and consistency of a research instrument, with a minimum value of 0.60 indicating sufficient reliability (Nunnally, 1978).

- A. The analysis of all 12 variables from the questionnaire that define the impact of lean manufacturing and six sigma implementation gave a Cronbach's alpha coefficient of 0.902.

¹ ISTIA department is working with many companies that practical qualities approach.

Table 3.2 Reliability for the impact of lean manufacturing and six sigma

Benefits	Cronbach's Alpha
Increase profit	.896
Improve quality	.897
Reduces variation	.909
Reduces cost	.900
Improves productivity	.890
Reduces Lead-time	.890
Increases suggestions from the employees	.891
Involves employees	.885
Increase Customer satisfaction	.889
Decreases Inventory	.898
Reduce turnover rate	.891
Creates safety environment	.891

Based on Table 3.2, we can observe the scale measuring the increase in profit (0.896), improve quality (0.897), Reduce variation (0.909), reduce cost (0.900, improve productivity (0.890), reduce lead time (0.890), suggestion from the employees (0.891), involve employees (0.885), Customer satisfied (0.889), decrease inventory (0.898), reduce turnover rate (0.891), safety environment (0.891). Cronbach's alpha results indicate the presence of a high internal consistency of the scales. Therefore, the variable set met the reliability requirements of the analysis.

B. The analysis of all 27 variables for application of lean manufacturing and six sigma gave a Cronbach's alpha coefficient of 0.87

Table 3.3 Reliability for lean manufacturing and six sigma tools

Tools	Cronbach's Alpha	Tools	Cronbach's Alpha
5S	.873	Kanban	.867
Kaizen team	.871	Check sheet	.872
Standardized Work	.871	Pareto chart	.877
TPM	.869	Design of Experiment	.868
Takt time	.868	Control chart	.870
Once piece flow	.865	Cause and effect diagram	.874
SMED	.872	Flow chart	.869
Cellular lay-out	.873	Voice of Customer	.872
Poka-yoke	.866	Failure Mode and Effect Analysis FMEA	.872
Visual Control	.872	Defects per million opportunities	.869
Gemba	.867	DMAIC	.885
Brainstorming	.874	Regression analysis	.874
Value Stream Mapping	.868	Regression analysis	.867
PDCA	.876		

As shown in Table 3.3, the Cronbach's alpha coefficient ranges from 0.865 to 0.873. Thus, the variables met the reliability requirements of the analysis.

C. The analysis of all the variables from the questionnaire that defined the success of lean manufacturing gave a Cronbach's alpha coefficient of 0.85. The corresponding analysis for six sigma gave a Cronbach's alpha coefficient of 0.95.

Table 3.4 Reliability for Success factors Lean manufacturing and six sigma

Success factors for lean	Cronbach's Alpha	Success factors for six sigma	Cronbach's Alpha
Top Management commitment and support	.851	Top Management commitment and support	.957
Involvement of employees	.848	Linking six sigma to customers	.956
Linking lean method to suppliers	.859	Involvement of employees	.955
Education and training	.849	Linking six sigma method to suppliers	.959
Communication	.854	Education and training	.953
Linking lean Method to the business strategy	.844	Communication	.953
Consultant participation	.875	Linking six sigma Method to the business strategy	.955
Understanding the tools and techniques within lean method to the employees that perform job in shop floor	.837	Consultant participation	.961
Understanding the tools and techniques within lean to the employees that perform job in an office	.833	Understanding the tools and techniques within six sigma to the employees that perform job in shop floor	.954
Cultural change	.829	Understanding the tools and techniques within six sigma to the employees that perform job in an office	.955
Monitoring and evaluation of performance	.840	Cultural change	.954
Skills and expertise	.845	Project prioritization and selection, reviews and tracking	.953
Leadership	.833	Skills and expertise	.957
Kaizen team	.851	Belt system	.959
Reward system	.839	Linking Six Sigma to human resources	.955
Linking lean to customers	.846	Reward system	.959
Linking lean to human resources	.833	Project Management skills	.954
Project Management skills	.839		

These indicated the strong reliability data collected from the survey, indicating that the variable met the reliability and validity requirements of the analysis. This further indicated that the results were acceptable.

3.5. Testing the Normality

The purpose of test the normality is to define either the data follow a normal distribution or not, consequently that guide us to determine of using the correct statistical tests: Parametric test or Non Parametric test. Two tests were conducted, Kolmogorov-Smirnov test and Shapiro-Wilk test for the assessment of normality. Using Kolmogorov-Smirnov test and Shapiro-Wilk test to determine the normality, consequently if p-value is less than 0.05, the normality assumption, can be rejected and if p-value is greater than 0.05, there is evidence to accept the normality

assumption. However, we test the normality for the effective of lean manufacturing and six sigma, tools, success factors as shows below:

A. Testing the normality for the entire variable measuring the effective of lean manufacturing and six sigma implementation. The hypotheses for test of normality are shown below:

H₀: The variables (impact of lean manufacturing and six sigma) does not follow normal distribution

H_a: The variables (impact of lean manufacturing and six sigma) does follow normal distribution

The decision would be:

Ha is accepted If Sig > α (follow normal distribution)

Ha is rejected If Sig < α (Not follow normal distribution).

Table. 3.5 Test of normality for impact of implementing lean manufacturing and six sigma

Impact	Kolmogorov-Smirnova	Shapiro-Wilk
	Sig.	Sig.
Increase profit	.000	.000
Improve quality	.000	.000
Reduces variation	.000	.000
Reduces cost	.000	.000
Improves productivity	.000	.000
Reduces Lead-time	.000	.000
Increases suggestions from the employees	.000	.000
Involves employees	.000	.000
Increase Customer satisfaction	.000	.000
Decreases Inventory	.000	.000
Reduce turnover rate	.000	.000
Creates safety environment	.000	.000

We can observe the test for distribution that all variable values were significantly different than a normality distribution since entire value variable of significant level are less than 0.05. Therefore, non-parametric tests were used such as Spearman correlation coefficients, Binomial test, Mann-Whitney test, and so on.

B. Testing the normality for the entire variable measuring the tools and technique of lean manufacturing and six sigma are shown Table 3.6.

H₀: The variables (lean manufacturing and six sigma practices) does not follow normal distribution

H_a: The variables (lean manufacturing and six sigma practices) does follow normal distribution

It shows the probability for the entire variable value are significant, since P-value are less than 0.05, so we accepted (H₀) that these data or variable are different from normal distribution.

Table 3.6 Test of normality for tools and technique of lean manufacturing and six sigma

Tools	Kolmogorov-Smirnova	Shapiro-Wilk	Tools	Kolmogorov-Smirnova	Shapiro-Wilk
	Sig.	Sig.		Sig.	Sig.
5S	.000	.000	Kanban	.016	.007
Kaizen team	.003	.003	Check sheet	.000	.002
Standardized Work	.000	.001	Pareto chart	.000	.003
TPM	.000	.004	DOE	.000	.000
Takt time	.008	.002	Control chart	.012	.004
Once piece flow	.000	.000	Cause and effect diagram	.000	.001
SMED	.006	.003	Flow chart	.001	.005
Cellular lay-out	.000	.000	VOC	.031	.008
Poka-yoke	.000	.003	FMEA	.000	.002
Visual Control	.007	.004	DPMO	.000	.000
Gemba	.011	.004	DMAIC	.000	.000
Brainstorming	.001	.001	Regression analysis	.000	.000
Value Stream Mapping	.000	.001	PDCA	.000	.000

C. Test the normality for the entire variable for success factors of implementing lean manufacturing and six sigma.

H₀: The variables (Success factors of lean manufacturing and six sigma) does not follow normal distribution

H_a: The variables (Success factors of lean manufacturing and six sigma) does follow normal distribution

The decisions of normality were based on the results of Kolmogorov test and Shapiro test. The investigation of normality test provided that these data for measuring the success factors of lean manufacturing and six sigma are not normally distributed (P-value less the 0.05). The result is shown in Table 3.7. Consequently non parametric test is appropriated, a non-parametric test was applied to all the data in this study (e.g., Spearman's rho, Kruskal–Wallis test, Mann–Whitney test, Kruskal–Wallis test).

Table 3.7 Test of normality for tools and technique of lean manufacturing and six sigma

Success factors for Lean manufacturing	Kolmogorov-Smirnova	Shapiro-Wilk	Success factors for Six Sigma	Kolmogorov-Smirnova	Shapiro-Wilk
	Sig	Sig		Sig	sig
Top Management commitment and support	.000	.000	Top Management commitment and support	.000	.000
Involvement of employees	.000	.000	Linking six sigma to customers	.009	.010
Linking lean method to suppliers	.000	.000	Involvement of employees	.000	.000
Education and training	.000	.000	Linking six sigma method to suppliers	.000	.003
Communication	.000	.000	Education and training	.000	.000
Linking lean Method to the business strategy	.000	.000	Communication	.000	.000
Consultant participation	.001	.008	Linking six sigma Method to the business strategy	.003	.001
Understanding the tools within lean method to the employees that perform job in shop floor	.000	.000	Consultant participation	.000	.004
Understanding the tools within lean to the employees that perform job in an office	.003	.004	Understanding the tools within six sigma to the employees that perform job in shop floor	.007	.012
Cultural change	.000	.000	Understanding the tools within six sigma to the employees that perform job in an office	.002	.013
Monitoring and evaluation of performance	.000	.000	Cultural change	.001	.003
Skills and expertise	.000	.000	Project prioritization and selection, reviews and tracking	.000	.000
Leadership	.000	.000	Skills and expertise	.000	.000
Kaizen team	.000	.007	Belt system	.001	.005
Reward system	.000	.003	Linking Six Sigma to human resources	.002	.011
Linking lean to customers	.000	.005	Reward system	.000	.000
Linking lean to human resources	.000	.001	Project Management skills	.000	.001
Project Management skills	.000	.006			

3.6. RESULT OF THE DEMOGRAPHICS (Descriptive statistics)

Descriptive statistics were used in analyzing and interpreting the survey results. In order to recognize companies' status with regard to implementing lean manufacturing and six sigma, the study considered aspects such as the general profile of the organization, the type of industry, the age of the company, the positions of the respondents to the survey, the number of employees, and the duration over which lean manufacturing or six sigma had been implemented.

3.6.1. Job Title

The results of the survey derived from the responses from 33 enterprises have shown that all of the respondents are experts in lean manufacturing and six sigma, such as consultants, general managers, project leaders, operation managers, and quality managers. Figure. 3.1 shows that (48.8%) sixteen of respondents were responsible of quality (18.2%), six of respondents were consultant (9.1%), two of respondents were project leader (6.1%), two of respondents were general manager (6.1%), two of respondents were operation manager and (12%) four of respondents were other qualified professional such as CEO enterprise, industrialization manager, supply chain manager and responsible for business development whose had sufficient knowledge for lean manufacturing and six sigma.

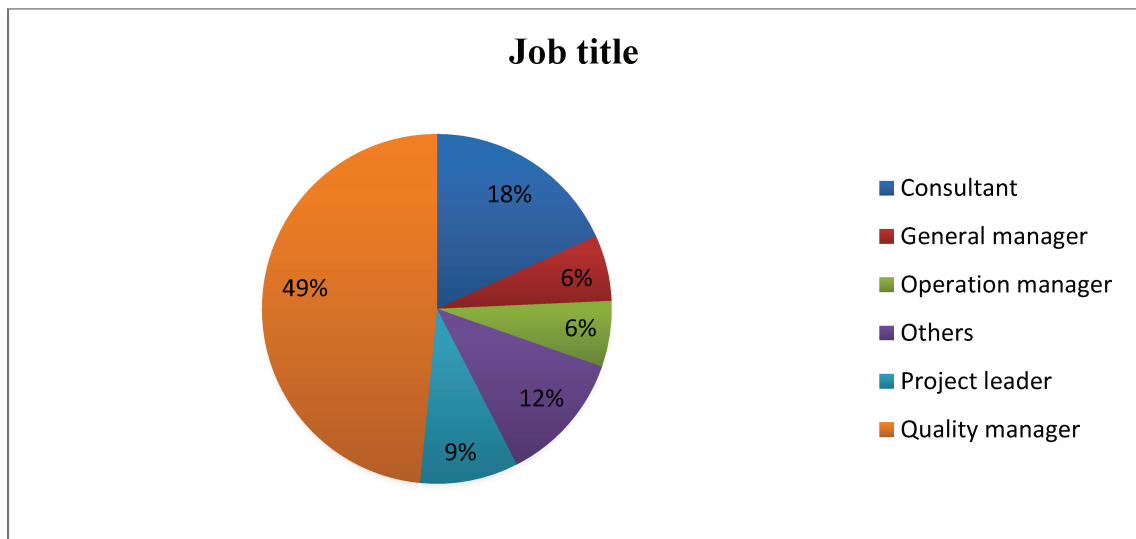


Figure 3.1: Classification of companies based on professional

3.6.2. Type of industry

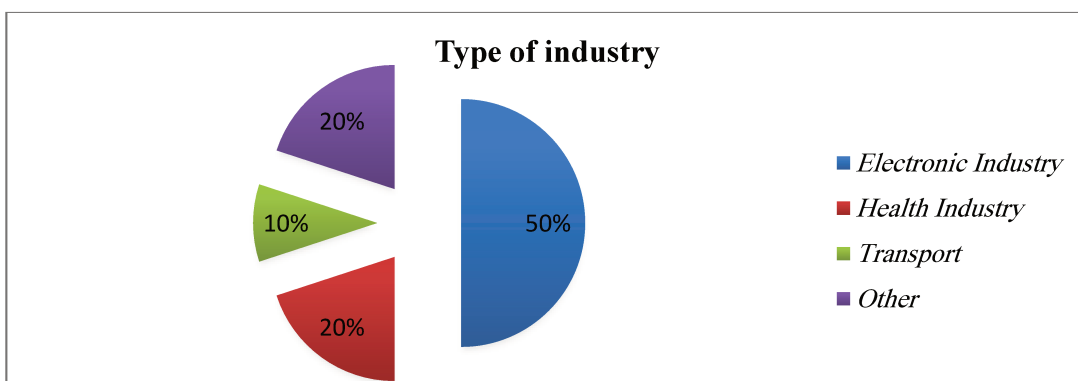


Figure 3.2: Classification of companies based on type Industry

Figure 3.2 shows that the companies come from various type of industry that including (30.3%) ten companies from electronics industries, (21.2%) seven companies from automotive industries, (12.1%) four companies from health industries, (6.1%) two companies from transportation industries, (18.2%) six companies from service and (12.1%) four companies were from other industries such as energy (Oil and Gas), food cooperage and aerospace industries.

3.6.3. Age of the organizations

Table 3.8 represents age of the organizations, majority of the age organizations (75.8%) were more than fifteen years. Four organizations (12.1 %) were between five years and ten years. Three organizations (9.1%) were between ten years and fifteen years and an organization (3%) were less than 5 years.

Table 3.8 Age of the organizations

Age	Frequency	Percent
Less than 5 years	1	3.0
Between 5 and 10 Years	4	12.1
Between 10 and 15 years	3	9.1
More than 15 Years	25	75.8
Total	33	100.0

3.6.4. Number of employees

Table 3.9 shows the classification of the surveyed organizations in terms the number of employees. Twenty one companies (63.3%) were from employed up more than two hundred and fifty employees, followed by 6 companies (18.2%) were from 50 to 249 employees, 4 companies (12.1%) were from 10 to 49 employees, and 2 companies (6.1%) were less than 10 employees. According to Europe Commission, we defined two categories: organizations that employed up to two hundred and fifty employees or less are SME and that employed over 250 employees are large organization.

Table 3.9 Number of employees

Number of employees	Frequency	Percent
From 0 to 9 employees (Micro companies)	2	6.1
From 10 to 49 employees (Small companies)	4	12.1
From 50 to 249 employees (Medium companies)	6	18.2
From 250 and more (Large companies)	21	63.6
Total	33	100.0

Table 3.9.1 shows conclusions of this investigation that 36.4% of responding organizations were SME and 63.6% were large organization.

Table 3.9.1 Size of companies

Size of companies	Frequency	Percent
SME	12	36.4
Large companies	21	63.6
Total	33	100.0

3.6.5. Type of certification

Table 3.10 represents that (78.8%) majority of the companies were certified by various type of certification. on the other hand, there were seven companies (21.2%) had not certified any type of these certification. A majority of the companies were certified by various types of certification. In this regard, 23 of surveyed companies, representing 69.7% are ISO 9001 Quality Management Systems certified; 14 of the companies or 42.4%, are ISO 14001 Environmental Management

Standard certified, 7 of the companies or 18.2%, are OHSAS18001 Occupational Health and Safety Assessment certified; and 5 of the companies or 15.1 % are ISO13485 International organization for standardization certified.

Table 3.10 Type of certification

Accreditation standardization	NO	Percent	Type of certification Standardization	NO	Percent	Percent (Yes)
Yes	26	78.8	ISO 9001	23	37.7%	69.7%
			ISO 14001	14	23%	42.4%
			EN 9100	7	11.5%	21.2%
			OHSAS18001	6	9.8%	18.2%
			ISO13485	5	8.2%	15.2%
			ISOTS16949	6	9.8%	18.2%
NO	7	21.2		33	100	

3.6.6. Belt System

Majorities of the organizations (63.6%) didn't employ any classifications of belt system; champions, master black belts, black belts and green belts and few organization (36.4 %) employ belts system within their organization, respectively (Table 3.11). In few organizations (36.4 %) have employed belts system, the results show that belt system varies from company to other company, (21%) employ yellow belt, (30.4%) employ green belt, (17.4%) employ black belt, (17.4%) employ master black belt, and (8.7%) employed champion.

Table 3.11 Belts system status

Belt system	Frequency	Percent	Type of belt system	NO	Percent
Yes	12	36.4	Yellow belt	6	26.1%
			Greenbelt	7	30.4%
			BB	4	17.4%
			MBB	4	17.4%
			Champion	2	8.7%
No	21	63.6	None	0	0%

3.6.7. Methods implemented

Table 3.12 presents the status of lean manufacturing and six sigma implementation within French industries. (60.6%) Twenty companies have implemented lean Manufacturing only even though most of these companies have been implementing six sigma tools practices such as DOE (61.9%), DPMO (66.7%), FEMA (81%), and (47.8%) DMAIC (47.8%) and control chart (71.4%). Nine companies had implemented lean manufacturing and six sigma and four companies (12.1%) have not implemented any of these method. Even though these companies have been implementing many of the lean manufacturing and six sigma practices but it may not called either lean manufacturing or six sigma in their organizations.

Table 3.12 Implementation methods

Method	Frequency	Percent
Lean Manufacturing	20	60.6
Lean manufacturing and six sigma	9	27.2
Limited lean and six sigma tools	4	12.1
Total	33	100.0

3.6.8. Numbers of years

Table 3.13 displays the number years of implementing the method. The majority (48.5%) of French organizations of our sample have implemented the methods (less than three years). This finding suggests that high tendency of French organization have recently implemented quality approach (practice lean manufacturing and six sigma). (27.3%) from three to six years, 6.1% from six to nine years, and 18.2% for a period nine years and more.

Table 3.13 Numbers of years have enterprises implemented lean and six sigma methodologies

Number of years	Frequency	Percent
Less than 3 years	16	48.5
Between 3 and 6 years	9	27.3
Between 6 and 9 years	2	6.1
9 years and more	6	18.2
Total	33	100.0

3.6.9. Company performance

The level of impact of implementing lean manufacturing and six sigma have make-up as follow: 1 is strongly disagree; 2 is disagree; 3 is neutral; 4 is agree; and 5 is strongly agree. A higher score for every benefit close to value = 5 that implied stronger agreement of the respondents on it, and lower score for each benefit close to value = 1 that implied stronger disagreement. The impacts of implementing of lean manufacturing and six sigma. The results are presented in Table 3.14.

Table 3.14 Performance measure for all companies

Main performance	Mean	Performance measure	Min	Max	Mean	STD
Financial Performance:	3.98	Increases profit	2	5	3.88	.893
		Reduces cost	2	5	4.09	.980
Operational Performance:	3.95	Reduces Lead-time	1	5	4.18	.983
		Improves productivity	1	5	4.21	.992
		Reduces variation	2	5	4.00	.901
		Customer satisfaction	1	5	3.91	1.011
		Decreases Inventory	1	5	3.91	1.011
		Improve quality	2	5	4.27	.674
Innovation performance	3.41	Safety environment	1	5	3.21	1.083
		Increases suggestions from the employees	1	5	3.67	.990
		Involves employees	1	5	3.76	1.001
		Reduce turnover rate	1	4	2.82	.808

3.6.10. Extend lean manufacturing & Six Sigma

In order to understand the situation of lean manufacturing and six sigma practices, the respondents were asked also to identify the extending level for lean manufacturing and six sigma implementation within their organization using a five-point scale, choosing from 1= “not implemented to any department ” to 5= “Implemented in all departments including supplier”.

The Table 3.15 shows majority of the enterprise are not extend six sigma to any department that cause by larger portion of the enterprise were implemented lean manufacturing even though most of these companies had been implementing six sigma practices such as DMAIC, DPMO, FEMA, control chart and DOE.

Table 3.15 Extending lean and six sigma method

Extending method	Lean Manufacturing	Six sigma
Not to any department	12.1%	72.7%
Few departments	12.1%	12.2%
Some departments	36.4%	9.1%
All departments	36.4%	6.1%
All departments including supplier	3%	0%

The results show that 36.4% of the French companies embraced lean in whole departments and 36.4% of the French companies extended lean to at least some departments. 12.1% of the participating French companies extended lean in few departments. Another 12.1% of the participating French companies had not extended lean to any departments and one company representing 3%, extended lean to all departments including the supplier. On the other hand, 72.7% of the companies, representing a majority, had not implemented six sigma to any department. Results indicated that 12.1% of the participating French companies extended six sigma in a few departments. Three companies representative of 9.1% of the participating French companies implemented six sigma in some departments. 6.1% of the companies extended six sigma to whole departments and no companies applied six sigma to whole departments including suppliers. Figure 3.3 was recognized for providing the status of range through the implementation of lean manufacturing and six sigma.

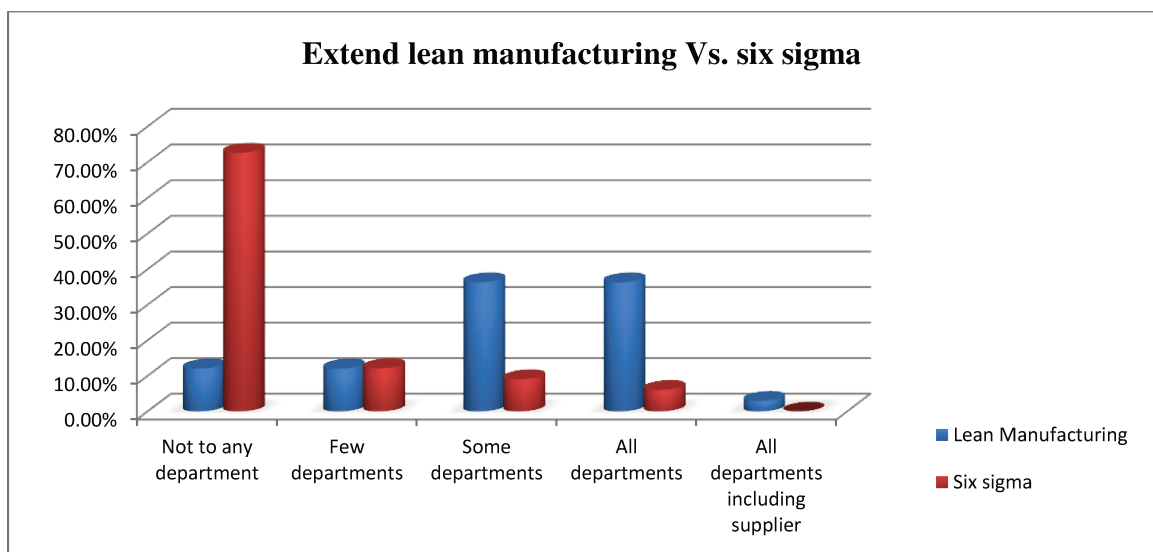


Figure 3.3: Extending of lean manufacturing and six sigma implementation

3.6.11. Tools and techniques of lean Manufacturing & Six Sigma

Lean manufacturing and six sigma tools and techniques are measured on a five -point scale. Table 3.16 shows the tools and techniques that are relevant to the implementation of lean manufacturing and six sigma within organizations are investigated; each item was measured using a five point Likert scale. Relative scales ranged from 1 = no implementation to 5 = complete implementation. This is adopted by **Shah and Ward (2007)**. A higher score on the Likert scale demonstrates that lean manufacturing and six sigma techniques are used and implemented more extensively. On the other hand, a lower score on the Likert scale indicates that lean manufacturing and six sigma tools are not used or implemented extensively. However, Responses from the survey questionnaires show that lean manufacturing and six sigma tools have applied but the level of implementation vary from company to other company.

Table 3.16 Status level of lean manufacturing and six-sigma tools

Tools and technique	N	Min	Max	Mean	Std. Deviation
PDCA	33	1	5	4.00	.901
Cause and effect diagram	33	1	5	3.70	.951
5S	33	1	5	3.67	.990
Visual Control	33	1	5	3.64	1.055
Standardized Work	33	1	5	3.64	.929
Brainstorming	33	2	5	3.64	1.113
Pareto chart	33	1	5	3.48	1.149
Flow chart	33	1	5	3.30	1.015
FMEA	33	1	5	3.12	1.244
Voice of Customer	33	1	5	3.12	1.317
Value Stream Mapping	33	1	5	3.12	1.386
Kaizen team	33	1	5	3.12	1.386
Check sheet	33	1	5	3.00	.968
Gemba	33	1	5	2.97	1.357
TPM	33	1	5	2.76	1.032
Kanban	33	1	5	2.64	1.220
Poka-yoke	33	1	5	2.64	1.168
SMED	33	1	5	2.58	1.324
Takt time	33	1	5	2.52	1.302
Control chart	33	1	5	2.52	1.253
Defects per million opportunities	33	1	5	2.48	1.482
DMAIC	33	1	5	2.33	1.451
Once piece flow	33	1	5	2.27	1.306
Design of Experiment	33	1	5	2.15	1.064
Cellular lay-out	33	1	5	2.06	1.321
Regression analysis	33	1	3	1.48	.667

CHAPTER 4.

ANALYSIS THE IMPACT OF LEAN MANUFACTURING AND SIX- SIGMA IMPLEMENTATION

4. Analysis the impact of lean Manufacturing and six-sigma implementation on performance outcomes

4.1. Introduction

The methodology of six sigma aims at identifying and eliminating sources of variability (Breyfogle, 1999). Lean manufacturing, on the other hand, is concerned with the identification and elimination of waste arising from non-value-added activities and with improvements in quality (Wilson, 2010). The aim of this chapter is to determine the performance outcomes for industries practicing lean manufacturing and/or six sigma, considering all 33 companies from the survey. The influence on financial, operational, and innovation performance outcomes are revealed (Alhuraish et al., 2016c). The study then seeks to determine the relative factors (such as age, period of time, range of lean manufacturing and six sigma, belt system, etc.) that are associated with the success of implementation of lean manufacturing and/or six sigma, in order to determine which factors support performance improvements and which do not. Table A presents a summary of chapter 4.

Table A. Summary of the chapter 4

Problem	Objective	Results
First, there is little in the literature describing how French companies are currently performing with the implementation of lean manufacturing and six sigma. Second, many companies have failed to implement lean manufacturing or six sigma or combinations of these and the literature review has revealed several factors key to the success of implementing lean manufacturing and six sigma, but no previous studies have compared lean manufacturing and six sigma across common success factors.	The aim of this chapter is to determine the performance outcomes for industries practicing lean manufacturing and/or six sigma in French industry, and the relationships between implementing lean manufacturing and six sigma at the same time, ISO certification, the period and range of implementation, the level of success, company size, and the use of a belt system. This chapter also investigates the key success factors when implementing lean manufacturing and six sigma separately, in order to reveal the importance of success factors for each method.	This study has found that lean manufacturing and six sigma improve companies' performance. The findings indicate that there is no relationship between whether lean manufacturing and six sigma are implemented simultaneously or separately on performance outcomes, with the exception of reduction in turnover rate and decreased inventory, and that size has no influence on financial or operational performance outcomes. The results of this study show that the implementation of lean manufacturing and six sigma in all departments improves both operational and innovation performance. Moreover, it is found that the use of a belt system improves quality and reduces costs and variation. It is also found that in comparisons between lean manufacturing and six sigma methodologies in terms of identical success factors, only some factors are statistically significant.

4.2. Impact of lean Manufacturing and/or six-sigma implementation on performance outcomes

A statistical analysis was performed in order to determine how the implementation of lean manufacturing and/or six sigma impacted performance outcomes. The statistical analysis was

conducted using the binomial test, because of the abnormal nature of the variables relevant to determining the significance of the impact of lean manufacturing and/or six sigma implementation on company performance for all 33 companies. Before determining how the implementation of lean manufacturing and/or six sigma impacted performance outcomes, we performed a Spearman correlation among the main variables in order to understand the relationship between financial, operational, and innovation performance. The results for the Spearman rho correlation are shown in Table 4.1. Positive correlations were found between financial performance and both operational and innovation performance. There was a significant association (or relationship) between financial performance and operational performance ($r = 0.600$, $p\text{-value} < 0.01$) and innovation performance ($r = 0.455$, $p\text{-value} < 0.01$). Increased financial performance corresponded to moderately increased levels of operational and innovation performance. The Spearman rho data analysis also revealed a positive and significant correlation between operational and innovation performance ($r = 0.616$, $p\text{-value} < 0.01$).

Table 4.1 Correlation among financial, operational, and innovation performance

Correlation	Financial	Operational	Innovation
	Spearman's Coefficient	Spearman's Coefficient	Spearman's Coefficient
Financial	1.000	.600**	.445**
Operational	.600**	1.000	.616**
Innovation	.445**	.616**	1.000

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

To assess performance outcomes for all 33 French companies in the study implementing lean manufacturing and/or six sigma, measures of financial performance (reduced cost and increased profit), operational performance (improved quality, reduced variation, improved productivity, reduced times, increased customer satisfaction, decreased inventory, and improved safety environment), and innovation performance (greater involvement of and more suggestions from employees and reduced turnover rate) were investigated. Therefore, a binomial test was conducted to detect whether or not there were significant impacts of lean manufacturing and/or six sigma implementation on companies in terms of their financial, operational, and innovation performance.

A. Evaluation of lean manufacturing and six sigma implementation on the basis of financial performance: Testing hypothesis

- **Increase profit**

The results of the frequency analysis of increased profit for all 33 companies are varied. Figure 4.1 shows the frequency of increased profit when implementing lean manufacturing and/or six sigma. In order to determine whether the implementation of lean manufacturing and /or six sigma has any influence in terms of increased profit, a binomial test was conducted, with the following results.

Null hypothesis: lean manufacturing and six sigma implementation have not a positive impact on increase profit. $H_0: P \leq 0.60$

Alternative hypothesis: Lean manufacturing and six sigma implementation have a positive impact on increase profit. $H_a: P > 0.60$

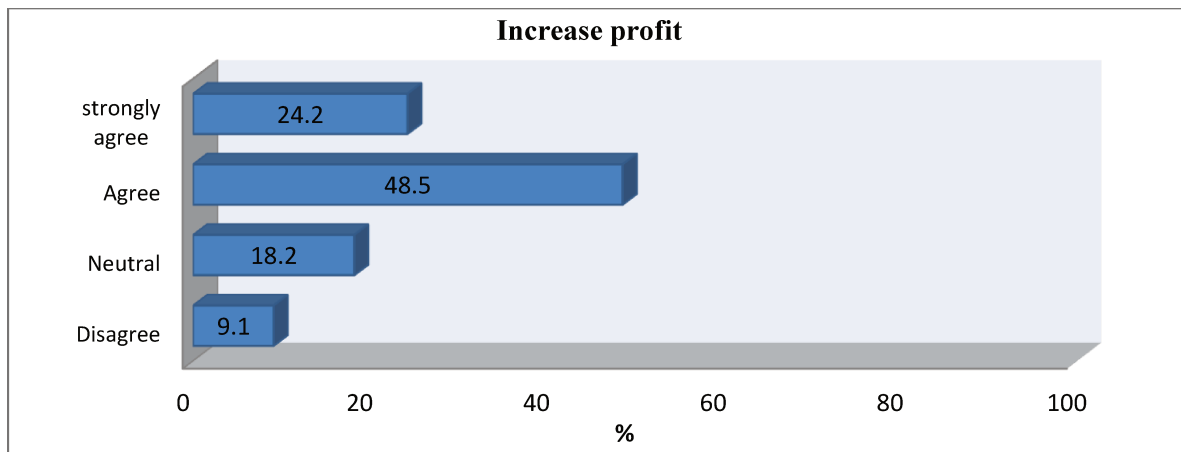


Figure 4.1: Frequency of responses enterprises on increase profit

Since the p-value (0.014) was less than the alpha value of 0.05, the null hypothesis is rejected. It is seen that the observed proportion (0.73) of agree and strongly agree is significantly greater than the test proportion (0.60). It can be concluded that companies implementing lean manufacturing and/or six sigma realize at least a 60% increase in profits. By inference, then, at least 60% of French companies moderately or strongly agree that the implementation of lean manufacturing and/six sigma improves profits. Therefore, these results suggest that positive agreements are more common than disagreements on increased profit.

Table 4.2 The effect of lean manufacturing and six sigma implementation on increased profit

Increase profit	Binomial Test				
	Category	N	Observed Prop.	Test Prop.	Sig. (2-tailed)
Group 1	<= 3	9	.27	.60	.014
Group 2	> 3	24	.73		
			1.00		

- **Reduces cost**

Figure 4.2 shows the frequency of reduced cost on implementing lean manufacturing and/or six sigma. It shows that 39.4 % strongly agree, 42% agree, 6.1% neutral, 12.1 disagree, and 0% strongly disagree. However, a Binomial test was conducted to verify the influence of implementing lean manufacturing and/or six sigma.

Null hypothesis: Lean manufacturing and six sigma implementation have not a positive impact on reduces cost. $H_0: P \leq 0.60$

Alternative hypothesis: Lean manufacturing and six sigma implementation have a positive impact on reduces cost. $H_a: P > 0.60$

The result of the test for reduced cost is considered to be significant (p-value < 0.05). It shows that the observed proportion (0.82) of agree and strongly agree is significantly greater than the test proportion (0.60). This suggests that the null hypothesis should be rejected, since lean manufacturing and/or six sigma have shown positive influences on cost reduction. Therefore, the results indicate that positive agreements are more common than disagreements on reduced cost.

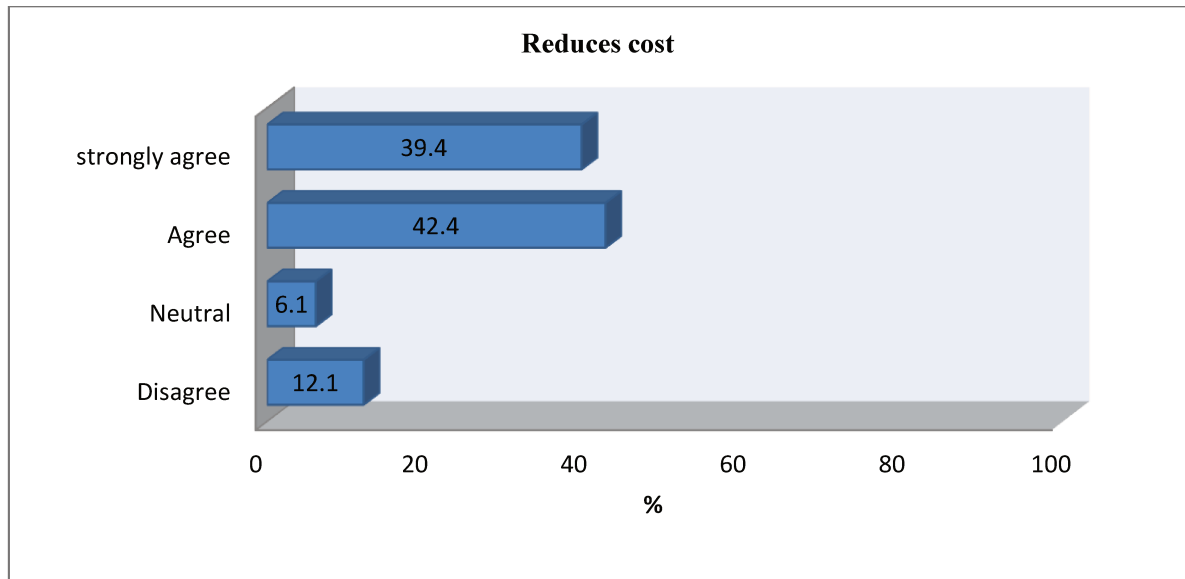


Figure 4.2: Frequency of responses enterprises in reduce cost

Table 4.3 The effect of lean manufacturing and six sigma implementation on reduced cost

Binomial Test					
Reduces cost	Category	N	Observed Prop.	Test Prop.	Sig. (2-tailed)
Group 1	≤ 3	6	.18	.60	.000
Group 2	> 3	27	.82		
Total		33	1.00		

B. Evaluation of lean manufacturing and six sigma implementation on the basis of operational performance

▪ Improve quality

Figure 4.3 exhibits the frequency of improves quality through the implementation of lean manufacturing and six sigma within all 33 companies.

Null hypothesis: Lean manufacturing and six sigma implementation have not a positive impact on improve quality. $H_0: P \leq 0.60$

Alternative hypothesis: Lean manufacturing and six sigma implementation have a positive impact on improve quality. $H_a: P > 0.60$

Based on the binomial test results, the null hypothesis is rejected. The Binomial test results reveal that at least 60% of company that implementing lean manufacturing and/or six sigma methodologies realize improvement in quality since the value over 3 is consistent with an agreement of quality. It shows that observed proportion (0.94) of agree and strongly agree is significantly greater than test proportion (0.60). It can be oblique that the alternative hypothesis is accepted. Therefore, it can be concluded that lean manufacturing and/or six sigma implementation corresponds with a positive impact on improved quality.

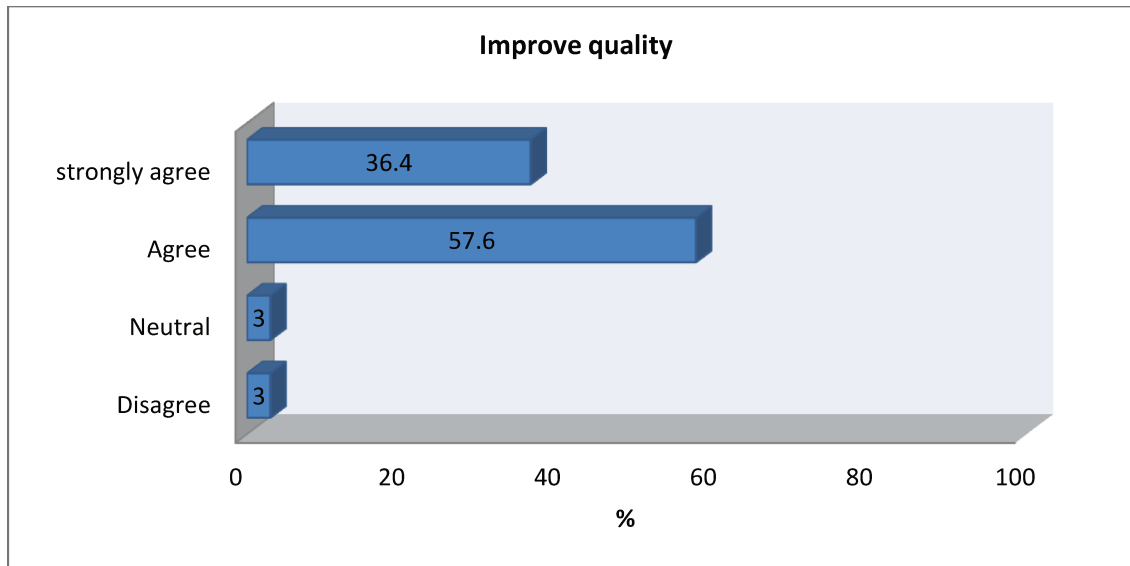


Figure 4.3: Frequency of responses enterprises in improve quality

Table 4.4 The effect of Lean manufacturing and six sigma implementation on improved quality

Binomial Test					
Improve quality	Category	N	Observed Prop.	Test Prop.	Sig. (2-tailed)
Group 1	<= 3	2	.06	.60	.000
Group 2	> 3	31	.94	.70	.000
Total		33	1.00	.90	.000

▪ Reduce variation

Figure 4.4 exhibits the frequency of reduces variation through the implementation of lean manufacturing and six sigma within all 33 companies.

Null hypothesis: Lean manufacturing and six sigma implementation have not a positive impact on reduces variation. $H_0: P \leq 0.60$

Alternative hypothesis: Lean manufacturing and six sigma implementation have a positive impact on reduces variation. $H_a: P > 0.60$

The result of the test for reduced cost is considered to be significant ($p\text{-value} < 0.05$). It is seen that the observed proportion (0.82) of agree and strongly agree is significantly greater than the test proportion (0.60). This suggests that the null hypothesis should be rejected. Therefore, lean manufacturing and/or six sigma have shown positive influences on cost reduction

Table 4.5 The effect of Lean manufacturing and six sigma implementation on reduced variation

Binomial Test					
Reduces variation	Category	N	Observed Prop.	Test Prop.	Sig. (2-tailed)
Group 1	<= 3	9	.27	.60	.014
Group 2	> 3	24	.73		
Total		33	1.00		

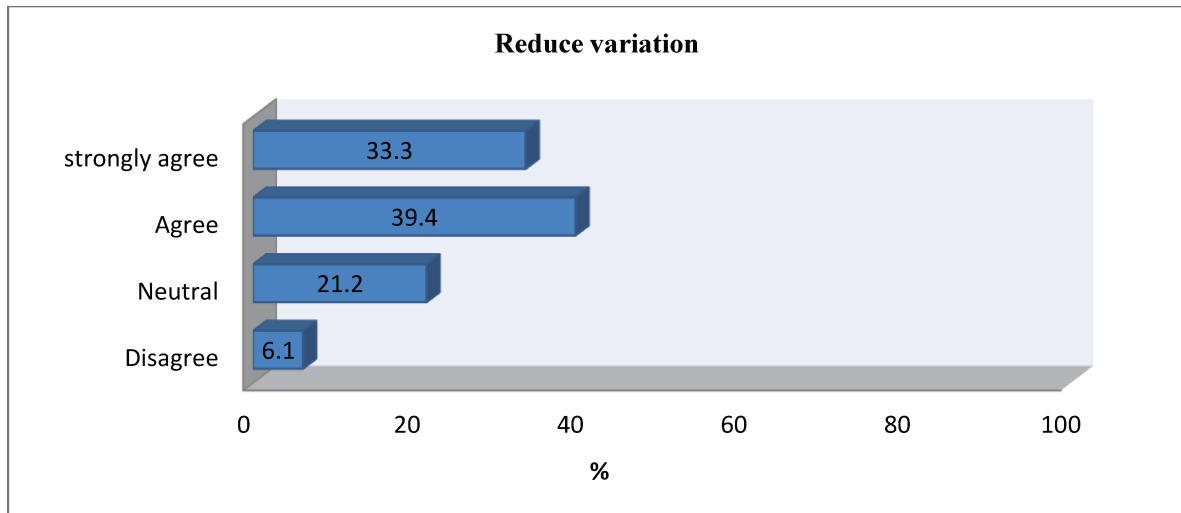


Figure 4.4: Frequency of responses enterprises in reduce variation

- **Improves productivity**

Figure 4.5 exhibits the frequency of improves productivity through the implementation of lean manufacturing and/or six sigma.

Null hypothesis: Lean manufacturing and six sigma implementation have not positive impact on improve productivity. $H_0: P \leq 0.60$

Alternative hypothesis: Lean manufacturing and six sigma implementation have positive impact on improve productivity. $H_a: P > 0.60$

Table 4.6 The effect of Lean manufacturing and six sigma implementation on improved productivity

Binomial Test					
Improves productivity	Category	N	Observed Prop.	Test Prop.	Sig. (2-tailed)
Group 1	≤ 3	6	.18	.60	.000
Group 2	> 3	27	.82		
Total		33	1.00		

The result of the test for improve productivity is considered to be significant (p value < 0.05). This finding supports rejecting the null hypothesis (H_a). It is seen that the observed proportion (0.82) of agree and strongly agree is significantly greater than test proportion (0.60). Consequently, lean manufacturing and/or six sigma implementation have a positive impacts on improved productivity.

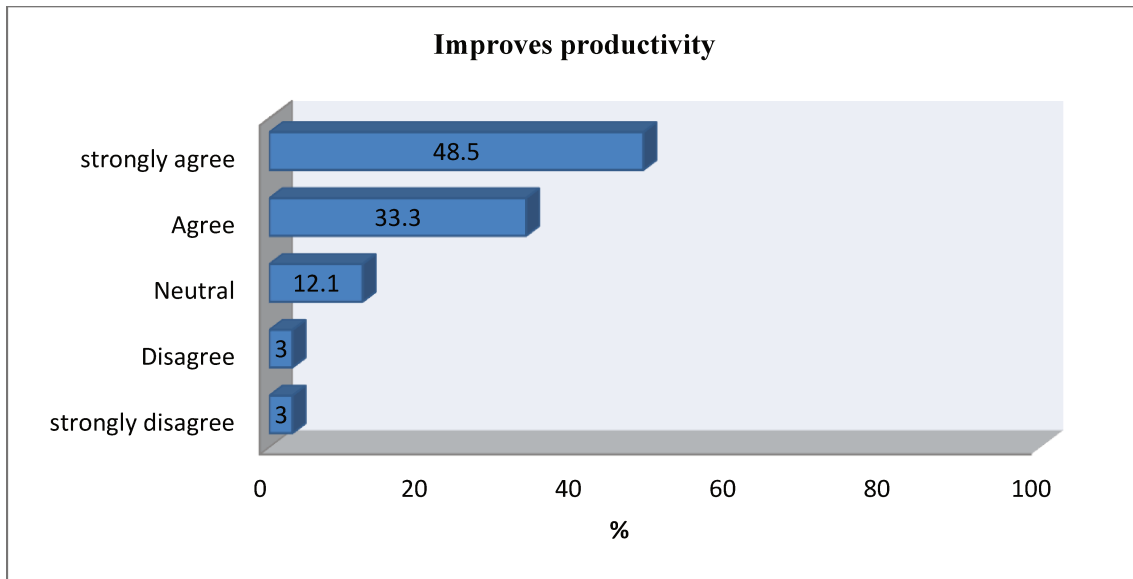


Figure 4.5: Frequency of responses enterprises in improve productivity

- **Reduce time**

Figure 4.6 exhibits the frequency of reduce time through the implementation of lean manufacturing and/or six sigma.

Null hypothesis: Lean manufacturing and six sigma implementation have not a positive impact on reduce lead time. $H_0: P \leq 0.60$

Alternative hypothesis: Lean manufacturing and six sigma implementation have a positive impact on reduce lead time. $H_a: P > 0.60$

Table 4.7 The effect of Lean manufacturing and six sigma implementation on reduced time

Binomial Test					
Reduce time	Category	N	Observed Prop.	Test Prop.	Sig. (2-tailed)
Group 1	≤ 3	4	.12	.60	.000
Group 2	> 3	29	.88		
Total		33	1.00		

The result of the test for reduce time is considered to be significant ($p\text{-value} < 0.05$). This finding supports the rejection of the null hypothesis (H_a). It is seen that the observed proportion (0.88) of agree and strongly agree is significantly greater than test proportion (0.60). Consequently lean manufacturing and/or six sigma implementation have a positive impacts on reduced time.

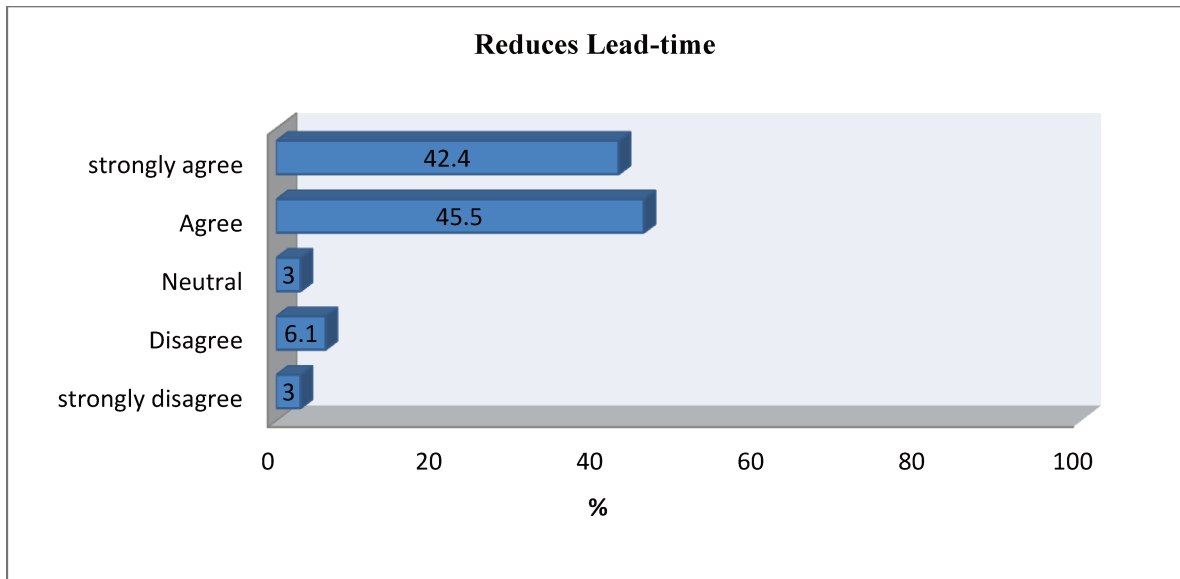


Figure 4.6: Frequency of responses enterprises in reduce time

- **Increase customer satisfaction**

Figure 4.7 exhibits the frequency of customer satisfied through the implementation of lean manufacturing and six sigma within all 33 companies.

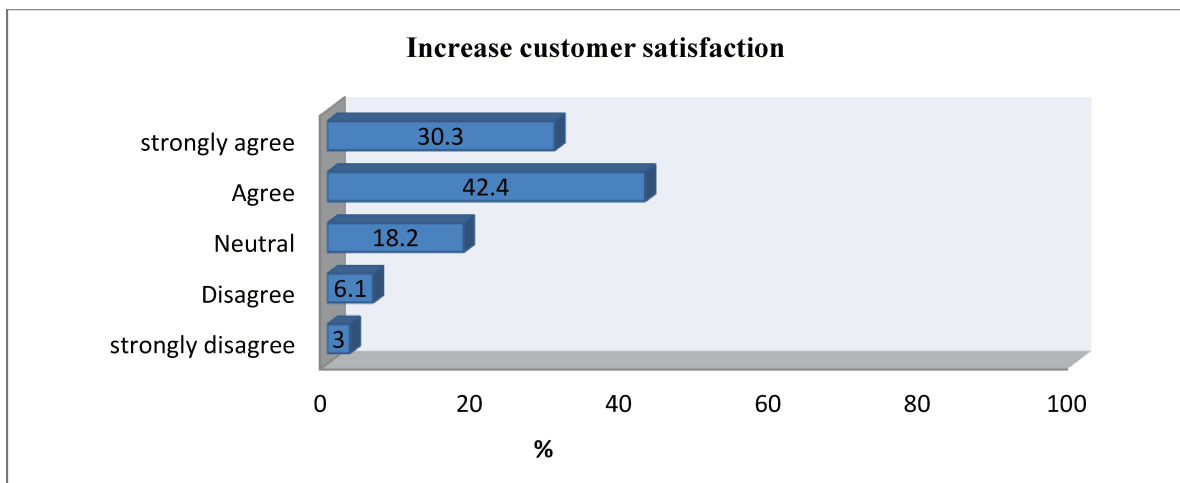


Figure 4.7: Frequency of responses enterprises in customer satisfaction

Null hypothesis: Lean manufacturing and six sigma implementation have not a positive impact on increase customer satisfaction $H_0: P \leq 0.60$

Alternative hypothesis: Lean manufacturing and six sigma implementation have a positive impact on increase customer satisfaction. $H_a: P > 0.60$

Table 4.8 The effect of lean manufacturing and six sigma implementation on customer satisfaction

Increase Customer satisfaction	Binomial Test				
	Category	N	Observed Prop.	Test Prop.	Sig. (2-tailed)
Group 1	≤ 3	9	.27	.60	.014
Group 2	> 3	24	.73		
Total		33	1.00		

The result of the test for customer satisfaction is considered to be significant ($p\text{-value} < 0.05$). This finding supports the rejection of the null hypothesis (H_a). It is seen that the observed proportion (0.73) of agree and strongly agree is significantly greater than test proportion (0.60). Consequently lean manufacturing and/or six sigma implementation have a positive impacts on customer satisfaction.

- **Decreases inventory**

Figure 4.8 exhibits the frequency of decrease inventory through the implementation of lean manufacturing and six sigma with all 33 companies.

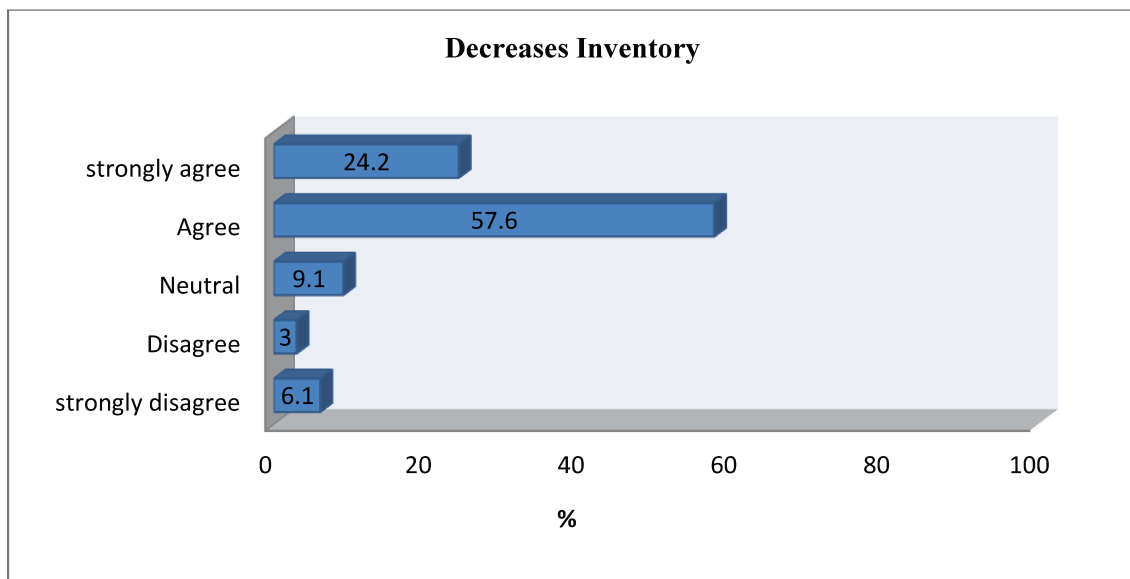


Figure 4.8: Frequency of responses enterprises in decreases inventory

Null hypothesis: Lean manufacturing and six sigma implementation have not a positive impact on decreases inventory $H_0: P \leq 0.60$

Alternative hypothesis: Lean manufacturing and six sigma implementation have a positive impact on decreases inventory $H_a: P > 0.60$

Table 4.9 the effect of Lean manufacturing and six sigma implementation on decreased inventory

Binomial Test					
Decreases Inventory	Category	N	Observed Prop.	Test Prop.	Sig. (2-tailed)
Group 1	≤ 3	6	.18	.60	.000
Group 2	> 3	27	.82		
Total		33	1.00		

The result of the test for decrease inventory is considered to be significant ($p\text{-value} < 0.05$). It is seen that the observed proportion (0.82) of agree and strongly agree is significantly greater than test proportion (0.60). This finding supports the rejection of the null hypothesis (H_a). Consequently lean manufacturing and/or six sigma implementation have a positive impacts on decreased inventory.

- **Create safety environment in the enterprises**

Figure 4.9 exhibits the frequency of safety environment through the implementation of lean

manufacturing and six sigma with all 33 companies.

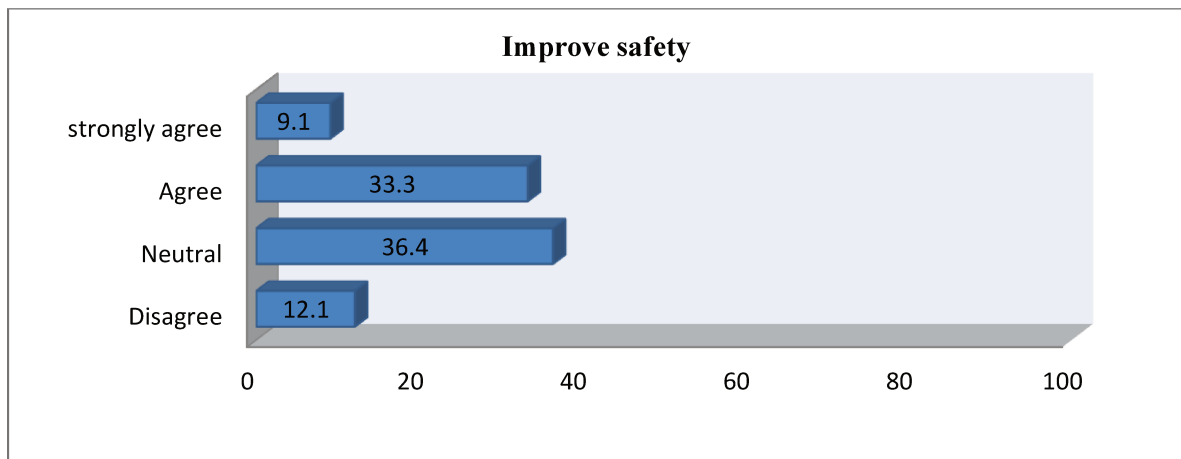


Figure 4.9: Frequency of responses enterprises in improve safety environment

Null hypothesis: Lean manufacturing and six sigma implementation have not a positive impact on improve safety environment $H_0: P \leq 0.60$

Alternative hypothesis: Lean manufacturing and six sigma implementation have a positive impact on improve safety environment. $H_a: P > 0.60$

Table 4.10 the effect of Lean manufacturing and six sigma implementation on safety environment

Creates safety environment in the enterprise	Binomial Test				
	Category	N	Observed Prop.	Test Prop.	Sig. (2-tailed)
Group 1	≤ 3	19	.58	.60	.487
Group 2	> 3	14	.42		
Total		33	1.00		

The result of the test for safety environment is considered to be significant ($p\text{-value} > 0.05$). This finding supports the rejection of the null hypothesis (H_a). It is seen that the observed proportion (0.42) of agree and strongly disagree is not significantly greater than test proportion (0.60). Consequently lean manufacturing and six sigma implementation have not a positive impacts on safety environment in the enterprises.

C. Evaluation of lean manufacturing and six sigma implementation on the basis of innovation performance

- **Increases suggestions from the employees**

Figure 4.10 shows the frequency of increase suggestion by the employees through the implementation of lean manufacturing and six sigma with all 33 companies.

Null hypothesis: Lean manufacturing and six sigma implementation have not a positive impact on increases suggestions from the employees. $H_0: P \leq 0.60$

Alternative hypothesis: Lean manufacturing and six sigma implementation have a positive impact on increases suggestions from the employees. $H_a: P > 0.60$

Table 4.11 The effect of Lean manufacturing and six sigma implementation on increased suggestions

Increases suggestions from the employees	Binomial Test				
	Category	N	Observed Prop.	Test Prop.	Sig. (2-tailed)
Group 1	<= 3	10	.30	.60	.035
Group 2	> 3	23	.70		
Total		33	1.00		

Since the p-value (0.035) was less than the alpha value of 0.05, it can be considered significant. Therefore, this findings support the rejection of the null hypothesis. It is seen that the observed proportion (0.70) of agree and strongly agree is significantly greater than test proportion (0.60). As a result, it can be concluded that lean manufacturing and six sigma implementation have a positive impacts on employees' suggestions.

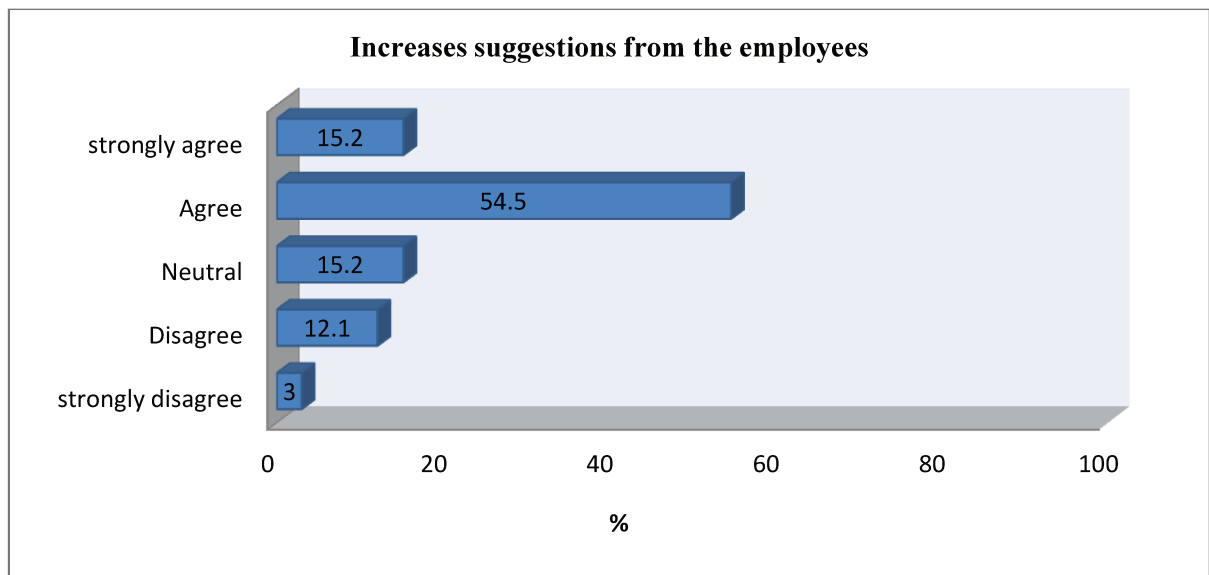


Figure 4.10: Frequency of responses enterprises in increases suggestions from the employees

▪ Involve employees

Figure 3.14 shows the frequency of involve the employees through the implementation of lean manufacturing and six sigma with all 33 companies

Null hypothesis: Lean manufacturing and six sigma implementation have not positive impact on involves employees $H_0: P \leq 0.60$

Alternative hypothesis: Lean manufacturing and six sigma implementation have positive impact on involves employees. $H_a: P > 0.60$

Table 4.12 the effect of Lean manufacturing and six sigma implementation on involved employees

Binomial Test					
Involvement employees	Category	N	Observed Prop.	Test Prop.	Sig. (2-tailed)
Group 1	<= 3	8	.24	.60	.005
Group 2	> 3	25	.76		
Total		33	1.00		

The result of the test for employees is considered to be significant ($p\text{-value} < 0.05$). This finding supports the rejection of the null hypothesis (H_0). Therefore, lean manufacturing and six sigma implementation have a positive impacts on employee's involvement. It is seen that the observed proportion (0.76) of agree and strongly agree is significantly greater than test proportion (0.60). Therefore, it can suppose that the employees are satisfied regarding lean manufacturing and/or six sigma implementation.

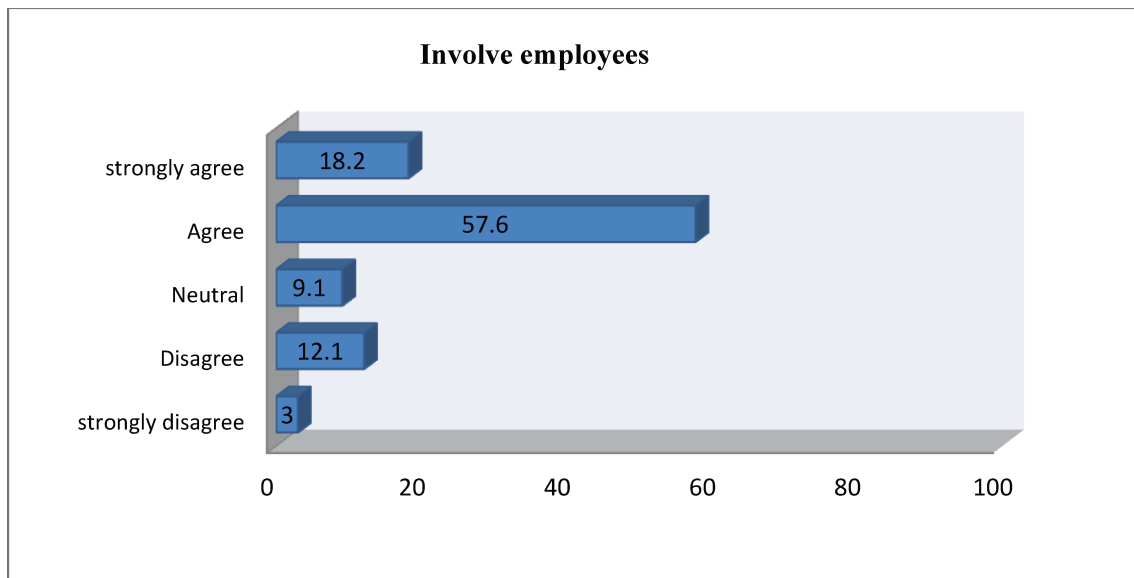


Figure 4.11: Frequency of responses enterprises in involve employees

▪ Reduce turnover rate

Figure 3.15 shows the frequency of reduce turnover rate through the implementation of lean manufacturing and six sigma with all 33 companies

Null hypothesis: Lean manufacturing and six sigma implementation have not a positive impact on reduce turnover rate $H_0: P \leq 0.60$

Alternative hypothesis: Lean manufacturing and six sigma implementation have a positive impact on reduce turnover rate. $H_a: P > 0.60$

Table 4.13 the effect of Lean manufacturing and six sigma implementation on reduced turnover rate

Binomial Test					
Reduce turnover rate	Category	N	Observed Prop.	Test Prop.	Sig. (2-tailed)
Group 1	<= 3	19	.58	.60	.487
Group 2	> 3	14	.42		
Total		33	1.00		

The result of the test is not significant ($p\text{-value} < 0.05$). This finding supports the acceptance of the null hypothesis (H_a). It is seen that the observed proportion (0.42) agree and strongly agree is not significantly greater than test proportion (0.60). Consequently, lean manufacturing and/or six sigma implementation have not a positive impacts on reduce turnover rate. As a result, it can be concluded that lean manufacturing and/or six sigma implementation have not a negative impacts on reduce turnover rate.

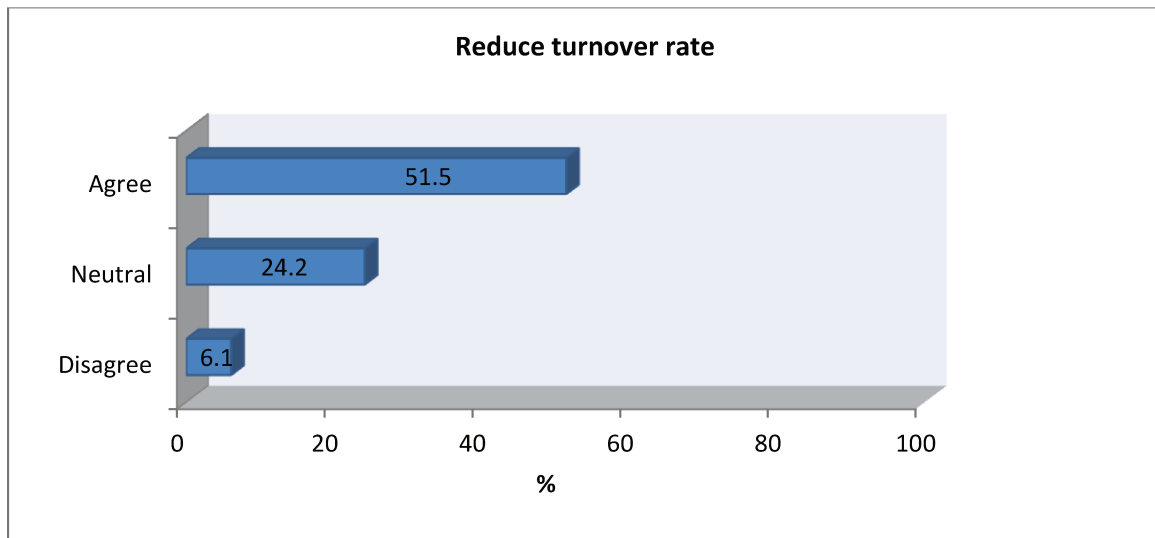


Figure 4.12: Frequency of responses enterprises in reduce turnover rate

Therefore, it has been demonstrated that the implementation of lean manufacturing and/or six sigma supports an increase in performance outcome within 33 companies. Therefore, we investigate the relation with variables such as age, period of implemented lean manufacturing and six sigma, range of lean manufacturing and six sigma, implemented lean manufacturing and six sigma at the same time or not and so on. In order to determine which variables play a significant role in enhancing companies' performance.

4.2.1. Age

The relationships between the various ages of the organizations relating to companies performance were conducted with Kruskal Wallis test. The result indicate ($p\text{-value} > 0.05$) no significant difference between various age of the organizations and all twelve variable such as improve quality, reduce cost, improve productivity. Additionally the Spearman's rho correlation resulted emphasis that the benefit has no influenced by age of the organization. This finding proposes that different ages of companies have a similar impact on company performance.

4.2.2. Period of implementing lean manufacturing and six sigma

In order to verify whether there are significant difference respondent between the years of implementing lean manufacturing and six sigma methods related on the impact on the company performance (on the financial, operational and innovation dimension). Kruskal Wallis test was

used. The results of the Kruskal Wallis test indicated that there were statistically ($p\text{-value} < 0.05$) significant differences existing between the three groups on increase profit and reduce variation. Performance was also measured by reference to the period of time utilized in the implementation of lean manufacturing and/or six sigma. The range of mean score for period less than 3 years was 2.69 to 4.06, the range of mean score for 3 to 6 years was 2.67 to 4.22 and the range of mean score for more than 6 years was 3.25 to 4.75 of practicing lean manufacturing and/or six sigma. The longer these practices were in place, the greater the outcomes for financial and operational performance. In order to emphasize that we have used spearman correlation to identify the association between the number of years and companies performance. Spearman's rho data analysis revealed positive and significant correlation between companies performance and number of years for implementing lean manufacturing and/or six sigma ($r = 0.851^*$, $p\text{-value} < 0.05$).

Table 4.14 Mean on performance outcome across period of time

Main performance	Benefit / period	Less than 3 years		Between 3 to 6 years		More than 6 years		Kruskal Wallis test
Financial performance		Mean	STD	Mean	STD	Mean	STD	
	Increase profit	3.50	.966	4.00	.707	4.50	.534	.045*
Operational performance	Reduces cost	3.75	1.183	4.33	.707	4.50	.535	.249
	Reduces variation	3.87	.885	3.56	.882	4.75	.463	.028*
	Improve quality	4.06	.772	4.22	.441	4.75	.463	.068
	Improves productivity	4.00	1.211	4.22	.833	4.63	.518	.481
	Reduces Lead-time	3.94	1.237	4.22	.667	4.63	.518	.352
	Creates safety environment	3.00	1.03	3.00	1.225	3.88	.835	.288
	Customer satisfaction	3.94	.929	3.33	1.225	4.50	.535	.153
	Decreases Inventory	4.00	.816	3.67	1.581	4.00	.535	.670
Innovation performance	Involves employees	3.50	1.033	3.78	1.202	4.25	.463	.322
	reduce turnover rate	2.69	.704	2.67	1.118	3.25	.463	.310
	Increases suggestions from the employees	3.50	1.033	3.67	1.225	4.00	.535	.519

As demonstrated in Table 4.14, the average values increased in virtually all items the longer lean manufacturing and/or six sigma method have been practiced. Specifically, values increase over 4 where these methodologies have been in practice for more than 6 years. An overall, this infers that years of implementing lean manufacturing and/or six sigma methods influence to the companies performance in terms of increase profit and reduce variation.

4.2.3. Implementing lean manufacturing and six sigma simultaneously

The respondents were asked a closed question (Yes or No) to indicate whether or not their organizations have implemented both lean manufacturing and six sigma at the same time. The results are displayed in Table 4.15, and show that the majority of sampled companies (81.8%) have not implemented lean manufacturing and six sigma simultaneously.

Many authors have pointed out that simultaneous implementation of lean manufacturing and six

sigma allows companies to achieve improvements in quality, and reduce costs and cycle time (George, 2002; Breyfogle, 1999, Gamal Aboelmaged, 2010). However, these authors have not taken into consideration the capability of an organization to implement both methods simultaneously (Alhuraish et al., 2014a). The present study shows the following:

Table 4.15 The status on implemented both methodologies simultaneously

Companies implemented lean manufacturing and Six Sigma Simultaneously	Frequency	Percent
Yes	6	18.2
No	27	81.8
N	33	100.0

- ✚ Only a few companies (18.2%) implemented lean manufacturing and six sigma at the same time.
- ✚ It is the author's opinion that such simultaneous implementations may not be feasible for SMEs and even some large companies. Indeed, Table 3.32 suggests that simultaneous implementation of the two methods may not be easy to accomplish. As Bertels (2003) points out, "organization should be mature enough and have a clear strategy to combine lean and six sigma at the same time".

To determine whether there is a relationship between the implementation of lean manufacturing and six sigma either simultaneously or separately and companies' financial, operational, and innovation performance, a chi square test was conducted, with the following results.

I. Financial performance

▪ Increase profit

H₀: Implemented lean manufacturing and six sigma simultaneously and increase profit are not independent

H_a: Implemented lean manufacturing and six sigma simultaneously and increase profit are independent

Chi square test was conducted to determine whether or not there is a relationship between increased profit and the organization implemented lean manufacturing and six sigma simultaneously. Figure 4.13 exhibits the percentage of comparable performance outcomes of increased profit through the implementation of lean manufacturing and six sigma simultaneously and separately. There is no statically significant relationship between implemented lean manufacturing and six sigma simultaneously and increase profit since the p-value was greater than or equal to the significance level 0.05 ($\chi^2 = 2.190$, $df = 3$, $p\text{-value} = 0.543$).

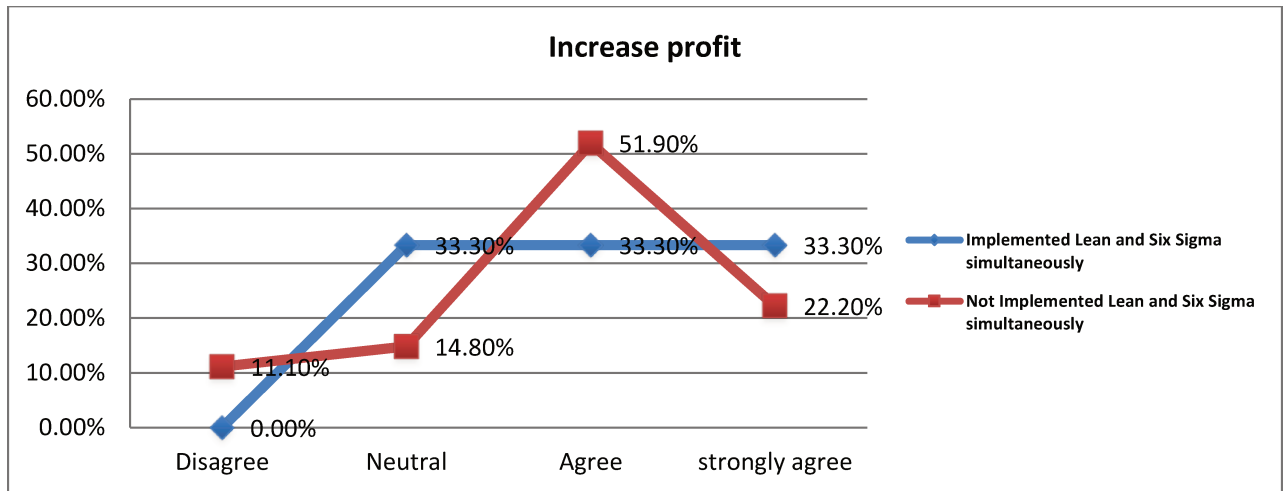


Figure 4.13: Status of increase profit on implemented lean and six sigma simultaneously

Therefore, there is no relationship between companies that implemented lean manufacturing and six sigma simultaneously and increased profit. The alternative hypothesis is therefore rejected (H_0). As when the distributions of increase profit between implemented lean manufacturing and six sigma simultaneously and separately are large enough to accept alternative hypothesis, meaning that these two variable of implemented lean manufacturing and six sigma simultaneously do not effect in increased profit within French industry.

▪ Reduce cost

H_0 : Implemented lean manufacturing and six sigma simultaneously and reduce cost are not independent

H_a : Implemented lean manufacturing and six sigma simultaneously and reduce cost are independent

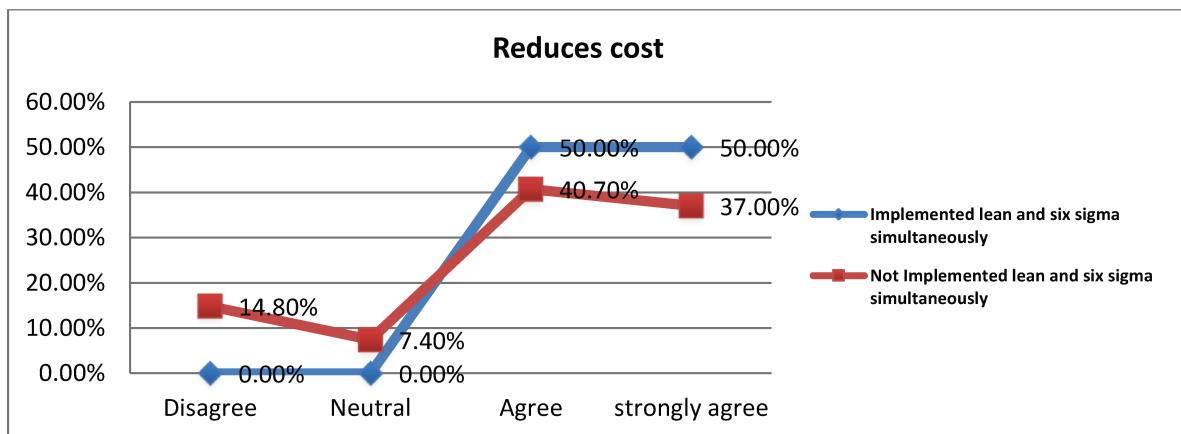


Figure 4.14: Status of reduce cost on implemented lean manufacturing and six sigma simultaneously

A chi square test was conducted for measuring the relationship between companies that had implemented lean manufacturing and six sigma methods at the same time and those that had not implemented lean manufacturing and six sigma methods simultaneously (See Figure 4.14). Findings reveal that there is no significant relationship between companies implementing lean manufacturing and six sigma simultaneously and reduced cost ($\chi^2 = 1.642$, $df = 3$, $p\text{-value} = 0.650$).

Consequently, the alternative hypothesis was rejected (H_0). This indicates implementing lean manufacturing and six sigma simultaneously have no effected on increased profit. Therefore, the pattern of the relationship seems to be implemented lean manufacturing and six sigma simultaneously and separately tend to get similar result on reducing cost.

II. Operational performance

▪ Improve quality

H₀: Implemented lean manufacturing and six sigma simultaneously and improve quality are not independent

H_a: Implemented lean manufacturing and six sigma simultaneously and improve quality are independent

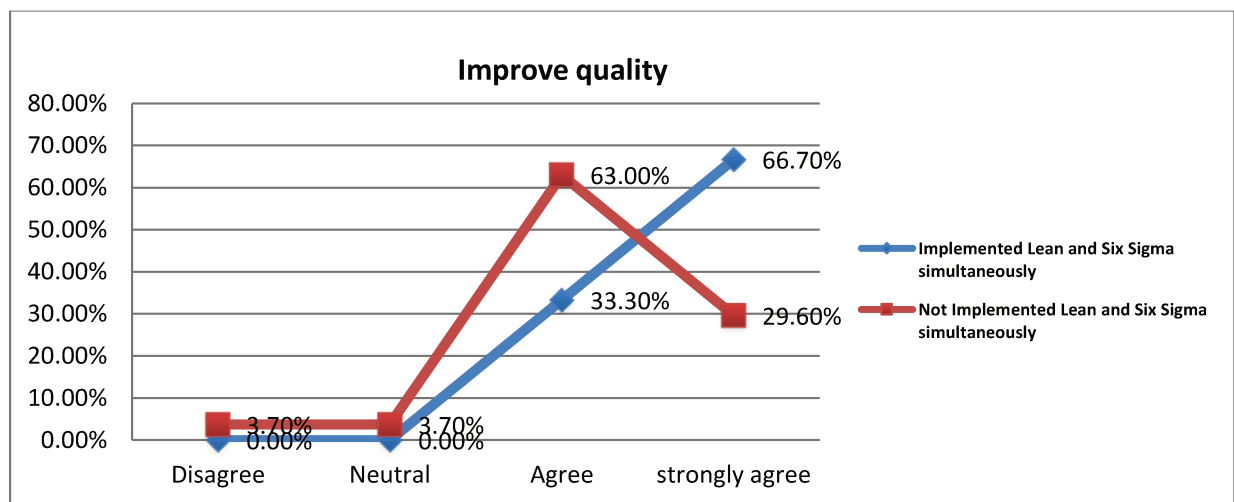


Figure 4.15: Status of improve quality on implemented lean manufacturing and six sigma simultaneously

The chi square test showed no statistically significant relationship between improved quality and implementing lean manufacturing and six sigma simultaneously. This means implementing lean manufacturing and six sigma either simultaneously or separately showed no differences in improved quality ($\chi^2 = 3.045$, $df = 3$, $p\text{-value} = 0.385$). Consequently, the alternative hypothesis was rejected (H_0). Thus, the alternative hypothesis states that implementing lean manufacturing and six sigma simultaneously and improved quality are not independent. The pattern of the relationship seems to be implemented lean manufacturing and six sigma simultaneously and separately tend to get similar result on improve quality.

▪ Reduce variation

H₀: Implemented lean manufacturing and six sigma simultaneously and reduce variation are not independent

H_a: Implemented lean manufacturing and six sigma simultaneously and reduce variation are independent

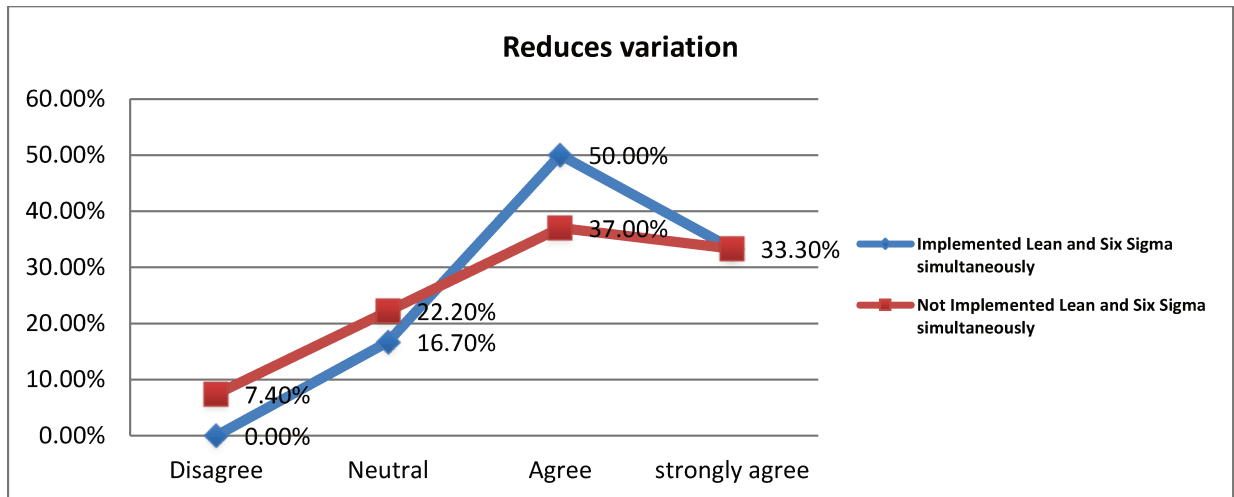


Figure 4.16: Status of reduce variation on implemented lean and six sigma simultaneously

A chi square test was conducted. Findings showed no significant relationship between implementing lean manufacturing and six sigma simultaneously and reduced variation ($\chi^2 = 0.735$, $df = 3$, $p\text{-value} = 0.867$), meaning that applying lean manufacturing and six sigma at the same time have no influence on improved quality. The alternative hypothesis was rejected (H_0). Therefore, it can be concluded that implementing lean manufacturing and six sigma simultaneously and reduced variation are not independent (H_0), meaning that these two variable of implemented lean manufacturing and six sigma simultaneously or separately do not effect in reducing variation.

▪ Improve productivity

H_0 : Implemented lean manufacturing and six sigma simultaneously and improve productivity are not independent

H_a : Implemented lean manufacturing and six sigma simultaneously and improve productivity are independent

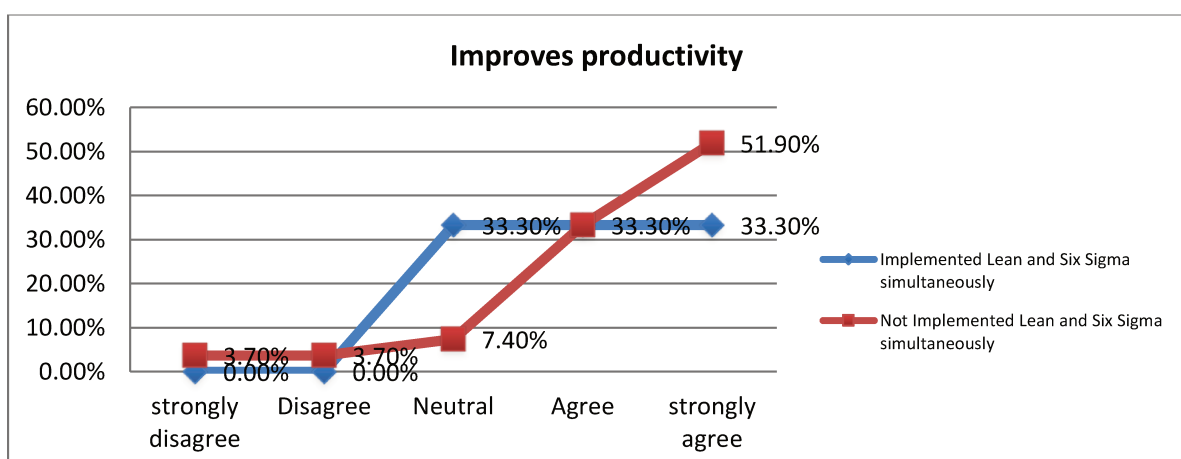


Figure 4.17: Status of improve productivity on implemented lean and six sigma simultaneously

The chi Square test showed no statistically significant relationship between improved productivity and implementing lean manufacturing and six sigma simultaneously ($\chi^2 = 3.514$, $df = 4$, $p\text{-value} = 0.476$). Therefore, the alternative hypothesis was rejected (H_0), which states that

implementing lean manufacturing and six sigma simultaneously and improved productivity are not independent. The pattern of the relationship seems to be implemented lean manufacturing and six sigma simultaneously and separately tend to get similar result on improve productivity.

▪ Reduce time

H₀: Implemented lean manufacturing and six sigma simultaneously and reduce time are not independent

H_a: Implemented lean manufacturing and six sigma simultaneously and reduce time are independent

The chi square test showed no statistically significant relationship between reduced time and implementing lean manufacturing and six sigma simultaneously ($\chi^2 = 7.039$, $df = 4$, $p\text{-value} = 0.134$). Therefore, the alternative hypothesis was rejected (H_0).

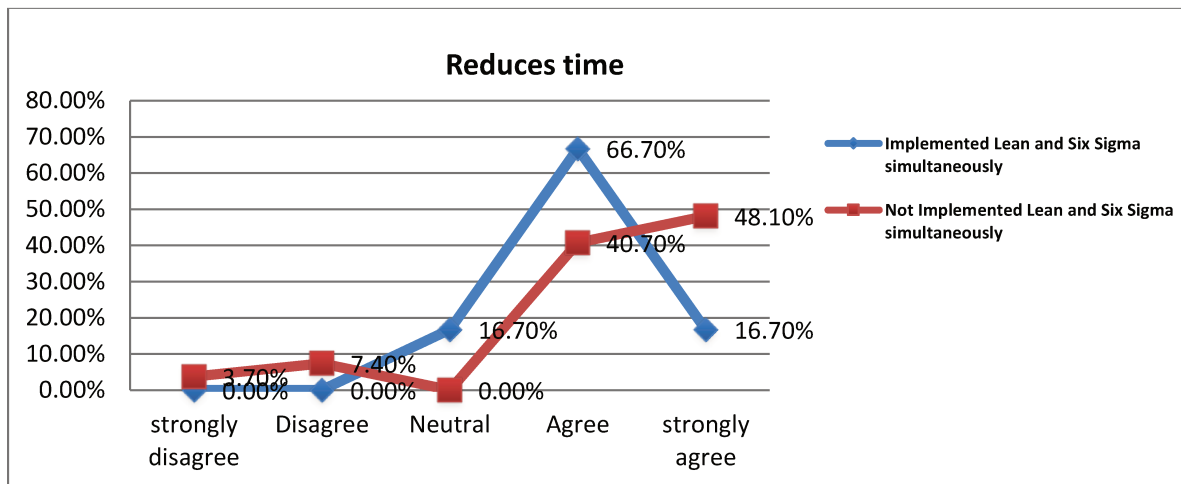


Figure 4.18: Status of reduce time on implemented lean and six sigma simultaneously

Concluding that implementing lean manufacturing and six sigma simultaneously and reduced time are not independent. Therefore, the pattern of the relationship seems to be implemented lean manufacturing and six sigma simultaneously and separately tend to get similar result on reducing time.

▪ Create safety environment

H₀: Implemented lean manufacturing and six sigma simultaneously and create safety environment are not independent

H_a: Implemented lean manufacturing and six sigma simultaneously and create safety environment are independent

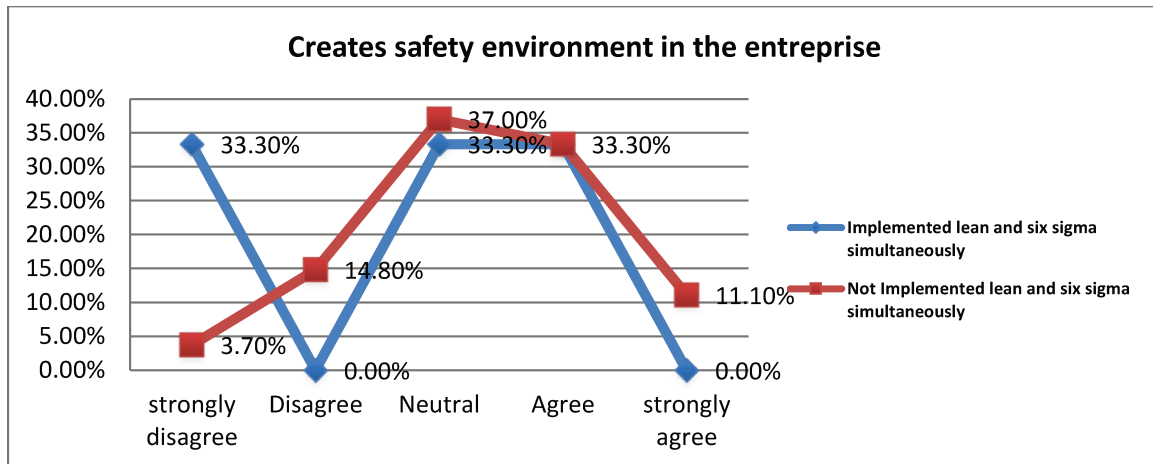


Figure 4.19: Status of safety environment on implemented lean and six sigma simultaneously

The Chi Square test showed no statistically significant relationship between the creation of a safe environment and implemented lean manufacturing and six sigma simultaneously ($\chi^2 = 6.315$, $df = 4$, $p\text{-value} = 0.177$). Therefore, the alternative hypothesis was rejected (H_0), concluding that implementing lean and six sigma simultaneously and creating a safe environment rates with the enterprises are not independent. The pattern of the relationship seems to be implemented lean manufacturing and six sigma simultaneously and separately tend to get similar result on safety environment.

▪ Decrease inventory

H_0 : Implemented lean manufacturing and six sigma simultaneously and decrease inventory are not independent

H_a : Implemented lean manufacturing and six sigma simultaneously and decrease inventory are independent

The Chi Square test showed statistically significant relationship between decreased inventory and implementing lean manufacturing and six sigma simultaneously ($\chi^2 = 11.536$, $df = 4$, $P\text{-value} = 0.021$). Therefore, the alternative hypothesis was accepted (H_a), concluding that implementing lean manufacturing and six sigma simultaneously and decreased inventory are independent.

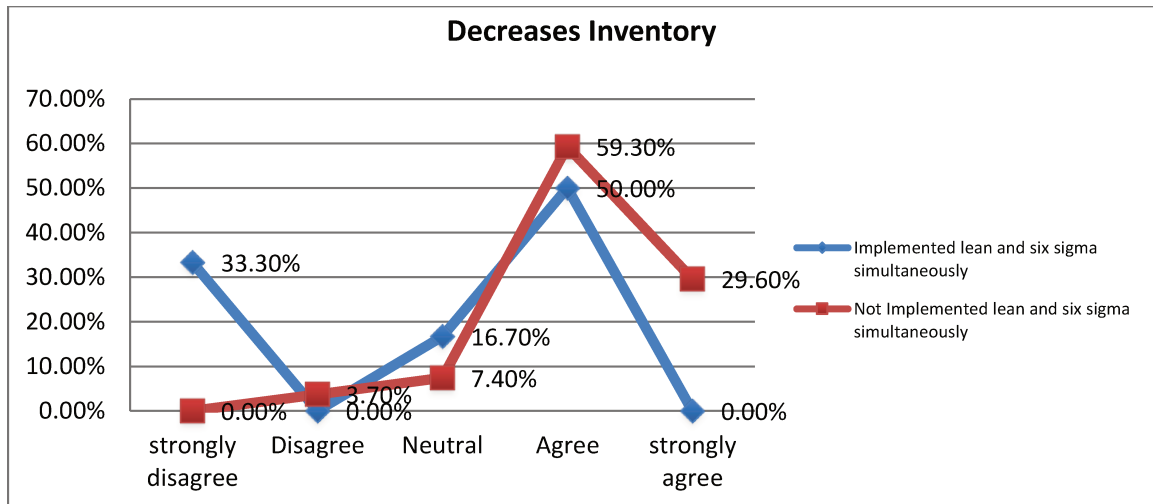


Figure 4.20: Status of decrease inventory on implemented lean and six sigma simultaneously

▪ Increase customer satisfaction

H₀: Implemented lean and six sigma simultaneously and increase customer satisfaction are not independent

H_a: Implemented lean and six sigma simultaneously and increase customer satisfaction are independent

The chi square test showed no statistically significant relationship between increased customer satisfaction and implementing lean manufacturing and six sigma simultaneously ($\chi^2 = 7.744$, $df = 4$, $p\text{-value} = 0.101$). Therefore, the alternative hypothesis was rejected (H_0); concluding that implementing lean manufacturing and six sigma simultaneously and increased customer satisfaction are not independent.

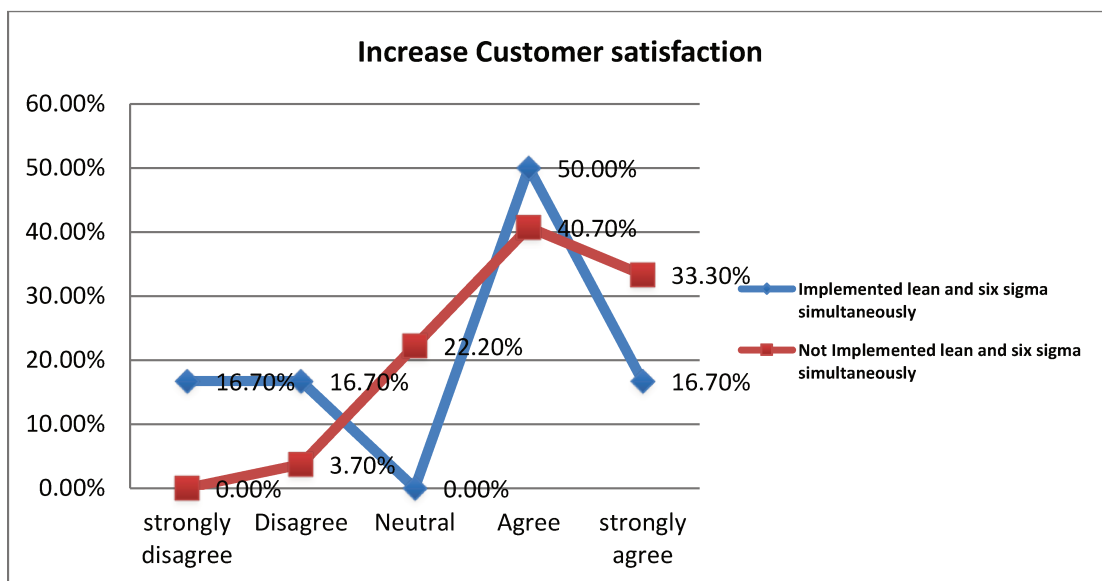


Figure 4.21: Status of increase customer satisfaction on implemented lean and six sigma simultaneously

The pattern of the relationship seems to be implemented lean manufacturing and six sigma simultaneously and separately tend to get similar result on increased customer satisfaction.

III. Innovation performance

- Increase suggestion from the employees

H₀: Implemented lean and six sigma simultaneously and increase suggestion from the employees are not independent

H_a: Implemented lean and six sigma simultaneously and increase suggestion from the employees are independent

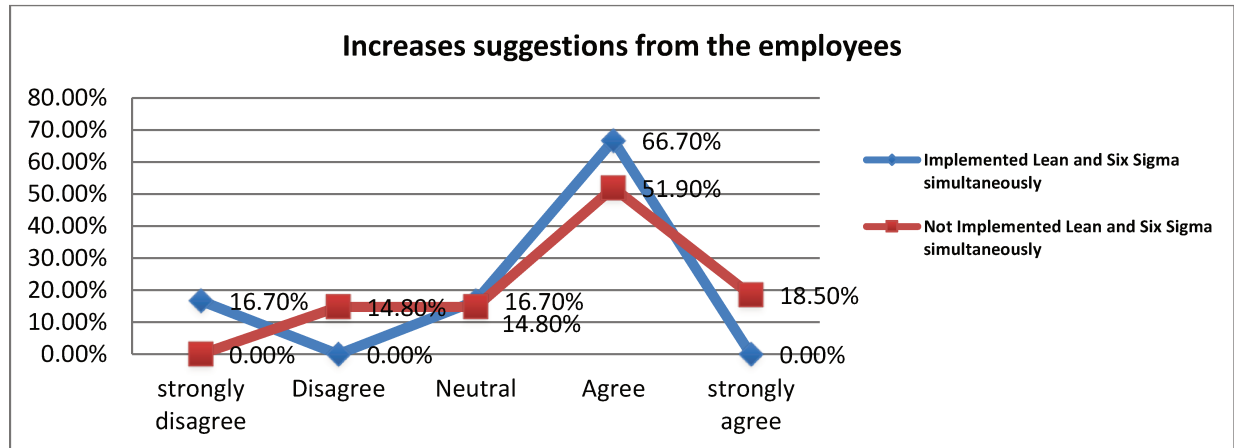


Figure 4.22: Status of increase suggestion from the employees on implemented lean and six sigma simultaneously

The chi square test showed no statistically significant relationship between increased suggestions from employees and implementing lean manufacturing and six sigma simultaneously ($\chi^2 = 6.709$, $df = 4$, $p\text{-value} = 0.152$). Therefore, the alternative hypothesis was rejected (H_0), concluding that implementing lean and six sigma simultaneously and increased suggestion from employees are not independent. The pattern of the relationship seems to be implemented lean manufacturing and six sigma simultaneously and separately tend to get similar result on increased suggestions from employees.

- Involve employees

H₀: Implemented lean and six sigma simultaneously and involve employees are not independent

H_a: Implemented lean and six sigma simultaneously and involve employees are independent

The chi square test showed no statistically significant relationship between involved employees and implementing lean manufacturing and six sigma simultaneously ($\chi^2 = 5.934$, $df = 4$, $P\text{-value} = 0.204$). Therefore, the alternative hypothesis was rejected (H_0), concluding that implementing lean manufacturing and six sigma simultaneously and involved employees are not independent. The pattern of the relationship seems to be implemented lean manufacturing and six sigma simultaneously and separately tend to get similar result on involved employees.

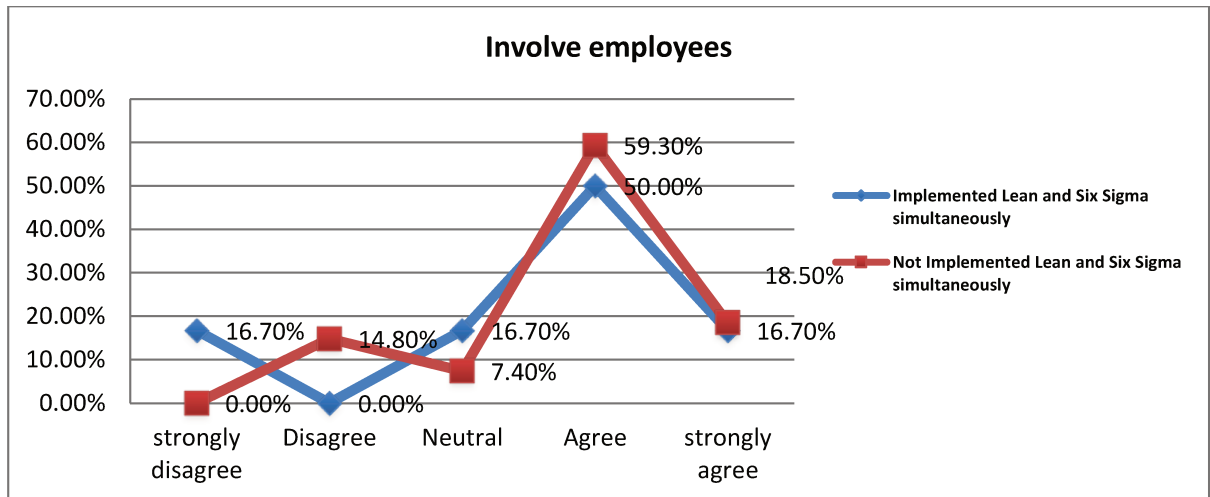


Figure 4.23: Status of involve employees on implemented lean and six sigma simultaneously

▪ Reduce turnover rate

H₀: Implemented lean and six sigma simultaneously and reduce turnover rate are not independent

H_a: Implemented lean and six sigma simultaneously and reduce turnover rate are independent

The chi square test showed a statistically significant relationship between reduced turnover rates and implementing lean manufacturing and six sigma simultaneously ($\chi^2 = 12.174$, $df = 3$, $p\text{-value} = 0.007$). Therefore, the alternative hypothesis was accepted (H_a), concluding that implementing lean manufacturing and six sigma simultaneously and reduced turnover rate are independent.

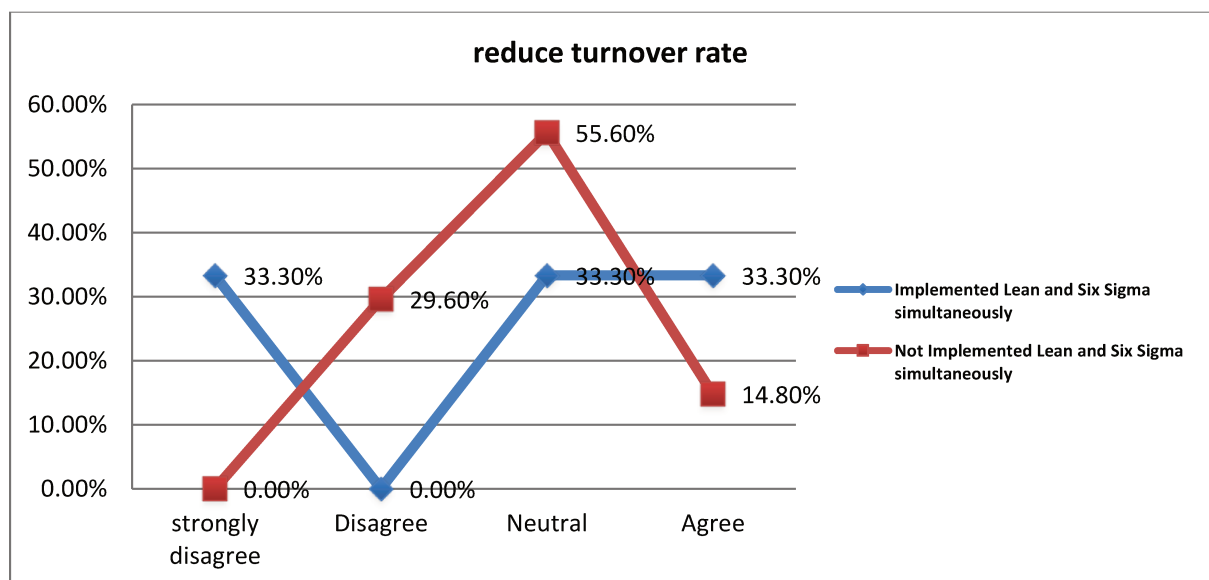


Figure 4.24: Status of reduce turnover rate on implemented lean and six sigma simultaneously

I. Statement that SME should follow for implementing Lean Manufacturing and Six Sigma

The experts were asked to answer questions by selecting one statement that SME (Recommended) should follow for implementing lean manufacturing and six sigma. Table

4.16 presented the status that SME should follow for implementing lean manufacturing and six sigma.

Table 4.16 Statement that SME should follow for implementing lean and six sigma

Statement	Frequency	Percent
Implement First lean and then six sigma	14	42.4
Implement Lean and six sigma in the same time	4	12.1
Implement First six sigma and then lean	2	6.1
Doesn't matter	4	12.1
Doesn't know	9	27.3
Total	33	100.0

However, based on the results that we received from all 33 companies, we observed that some companies implemented lean manufacturing and six sigma at the same time (18%), whereas other companies (81.8%) either implemented lean manufacturing and six sigma at different times or implemented lean manufacturing only. These companies and their responses are summarized and compared in Table 4.17. The respond have difference opinion regarding statement that SME should begin with their companies. Some companies (27.3%) responded that they did not know; a larger proportion (42.4%) suggested implementing lean manufacturing initially, followed by six sigma; and (6.1%) suggested implementing six sigma initially, followed by lean manufacturing (**Alhuraish et al., 2014a**). We expected that, with regard to the order of implementation of the two approaches, a high percentage would respond 'Does not matter', because although lean manufacturing can be used to improve the process flow, six sigma can be used to identify problems from a different perspective. Also, **Bertels, (2003)** indicated that, irrespective of the starting point, every manufacturing process can benefit from the application of both methods.

Table 4.17 Status of lean and Six Sigma and their recommended to begin implemented in case SME

Companies implemented lean and Six Sigma in the same time	Lean First then six sigma	six sigma First then lean	Lean and six sigma Simultaneously	Doesn't know	Doesn't matter
Yes (18.2%)	50.0%	33.3%	16.7%	0.0%	0.0%
No (81.8%)	40.7%	0.0%	11.1%	33.3%	14.8%

It was surprising that so few companies implemented both methods simultaneously, and that the recommended approach among SMEs was to implement one of these methods before the other (50% + 33%=83.3%). This could be explained by the limited resources available to SMEs in terms of finance and time. It may also be due to a certain extent to a lack of awareness among companies in France of the advantages of simultaneous implementation, since a number of experts answered "Don't know". A review of the literature also reveals similar issues. Therefore, with regard to the implementation of lean manufacturing or six sigma or both simultaneously, it is necessary to determine the most appropriate approach for a given company, based on its awareness of the critical success factors for each method, and its ability to apply these (see Chapter 6).

II. Reasons of not implementing Lean and Six Sigma simultaneously

The study seeks also why these two methodologies are not implemented simultaneously with their organization. The main reason: the lack of awareness (38%), because of the company culture (22%), lack of top management commitment (12%) and finance (6.0%).

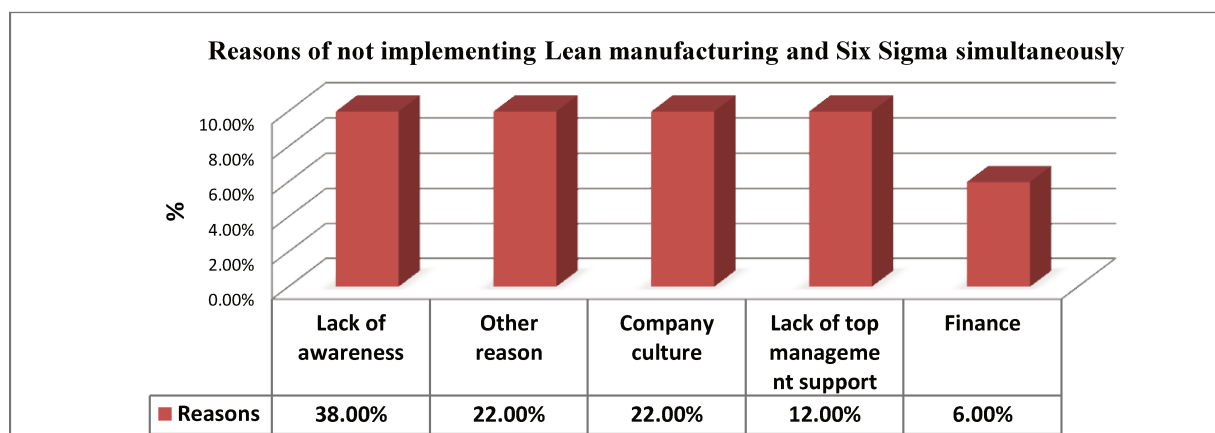


Figure. 4.25: Reasons of not implementing lean manufacturing and six sigma simultaneously

Other reason were found such the following reason:

- Implemented lean manufacturing method has often enough,
- Less resource,
- Sigma is too complicated.
- Better to have a good basis via lean, the rest will follow naturally, and the two methods do not addressing the same types of problems.

III. Reasons of implementing Lean and Six Sigma simultaneously

On the other hand, the reasons of implementing lean manufacturing and six sigma simultaneously are investigate as well. As shown in the Figure 4.26, majority of the reasons for implementing both methods simultaneously were indicate to get rapid improvement (38.2%), this results supported by **George (2002)**; (20.6%) of the respondents were indicated increase customer satisfaction and another (20.6%) were indicated lack of improvement, if we implement lean and six sigma separately. Only one company (2.9 %) was indicated to improve sale.

Others reasons have been mentioned of implementing both method simultaneously such as improving safe environment, sustainable result, reduce time, and an organization indicate rapid improvement while at the same time, he/she proposed suggestion that should be implemented lean manufacturing and six sigma separately with success, as their organization had implemented both method in sequence 5S, Kaizen, Poka yoke, Small Group Projects, Quality Circle, lean, six sigma and three responded had not indicated any of these reasons. However, from literature review many author emphasis implementation of lean manufacturing and six sigma simultaneously to achieve better results; such as improve performance, satisfied customer, increase profit. The implementation of both methods simultaneously may not be able to achieve by all organizations and especially for SME and we have observed that there is evident that companies have implemented one of these method either lean or six sigma before other one

successfully (kumar and Antonty 2009, Roland, 2010). Furthermore, based in our result that we detected some companies have not implemented lean manufacturing and six sigma at the same time. Therefore, from all above of these reasons, we attempted to help companies that planning to implement either lean manufacturing or six sigma or both method at the same time, to determine best method that fit with their companies, based on capability to apply the critical success factors of each method (see section 6).

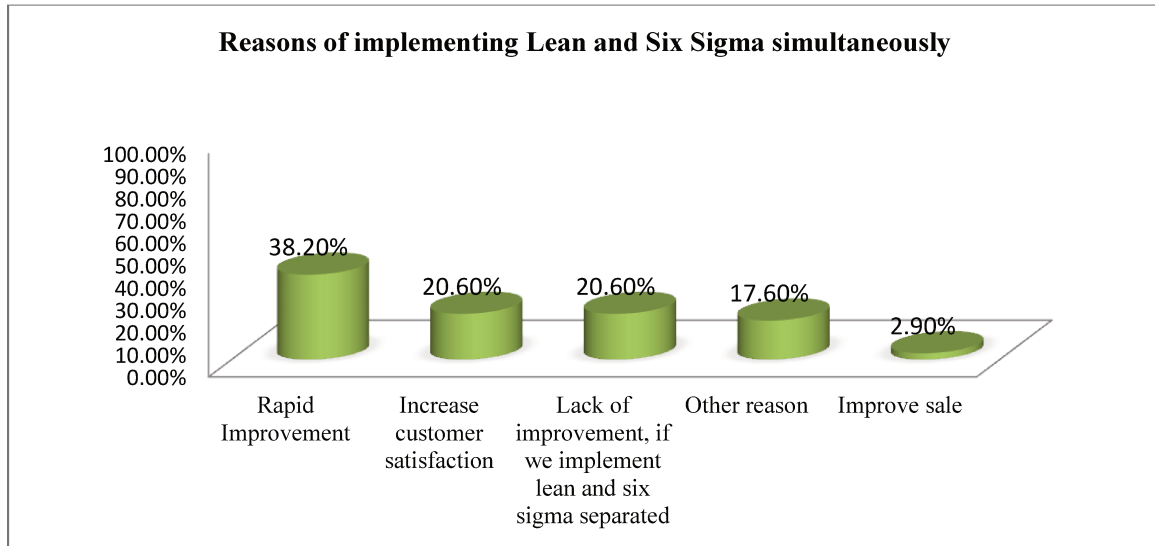


Figure 4.26: Reasons of implementing lean manufacturing and six sigma simultaneously

IV. Organizations have any accreditation standardization Vs. Lean Manufacturing and Six sigma

In order to determine whether or not there were any relation or influences of certification such as ISO 9001, ISO 1400 etc, on implementing of lean manufacturing and six sigma in the same time, a chi square test was conducted. Consequently, chi-square tests build the following hypothesis:

Ho: No relation between these certification and implementing both method simultaneously

Ha: A relation between these certification and implementing both method simultaneously

Research resulted as shown in Table 4.18 indicate that majority of these companies applied quality standard (84.6%) did not implement lean manufacturing and six sigma simultaneously and few companies who applied quality standard (15.4%) have implemented lean manufacturing and six sigma simultaneously. On the other hand, (71.4%) have not been certified any type of certification and have implemented lean manufacturing and six sigma simultaneously. (28.6%) certified companies have implemented lean manufacturing and six sigma simultaneously. The null hypothesis is accepted as chi square test showed no statistically significant relationship between certification companies such as ISO 9001, ISO 14001, EN 9100 and implementing lean manufacturing and six sigma simultaneously ($\chi^2 = 0.645$, $df = 1$, $P\text{-value} > 0.05$). Therefore, results indicate that these certification have no influence on implementing lean manufacturing and six sigma in the same time.

Table 4.18 citification vs. Lean manufacturing and six sigma

Organization has any accreditation standardization?		Organization implemented both methods simultaneously?		Total
		Yes	No	
Yes	Count	4	22	26
	%	15.4%	84.6%	100.0%
No	Count	2	5	7
	%	28.6%	71.4%	100.0%
Total				33

4.2.4. Extending lean Manufacturing and six sigma

Further analyses were conducted to determine the impact of extending lean manufacturing and six sigma methodologies on performance outcomes. Therefore, we compared the mean score of the companies performance between using lean manufacturing method to all departments and those that had not implemented lean manufacturing to any department (Alhuraish et al., 2015a). A similar criterion was followed for six sigma. There were two extending levels in the results: extending to all departments or not extending to any department. A score of 1 referred to no extending to any department and a score of 4 referred to extending to all departments. The results indicating the mean scores of extending level for lean manufacturing and six sigma within the organization across the impact on performance outcome are presented in the Table 4.19. It shows increasing of extending lean manufacturing and six sigma reflected to rise company operational and innovation performance such as improve quality, reduce variation, reduce cost, improve productivity, reduce time and involves employees. On the other hand, implementing lean manufacturing to all department assistants more to decreases inventory compared to six sigma. Lean manufacturing including various tools such as value stream mapping, 5S, TPM etc, that advantage to decrease inventory. Six sigma contains advanced statistical tools that specifically apply it only when the issue are vague that help to diagnose the complex problem in improving decrease inventory (Snee, 2010). Additionally, lean manufacturing emphasis to attack the seven type of waste, one of these waste focus in reducing inventory. Therefore, implementing lean manufacturing to all departments may get surplus positive to decrease inventory. However, the results indicating the mean scores of extending level for lean manufacturing and six sigma within the organization and the impact on performance are presented in the Table 4.19. Mann Whitney U test was used at 1% and 5% for measuring differences in financial operational performance and innovation performance between two sample companies that had not implemented lean manufacturing and six sigma methods in any department and those that implemented lean manufacturing and six sigma methods in all departments. This was a non-parametric test for abnormal distributions. Table 4.20 illustrates (P-value and Z-value) the comparative differences between companies that implemented the method in all department and companies that did not implement the method at all, against performance outcome. The result of the study considers significant if the p value < 0.05. This finding that there are significant differences in improved quality between companies not implementing six sigma to any department and those implementing six sigma in all departments (p value < 0.05). The differences were indicated in the range of a mean value from 4.17 to 5. As well for lean manufacturing, there was a significantly higher difference in the creation of a safe environment, employee involvement and reduce

turnover rate within the organization. Companies implementing lean manufacturing in all departments are significantly higher compared to companies not implementing lean manufacturing in any department ($P\text{-value} < 0.05$). The differences were in the range of a mean value of 2.50, 2.75 and 2.00 to 3.67, 4.08 and 2.83. Implementation lean manufacturing to all department support to make the employees more involvement and creates more safety environment. **Gunasekaran and Lyu (1997)**, found that implementing (JIT) lean tools supports improvement in the safety environment and the quality within the enterprise. For example, deploying the 5S system, visual controls supported cleaning up and organizing the workplace through removing all unnecessary items for making the workplace clean and creating a safe environment in the enterprise. It can be interpreted, based on the results that through implementing and practicing lean manufacturing in all departments, employees become more involved and are more likely to improve safety within the organization. Permitting employees suggestions and input is an opportunity for greater employee involvement and participation in the company. Continuous improvement will laid to improve the performance of quality by collecting employees suggestion that can reflect to eliminate source of waste, improve quality and reduce inventory (**Powell et al., 2013**).

Table 4.19 Comparable between the extending level for lean and six sigma

Impact performance	Extending level	Lean manufacturing	six sigma
Increase profit	Not to any department	3.25	3.82
	All department	4.00	3.50
Improve quality	Not to any department	4.00	4.17
	All department	4.25	5.00
Reduces variation	Not to any department	3.75	3.87
	All department	3.92	4.50
Reduces cost	Not to any department	3.75	4.00
	All department	4.33	4.50
Improves productivity	Not to any department	3.50	4.30
	All department	4.50	4.50
Reduces Lead-time	Not to any department	3.50	4.30
	All department	4.42	4.50
Increases suggestions from the employees	Not to any department	2.75	3.74
	All department	3.92	3.50
Involves employees	Not to any department	2.75	3.83
	All department	4.08	4.00
Increase Customer satisfaction	Not to any department	3.75	4.13
	All department	4.00	3.50
Decreases Inventory	Not to any department	3.75	4.22
	All department	4.17	2.50
Reduce turnover rate	Not to any department	2.00	2.83
	All department	2.83	2.00
Creates safety environment	Not to any department	2.50	3.39
	All department	3.67	2.50

However, involvement and suggestion of the employees are complemented each other, and we asked these two factors, in order to determine whether employees had job satisfaction and contributed to performance within the organization in terms of implementing lean manufacturing and/or six sigma, employees participation/involvement and suggestions were measured. Results show extensive agreement by employees in the implementation of lean manufacturing to all

department. Therefore, it has discover with this research that implemented lean manufacturing support to increase the suggestion and the involvement of the employees (Alhuraish et al., 2015b). On the other hand, implementing and practicing six sigma in all departments serves to improve quality. The main achievement linked to the implementation of lean manufacturing and six sigma in all departments is increased companies performance. In the other side, it displays there is a negative impact of implementing lean manufacturing to all department of increasing reduce turnover rate. As it may cause of lean method focus to added value only within the organization that could reflect to increase reduce number of the employees that their work useless with the organization. For example, Work cell layout identifies and removes or reduces inefficiencies including equipment and people (George et al., 2005). So in this research resulted showed significant of increasing to reduce number of employees with the organizations that cause of implemented lean manufacturing to all departments (Alhuraish et al., 2015b).

Table 4.20 Comparable impact in performance of extending the level of lean and six sigma

Impact performance	Six sigma		Lean Manufacturing	
	Z	P-Value	Z	P-Value
Increase profit	-0.58	0.562	-1.478	0.139
Improve quality	-2.015	0.044*	-1.137	0.256
Reduces variation	-0.912	0.362	-0.445	0.657
Reduces cost	-0.718	0.473	-0.996	0.319
Improves productivity	-0.211	0.833	-1.268	0.205
Reduces Lead-time	-0.16	0.873	-1.268	0.205
Increases suggestions from the employees	-0.46	0.645	-1.917	0.055
Involves employees	-0.26	0.795	-2.114	0.034*
Increase Customer satisfaction	-0.407	0.684	-0.838	0.402
Decreases Inventory	-1.517	0.129	-1.497	0.134
Creates safety environment	-0.6	0.548	-2.154	0.031*
Reduce turnover rate	-1.063	0.288	-2.499	0.14*

Note. 2 tailed Significance level on Mann–Whitney test: *P < 0.05; **P < 0.01

4.2.5. Degree of success of adoption Lean Manufacturing & Six Sigma

The respondents were asked for the degree of success of implementing the lean manufacturing and sigma methods on a five-point scale where 1=Not successful to 5= totally successful (0=Not implemented either lean manufacturing or six sigma method with their companies. The presented result illustrated the estimation success of implementing lean manufacturing and six sigma separately. The entire thirty-three companies were investigated to determine the level of success. According to our resulted were presented in above Table 4.21, four companies were not implemented lean manufacturing with their companies (4 %; Lean manufacturing); and twenty-four were not implemented six sigma with their companies (72.7%; Six sigma). Only (6.1%) of the respondents indicate that the initiative was a totally success for implementing lean manufacturing while (3%) indicate initiative was a totally success for implementing six sigma. Lean implementation having a higher proportion was (33.3%) that very successful. On contrast, six-sigma implementation whereby only (3%) was very successful. (24%) of respondents

enterprises indicates were successful of implementing lean while (9.1%) successful of implementing six sigma. (18.2%) of respondents that indicates were slightly successful of implementing lean while (6.1%) slightly successful of implementing six sigma and both methods have the equal percentage (6.1%) as respondents enterprises indicate that the initiatives were a total failure for implementing lean manufacturing, six sigma.

Table 4.21 Success degree of implementation lean Manufacturing, six sigma

Level of success	Lean Frequency	Percent	Six sigma Frequency	Percent
Not implemented	4	12.1	24	72.7
1-Not successful	2	6.1	2	6.1
2-Slightly successful	6	18.2	2	6.1
3-Successful	8	24.2	3	9.1
4-Very successful	11	33.3	1	3.0
5-Totally successful	2	6.1	1	3.0
Total	33	100.0	33	100.0

Companies did not participate the estimation of success rate because neither lean manufacturing nor six sigma implemented

It showed high frequency on the successful of implementing lean manufacturing than six sigma methodologies, it may cause by larger part of the responded were implemented lean manufacturing.

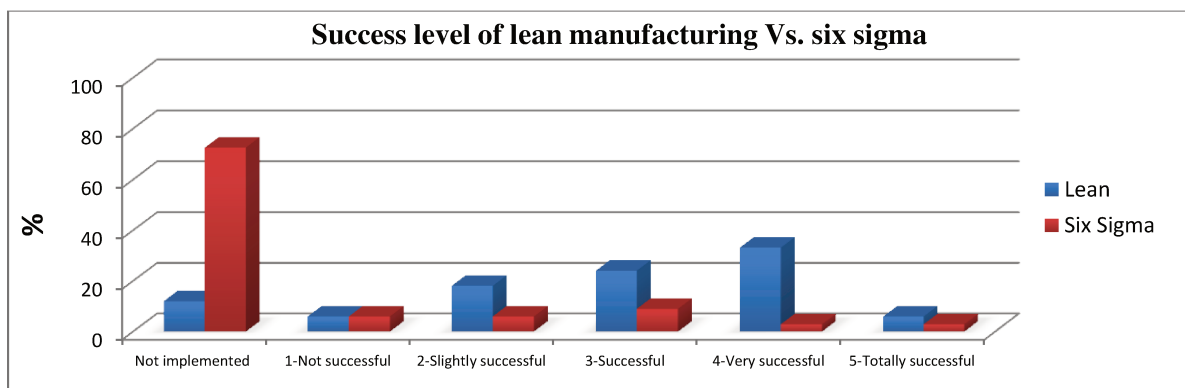


Figure 4.27: Success level for lean manufacturing and six sigma implementation

Table 4.21.1 showed the average level success of implementing lean manufacturing and six sigma. The average score success of implementing lean manufacturing (3.17) is higher than the average score success of implementing six sigma (2.67). The companies whose success levels were anonymous were not included in the analysis due to the fact that they had not implemented either lean manufacturing or six sigma. Therefore, we collapsed the response of not implemented with their companies into missing value.

Table 4.21.1 Estimate the level of success of each method

Estimate the level of success	N	Min	Maximum	Mean	Std. Deviation
Lean Manufacturing	29	1	5	3.17	1.071
Six Sigma	9	1	5	2.67	1.323

Missing data (from n = 33 to n = 29) reduced the sample based on companies didn't implement lean in their view

Missing data (from n = 33 to n = 9) reduced the sample based on companies didn't implement sigma in their view

4.2.5.1. Extending lean Manufacturing and six sigma & success level

To analyze the impact of extending lean manufacturing within the organization as opposed to its implementation in just a few departments, or some departments, or all departments or all department including the supplier a bivariate correlation coefficient test were conducted. The test explored relationships between extending lean manufacturing and levels of success.

Table 4.22 Extending lean manufacturing against the success level

Extending lean manufacturing	Estimate the level of success of lean manufacturing method				
	Not successful	Slightly successful	Successful	Very successful	Totally successful
Implemented in few departments	0.0%	50.0%	25.0%	25.0%	0.0%
Implemented in some departments	8.3%	25.0%	41.7%	25.0%	0.0%
Implemented in all departments	8.3%	8.3%	8.3%	58.3%	16.7%
Implemented in all departments including supplier	0.0%	0.0%	100.0%	0.0%	0.0%

Table 4.22 shows the status of extending lean manufacturing across success levels. Most companies that implemented lean manufacturing in all department have more successful (58%) in implementing lean manufacturing compared to companies that implemented lean manufacturing either in few departments that can result in slight success (See Figure 4.28). It would appear that implementing lean manufacturing in all departments is more supportive of successful lean manufacturing. It seems implementing lean manufacturing in all departments correspond with successful lean manufacturing

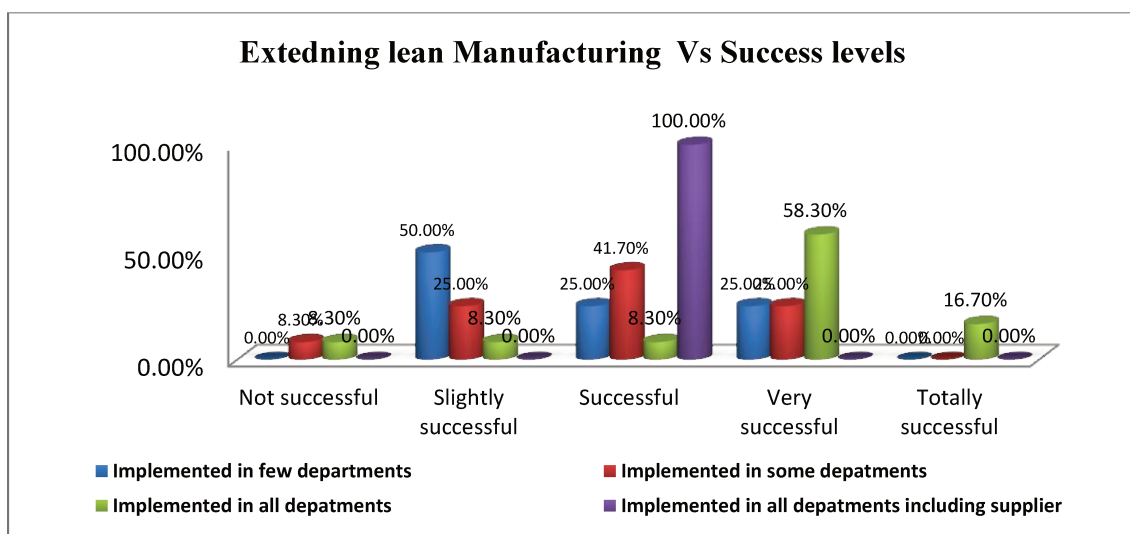


Figure 4.28: Extending lean manufacturing against the success level

Table 4.23 above illustrates the level of success that corresponds with the departmental levels of implementation of six sigma. Only a few organizations extended six sigma to departments in this study

since a majority of the enterprises had not extended or implemented six sigma to any department. (See figure 4.29). Even though. It can noticed that for companies extending six sigma to either some departments or all departments, six sigma success levels were accomplished.

Table 4.23 Extending six sigma against success level

Extending lean manufacturing	Estimate the level of success of lean manufacturing method				
	Not successful	Slightly successful	Successful	Very successful	Totally successful
Implemented in few departments	0.0%	0.0%	66.7%	33.3%	0.0%
Implemented in some departments	8.3%	25.0%	41.7%	25.0%	0.0%
Implemented in all departments	0.0%	50.0%	0.0%	0.0%	50.0%

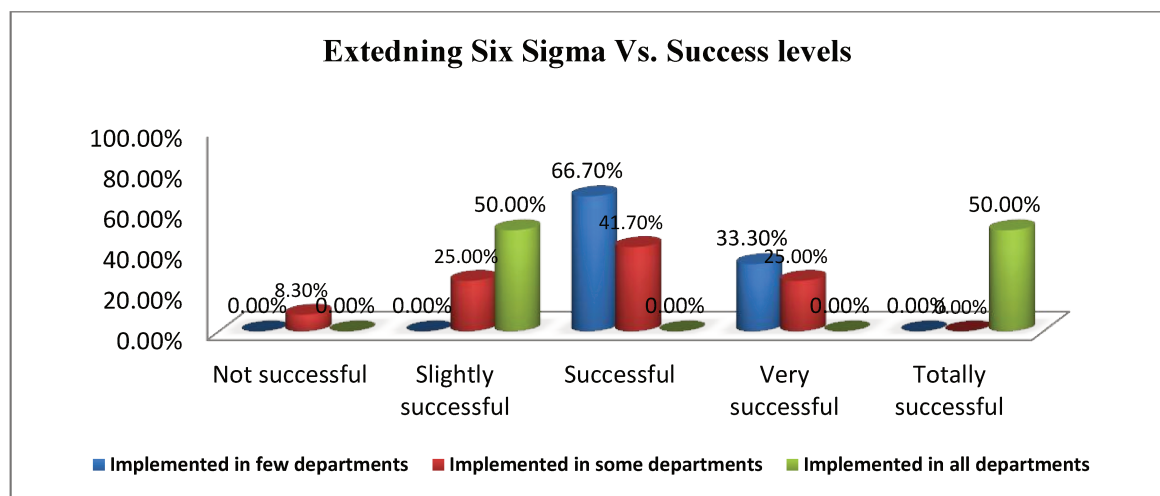


Figure 4.29: Extending lean manufacturing against the success level

4.2.5.2. Extend lean Manufacturing and six sigma method between SME and large companies

The status of extending lean manufacturing between SME and large companies. Table 4.24 shows the status of extending lean manufacturing within SME and large companies.

Table 4.24 Extend of lean manufacturing

Lean	EXTENSION OF LEAN METHOD				
	Not implemented in any department	Implemented in few departments	Implemented in some departments	Implemented in all departments	Implemented in all departments including supplier
SME	25.0%	8.3%	41.7%	16.7%	8.3%
Large	4.8%	14.3%	33.3%	47.6%	0.0%

To examine whether the equality of two sample between SME and large companies regarding extend lean manufacturing and six sigma method, we conducted a chi-square test. The p-value for test is 0.152 indicates that the sample distribution is not significantly different at an alpha

level of 0.05. This infers were no difference between SME and large companies concerning extend lean manufacturing method (Chi-square value = 6.711, degree of freedom =4, P-value = 0.152).

Table 4.25 Extend of six sigma

Six sigma	EXTENSION OF Six Sigma				
Size of companies	Not implemented in any department	Implemented in few departments	Implemented in some departments	Implemented in all departments	Implemented in all departments including supplier
SME	75.0%	16.7%	8.3%	0.0%	0.0%
Large	66.7%	9.5%	14.3%	9.5%	0.0%

P-value for extending six sigma method test is 0.623 indicates that the sample distribution is not significantly different at an alpha level of 0.05, since $p=0.623$, this infers were no difference between SME and large companies concerning extend six sigma method (Chi-square value = 1.764, degree of freedom =3, P-value = 0.623). It seems that SME and large companies have similarity of extending six sigma method.

4.2.5.3. Estimation the level of success of lean Manufacturing and Six sigma between SME and large companies

We made investigation to identify the level of lean manufacturing and six sigma success within SME and large companies (See Table 4.26). Chi-squared were used to analysis the data. There is no statically significant finding (Chi-square value = 2.117, degree of freedom = 4, p-value =0.714). There is no association between SME and large companies in terms level of lean successes. The results indicate an equality success of lean method between SME and large companies.

Table 4.26 Level of lean manufacturing success

Lean	Estimate the level of success of lean method				
Size of companies	Not successful	Slightly successful	Successful	Very successful	Totally successful
SME	0.0%	11.1%	33.3%	44.4%	11.1%
Large	10.0%	25.0%	25.0%	35.0%	5.0%

There is also no statically significant finding (Chi-square value = 3.750, degree of freedom = 4, p-value =0.441). There is no association between SME and large companies in terms level of six sigma successes. The results indicate an equality success of six-sigma method as well between SME and large companies (see Table 4.27). There were no remarkable differences between SME and large companies across level of success for lean manufacturing and six sigma. It may cause that majorities of these companies (SME and large companies) have recently implemented both method.

Table 4.27 Level of six-sigma success

Six sigma	Estimate the level of success of six sigma method				
Size of companies	Not successful	Slightly successful	Successful	Very successful	Totally successful
SME	0.0%	33.3%	33.3%	33.3%	0.0%
Large	33.3%	16.7%	33.3%	0.0%	16.7%

4.2.6. Belt system

Finally, In order to identify the effected side of belt system of six sigma, non-parametric test was used to compare between the companies used of belt system and those are not across companies performance, The level of performance outcome was found to be significantly different between companies that employed belt systems and those that did not for three attribute, these attribute are improved quality, reduced variation and reduced cost. These findings support that belt systems produce a higher average of improved quality (4.67), reduced variation (4.42), and reduced cost (3.76) compared to companies that had not employed belt systems within their organization. The results indicate that belt systems can function to improve and increase companies performance. There is evidence that belt systems contain in this sample that have positive impact to increase operational performance. Belt system considered as a key success factor for the six sigma implementation and these include belt categories such as green belt, black belt, master black belt (**Kwak and Anbari, 2006**). The test shows a statistically significant difference between companies in terms of improved quality (p-value= 0.0006), reduced variation (p-value=0.048) and reduced cost (p-value=0.008) (see Table 4.28). The utility of the belt system is confirmed by a study that revealed that using a belt system realized significant savings and profits (**Harry, 1998, George, 2002**). The remaining factors (p-value > 0.05) such as reduced cost, decreased inventory, improved productivity etc. do not show significant difference between companies executing belt system or not. Figure 3.33 exhibits the advantage of comparable performance outcomes of improved quality, reduce cost and reduce variation through the employment of belt system. There are statically significant since the p-value was lower than significance level 0.05. Thus, it can be concluded that the belt system is useful for improving quality and reducing variation, and reducing cost but shows no other effect in the French industries. This is suggested that belt systems are related to six sigma methodology, which is focused more sharply on reducing variation and improving quality. The level of benefit was presented in in the Box Plot that is shown in Figure 4.30.

Table 4.28 The results of a comparison between companies that used belt systems & not used

Benefit	Belt system	N	Mean	STD	Z-Value	P-Value
Increase profit	Yes	12	4.16	.834	-1.327	0.184
	No	21	3.71	.902		
Improve quality	Yes	12	4.67	.492	-2.744	0.006**
	No	21	4.05	.669		
Reduces variation	Yes	12	4.42	.669	-1.98	0.048*
	No	21	3.76	.944		
Reduces cost	Yes	12	4.67	.492	-2.661	0.008**
	No	21	3.76	1.044		
Improves productivity	Yes	12	4.42	.793	-0.793	0.428
	No	21	4.10	1.091		
Reduces Lead-time	Yes	12	4.25	.622	-0.411	0.681
	No	21	4.14	1.153		
Increases suggestions from the employees	Yes	12	3.83	1.030	-0.945	0.345
	No	21	3.57	.978		
Involves employees	Yes	12	3.92	1.084	-0.899	0.369
	No	21	3.67	.966		
Increase Customer satisfaction	Yes	12	3.83	1.267	-0.099	0.921
	No	21	3.95	.865		
Decreases Inventory	Yes	12	3.58	1.311	-1.05	0.294
	No	21	4.10	.768		
Reduce turnover rate	Yes	12	3.00	1.044	-1.426	0.154
	No	21	2.71	.644		
Creates safety environment in the enterprise	Yes	12	3.25	1.215	-0.431	0.666
	No	21	3.19	1.030		

Note: 2 tailed Significance level on Mann–Whitney test: *P < 0.05; **P < 0.01

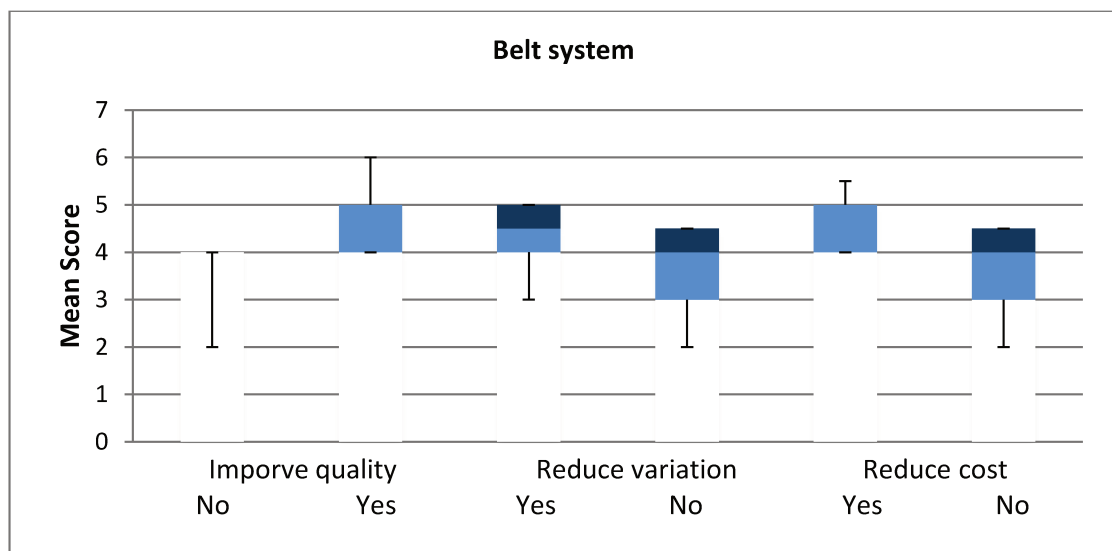


Figure 4.30: Comparison belt systems (Yes) vs. no belt system (No) across companies performance

4.3. The key success factors of Lean Manufacturing Versus Six Sigma

The basic reason for organizations to adopt six sigma and lean manufacturing is the success that these methods have achieved in companies such as Motorola and Toyota (Andersson et al., 2006). A number of success factors that have proved critical for the successful implementation

of six sigma have been highlighted most frequently in the literature (**Antony and Banuelas, 2002; Coronado and Antony, 2002; Antony et al., 2005; Kwak and Anbari, 2006; Gamal Aboelmaged, 2010; Antony, 2011; Brun, 2011; Zailani and Sasthriyar, 2011**). These factors include, among others, involvement and commitment by top management, linking six sigma to suppliers, and linking six sigma to customers. Taking these factors into consideration enables a company to draw up a suitable plan for implementing six sigma (**Kumar et al., 2007**). As lean manufacturing and six sigma complement each other (**George, 2002; Breyfogle, 1999; George, 2003; Arnheiter and Maleyeff, 2005; Gamal Aboelmaged, 2010; Antony, 2011; Snee, 2011**), these factors also play a key role in the successful implementation of lean manufacturing. Lean manufacturing is adopted by companies to reduce production costs and to eliminate waste from the production mechanism (**Wilson, 2010**), while six sigma is concerned with the identification and elimination of defects in business procedures by paying attention to the performance attributes that are considered critical for customers (**Breyfogle, 1999**). Although many companies are currently carrying out research in order to maximize performance through implementing lean manufacturing and six sigma, there are many industries that often fail to implement either lean manufacturing (**Scherrer-Rathje et al., 2009**) or six sigma (**Chakravorty, 2009**), or a combination of these methods (**Antony, 2011**). Therefore, this chapter aims to identify the factors that are essential for successful implementation of lean manufacturing and six sigma. From the literature review, it is evident that there exist many factors shared by lean manufacturing and six sigma that lead to successful implementation. These factors include, among others, communication, culture change, and top management commitment. These common factors may or may not have identical degrees of importance for lean manufacturing and six sigma. In order to examine this, a survey was performed to allow a comparison between these methods in terms of their shared success factors. These factors were evaluated by experts in lean manufacturing and six sigma or by those responsible for quality control in their organization in order to distinguish the success factors for each method and to identify their priority for the respective method.

The findings revealed that there are statistically significant differences in the level of importance of their shared success factors between lean manufacturing and six sigma, including culture change, communication, and involvement of employees, among others. Furthermore, a number of similarities regarding the success factors shared by lean manufacturing and six sigma methodologies were found, such as top management commitment, skill and expertise, as well as linking of the method to suppliers (**Alhuraish et al., 2016a**). According to **Andersson et al., (2006)** there may exist a number of important issues concerning similarities as well as differences between the lean and six sigma methods that have not yet been discovered. Hence, this study provides an assessment of the comparisons that have been made of the key success factors underlying both lean manufacture and six sigma, which might be helpful for companies when they decide upon the methods to be adopted, depending on their organizational needs and their ability to implement these methods. The main question for consideration is therefore: What are the success factors that aid companies in the successful application of lean manufacturing and six sigma?

This section has been organized as follows: The analysis of the results and the discussion of the comparison between lean manufacturing and six sigma across the success factors. Secondly, identification has also been made on the most critical factors for the implementation of the lean manufacturing to companies that have successfully implemented lean manufacturing as well as the most critical factors for the implementation of six sigma for companies that have successfully implemented six sigma. Finally, the discussion as to why the comparison of both methods could be valuable has been provided it.

4.3.1. Compare success factors Lean Manufacturing & Six Sigma

A comparison of 15 success factors shared by lean manufacturing and six sigma has been made. Since the data that were used in this study were ordinal, the Wilcoxon signed rank test was used. This, being a non-parametric test, has been designed to test repeated measures, such as the comparison between lean manufacturing and six sigma, using identical success factors. An analysis was conducted to determine whether the two grouping variables (group 1= lean manufacturing, group 2= six sigma) were significantly different from each other with respect to their level of importance for identical success factors. The purpose of the analysis was to find the differences and similarities between the common or identical success factors of lean manufacturing and six sigma, in terms of the following hypotheses:

H_0 : There are no statistically significant differences between lean manufacturing and six sigma with regard to common success factors.

H_a : There are statistically significant differences between lean manufacturing and six sigma with regard to common success factors.

The key success factors for lean manufacturing and six sigma are presented in Table 4.29, which shown a statistical average for each success factor. It can be seen that there are differences in the level of importance for each method: for example, the second most important success factor for six sigma, with mean value 3.55, is project prioritization and selection and review tracking. **Antony (2004)** found that project prioritization and selection was the most important critical success factor of implementing six sigma. On the other hand, communication was the second most important factor when implementing lean manufacturing, with a mean value of 4.39. For both lean manufacturing and six sigma, linking the method to the supplier was the least important factor (with mean score 2.58 for lean manufacturing and 2.33 for six sigma). This indicates that French companies are not interested in linking method to supplier. The aims of lean manufacturing and six sigma are not only to minimize variation but also to reduce lead time within the organization, although longer lead times cause organizations to increase inventory and decrease productivity. Therefore, it is advisable to encourage suppliers to adopt lean six sigma, since this helps to improve quality and productivity (**George, 2002 and 2003**).

As shown in Table 4.30, some factors were found to be statistically insignificant and others statistically significant in the comparison between lean manufacturing and six sigma for identical

success factors. The results shows no significant difference between the lean manufacturing and six sigma methodologies with regard to some of the identical success factors ($p > 0.05$ and 0.01). These factors are top management commitment and support, linking of method to supplier, skill and expertise, linking of method to customer, consultant participation, and reward system and project management skills. This implies that these factors were equally important when implementing either lean manufacturing or six sigma. Top management commitment and support had the same level of importance for both lean manufacturing and six sigma and ranked first among the critical factors, with a mean score value of 4.70 for lean manufacturing and 4.33 for six sigma. Skills and expertise ranked as the tenth most important factor for implementing lean manufacturing (with a mean score of 3.64) and the sixth most important for implementing six sigma (with a mean score of 3.45). However, the main conclusion from Figure 4.31 and the Wilcoxon test was that lean manufacturing and six sigma show similar levels of successful implementation across the common or identical success factors, but show different priority factors within French industry.

On the other hand, this study found statistically significant differences between lean manufacturing and six sigma in terms of some of their common or identical success factors when the Wilcoxon signed rank test was conducted, since the p-value was lower than the significance level of 0.05 and 0.01. The first factor showing a significant different between lean manufacturing and six sigma was the involvement of employees, with a mean score of 4.24 for lean manufacturing but 3.55 for six sigma. The average mean scores for lean manufacturing were significantly higher than those for six sigma. The alternative hypothesis (statistically significant difference between lean manufacturing and six sigma in terms of involvement of employees) was accepted. Therefore, this implied that lean manufacturing needs greater involvement of employees than six sigma. Various other investigations by both academics and practitioners have supported this result. According to **Antony (2011)**, implementation of six sigma does not include people in improvement tasks, while implementation of lean manufacturing requires people engaged at the grassroots level with the help of continuous and creative activities such as establishment of a Kaizen team. Furthermore, people require specific set of skills and competencies before handling projects associated with the implementation of six sigma in an organizational framework.

Table 4.29 A comparable the success factors of implementing lean manufacturing and six sigma

Rank	Success factors Lean	Mean	Success factors Six sigma	Mean
1	Top Management commitment and support	4.70	Top Management commitment and support	4.33
2	Communication	4.39	Project prioritization and selection, reviews and tracking	3.55
3	Involvement of employees	4.24	Involvement of employees	3.55
4	Linking lean Method to the business strategy	3.97	Linking six sigma Method to the business strategy	3.52
5	Education and training	3.97	Communication	3.52
6	Understanding the tools and techniques within lean method to the employees that perform job in shop floor	3.97	Skills and expertise	3.45
7	Cultural change	3.97	Education and training	3.45
8	Monitoring and evaluation of performance	3.82	Cultural change	3.30
9	Leadership	3.67	Understanding the tools and techniques within six sigma to the employees that perform job in shop floor	3.06
10	Skills and expertise	3.64	Linking six sigma to customers	3.06
11	Understanding the tools and techniques within lean to the employees that perform job in an office	3.61	Project Management skills	3.06
12	Project Management skills	3.36	Understanding the tools and techniques within six sigma to the employees that perform job in an office	2.91
13	Linking lean to customers	3.30	Linking Six Sigma to human resources	2.73
14	Linking lean to human resources	3.15	Consultant participation	2.64
15	Kaizen team	3.06	Belt system	2.61
16	Consultant participation	2.85	Reward system	2.39
17	Linking lean method to suppliers	2.58	Linking six sigma method to suppliers	2.33
18	Reward system	2.58		

Feng and Manuel (2008) indicated that implementation of six sigma can be performed without the involvement of either a Master Black Belt or a Green Belt. On the other hand, **Kumar and Antony (2009)** pointed out that one of the reasons why SMEs failed to implement lean at the first attempt was involvement of employees. However, based on the results of this study and the findings from the literature review, it is clear that the degree of involvement of employees in lean manufacturing is more critical for the success of the implementation than in the case of the six sigma method. Consequently, it is suggested that companies wanting to implement lean manufacturing need the capacity for extensive involvement of employees.

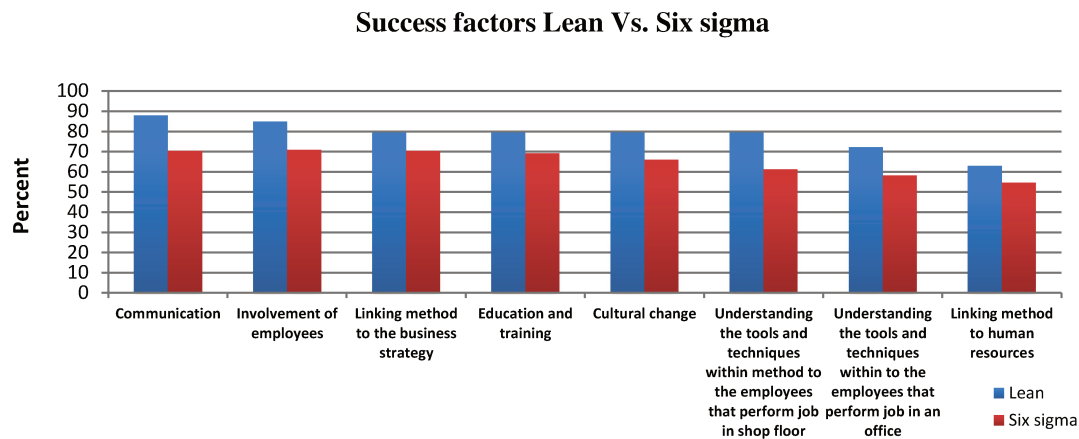


Figure 4.31: Comparison lean manufacturing vs. six sigma across key success factors that statistically significant

Table 4.30 The key success factors of implementing Lean vs. Six Sigma

Success factors	Z	P-value
Top management commitment and support	-1.414	.157
Involvement of employees	-2.946	.003**
Linking the method to suppliers	-1.356	.175
Education and training	-2.173	.030
Communication	-3.593	.000**
Linking method to the business strategy	-1.982	.048*
Consultant participation	-1.144	.235
Understanding the tools and techniques within method to the employees that perform job in shop floor	-3.170	.002**
Understanding the tools and techniques within to the employees that perform job in an office	-2.674	.007**
Cultural change	-2.664	.008**
Skills and expertise	-.794	.427
Reward system	-1.191	.234
Linking the method to customers	-1.052	.293
Linking the method to human resources	-2.336	.019*
Project Management skills	-1.482	.138

Note: Significant level of important factors on Wilcoxon signed ranks test at the 0.05*, 0.01** level of significance

Communication was the second factor that showed a significant difference between lean manufacturing and six sigma. For lean manufacturing, communication was the highest-priority success factor, with a mean value of 4.39, compared with 3.52 for the six sigma method. This may be explained by the fact that lean manufacturing excludes the organizational infrastructure, thereby reducing the contribution of communication, whereas in contrast six sigma requires the construction of organizational infrastructure (MBB, BB, and GB) and thereby encourages the development of a common language of communication amongst employees. According to **George (2003)**, it is for this reason that lean manufacturing needs to be complemented by six sigma. Therefore, the data reported in the present study indicate that a higher degree of communication is required to implement lean manufacturing successfully than to implement six sigma. For lean manufacturing to be implemented successfully, intensive communication amongst employees is essential; **Manotas Duque and Rivera Cadavid (2007)**, **Pingyu and Yu**

(2010), and Scherrer-Rathje et al. (2009) have all confirmed that lack of communication in an organization results in an unsuccessful implementation of lean manufacturing. Although it is true that effective communication also ensures successful implementation of six sigma within an organizational framework (Coronado and Antony, 2002; Ho et al., 2008).

Lean manufacturing originated in the automobile industry in the context of Japanese organizational culture, with the aim of improving process flow through elimination of waste, whereas six sigma originated in the electronics industry in an American organizational culture and tries to encourage effectiveness through enhancement of quality and accuracy through reduction in variations (Chen, 2009; Laureani and Antony, 2010). The literature review revealed that organizational culture and changes in management are important critical factors for the implementation of lean manufacturing and six sigma. Although the tools used in lean manufacturing are more analytical in nature, those used in six sigma are more statistical (Andersson et al., 2006). Hence, lean manufacturing requires a substantial change in the behavior of employees such that they establish good habits in their work environment. Because of this, some companies hold the view that the lean method can only succeed within a Japanese organizational culture, although this is a misunderstanding of the lean philosophy (Arnheiter and Maleyeff, 2005). On the other hand, for six sigma, it is more important that employees fully understand the concept of problem-solving through techniques such as the DMAIC framework, DPMO, and DOE, as well as by adopting a statistical way of thinking (Kwak and Anbari, 2006). Although culture change is a success factor for implementing both lean manufacturing and six sigma, significant differences ($p\text{-value} < 0.01$) were found between the two methodologies. The average mean scores for lean manufacturing were significantly higher than those for six sigma. This indicates that lean manufacturing needs greater changes in culture than six sigma. An example of this is given by the 5S system, whose operation involves unique lean manufacturing tools and techniques that help reduce waste. It is easy to understand the concept of 5S, but employees may have difficulties in performing it on a daily basis, since it requires changes in individuals' behavior. The 5S system requires that employees practice 5S as a routine task within their work environment (Gunasekaran, 1997). Puvanasvaran et al. (2009) pointed out that very few companies have succeeded in implementing lean manufacturing practices, one of the reasons for which being the distinctive behavior displayed by employees in the workplace. Furthermore, behavioral change is considered as key to the sustainable and successful development and implementation of lean manufacturing (Emiliani, 1998). In addition, Wilson (2010) stressed the importance of ensuring that evaluations are based upon people's behavior and not just word-of-mouth. Hence, it must be noted that lean manufacturing requires a substantial change in the behavior of employees such that they establish good habits in their work environment. Nave (2002) suggested that selecting an appropriate method depended on organizational culture and that changing the culture of an organization is imperative for successful implementation of the method. Consequently, it is important for companies to decide whether they are capable of changing their organizational culture to lean manufacturing or to six sigma or to a combination of these. Thus, identifying and choosing an appropriate method depends on the capacity of the company to change its culture. Additionally, the literature review pays considerable attention to the implications at shop floor level of the implementation of lean manufacturing relative to that of six sigma. It has been found that six sigma involves little immediate participation from

employees on the shop floor, because several months are required to collect data (Pojasek, 2003), whereas lean manufacturing can achieve rapid improvements through the effect of Kaizen events on the shop floor. From the results of the current study, it appears that it may be more important for the lean manufacturing method than for six sigma that all employees on the shop floor acquire an understanding of the concept of the method; however, future research is needed to confirm this.

The rest of the factors were significantly different ($p\text{-value} < 0.01$ and 0.05). They included understanding the tools and techniques within method, education and training, linking the method to the business strategy and linking the method to human resources between lean manufacturing and six sigma. This was a remarkable result, although it was hard to clarify the reasons since these factors are important for the implementation of lean manufacturing and six sigma. The main conclusion from Figure 4.32 and the Wilcoxon signed ranks test that lean and six sigma have seven significantly different factors with respect to the level of importance to successful implementation between lean manufacturing and six sigma with French industries.

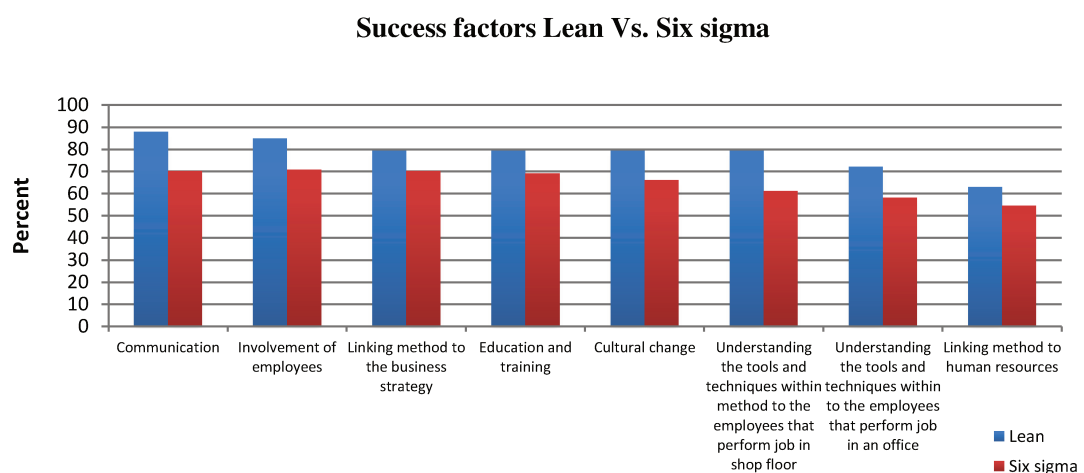


Figure 4.32: Comparison lean vs. six sigma across key success factors that statistically insignificant

Others success factor that has been mentioned by the respondents from the open end of the questionnaire to successful implementation of six sigma that six sigma is a method required to use on specific cases with a small number of people (tools complex), strong knowledge of statistics, and culture of statistical evidence, while to succeed in the implementation of lean manufacturing is to implement GEMBA (Helpful to be able to see and understand the problems) and finance.

The respondents were finally asked to rate the degree of success of implementation of each of lean manufacturing and six sigma using a five point scale, choosing from 1= Not successful to 5= Totally successfully. The level of success was summarized in the Box Plot shown in Figure 4.33. The companies whose success levels were anonymous were not included in the analysis due to the fact that they had not implemented either lean manufacturing or six sigma (Did not participate in the estimation of the success implementation) with their organization. Therefore,

the response of not implemented was excluded with their companies into missing value. Majority of the companies (N=29) did participate in the level of success for the implementation of the lean manufacturing as compared to few companies (N=9) that did participate in the level of success for the implementation of six sigma.

A. Critical factors for the implementation of the lean manufacturing to companies that have successfully implemented lean manufacturing

Further analysis was made for the 21 out of the 29 companies that implemented lean manufacturing successfully by excluding companies that were not successful and those slightly successful. This helped in recognizing the most critical success factors for the implementation of lean manufacturing within their companies. A mean value less than 4 was also excluded due to the fact that it was not considered critical for the successful implementation of lean manufacturing. Table 4.31 shows top management commitment, communication, involvement of employees, culture change, linking lean method to the business strategy, education and training, monitoring and evaluation of performance are the most critical factors of implementing lean manufacturing.

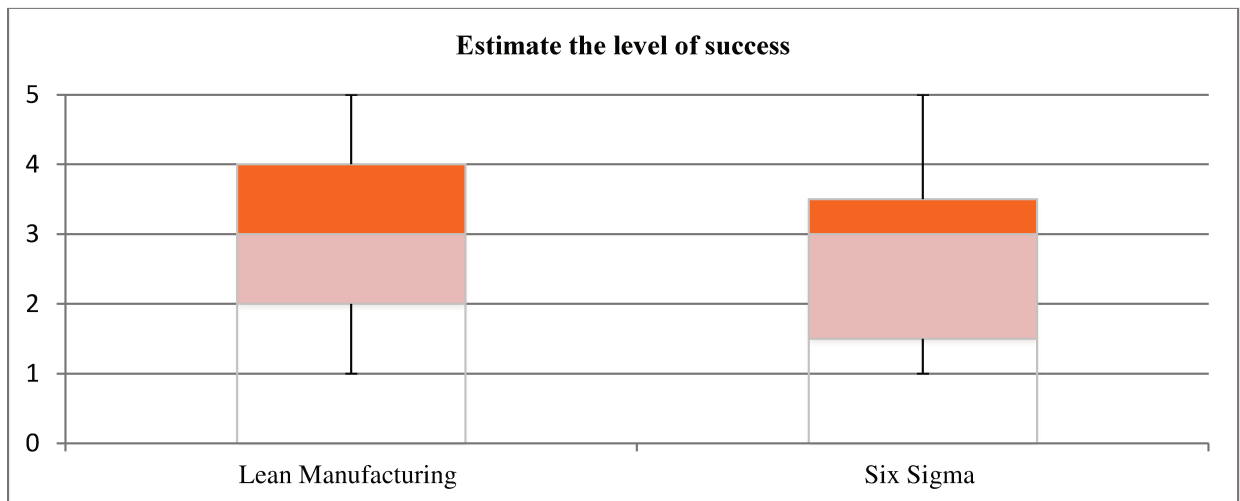


Figure 4.33: Box plot showing the distribution of success level between lean manufacturing vs. six sigma

Table 4.31 Success factors of implementing lean manufacturing

Success factors of implementing lean	Mean
Top Management commitment and support	4.86
Communication	4.43
Involvement of employees	4.24
Cultural change	4.14
Linking lean Method to the business strategy	4.05
Education and training	4.05
Monitoring and evaluation of performance	4.00

B. Critical factors for the implementation of the Six Sigma to companies that have successfully implemented Six Sigma

A similar criterion was followed for the six sigma, although the sample size was significantly smaller having only 9 companies that participated in the success level for six sigma. We made

the analysis to compare between lean manufacturing and six sigma to the companies that have successful implementation. 5 out of 9 companies that successfully implemented six sigma were included and the other four companies were excluded since they were either not successful or were slightly successful. This helped in recognizing the most critical factors and the manner in which these companies have the most success factors of implementing six sigma. As shown in Table 4.32, top management commitment, communication, education and training, skills and expertise and communication are the most critical success factors for six sigma.

Table 4.32 Success factors of implementing six sigma

Success factors six sigma	Mean
Top Management commitment and support	5.00
Communication	4.20
Education and training	4.20
Skills and expertise	4.00

Some observation from the Tables 4.31 and 4.32, it was found out that the top management support is the one that was critical to success of implementing either lean manufacturing or six sigma. It was also found out that culture change and involvement of the employees emphasized what was previously illustrated that these factors are critical to success of implementing lean manufacturing. On the other hand, skill and expertise is critical factors to success the implementation of six sigma. This study only used a small sample for six sigma, it is recommended that a large sample should be used for six sigma in future research in order to verify the success factors of implementing six sigma for the companies that have successfully implemented six sigma.

4.3.2. The reason of the comparison of both methods could be valuable

Key success factors are required and expected to enhance the success of implementing either lean manufacturing or six sigma. Consequently, this has made it necessary to test the success factors so as to identify the similarities and difference between lean manufacturing and six sigma to expose the level of importance concerning the key success factors for each method. Therefore, the results found in this paper can be useful in the comparison between lean manufacturing and six sigma for several reasons:

Firstly, the results indicated that there were significant differences between implementing lean manufacturing and six sigma across success factors as well as difference in priority factors for each method. So companies which are willing to apply lean manufacturing or six sigma or both methodologies at the same time can be aware and more focused or concentrated on understanding the factors that raise the successful implementation of the methodologies.

Secondly, as reported in the literature, an organization can achieve a significantly rapid improvement in both efficiency and production when there is simultaneous application of both lean manufacturing and six sigma, whereas implementation of either of lean or six sigma before the other may bring about lack of improvement in terms of inventory, added value, the combined lean and six sigma have the effect of improving process speed, inventory, reduced recycled time,

added value, among other improvements (George, 2002; Breyfogle, 1999; Arnheiter and Maleyeff, 2005; Sorqvist, 2009; Gamal Aboelmaged, 2010; Pepper and Spedding, 2010). There are many advantages of implementing both lean manufacturing and six sigma that are acquired by implementation of both methods simultaneously, but the organization requires maturity and clear strategy (Bertels, 2003). However, the simultaneous implementation of both methods lean and six sigma may not be achievable by every organizations, especially SME, due to lack of resources such as time, finance, expert. Various researchers have studied organizations, which have implemented lean and six sigma at different times, by beginning with one method either lean (Kumar and Antony, 2009), or six sigma (Snee, 2010) followed by the other with success. One of the important factors that researchers often fail to take into consideration when recommending simultaneous implementation of lean manufacturing and six sigma is the fact that some organizations lack sufficient resources for implementing both philosophies simultaneously. This has prompted most companies to try to identify the best method between lean manufacturing or six sigma or theory constrain that is the most applicable in their organization and the implementation of one of the methods may yield similar result due to the fact that each method can bring valuable idea, concept and technique to the organization (Nava, 2002). Furthermore, the experts were asked to answer questions by selecting one statement that SME should follow when implementing lean manufacturing and six sigma. The results displayed in Table 4.33 shows that the majority of sampled companies (81.8%) have not implemented both lean manufacturing and six sigma simultaneously. Furthermore, the results demonstrated that a few respondents preferred to begin the implementation of lean manufacturing and six sigma in SME simultaneously.

Table 4.33 Status integration of lean and Six Sigma and their recommended to begin implemented in case SME

Companies implemented lean and Six Sigma in the same time	Lean First then six sigma	six sigma First then lean	Lean and six sigma Simultaneously	Doesn't know	Doesn't matter
Yes (18.2%)	50.0%	33.3%	16.7%	0.0%	0.0%
No (81.8%)	40.7%	0.0%	11.1%	33.3%	14.8%

Additionally, the results show, surprisingly, that some companies that implemented lean and six sigma simultaneously and had recommended the implementation of one of the methods before the other. This can be explained by the fact that SME have fewer resources and do not have the capacity to implement lean and six sigma simultaneously (Alhuraish et al., 2014b). Therefore, since it has been proven that the implementation of either of lean manufacturing and six sigma at different time can also be successful, it is very significant to consider the factors that influence successful implementation of each method. According to Kumar et al., (2006) clear guidance in the framework is lacking during the project's initial stages on which of the methods is suitable between either lean or six sigma or combination of lean and six sigma. Thus, deciding on whether an organization is to begin with either lean or six sigma depends on factors such as the organization capability to implement either of the two methods, once the organization gets positive impact and growth, it can integrate it with other method since the integration of lean manufacturing and six sigma work more effective to improve quality, improve productivity and satisfy customer.

Lastly, as it has been found that there were significant difference between lean manufacturing and six sigma methodologies with respect to level of importance, it is valuable to make organization aware of the critical factors as well as the priority factors for each method. Consequently, a company may have clear guidance to determine appropriate method (whether to implement lean manufacturing or six sigma or both methods) in order to make the necessary plans for the implementation by taking into consideration the success factors of each method.

4.4. Conclusion

Based on the results of this chapter, it can be concluded that French companies are implementing lean manufacturing and/or six sigma with significant performance outcomes. It appears also that many companies within the French industry have recently begun to implement lean manufacturing and/or six sigma. It seems that there is greater interest among French companies in implementing lean manufacturing than six sigma. According to the results of the chi square test, all French companies that had implemented lean manufacturing and six sigma either at the same time or separately had similar outcomes in terms of financial, operational and innovation performance, with the exception of reduced turnover rate and decreased inventory. The duration of implementation of lean manufacturing and/or six sigma was correlated with a more positive impact on financial and operational performance. Additionally, the findings indicate that company size has no influence on financial and operational performance outcomes. The results of this study also specifically revealed that the use of six sigma in all departments helps to improve quality, while companies implementing lean manufacturing in all departments created a safe environment and improved employee involvement within the organization. On the other hand, implementing lean manufacturing in all departments reliefs to reduce turnover rate. Moreover, the findings reveal that the use of a belt system also helps to improve quality and reduce costs and variation. The results of this study thus suggest that companies can improve quality and performance through the implementation of lean manufacturing and six sigma. Therefore, companies should be aware and have an understanding of lean manufacturing and six sigma practices, since these methods can increase company performance. This research has revealed the positive aspects of implementing lean manufacturing and six sigma, namely, employee involvement and participation. Consequently, it can be inferred that implementing and practicing lean manufacturing and six sigma results in greater job satisfaction for employees, while the company in turn seeks and achieves continuous improvement. The effectiveness of implementing lean manufacturing and six sigma is manifested in increased profits and improved efficiency and quality. Each of these performance outcomes is accomplished through reductions in cost and productivity, improved employee involvement, the creation of a safe environment, improved customer satisfaction, improved lead times, and improvements in all other important aspects of total quality management. This work has also compared the success factors for implementing lean manufacturing and six sigma, in order to determine the differences and similarities in their level of importance as a means to help organizations focus on factors that aid the implementation of lean manufacturing and six sigma. Companies need guidance to avoid confusion when selecting improvement tools such as lean manufacturing and six sigma that are suited to the environment in which their business operates (**Chakravorty, 2009**). Therefore, it is

necessary to take into consideration the key success factors for each method so that companies can decide whether they have the capabilities to implement the success factors.

CHAPTER 5.

THE EFFECTIVENESS OF IMPLEMENTING LEAN MANUFACTURING AND SIX SIGMA PRACTICES

5. The effectiveness of implementing Lean Manufacturing and Six Sigma practices

5.1. Introduction

Many companies have gained performance advantages from implementing lean manufacturing and six sigma. We have statistically investigated these practices to determine their effectiveness with regard to company performance. The results show that the tools used in lean manufacturing and/or six sigma, such as 5S, TPM, Kanbn, and One Piece Flow, have supported increased financial performance in a majority of these companies. These companies benefit more compared with companies that have not implemented any quality tools. Additionally, an increased level of implementation of lean manufacturing and six sigma improves company performance. Moreover, companies that have implemented both methods have achieved better results than companies using either lean manufacturing alone or a limited set of tools from lean six sigma. The results of this study have revealed significant differences between SMEs and large companies in terms of a few tools, such as DMAIC, DPMO, and One Piece Flow. However, quality tools were found to increase innovation, operational, and financial performance in a variety of production areas, including reduced variation and cost, as well as improved employee participation and customer satisfaction. Table B presents a summary of chapter 5.

Table B. Summary of chapter 5

Problem	Objective	Results
The main investigation described in this chapter involves determination of the status of implementation of lean manufacturing and six sigma within French industry and the awareness by each company of quality tools concerned with financial, operational, and innovation performance.	The main objective is to identify the potential benefits of implementing lean manufacturing and six sigma and the relationship between these and company performance, in order to understand the effectiveness of each of these tools in terms of improved quality, reduced cost, improved productivity, employee involvement, among others.	The results indicate that there are several advantages in practicing lean manufacturing and six sigma with regard to improving company performance. An increase in the level of implementing lean manufacturing and/or six sigma corresponds to an increase in financial, operational, and innovation performance

5.2. Lean manufacturing and six sigma practices

The respondent companies were asked to demonstrate the tools, which they had implemented and not implemented from amongst the 26 available practices. It is evident from Table 5.1 that majority of the companies implemented quality practices. Most of these companies highly practiced Brainstorming, Standardized work, Visual Control, and PDCA, causes and effect diagram and 5S, indicating that the majority of these companies implemented the basic tools of lean manufacturing and six sigma.

Table 5.1 Lean manufacturing and six sigma tools

Tools	%
Brainstorming	100
Standardized Work	97
Visual Control	97
PDCA	97
Cause and effect diagram	97
5S	93.9
Pareto chart	93.9
Flow chart	93.9
Check sheet	90.9
TPM	84.8
VOC	84.8
FMEA	84.8
Kaizen team	81.8
Poka-yoke	81.8
VSM	81.8
Gemba	78.8
Kanban	78.8
SMED	72.7
Control chart	72.7
Takt time	69.7
Design of Experiment	63.6
DPMO	60.6
Once piece flow	57.6
DMAIC	57.6
Cellular layout	48.5
Regression analysis	39.4

On the other hand, few companies recognized the importance of statistical tools such as practices of Design of Experiment (DOE), Defect Per Million Opportunities (DPMO), DMAIC, and regression analysis. This showed lack of knowledge or awareness of statistical tools and challenges facing implementation of six sigma tools within these industry. Figure 5.1 shows the status of lean manufacturing and six sigma practices.

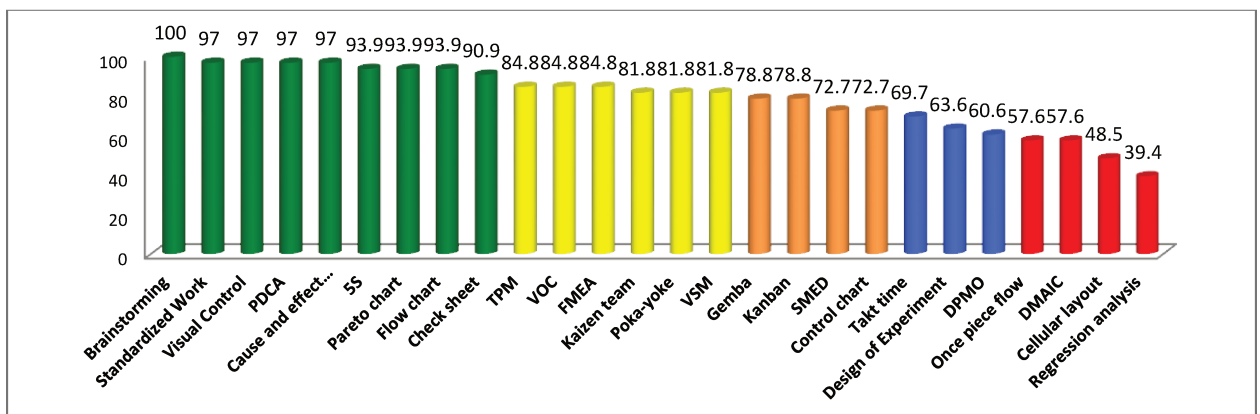


Figure 5.1 Status of lean manufacturing and six sigma practices

5.2.1. Implemented and not implemented lean manufacturing and six sigma practices across companies performance

A majority of lean manufacturing and six sigma tools support improvements in a company performance outcome. Therefore this research seeks to provide an in-depth evaluation for identifying the impact to which each of these tools can be implemented and practiced that support company performance. The statistical significance of implementing and practicing these tools will be demonstrated through the use of the Mann Whitney test in regards to companies that have implemented lean manufacturing and six sigma and companies that not have used either these tools. Results show that companies using lean manufacturing and six sigma effectively have seen improvement in performance outcomes in terms of increased profits, improved productivity compared to companies that have not implemented lean manufacturing or six sigma at all. The first of lean manufacturing tools show in Table 5.2 significant difference by conducting Mann Whitney test between companies implemented 5S and companies that not use 5S.

Table 5.2 Comparison impact performance across implemented and not implemented lean and six sigma tools

Impact Measure	Status the implementation	Mean 5S	Result	Mean Kaizen team	Result	Mean TPM	Result
Increase profit	Not Implemented	2.50	Sig.	3.50	Not	3.80	Not Sig.
	Implemented	3.96		3.96	Sig.	3.89	
Improve quality	Not Implemented	3.50	Not	3.83	Not	4.60	Not
	Implemented	4.32	Sig.	4.37	Sig.	4.21	Sig.
Reduces variation	Not Implemented	3.00	Not	3.67	Not	4.60	Not
	Implemented	4.06	Sig.	4.07	Sig.	3.89	Sig.
Reduces cost	Not Implemented	3.00	Not	3.33	Not	4.00	Not
	Implemented	4.16	Sig.	4.26	Sig.	4.11	Sig.
Improves productivity	Not Implemented	3.50	Not	3.83	Not	3.40	Not
	Implemented	4.26	Sig.	4.30	Sig.	4.36	Sig.
Reduces Lead-time	Not Implemented	3.00	Not	3.67	Not	3.40	Not
	Implemented	4.26	Sig.	4.30	Sig.	4.32	Sig.
Suggestions from the employees	Not Implemented	2.50	Not	3.50	Not	3.40	Not
	Implemented	3.74	Sig.	3.70	Sig.	3.71	Sig.
Involves employees	Not Implemented	2.50	Sig.	3.33	Not	3.20	Not
	Implemented	3.84		3.85	Sig.	3.86	Sig.
Increase Customer satisfaction	Not Implemented	2.00	Sig.	3.67	Not	3.40	Not
	Implemented	4.03		3.96	Sig.	4.00	Sig.
Decreases Inventory	Not Implemented	2.50	Not	4.17	Not	2.60	Sig.
	Implemented	4.00	Sig.	3.85	Sig.	4.14	
Reduce turnover rate	Not Implemented	1.50	Sig.	2.50	Not	2.20	Not
	Implemented	2.90		2.89	Sig.	2.93	Sig.
Creates safety environment	Not Implemented	2.00	Not	3.50	Not	2.80	Not
	Implemented	3.29	Sig.	3.15	Sig.	3.29	Sig.

Note. 2 tailed Significance level on Mann-Whitney test: *P < 0.05; **P < 0.01

Result shows that companies using 5S system have more positive impact in increase profit, involve employees and increase customer satisfied compared to companies that have not implemented 5S system at all. Therefore, it seems more supportive to increase financial, operational and innovation performance by implementing 5S. The study results also show that practicing TPM aids in the decrease of inventory compared to companies that do not use it. This is consistent with findings by **Venkatesh (2007)** who found that the implementation of TPM

leads to lower inventory while failure to implement TPM results in growth waste and cost such as machine malfunctions, loss in processes and an increase in customer dissatisfaction. This research reveals that there is a significant difference between companies that implement Takt time and those that do not (See Table 5.3). Companies implementing Takt time has realized increased profits, quality improvement, reduction of variation, reduced cost, improved productivity, a reduction in lead time compared to companies who have not implemented Takt time. Studies in the literature support these findings that through the implementation of Takt time, and responding to actual market demand companies not only save time, but also increase customer satisfaction (**Sharma, and Moody, 2001**). Additionally, there is also a significant difference between companies that implement one piece flow and companies that do not. Implementing One Piece Flow achieve greater customer satisfaction. Studies have shown that customers are generally unsatisfied where one piece flow processes are not achieved (**Shingo, 1988**). Therefore companies wishing to compete in consumer markets are well instructed to implement One Piece Flow effectively.

Table 5.3 Comparison impact performance across implemented and not implemented lean and six sigma tools

Impact measure	Status the implementation	Mean Takt time	Result	Mean Once piece flow	Result	Mean SMED	Result
Increase profit	Not Implemented	3.20	Sig.	3.71	Not Sig.	3.33	Not Sig.
	Implemented	4.17		4.00		4.08	
Improve quality	Not Implemented	3.90	Sig.	4.07	Not Sig.	4.11	Not Sig.
	Implemented	4.43		4.42		4.33	
Reduces variation	Not Implemented	3.50	Sig.	3.93	Not Sig.	4.11	Not Sig.
	Implemented	4.22		4.05		3.96	
Reduces cost	Not Implemented	3.30	Sig.	3.79	Not Sig.	3.89	Not Sig.
	Implemented	4.43		4.32		4.17	
Improves productivity	Not Implemented	3.60	Sig.	3.79	Not Sig.	3.67	Not Sig.
	Implemented	4.48		4.53		4.42	
Reduces time	Not Implemented	3.60	Sig.	3.79	Not Sig.	3.44	Not Sig.
	Implemented	4.43		4.47		4.46	
Suggestions from the employees	Not Implemented	3.40	Not Sig.	3.64	Not Sig.	3.33	Not Sig.
	Implemented	3.78		3.68		3.79	
Involves employees	Not Implemented	3.40	Not Sig.	3.57	Not Sig.	3.33	Not Sig.
	Implemented	3.91		3.89		3.92	
Increase Customer satisfaction	Not Implemented	3.40	Sig.	3.43	Sig.	3.56	Not Sig.
	Implemented	4.13		4.26		4.04	
Decreases Inventory	Not Implemented	3.50	Not Sig.	3.57	Not Sig.	3.22	Not Sig.
	Implemented	4.09		4.16		4.17	
Reduce turnover rate	Not Implemented	2.30	Sig.	2.57	Not Sig.	2.33	Not Sig.
	Implemented	3.04		3.00		3.00	
Creates safety environment	Not Implemented	2.80	Not Sig.	2.93	Not Sig.	2.78	Not Sig.
	Implemented	3.39		3.42		3.38	

Note. 2 tailed Significance level on Mann–Whitney test: *P < 0.05; **P < 0.01

It is shown in Table 5.4, identifies a significant benefit for companies practicing Poka-yoke. Poka-yoke has been determined to be a promising tool for increasing profits and reducing cost. By contrast, companies that fail to utilize poka-yoke tools have lagged behind companies that

do in terms of cost reduction and profit maximization. The poka yoke is effective for achieving defect free products and services (Shahin and Chasemaghahi, 2010). Practicing common lean manufacturing tools such as Gemba aids in identifying and understanding the problem. This study shows that using Gemba tools helps in increasing profits, reducing costs, improving quality compared to companies that not practice Gemba. It is an advantage to make practices of Gemba to demonstrate the entire process by eyes to identify the source of waste, instead of sitting at the office. This research shows that there is several advantages in practicing Kanban compared to companies that did not as it is shown in Table 5.5. The advantages include improved productivity, reduced cost, reduced time, decreased inventory, and the creation of a safe environment. Specifically, the use of Kanban tools supports the creation of a safer environment within the organization over companies that not practicing to practice lean manufacturing tool.

Table 5.4 Comparison impact performance across implemented and not implemented lean and six sigma tools

Impact measure	Status lean tools	Mean Poka-yoke	Result	Mean Gemba	Result	Mean VSM	Result
Increase profit	Not Implemented	3.16	Sig.	3.57	Not Sig.	3.33	Not Sig.
	Implemented	4.03		3.96		4.00	
Improve quality	Not Implemented	3.83	Not Sig.	3.71	Sig.	3.83	Not Sig.
	Implemented	4.37		4.42		4.37	
Reduces variation	Not Implemented	3.67	Not Sig.	3.29	Sig.	3.67	Not Sig.
	Implemented	4.07		4.19		4.07	
Reduces cost	Not Implemented	3.17	Sig.	3.14	Sig.	3.00	Not Sig.
	Implemented	4.30		4.35		4.33	
Improves productivity	Not Implemented	3.67	Not Sig.	3.71	Not Sig.	3.83	Not Sig.
	Implemented	4.33		4.35		4.30	
Reduces Lead-time	Not Implemented	3.50	Not Sig.	3.71	Not Sig.	3.50	Not Sig.
	Implemented	4.33		4.31		4.33	
Suggestions from the employees	Not Implemented	3.33	Not Sig.	3.29	Not Sig.	3.17	Not Sig.
	Implemented	3.74		3.77		3.78	
Involves employees	Not Implemented	3.17	Not Sig.	3.29	Not Sig.	3.17	Not Sig.
	Implemented	3.89		3.88		3.89	
Increase Customer satisfaction	Not Implemented	3.17	Sig.	3.43	Not Sig.	3.33	Not Sig.
	Implemented	4.07		4.04		4.04	
Decreases Inventory	Not Implemented	3.67	Not Sig.	4.14	Not Sig.	4.17	Not Sig.
	Implemented	3.96		3.85		3.85	
Reduce turnover rate	Not Implemented	2.00	Sig.	2.43	Not Sig.	2.17	Not Sig.
	Implemented	3.00		2.92		2.96	
Creates safety environment	Not Implemented	2.83	Not Sig.	3.29	Not Sig.	3.00	Not Sig.
	Implemented	3.30		3.19		3.26	

Note. 2 tailed Significance level on Mann-Whitney test: *P < 0.05; **P < 0.01

This study discovers that use of a flow chart is instrumental in involving and engaging employees in terms of suggestions and input (See Table 5.6). The flow chart also improves customer satisfaction as well compared to companies that not use these practices. Finally practicing a regression analysis also supports an increase in profits compared to companies not using of this kind of statistical tool. However, overall, the study shows that practicing lean manufacturing and six sigma enhances companies' performance. Specifically, there is a significant difference between companies using lean manufacturing and six sigma tools and those companies that have not implemented tools such as One Piece Flow, Flow Chart, 5S, Takt time, Gemba, Poka yoke, Kanban, etc. However, Figure 5.2 to Figure 5.4 clearly presents an overview of the performance outcomes for the companies implementing lean manufacturing and six sigma. Specifically,

illustrates a comparison between companies that implemented lean and six sigma, and companies that had not implemented at all. Estimates of the average value for each lean manufacturing and six sigma practice against companies implementing to no implemented at all, such as Figure 5.2 which shows the effectiveness of implementing lean manufacturing and six sigma practices for increasing profits.

Table 5.5 Comparison impact performance across implemented and not implemented lean and six sigma tools

Impact measure	Status lean tools	Mean Kanban	Result	Mean Check sheet	Result	Mean Pareto chart	Result
Increase profit	Not Implemented	3.28	Not Sig.	4.00	Not Sig.	3.50	Not Sig.
	Implemented	4.03		3.86		3.90	
Improve quality	Not Implemented	3.86	Not Sig.	4.67	Not Sig.	4.50	Not Sig.
	Implemented	4.38		4.23		4.26	
Reduces variation	Not Implemented	3.57	Not Sig.	4.33	Not Sig.	5.00	Not Sig.
	Implemented	4.12		3.97		3.94	
Reduces cost	Not Implemented	3.29	Sig.	4.33	Not Sig.	4.50	Not Sig.
	Implemented	4.31		4.07		4.06	
Improves productivity	Not Implemented	3.43	Sig.	4.00	Not Sig.	4.50	Not Sig.
	Implemented	4.42		4.23		4.19	
Reduces Lead-time	Not Implemented	3.43	Sig.	3.67	Not Sig.	4.50	Not Sig.
	Implemented	4.38		4.23		4.16	
Suggestions from the employees	Not Implemented	2.71	Sig.	2.67	Not Sig.	4.00	Not Sig.
	Implemented	3.92		3.77		3.65	
Involves employees	Not Implemented	2.71	Sig.	2.67	Not Sig.	4.00	Not Sig.
	Implemented	4.04		3.87		3.74	
Increase Customer satisfaction	Not Implemented	2.57	Sig.	2.33	Sig.	4.50	Not Sig.
	Implemented	4.27		4.07		3.87	
Decreases Inventory	Not Implemented	2.71	Sig.	2.33	Not Sig.	4.00	Not Sig.
	Implemented	4.23		4.07		3.90	
Reduce turnover rate	Not Implemented	1.86	Sig.	1.67	Sig.	3.00	Not Sig.
	Implemented	3.08		2.93		2.81	
Creates safety environment	Not Implemented	2.14	Sig.	1.67	Sig.	3.00	Not Sig.
	Implemented	3.50		3.37		3.23	

Note. 2 tailed Significance level on Mann–Whitney test: *P < 0.05; **P < 0.01

Table 5.6 Comparison impact performance across implemented and not implemented lean and six sigma tools

Impact measure	Status lean tools	Mean VOC	Result	Mean DPMO	Result	DMAIC	Result	Regression analysis	Result
Increase profit	Not Implemented	3.80	Not Sig.	3.84	Not Sig.	3.85	Not Sig.	3.65	Sig.
	Implemented	3.89		3.90		3.89		4.23	
Improve quality	Not Implemented	4.00	Not Sig.	4.46	Not Sig.	4.07	Not Sig.	4.15	Not Sig.
	Implemented	4.32		4.15		4.42		4.46	
Reduces variation	Not Implemented	4.00	Sig.	4.23	Not Sig.	3.86	Not Sig.	3.90	Not Sig.
	Implemented	4.00		3.85		4.11		4.15	
Reduces cost	Not Implemented	3.20	Not Sig.	4.15	Not Sig.	3.79	Not Sig.	3.90	Not Sig.
	Implemented	4.25		4.05		4.32		4.38	
Improves productivity	Not Implemented	4.00	Not Sig.	4.08	Not Sig.	4.14	Not Sig.	4.10	Not Sig.
	Implemented	4.25		4.30		4.26		4.38	
Reduces Lead-time	Not Implemented	4.00	Not Sig.	4.00	Not Sig.	4.07	Not Sig.	4.00	Not Sig.
	Implemented	4.21		4.30		4.26		4.46	
Suggestions from the employees	Not Implemented	3.40	Not Sig.	3.69	Not Sig.	3.86	Not Sig.	3.60	Not Sig.
	Implemented	3.71		3.65		3.53		3.77	
Involves employees	Not Implemented	3.40	Not Sig.	3.69	Not Sig.	3.86	Not Sig.	3.65	Not Sig.
	Implemented	3.82		3.80		3.68		3.92	
Increase Customer satisfaction	Not Implemented	3.40	Not Sig.	3.85	Not Sig.	3.79	Not Sig.	3.75	Not Sig.
	Implemented	4.00		3.95		4.00		4.15	
Decreases Inventory	Not Implemented	4.00	Not Sig.	3.77	Not Sig.	4.29	Not Sig.	3.85	Not Sig.
	Implemented	3.89		4.00		3.63		4.00	
Reduce turnover rate	Not Implemented	2.40	Not Sig.	2.77	Not Sig.	2.79	Not Sig.	2.55	Not Sig.
	Implemented	2.89		2.85		2.84		3.23	
Creates safety environment	Not Implemented	2.80	Not Sig.	3.00	Not Sig.	3.43	Not Sig.	2.95	Not Sig.
	Implemented	3.29		3.35		3.05		3.62	

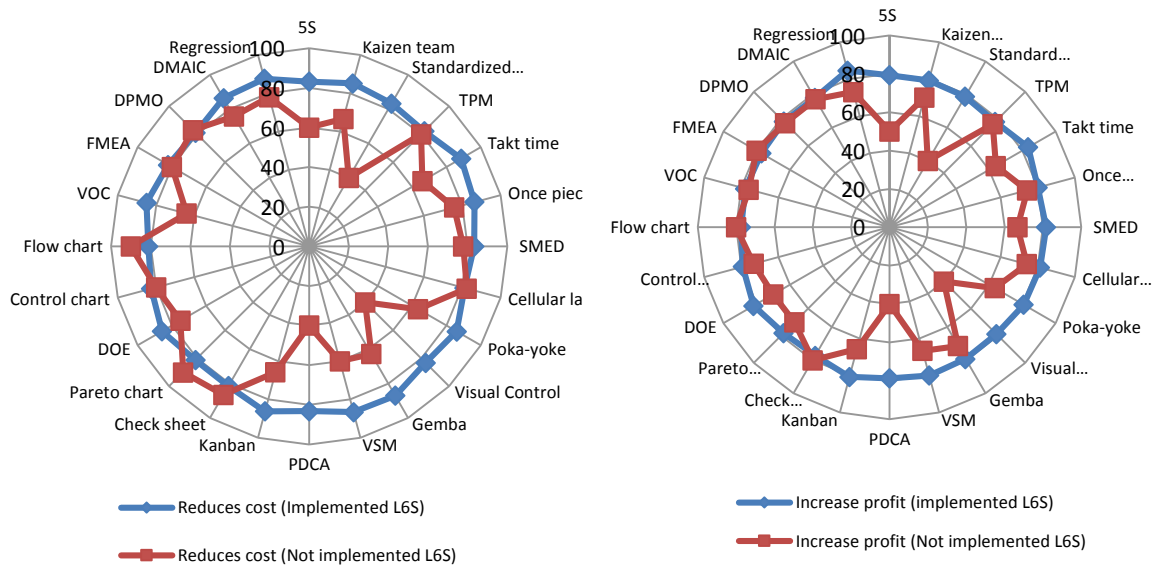
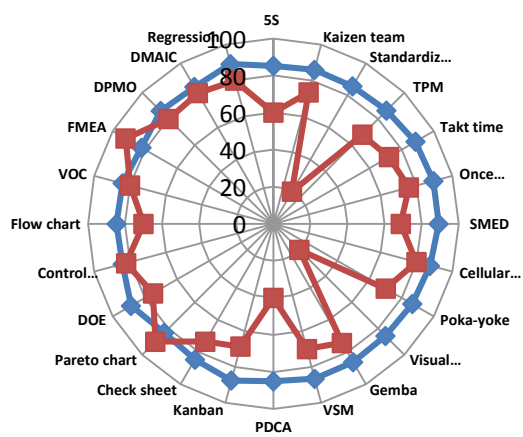
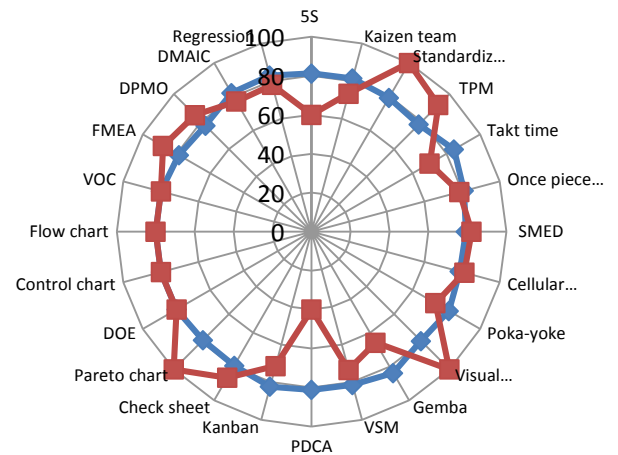


Figure 5.2: Comparison the effectiveness of lean manufacturing six sigma practices for financial performance.

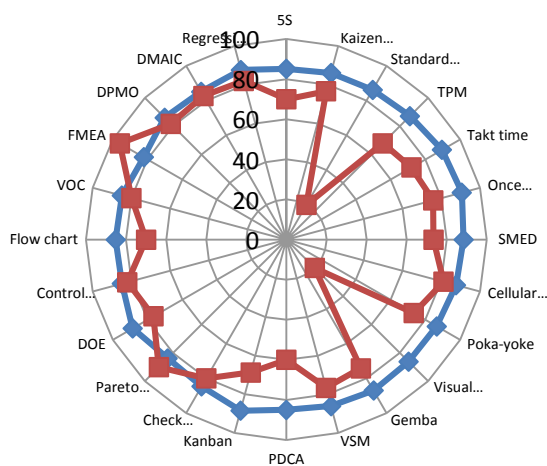
Obviously, lean manufacturing and six sigma practices demonstrate best practices for improving performance outcomes. It has observed that companies implementing lean six-sigma practices have achieved higher impact on increase profit as compared to other companies have not implemented lean six sigma practices at all. The above diagram shows that several tools support increased profits. The relevant tools are 5S, Poke Yoke, Kanban, VSM, Visual Control, PDCA, SMED, and Kaizen Team were perceived the highest by increase profit. In order to identify whether or not significant differences exist between companies that implemented lean and six sigma practices, and companies that had not implemented at all, the Mann Whitney U test was conducted. The results of the comparison show significant differences between two companies at 5% significant level on increased profits through 5S, Takt time, Poka Yoke, and PDCA. Additionally, lean manufacturing and six sigma practices support for reducing cost. The result of comparison show significant different between two companies at the 5% significant level on reduce cost by Takt time, Poka Yoke, Gemba,VSM, Kanban and Voice of Customer (VOC). These practices correlated and supported with reduced cost, compared to the companies that did not utilize these practices.



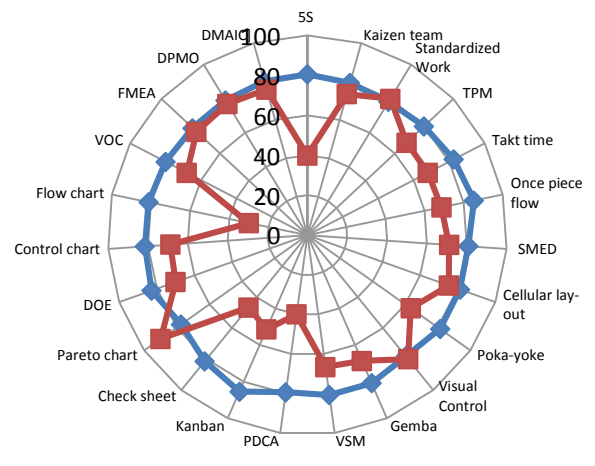
— Reduces time (Implemented L6S)
— Reduces time (Not Implemented L6S)



— Reduces variation (Implemented L6S)
— Reduces variation (Not implemented L6S)



— Improves productivity (Implemented L6S)
— Improves productivity (Not Implemented L6S)



— Increase Customer satisfaction
— Increase Customer satisfaction

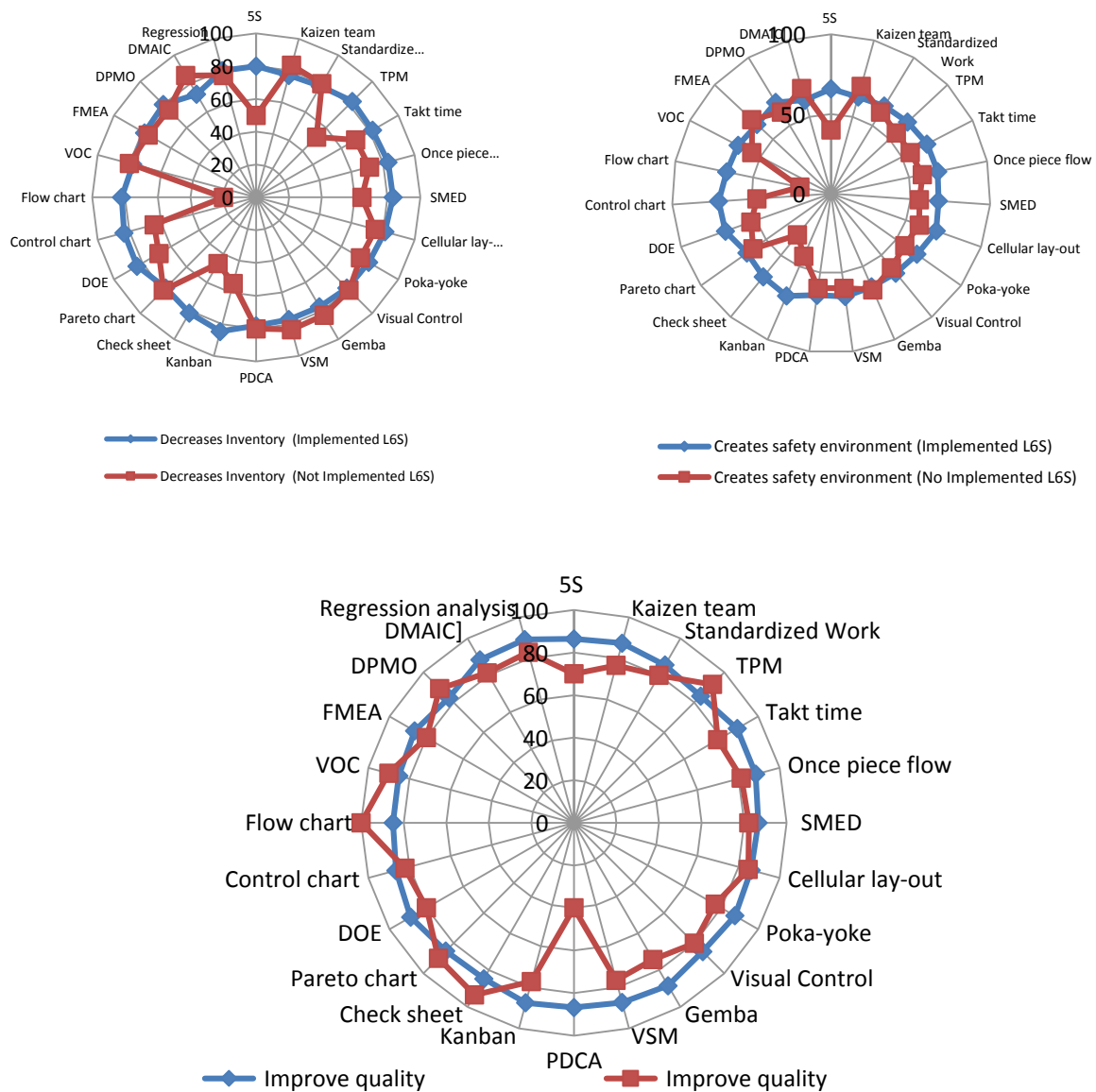


Figure 5.3: Comparison the effectiveness of lean and six sigma practices for operational performance

Lean manufacturing and six sigma practices support for operational performance. In the above diagrams is shown that the several tools support to increase operational performance such as 5S, PDCA, GEMBA, Kanban. It showed that companies implementing lean six-sigma practices have achieved greater impact on improve quality, compared to other companies have not implemented lean six sigma practices. The results of comparison show significant differences between two companies at the 5% significant level on improved quality by Takt time and Gemba. These improvements tools were observed in reduced waste, improve productivity and so on. However, it can therefore be inferred from these findings that companies that implement Takt time and Gemba realize more improvements in improve quality. Additionally, it showed interesting result

that companies implementing Gemba and takt time and 5S have achieved greater impact on reduce variation and improve quality as well. However, it can therefore be inferred from these findings that companies that implemented Takt time, Gemba and 5S can be supportive to improve quality and reduce variation. The above diagram shows that several tools support increased productivity. The relevant tools are One Piece flow, 5S, VSM, kanban, visual control, etc. The results of the comparison show significant differences between two companies at 5% significant level on improve productivity through Kanban. This implies that companies implementing (Kanban) practices expected to acquire improve productivity, compared to companies that had not implemented Kanban system. Additionally, kanban showed significant supportive for reducing time. Since the result of Mann Whitney test shows significant differences on reduce time by Kanban system too, since the p value less than 0.05. The results of the comparison show significant differences between two companies at the 5% significant level for increase customer satisfaction. 5S, Takt time, one piece flow, Kanban, check sheet, flow chart shows the effect of implementing these practices to increase customer satisfaction. Figure 5.3 obviously presents an overview of the increase customer satisfaction outcomes for the companies implementing lean manufacturing and six sigma, compared to companies that had not implemented at all. The results of the comparison show significant difference between two companies at the 5% significant level for decreased inventory by TPM, Kanban and Flow Chart. Therefore these practices can be linked to decreases in inventory with companies implemented these practices. The results of the comparison show significant differences between two companies at the 5% significant level on the creation of a safe environment through Kanban, Check Sheet, DOE, Control Chart and Flow Chart. These practices are therefore linked to support the creation of a safe environment. Therefore, it shows with this study several tools enhance the operational performance.

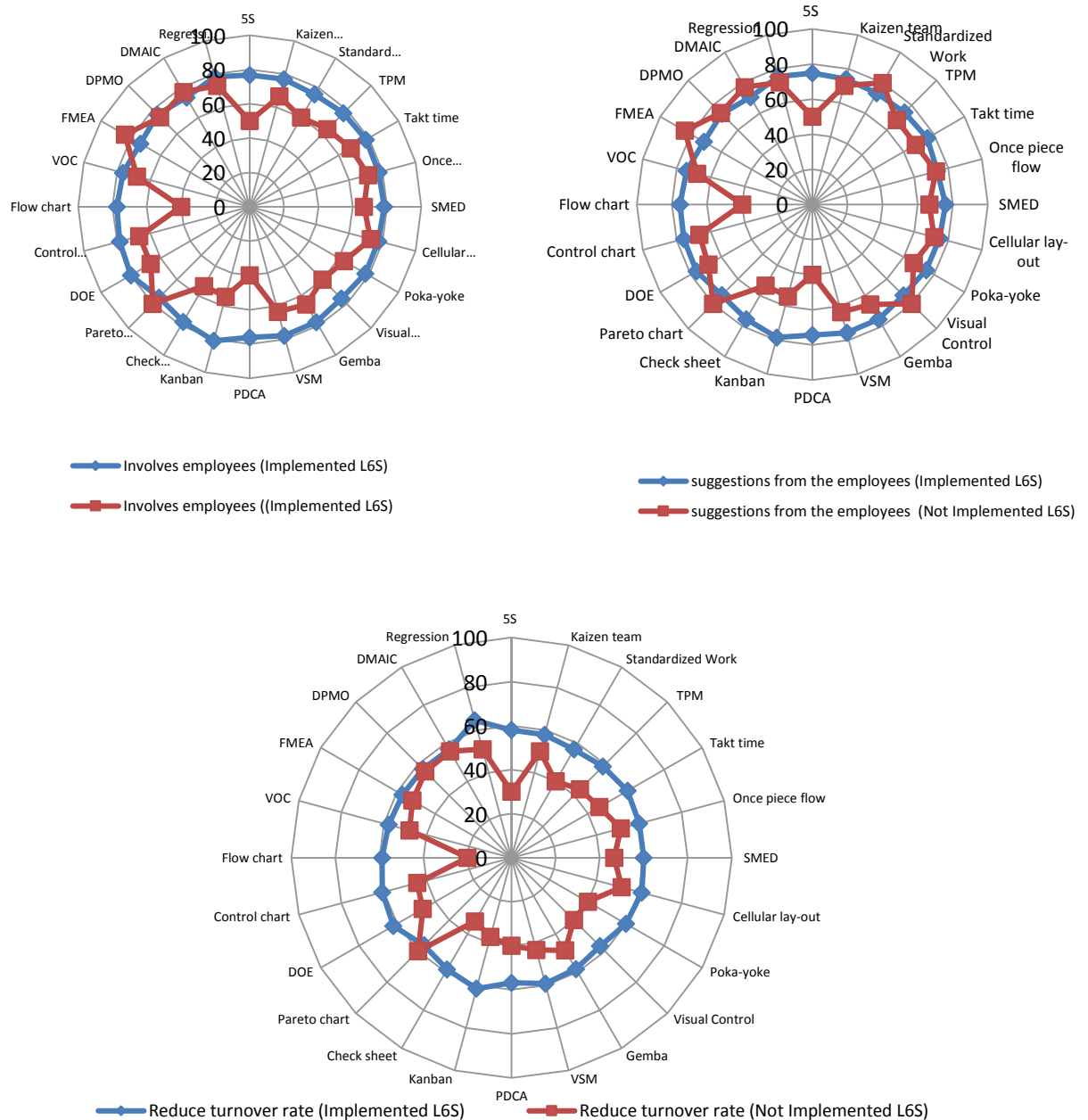


Figure 5.4: Comparison the effectiveness of lean six sigma practices for innovation performance.

Companies implementing lean six-sigma practices supportive on innovation performance. It found out increase suggestion from the employees, compared to other companies have not implemented quality practices. The above diagram shows that several tools support to increase suggestion from the employees. The relevant tools are Gemba, Check Sheet, 5S, VSM. The results of the comparison show significant differences between two companies at 5% significant level on increase suggestion from the employees through Flow chart. This indicates companies practicing quality tools such as Flow Chart can be supportive to collect idea from the employees,

compared to companies that had not implemented flow chart. Lean manufacturing and six sigma practices support to involve the employees as well. The result of Mann Whitney test shows significant differences on involve employees time by flow chart, 5S, and Kanban, since the p value less than 0.05. This implies companies achieve more supportive to engage the employees by implementing these practices, compared to other companies have not implemented this practices. Consequently, these practices therefore correlate with improvement in employees involvement. It seems Flow Chart is effective to support to employees engagement and suggestion.

5.2.2. SME and Large companies Vs. Lean manufacturing and six sigma practices

A review of literature indicates that large companies are more likely than SMEs to implement lean manufacturing and six sigma practices. Therefore this study seeks to determine the status of companies within this research. In order to make this determination a sample of 33 French Companies consisting of SMEs and large companies that vary from company to company in terms of practicing lean manufacturing and six sigma practices, were included in the study. However, we compared SME and large companies with companies that have implemented and have not implemented lean six sigma practices. The purpose of the comparisons was to identify whether or not size is linked to lean six sigma practices? A Chi Square was conducted on two categorical variables (2 X 2) to evaluate the relationship between SME and large companies across companies implementing and not implementing lean six sigma practices.

Ho: No relationship between size and lean manufacturing and six sigma practices

Ha: A relationship between size and lean manufacturing and six sigma practices

As illustrated in the Table 5.7 there are six significant practices out of the 26 at the significant level 0.05 indications for links between size and lean six sigma practices. The practices of lean manufacturing and six sigma are one piece flow, Gemba, Value Stream Map, Voice of customer, Defect Per Million Opportunities and DMAIC. While the significance level is less than 0.05, we can accept the alternative hypothesis Ha. In other words, we can conclude that there were relationships between SME and large companies in implementing these practices. Based on the results, it appears that large companies are more likely to implement these practices compared to SMEs. The results of this study have revealed significant differences between SMEs and large companies with respect to the use of several tools, notably DMAIC, DPMO, and One Piece Flow. Statistically, it would appear that SMEs have more difficulty in adopting them. Therefore, lean and six-sigma practices were linked to the size of companies within French industries. On the other hand, no significant relationship was found between SME and large companies to other lean six sigma tools such as TPM, PDCA, Kaizen, Stander work etc. An overall, size matters, since some lean manufacturing and six-sigma practices were influenced by the size of companies within French industries.

Table 5.7 Status of SME and Large against Lean Manufacturing and Six Sigma

Lean six sigma practices	Size of companies	Status of implementation Lean six sigma		P value
5S	Comparable	NOT Implemented	Implemented	0.17
	SME	0.00%	100.00%	
	Large companies	9.50%	90.50%	
Kaizen	SME	25%	75%	0.449
	Large companies	14.30	85.70%	
Standardized Work	SME	8.30%	91.70%	0.149
	Large companies	0.00%	100.00%	
TPM	SME	16.70%	83.30%	0.855
	Large companies	14.30%	85.70%	
Takt time	SME	50.00%	50.00%	0.065
	Large companies	19.00%	81.00%	
One piece flow	SME	66.70%	33.30%	0.032
	Large companies	38.60%	71.40%	
SMED	SME	16.70%	83.30%	0.289
	Large companies	33.30%	66.70%	
Cellular lay-out	SME	58.30%	41.70%	0.553
	Large companies	47.60%	52.40%	
Poka Yoke	SME	25.00%	75.00%	0.449
	Large companies	14.30%	85.70%	
Visual Control	SME	8.30%	91.70%	0.149
	Large companies	0.00%	100%	
Gemba	SME	50%	50%	0.002
	Large companies	4.8%	95.20%	
Brainstorming	SME	0.00%	100%	No statistics
	Large companies	0.00%	100%	
Value Stream Mapping	SME	41.70%	58.30%	0.008
	Large companies	4.80%	95.20%	
PDCA	SME	0.00%	100%	0.337
	Large companies	4.80%	95.20%	
Kanban	SME	33.30%	66.70%	0.205
	Large companies	14.30%	85.70%	
Check sheet	SME	16.70%	83.30%	0.263
	Large companies	4.80%	95.20%	
Pareto chart	SME	0.00%	100.00%	0.17
	Large companies	9.50%	90.50%	
Design of Experiment	SME	33.30%	66.70%	0.784
	Large companies	38.10%	61.90%	
Control chart	SME	25.00%	75.00%	0.824
	Large companies	28.60%	71.40%	
Flow chart	SME	8.30%	91.70%	0.685
	Large companies	4.80%	95.20%	
FEMA	SME	16.70%	83.30%	0.855
	Large companies	14.30%	85.70%	
VOC	SME	33.30%	66.70%	0.0029
	Large companies	4.80%	95.20%	
DPMO	SME	66.70%	33.30%	0.015
	Large companies	23.80%	76.20%	
DMAIC	SME	66.70%	33.30%	0.032
	Large companies	28.60%	71.40%	
Regression analysis	SME	75.00%	25.00%	0.193
	Large companies	52.40%	47.60%	

5.3. Degree Level of lean manufacturing and six sigma implementation

Lean manufacturing and six sigma tools and techniques are measured on a five-point scale. Table 5.8 shows the tools and techniques that are relevant to the implementation of Lean and Six Sigma

within organizations. Each item was measured using a five point Likert scale. Relative scales ranged from 1 = no implementation to 5 = complete implementation. A higher score on the Likert scale demonstrates that lean manufacturing and six sigma techniques are used and implemented more extensively. On the other hand, a lower score on the Likert scale indicates that lean manufacturing and six sigma tools are not used or implemented extensively. Responses from the survey questionnaires show PDCA the highest level score with mean value 4.0 that indicate majority of the enterprises within the thirty-three enterprises had commonly used of PDCA. An explanation for this finding that companies look to perform continues improvement in their process of product and service to improve the bottom line and increase customer satisfaction. Regression analysis was the least implementation with mean value 1.48. It interpret majority companies were not perform statistical analysis. The following Table 5.8 presented the tools range or level of all lean manufacturing and six sigma implementation that were applied within the thirty-three enterprises.

Table 5.8 Present the status of how do enterprises implemented lean and six-sigma tools

Tools and technique	N	Min	Max	Mean	Std. Deviation
PDCA	33	1	5	4.00	.901
Cause and effect diagram	33	1	5	3.70	.951
5S	33	1	5	3.67	.990
Visual Control	33	1	5	3.64	1.055
Standardized Work	33	1	5	3.64	.929
Brainstorming	33	2	5	3.64	1.113
Pareto chart	33	1	5	3.48	1.149
Flow chart	33	1	5	3.30	1.015
FMEA	33	1	5	3.12	1.244
Voice of Customer	33	1	5	3.12	1.317
Value Stream Mapping	33	1	5	3.12	1.386
Kaizen team	33	1	5	3.12	1.386
Check sheet	33	1	5	3.00	.968
Gemba	33	1	5	2.97	1.357
TPM	33	1	5	2.76	1.032
Kanban	33	1	5	2.64	1.220
Poka-yoke	33	1	5	2.64	1.168
SMED	33	1	5	2.58	1.324
Takt time	33	1	5	2.52	1.302
Control chart	33	1	5	2.52	1.253
Defects per million opportunities	33	1	5	2.48	1.482
DMAIC	33	1	5	2.33	1.451
Once piece flow	33	1	5	2.27	1.306
Design of Experiment	33	1	5	2.15	1.064
Cellular lay-out	33	1	5	2.06	1.321
Regression analysis	33	1	3	1.48	.667

5.3.1. Regression Analysis

A linear regression analysis and Spearman rho correlation were used to find out the impact of all lean and six sigma practices implementation on operational performance. However, in order to identify whether there are positive outcomes from little implementation, some implementation, wide implementation, complete implementation in terms of increasing company performance, a regression analysis was therefore used to identify the relationship between the level of lean and

six sigma implementation and companies performance. To identify the influence of lean manufacturing and six sigma implementation on companies that we aggregate mean scores of variable such as increase profit, reduce cost, improve quality, improve productivity etc, (dependent variable) and aggregate mean scores of lean manufacturing and six sigma practices such as 5S, Kaizen, TPM etc, (independent variable). Findings as shown in Table 5.9 were statistically significant (p-value= 0.00 and R square = 0.222). The results also showed significant correlation (p-value= 0.00, $R = 0.423^*$, $B \neq 0$), meaning that lean manufacturing and six sigma practices influenced the financial operational performance and it has positive relationship between the lean manufacturing and six sigma practices and company performance. Therefore it can be concluded that the more extensively a company implements these practices, the greater the performance outcomes. Since, we discovered that the implementation level of lean manufacturing and six sigma practices effectively of increases companies' performance. Therefore, we desire to determine which of these tools are effective for increasing company performance. Consequently, we conducted the chi square test to identify the relationship between financial performance and lean manufacturing and six sigma tools.

Table 5.9 Relationship between lean and six sigma tools and companies performance.

Model Summary					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	
1	.471 ^a	.222	.197	7.08909	
a. Predictors: (Constant), Tools					

ANOVA ^a						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	444.816	1	444.816	8.851	.006 ^b
	Residual	1557.912	31	50.255		
	Total	2002.727	32			
a. Dependent Variable: companies performance						
b. Predictors: (Constant), lean manufacturing and six sigma practices						

Coefficients ^a						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	27.265	6.387		4.269	.000
	Tools	.246	.083	.471	2.975	.006
a. Dependent Variable: company performance						

5.3.2. The level of lean manufacturing and six sigma implementation

In order to identify whether there are positive outcomes from little implementation, some implementation, wide implementation, complete implementation in terms of increasing the financial performance, we evaluate whether or not there is an association between levels of implementation and financial performance. Chi Square was therefore used to identify the relationship between the level of lean manufacturing and six sigma implementation and financial performance. Chi square test was used for five different levels of implementing lean manufacturing and six sigma.

As shown in Figure 5.5, increased implementation of 5S leads to improved financial performance, with many enterprises with wide or complete implementation of 5S agreeing or strongly agreeing on increased financial performance. In contrast, companies that either carried out only limited implementation of 5S or did not implement it at all did not agree that there was increased financial performance. Chi square test results were found to be equal to 0.001, which is less than the p-value of 0.05. Therefore, based on these results, it can be claimed that there is a relationship between the level of implementing 5S practices and financial performance ($\chi^2 = 33.245$, degree of freedom =12, p-value =0.001). Therefore, increased implementation of the 5S system supports increased financial performance.

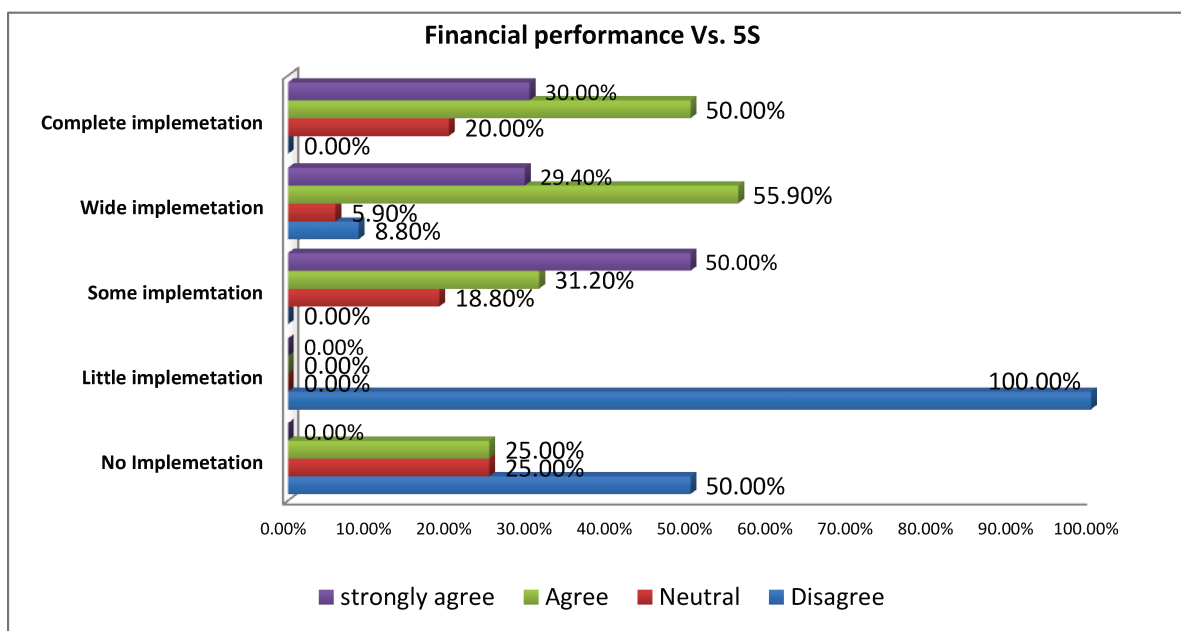


Figure 5.5: Comparison between Levels of 5S implementation and Financial Performance

Figure 5.6 shows the results of the chi square test for identifying whether or not there is a relationship between levels of implementation of Kaizen team practices and financial performance. Agreement scores indicating that wide or complete implementation was correlated with increased financial performance were good compared with disagreement scores that little or no implementation correlated with financial performance. The chi square test result was found to be equal to 30.38, with degree of freedom = 12, and p-value =0.001, which is less than 0.05. Therefore, the results indicate that there is a relationship between the level of implementation of Kaizen team practices and financial performance.

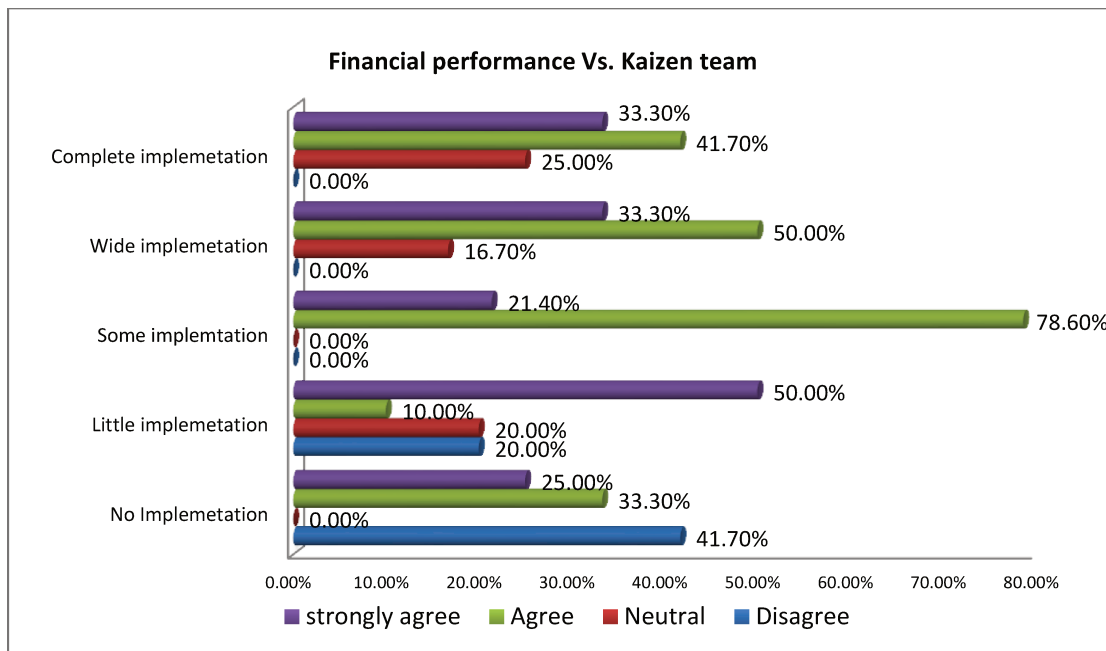


Figure 5.6: Comparison between Levels of kaizen implementation and Financial Performance

Figure 5.7 shows the results of the Chi square test for identifying whether or not there is a relationship between levels of implementation of stander work and financial performance. It can observe that either no implementation or little implementation of stander work reflected to week supportive to improve financial performance. On the other hand, wide and complete implementation of stander work was connected of improved financial performance. ($\chi^2 = 33.348$, degree of freedom =12, p-value =0.00), p-value is less than 0.05. Therefore, there is relationship between the level of implementation stander work practices and financial performance.

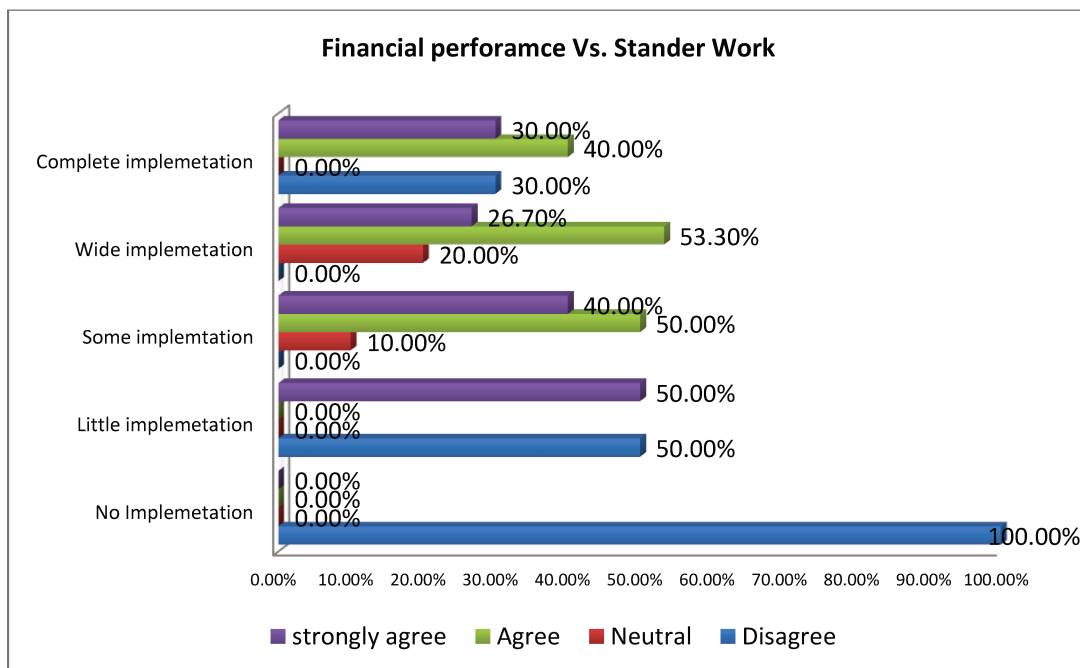


Figure 5.7: Comparison between Levels of Stander work implementation and Financial Performance

Figure 5.8 shows the results of the Chi square test for identifying whether or not there is a

relationship between levels of implementation of TPM and financial performance. Agreement scores indicating that wider and complete implementation was correlated with increased financial performance were good compared to disagreement scores that little to no implementation correlated with increased financial performance, even though that there were two companies completed implemented TPM practices, but they had disagree with increase financial performance. However, chi square test showed statistically significant relationship between increased financial performance and TPM ($\chi^2 = 23.260$, degree of freedom =12, p-value =0.026), an overall, there is relationship between level of implementation TPM practices and financial performance.

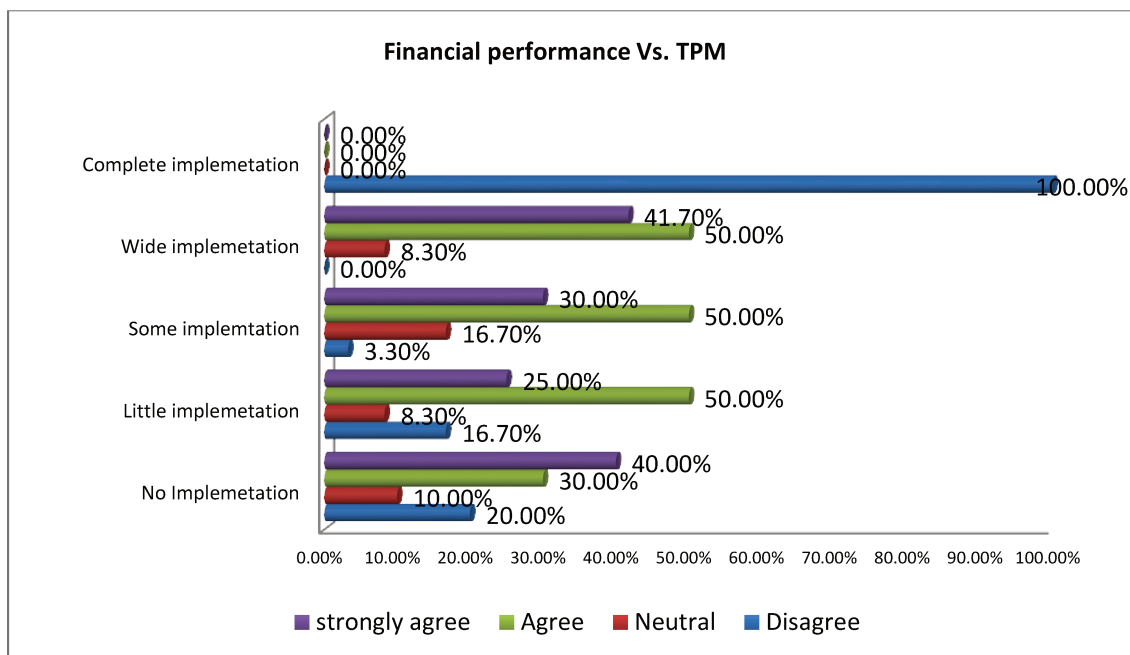


Figure 5.8: Comparison between Levels of TPM implementation and Financial Performance

Figure above 5.9 shows the results of the Chi square test for identifying whether or not there is a relationship between levels of implementation of Takt Time practice and financial performance. Agreement scores indicating that wider, some and complete implementation associated with increased financial performance compared to disagreement scores that no implementation associated with increased financial performance. Chi square test results found to be equal to 33.180, and P-value is less than 0.05. the null hypothesis rejected. Therefore there is relationship between the level of implementation Takt Time and financial performance.

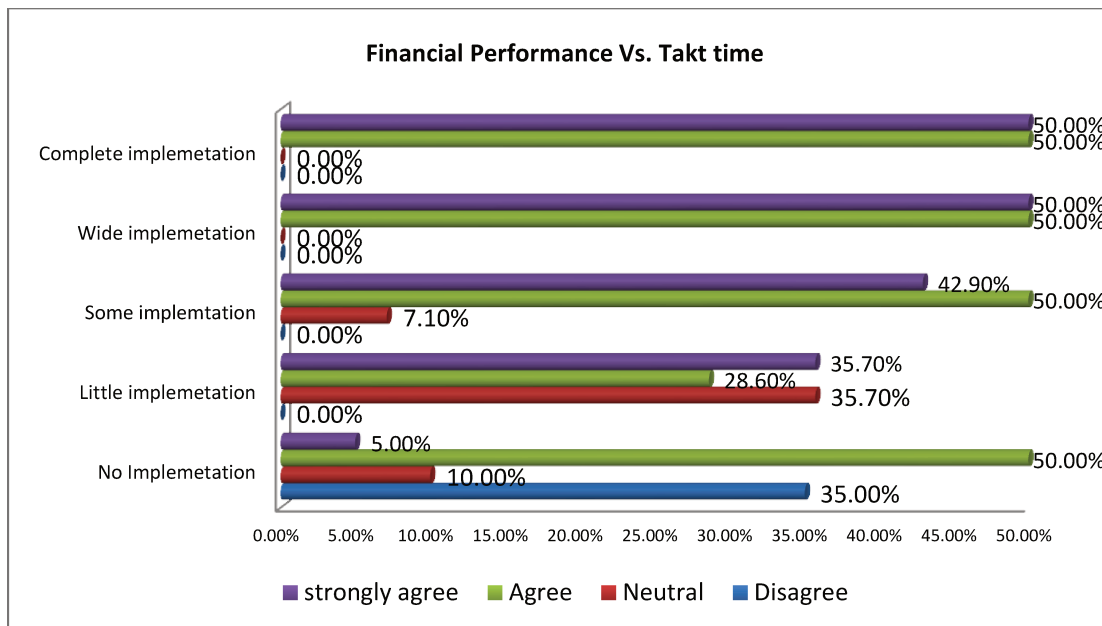


Figure 5.9: Comparison between Levels of Takt time implementation and Financial Performance

A chi square test was used for measuring the relationship between levels of implementation of One Piece Flow practices and financial performance. (see Figure 5.10). Findings reveal that there is significant relationship between levels of implementation of one piece flow practices and increase financial performance ($\chi^2=27.75$, degree of freedom =12, p-value=0.006). Consequently, the null hypothesis was rejected. Therefore, there is relationship between level of implementation One Piece Flow practices and financial performance.

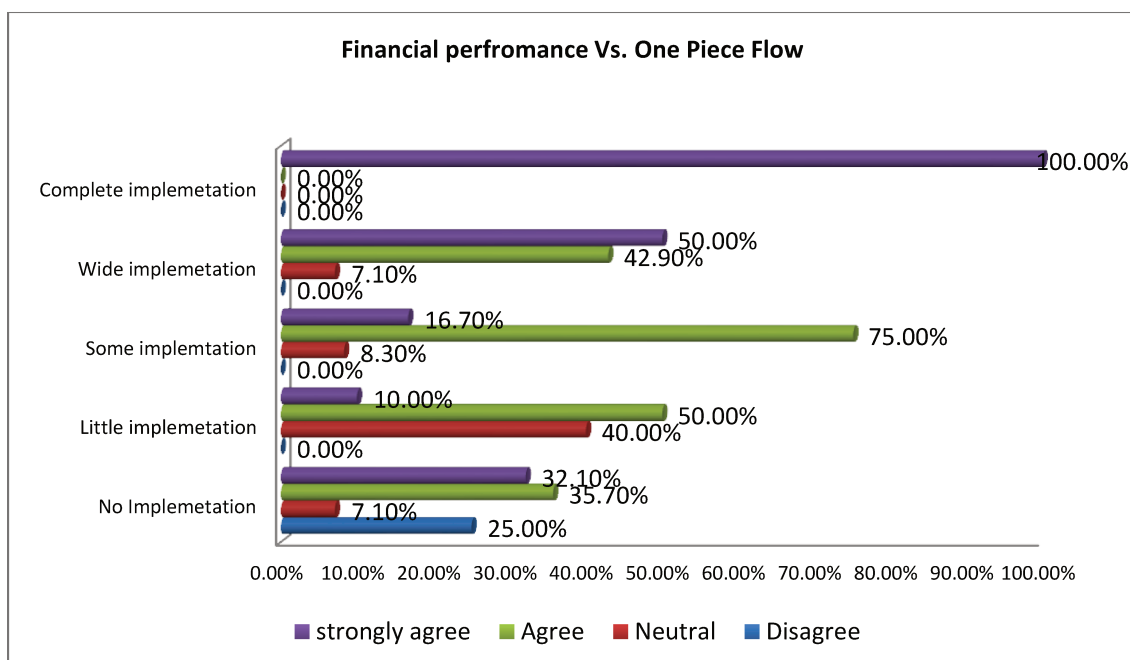


Figure 5.10: Comparison between Levels of One Piece Flow implementation and Financial Performance

Poka Yoke as shown in the Figure 5.11 illustrates that increased implementation of Poka Yoke practices almost supports increases in financial performance, since many enterprises with wide and complete implementation of Poka Yoke that agree and strongly agree that such companies

increase financial performance. A chi square test was used for measuring the relationship between levels of implementation of Poka Yoke practices and financial performance. Findings reveal that there is significant relationship between levels of implementation of Poka Yoke practices and increase financial performance ($\chi^2 = 33.779$, degree of freedom=12, p-value =0.00). Consequently, the null hypothesis was rejected. Therefore, there is relationship between level of implementation Poka Yoke and financial performance.

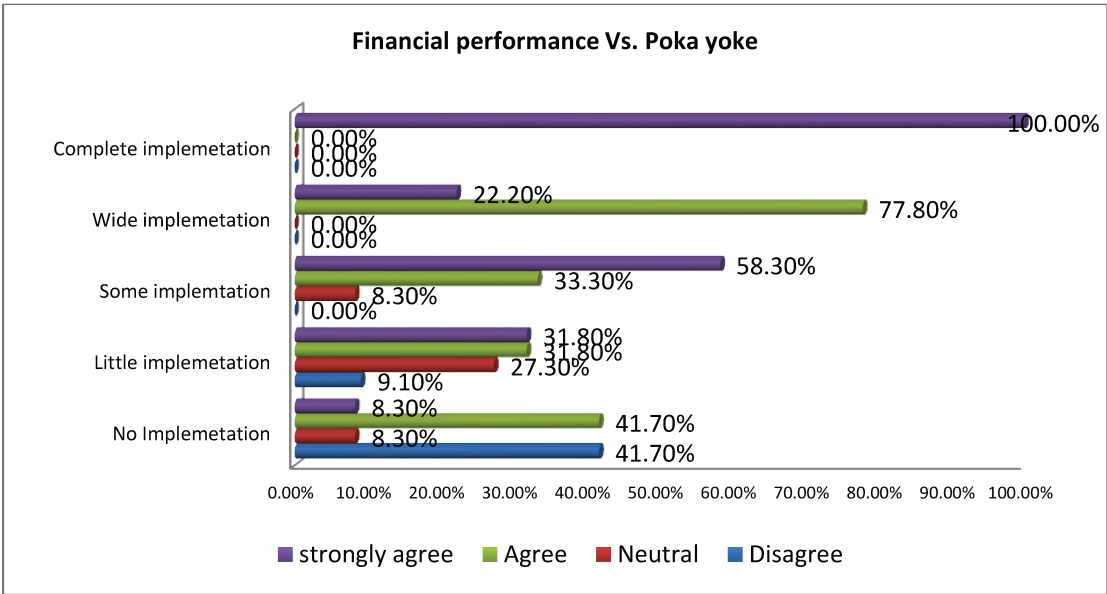


Figure 5.11: Comparison between Levels of Poka Yoke implementation and Financial Performance

Figure 5.12 above shows the results of the Chi square test for identifying whether or not there is a relationship between levels of implementation of visual control and financial performance. Agreement scores indicating that wider and complete implementation correlated with increased financial performance were good compared to disagreement scores that little to no implementation correlated with increased financial performance. ($\chi^2 = 33.826$, degree of freedom =12, p-value =0.001). The Chi square test results was found to be equal to 0.01, which is less than 0.05, so there is relationship between level of implementation visual control and financial performance.

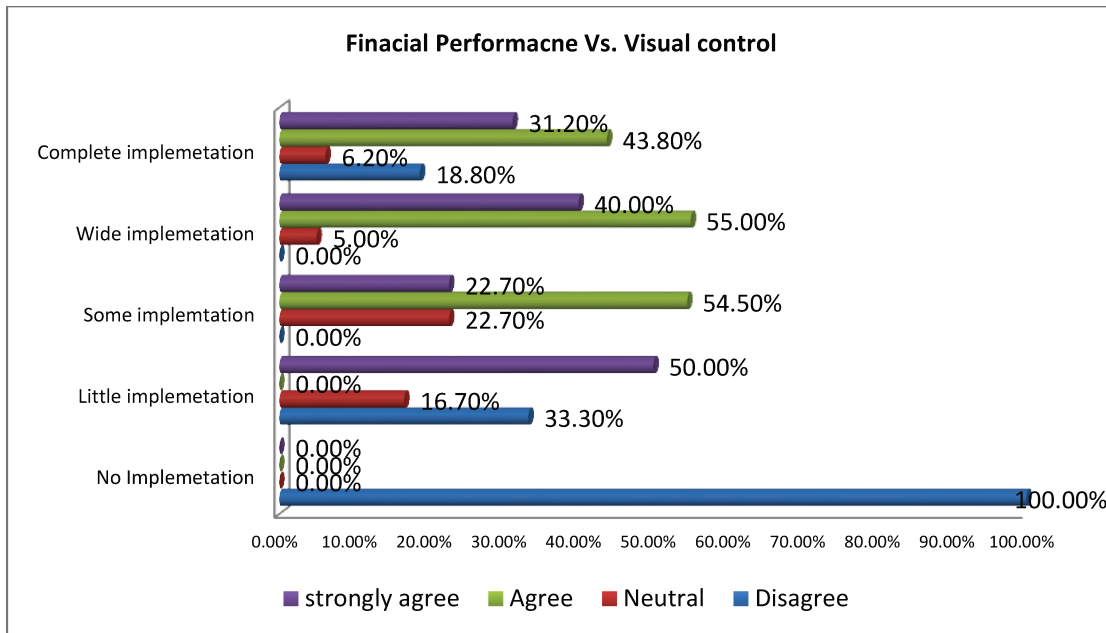


Figure 5.12: Comparison between Levels of visual control implementation and Financial Performance.

A chi square test was used for measuring the relationship between levels of implementation of Gemba practices and increase financial performance as shown in Figure 5.13. Findings reveal that there is significant relationship between levels of implementation of Gemba practices and increase financial performance ($\chi^2 = 26.410$, degree of freedom = 12, p-value = 0.009). Therefore, there is relationship between level of implementation Gemba practices and financial performance.

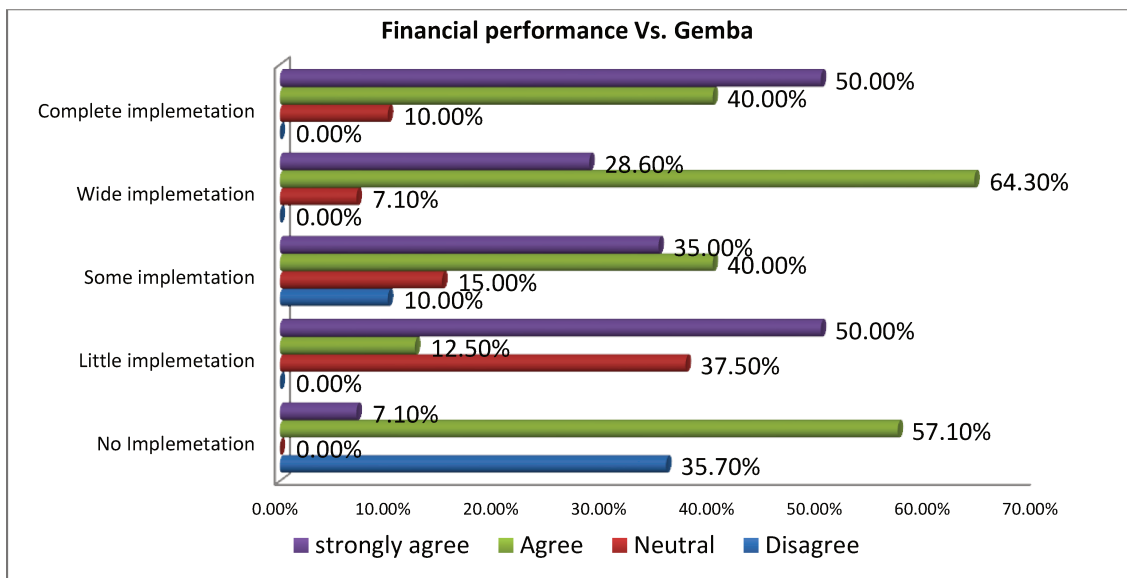


Figure 5.13: Comparison between Levels of Gemba implementation and Financial Performance.

Figure 5.14 shows the results of the Chi square test for identifying whether or not there is a relationship between levels of implementation of Value Stream Map practices and financial performance. Agreement scores indicating that wider and complete implementation associated with increased financial performance were good compared to disagreement or neutral scores that

little to some implementation associated with increased financial performance. ($\chi^2 = 46.337$, degree of freedom =12, p-value =0.00). The result of the test is significant (p value < 0.05). The chi square test showed a statistically significant relationship between Value Stream Map and financial performance.

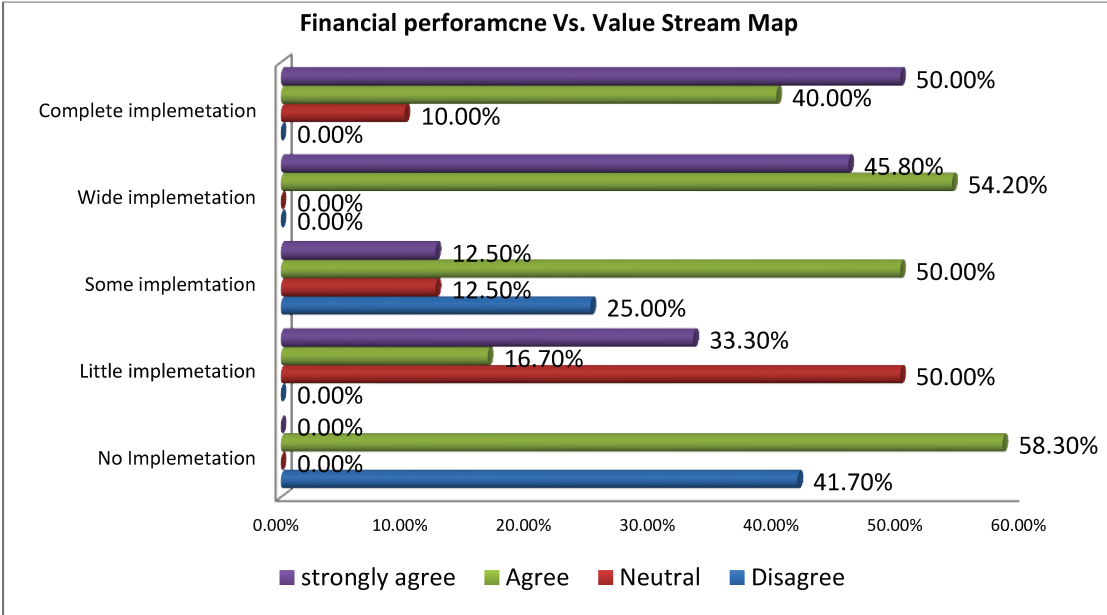


Figure 5.14: Comparison between Levels of VSM implementation and Financial Performance

Figure 5.15 shows the results of the Chi square test for identifying whether or not there is a relationship between levels of implementation of Kanban practices and financial performance. Agreement scores indicating that wider and complete implementation almost correlated with increased financial performance were good compared to disagreement scores that some, little and no implementation correlated with increased financial performance.

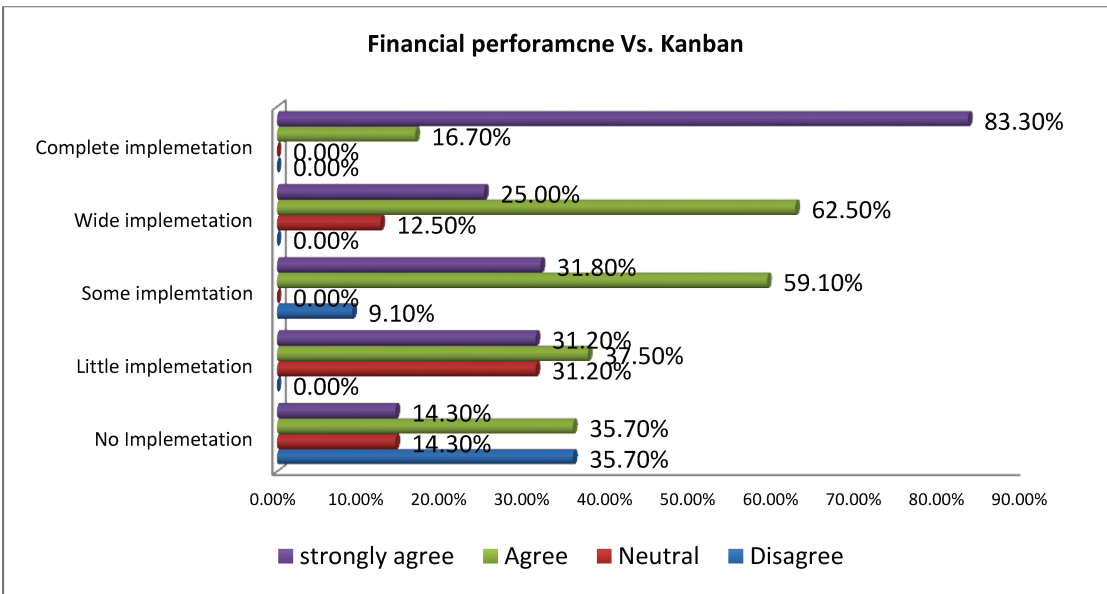


Figure 5.15: Comparison between Levels of Kanabn implementation and Financial Performance

The chi square test showed a statistically significant relationship between Kanban Practices and

financial performance ($\chi^2 = 29.326$, degree of freedom =12, p-value =0.01), Therefore, There is relationship between level of implementation Kanban and financial performance. There is significant relationship between levels of implementation of check sheet practices and increase financial performance ($\chi^2 = 23.899$, degree of freedom =12, p-value =0.006). Consequently, the null hypothesis was rejected. Therefore, there is relationship between level of implementation check sheet and financial performance.

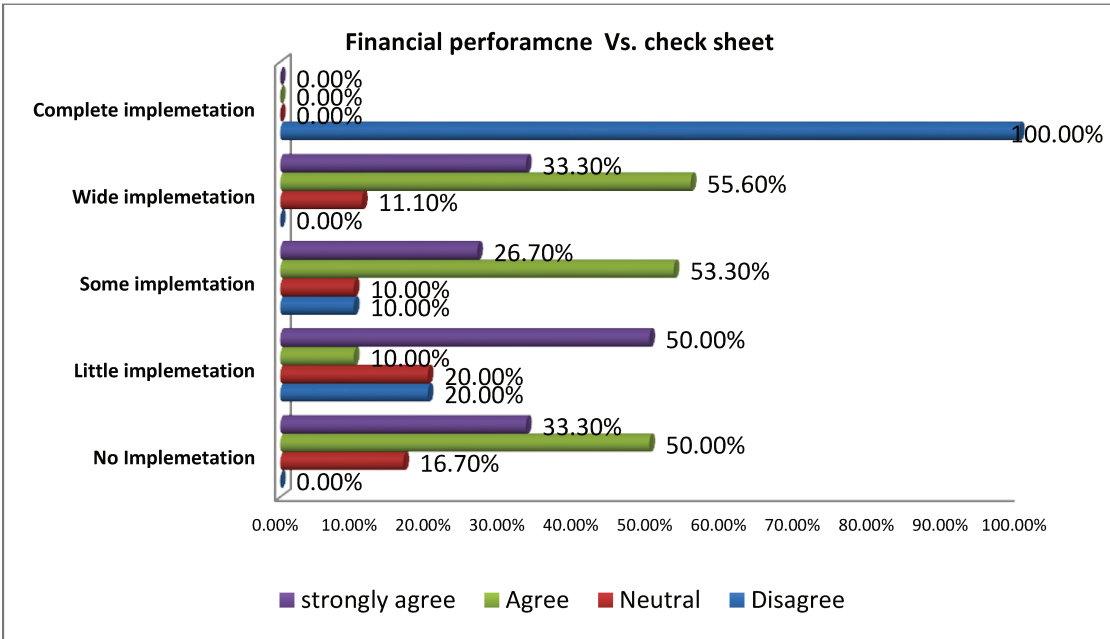


Figure 5.16: Comparison between Levels of check sheet implementation and Financial Performance

There is significant relationship between levels of implementation of cause and effect diagram practices and increase financial performance ($\chi^2 = 22.885$, degree of freedom =12, p-value =0.029) (see Figure 5.17).

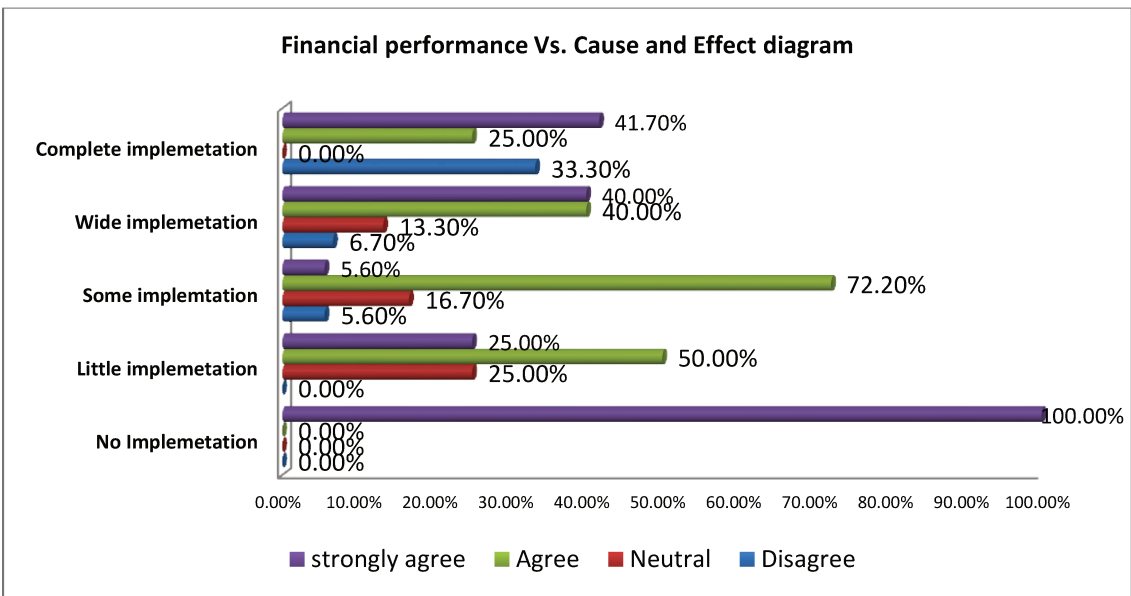


Figure 5.17: Comparison between Levels of cause and effect implementation and Financial Performance

Therefore, there is relationship between level of implementation cause and effect diagram and financial performance. Also, there is significant relationship between levels of implementation of Flow chart practices and increase financial performance ($\chi^2 = 27.968$, degree of freedom =12, p-value =0.006). Therefore, there is relationship between level of implementation Flow chart practices and financial performance (see Figure 5.18).

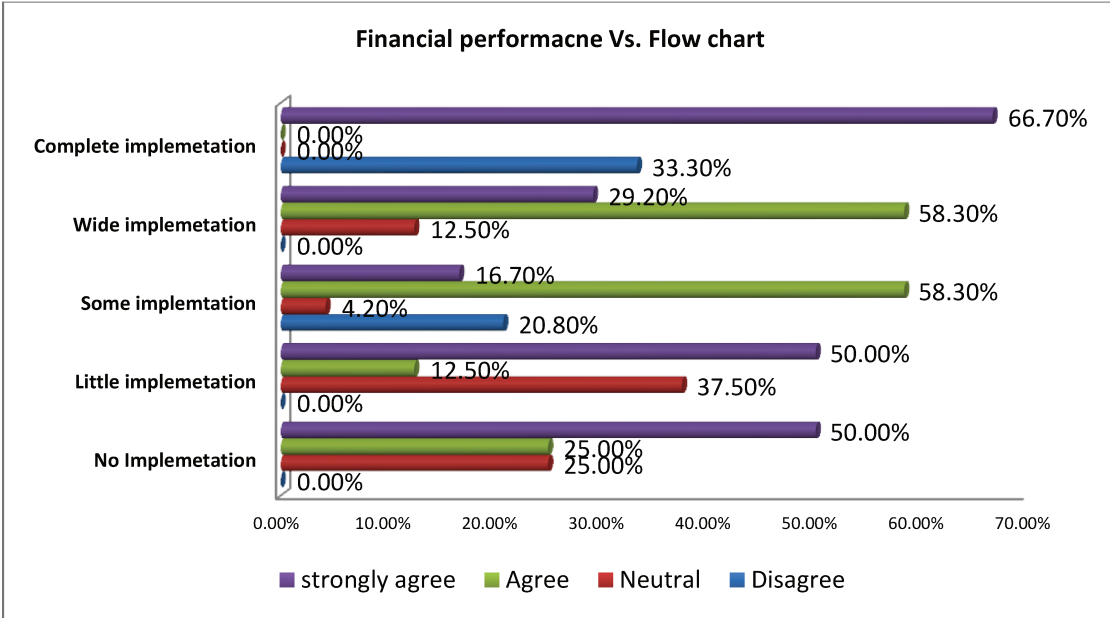


Figure 5.18: Comparison between Levels of flow chart implementation and Financial Performance

There is significant relationship between levels of implementation of FEMA practices and increase financial performance ($\chi^2 = 30.066$, degree of freedom =12, p-value =0.003). Therefore, there is relationship between level of implementation FEMA practices and financial performance (see Figure 5.19).

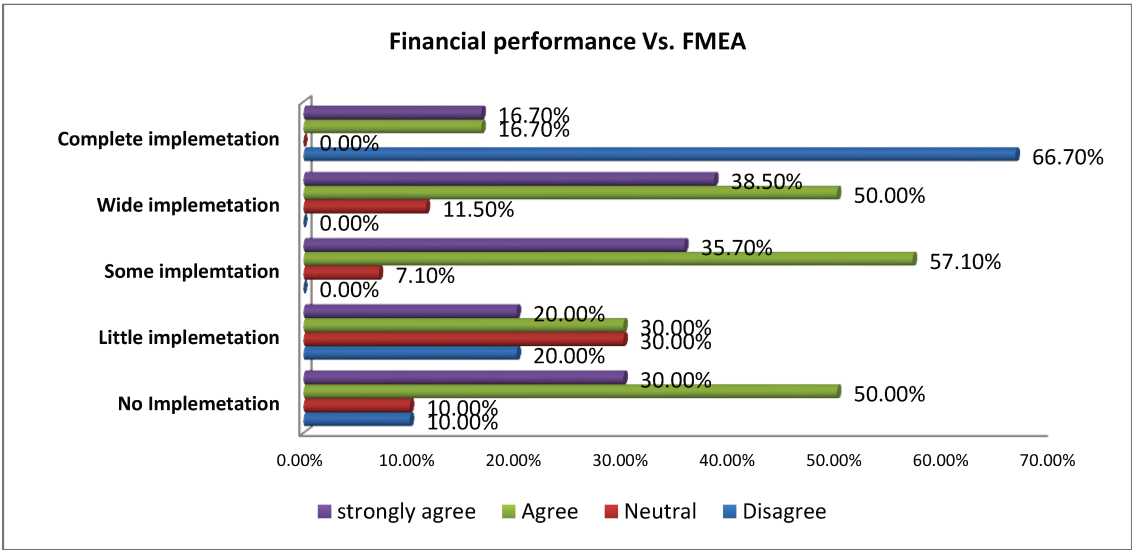


Figure 5.19: Comparison between Levels of FEMA implementation and Financial Performance

There is significant relationship between levels of implementation of DMAIC practices and increase financial performance ($\chi^2 = 31.817$, degree of freedom =12, p-value =0.001). Therefore, there is relationship between level of implementation DMAIC practices and financial performance (see Figure 5.20).

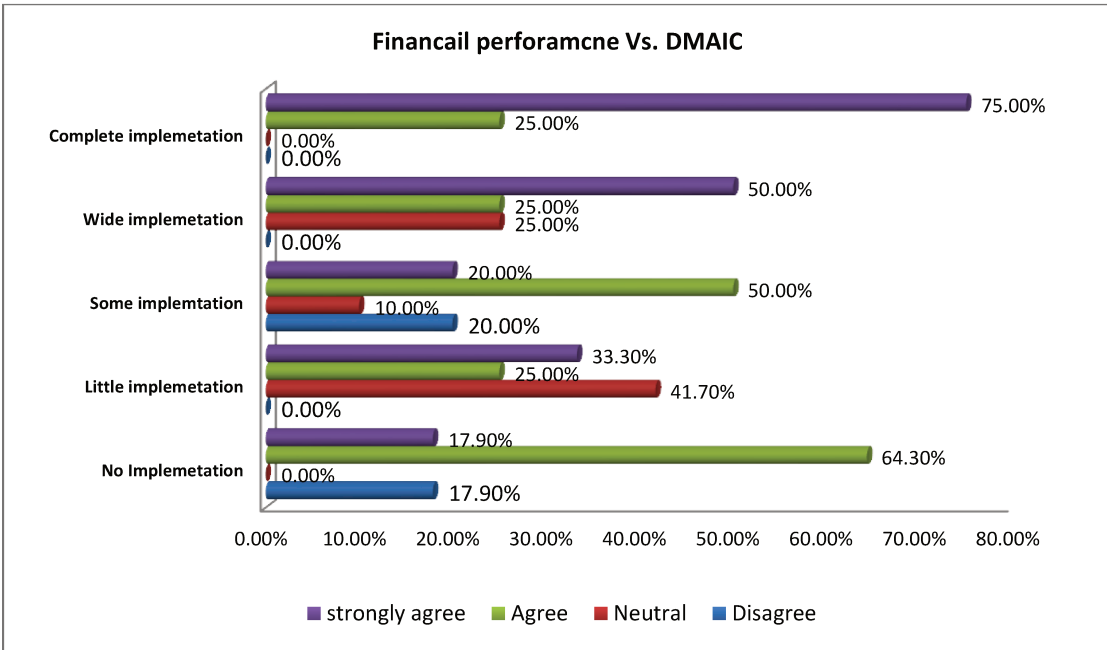


Figure 5.20: Comparison Between Levels of DMAIC implementation and Financial Performance

There is significant relationship between levels of implementation of SMED practices and increase financial performance ($\chi^2 = 30.883$, degree of freedom =12, p-value =0.002). Therefore, there is relationship between level of implementation SMED practices and financial performance (see Figure 5.21).

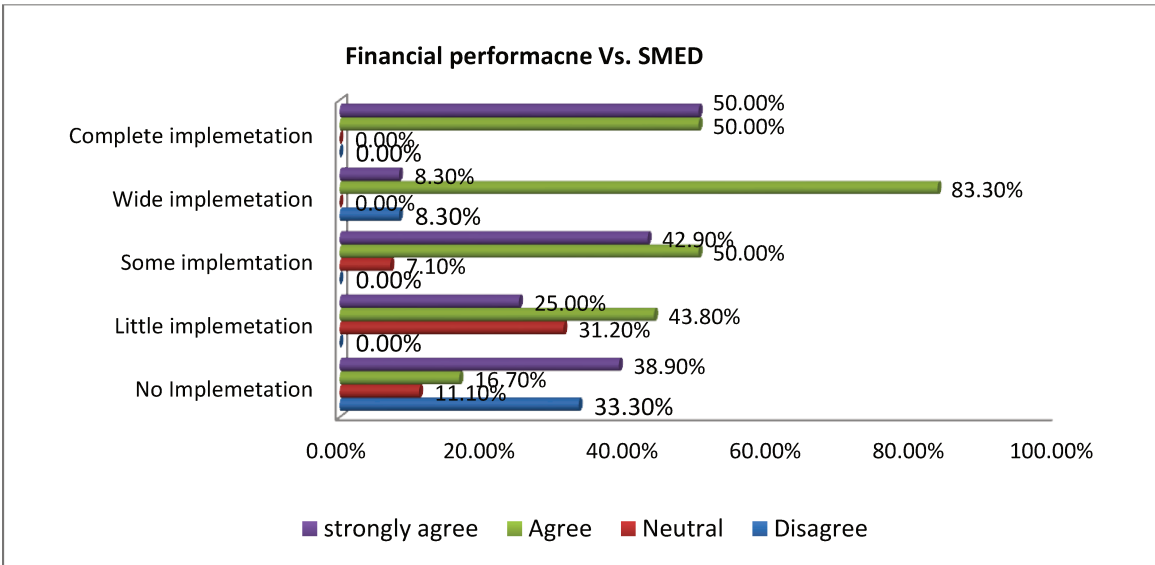


Figure 5.21: Comparison Between Levels of SMED implementation and Financial Performance

There is significant relationship between levels of implementation of regression analysis practices and increase financial performance ($\chi^2 = 16.270$, degree of freedom =6, p-value

=0.012). Therefore, there is relationship between level of implementation regression analysis practices and financial performance (see Figure 5.22).

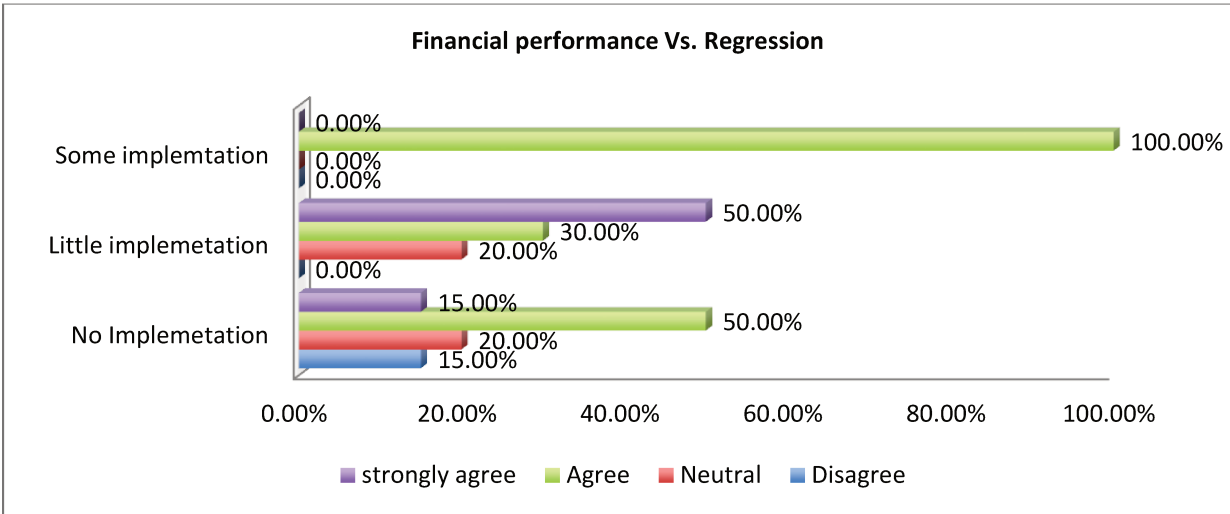


Figure 5.22: Comparison between Levels of regression analysis and Financial Performance

There is significant relationship between levels of implementation of PDCA practices and increase financial performance ($\chi^2 = 32.850$, degree of freedom =6, p-value =0.001). Therefore, there is relationship between level of implementing PDCA practices and financial performance. It shows PDCA practices reflected to disagreement scores that no implementation associated with increased financial performance (see Figure 5.23).

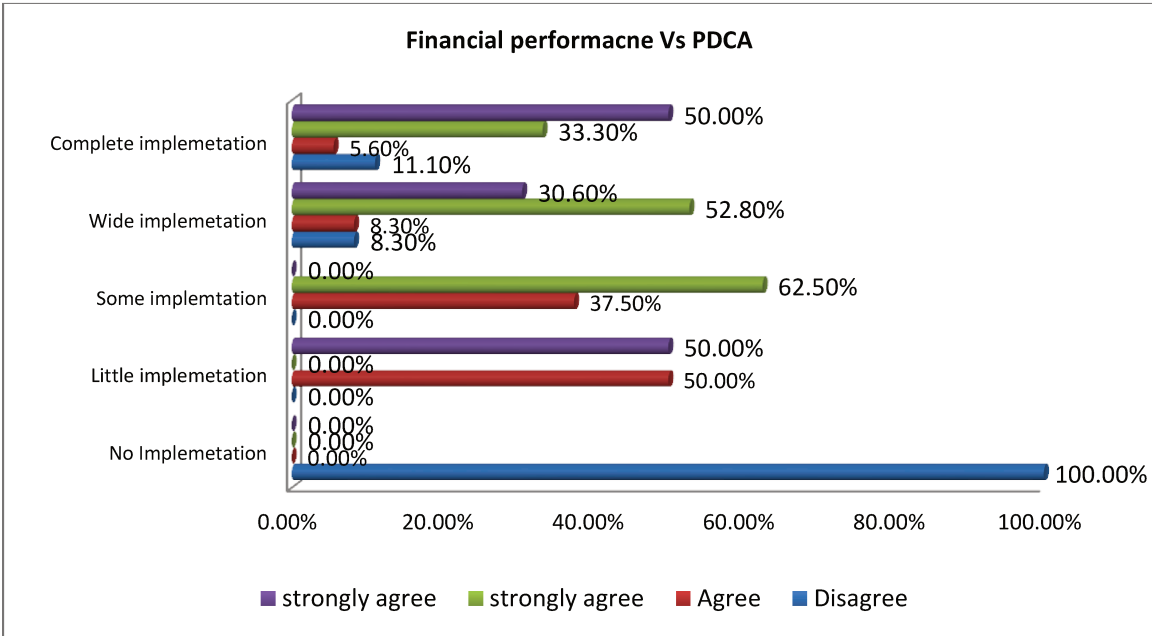


Figure 5.23: Comparison between Levels of PDCA and Financial Performance

There is significant relationship between levels of implementation of VOC practices and increase financial performance ($\chi^2 = 20.558$, degree of freedom =6, p-value=0.057). Therefore, there is margin significant relationship between level of implementation VOC practices and financial performance (see Figure 5.24).

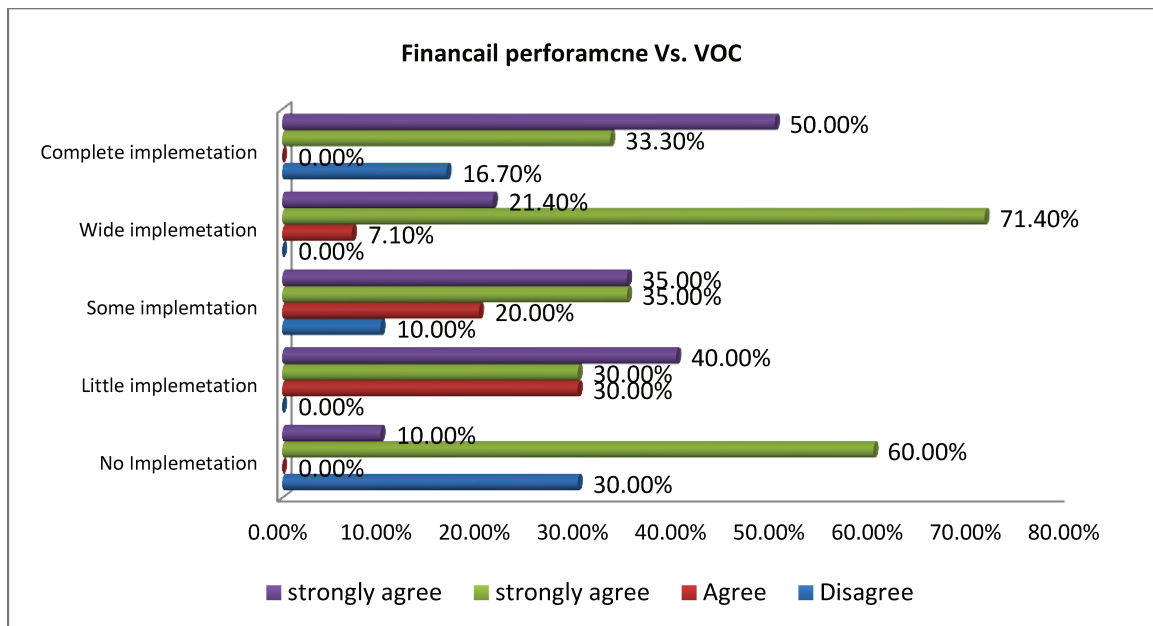


Figure 5.24: Comparison between Levels of voice of customer and Financial Performance

There is no significant relationship between levels of implementation of DPMO practices and increase financial performance ($\chi^2 = 15.722$, degree of freedom =12, p-value =0.204). Therefore, there is no relationship between level of implementing DPMO practices and financial performance in this study. This may cause in this study that only a small sample for companies practicing DPMO (see Figure 5.25).

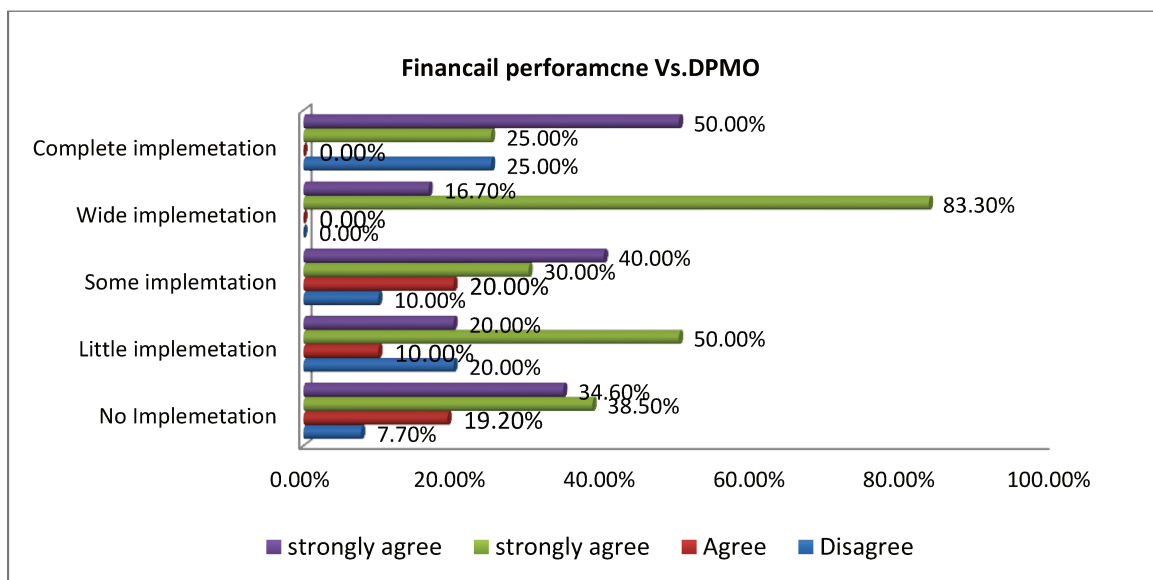


Figure 5.25: Comparison between Levels of DPMO and Financial Performance

There is significant relationship between levels of implementation of cause and control chart and financial performance ($\chi^2 = 17.249$, degree of freedom =12, p-value=0.140), which is more than alpha level (0.05). Therefore, there is no relationship between level of implementation control chart and financial performance (see Figure 5.26).

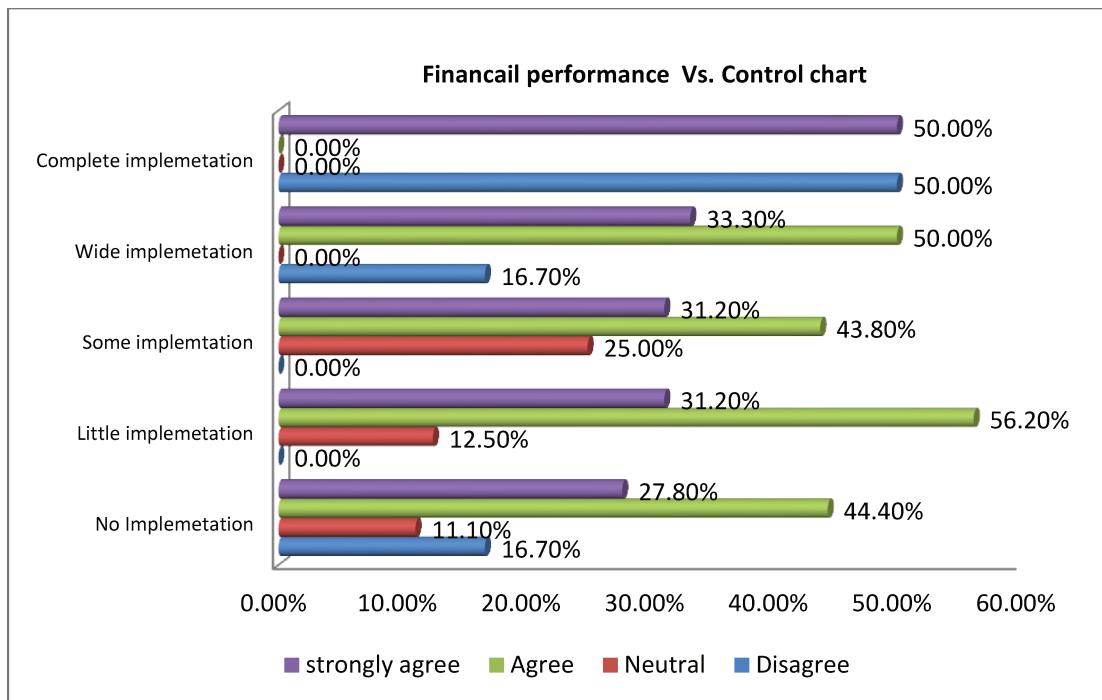


Figure 5.26: Comparison between Levels of control chart and Financial Performance

There is significant relationship between levels of implementation of cellular layout and financial performance ($\chi^2 = 18.090$, degree of freedom =12, p-value =0.113), which is more than alpha level (0.05). Therefore, there is no relationship between level of implementation cellular layout and financial performance.

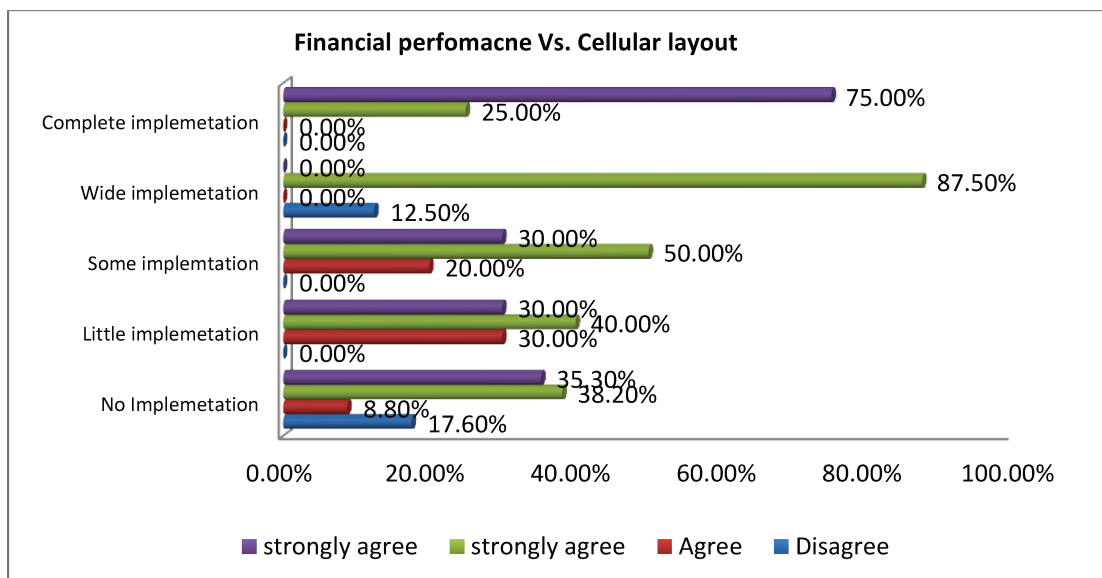


Figure 5.27: Comparison between Levels of cellular layout and Financial Performance

5.4. Degree level of implementing lean manufacturing and six sigma practices within respective organizations

Table 5.10 shows the tools and technique that were relevant to the implementation of lean manufacturing and six sigma within the French organizations participating in this study. Lean

manufacturing and six sigma practices were analyzed according to their implementation within their respective organizations. The purpose of the data collection and analysis was to identify how different companies practice these tools. Each item was measured using a five point Likert scale. Relative scales ranged from 1 = no implementation to 5 = complete implementation. A higher score for implementation demonstrates that lean manufacturing and six sigma techniques are used more extensively (Where these tools and techniques were implemented and used more commonly). On the other hand, a lower percentage indicates that lean manufacturing and six sigma tools are not used extensively.

Table 5.10 Range lean manufacturing and six sigma among three groups

Companies implemented lean manufacturing and six sigma		Companies implemented lean manufacturing		Companies using limited tools but not referring as lean and six sigma methods	
Practices	%	Practices	%	Practices	%
Brainstorming	88.8	PDCA	80	PDCA	75
PDCA	82.2	Visual Control	77	5S	70
Cause and effect	80	Standardized Work	76	Cause and effect	65
Pareto chart	77.8	5S	74	Flow chart	60
VSM	77.8	Cause and effect	73	VOC	55
Kaizen team	75.6	Flow chart	70	Brainstorming	55
Visual Control	73.4	Pareto chart	70	Standardized Work	55
Standardized Work	73.4	Brainstorming	69	Control chart	50
5S	73.4	Check sheet	65	Pareto chart	50
VOC	71.2	VSM	63	Check sheet	50
Gemba	71.2	Gemba	61	Visual Control	50
DMAIC	68.8	Kaizen team	60	TPM	45
Flow chart	60	VOC	60	Kaizen team	45
Takt time	57.8	TPM	58	DPMO	40
Check sheet	53.4	Kanban	57	Kanban	40
Poka-yoke	53.4	Poka-yoke	55	Poka-yoke	40
TPM	53.4	SMED	55	SMED	40
Control chart	51.2	DPMO	52	Once piece flow	40
DPMO	48.8	Takt time	51	DOE	35
DOE	48.8	Control chart	50	Takt time	30
Kanban	48.8	Once piece flow	45	Regression analysis	25
SMED	48.8	Cellular layout	44	DMAIC	25
Once piece flow	48.8	DOE	42	VSM	25
Cellular layout	42.2	DMAIC	41	Gemba	25
Regression analysis	33.4	Regression analysis	29	Cellular layout	25
	N=9		N=20		N=4

All of the tools and techniques of lean manufacturing and six sigma have been implemented at a variety of levels by the participant companies. Among all of the Lean manufacturing and six sigma practices, Plan Do Check Act (PDCA) is found to be the primary practices, with mean score 4.00. Other quality tools that have been extensively implemented is the cause and effect diagram with mean score 3.70 and 5S system with mean score 3.67. However, the least practiced

tools are regression analysis and Cellular layout.

Companies that implemented lean manufacturing and six sigma practices more extensively, either of the lean manufacturing or six sigma practices such as DMAIC, Design of experiment (DOE), regression analysis, VSM, GEMBA and kaizen, team take time (used more commonly), as opposed to other companies. VOC, as opposed to other companies, Additionally, the resulting percentage reveals a higher practicing of brainstorming that aids in performance areas such as creating new ideas, defining and solving the issues in the process. These practices are indications that these companies use more statistical tools and are more aware of lean manufacturing and six sigma practices. Therefore, these companies were more frequently implementing lean and six sigma practices. These practices demonstrated that these companies were intent on achieving continuous improvement within their organizations. Where companies that implemented lean manufacturing, also use the tools and techniques of six sigma such as DMAIC, and design of experiment, but only slightly practiced these tools. On the other hand, the results show more extensive practicing with tools and techniques such as 5S, TPM and kanban, and cellular layout. But also it was observed that Kaizen and VSM were not be the highest priority among companies that implanted lean manufacturing compared to companies implemented lean manufacturing and six sigma. Therefore, it seems companies implemented lean manufacturing and six sigma were found to be more matured of these practice. Other illustration explained by **Ronald (2010)** that lean tools can generate to use six-sigma project. For example if VSM discover complex problem without known the issue then six-sigma method might be the solution to resolve the problem (**Ronald, 2010**). Additionally, **George (2003)** states that both methods complemented each other. Therefore it can be interpreted from the literature review and our results that implemented both methods contributed to be more conscious and knowledgeable on lean manufacturing and six sigma practices. While companies that have not reported implementing lean manufacturing or six sigma methods, have the lowest extensive practice involving lean six sigma practices within their respective organizations. This indicates that these lean six sigma practices were implemented, but not used usually or were not commonly used. Even though, the results do reveal some measure of achievement in the improvement of company performance outcomes, as shown in the scores for performance outcomes in Table 3.36. However, Figure 5.27 shows the tools and technique that were relevant to the implementation of lean manufacturing and six sigma among three categories.

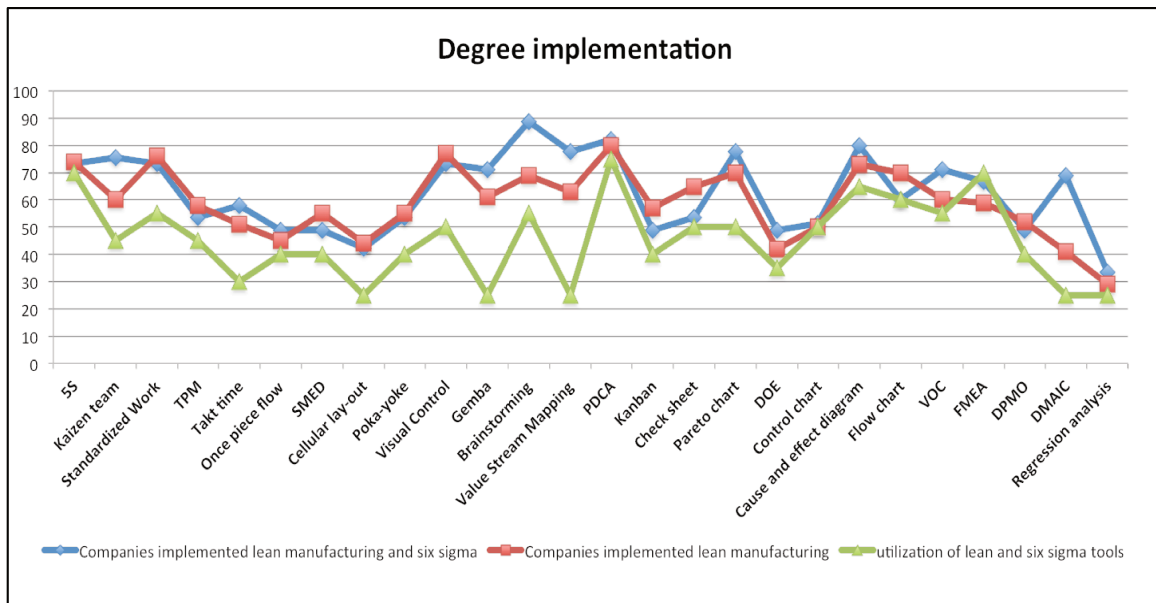


Figure 5.28: level of practicing lean manufacturing and six sigma among three categories

5.4.1. Size on the level Lean manufacturing and Six Sigma implementation

In order to verify this claim, Mann Whitney test is used in this research to determine whether there are any differences between SME and large companies in the level of implementation of lean six sigma practices at the level of significant 0.05. Based on the Table 5.11, some of these practices showed statistically significant differences between SME and large companies at significant level of 0.05.

These lean manufacturing and six sigma practices include one piece flows (The mean score for Large companies=2.71; SME=1.50), Gemba (The mean score for large companies=3.38; SME=2.25), DPMO (The mean score for large companies=3.00; SME=1.75), DMAIC (The mean score for large companies =2.67; SME=1.75), and no differences were found between SME and large organizations in this study related to other practices of lean and six sigma such as 5S, Kaizen team, Standerized work. However, large companies implement lean and six sigma practices on a wider scale than SMEs and use tools and techniques, especially six sigma methods such as DPMO and DMAIC that focus on the reduction of variation. DMAIC and DPMO are among the important fundamentals of implementing six sigma method. Being able to combine non-statistical and statistical tools and techniques in the implementation of the DMAIC model is among the factors necessary for the successful implementation of six sigma (Antony et al., 2005). For the most part, SMEs are hindered in the implementation of six sigma because they either lack awareness of six sigma or the resources necessary for implementing six sigma (Antony et al., 2005). It appears that SMEs within the French industries may have lacked the necessary resources in terms of finance, manpower, and skills. These constraints limit their ability to implement DMAIC and DPMO. SMEs have difficulty of implementing six sigma method within French industry.

Table 5.11 Degree level of lean six sigma implementation between SME and large companies

Lean six sigma practices	Z	p value
5S	-0.651	0.515
Kaizen team	-1.799	0.072
Standardized Work	-1.22	0.222
TPM	-1.15	0.25
Takt time	-1.829	0.067
Once piece flow	-2.556	0.011**
SMED (Single minute exchange of die)	-0.883	0.377
Cellular lay-out	-0.688	0.491
Poka-yoke	-0.174	0.861
Visual Control	-0.682	0.495
Gemba	-2.171	0.03*
Brainstorming	-1.22	0.222
Value Stream Mapping	-0.948	0.343
PDCA	-1.491	0.136
Kanban	-1.585	0.113
Check sheet	-1.434	0.151
Pareto chart	-0.8	0.424
Design of Experiment	-0.534	0.593
Control chart	-0.827	0.408
Cause and effect diagram	-0.758	0.449
Flow chart	-1.773	0.076
Voice of Customer	-1.708	0.088
Failure Mode and Effect Analysis FMEA	-0.156	0.876
Defects per million opportunities	-2.257	0.024*
DMAIC	-1.921	0.055*
Regression analysis	-1.427	0.154

Result is significant at the 0.05* and at 0.01** level (2-tailed)

On the other hand in order to improve process flows, lean tools and technique will be suitable. It shows that One Piece Flow and Gemba techniques appear to present SMEs with difficulties. In order to be a lean manufacturer it is required that the company adopts a way of thinking that focuses on making the product flow through value added processes via one piece flow, a “pull” system that reflects and is consistent with customer demands with the result that replenishment is consistent with what the next operation removes at short times (**Wilson, 2010**). One-piece flow that is underachieved will result in several issues such as, long manufacturing lead time, poor on-time delivery and large amounts of WIP. According **Doolen and Hacker (2005)** indicate that smaller companies have struggled involving with some lean practices, since small company have various customer and a schedule that changes all the time. Additionally Gemba technique one of lean technique is supporting to identify the entire process in the shop floor that helping to identify the issue and solving the problem (**Rahani and al-Ashraf, 2012**). It appears that SMEs encounter difficulties performing some of lean manufacturing and six sigma practices. Thus, this proposes that large companies are more probably to implement these tools more extensively compared to SME. No significant different at the 0.05 levels was found between SME and large companies in

the other practices of implementation lean and six sigma. From Mann Whitney test & Spearman's correlation indicate that size of companies have some impact on the implementation of lean six sigma tools and technique

5.5. Conclusion

Based on the results of this chapter, it can be concluded that companies are implementing lean manufacturing and/or six sigma practices with significant performance outcomes. These companies show improvements in operational, innovation, and financial performance. The majority of the companies studied were committed to continuous improvement, since PDCA was most frequently prioritized. Furthermore, the results reveal that companies implementing lean manufacturing alone are still unable to avoid using six sigma tools such as DMAC and DPMO. This demonstrates that lean manufacturing and six sigma are complementary tools. Moreover, companies that implemented both methods have observed that this results in higher levels of use of the associated tools compared with companies that either implemented lean manufacturing alone or used a limited number of tools from lean six sigma. It was found that there are significant differences between SMEs and large companies in terms of a few tools such as DMAIC, DPMO, and One Piece Flow. Lean manufacturing and six sigma tools were found to increase performance in terms of innovation, operational, and financial performance. Therefore, in order to compete through improving the efficiency and quality of services and products to achieve profit maximization, companies are advised to implement lean manufacturing and six sigma practices together.

Chapter 6.

Estimate of Companies Performance in the Implementation of Lean Manufacturing and Six Sigma with Decision Making Based on the Analytic Hierarchy Process

6. Estimate of Companies Performance in the Implementation of Lean Manufacturing and Six Sigma with Decision Making Based on the Analytic Hierarchy Process

6.1. Introduction

To optimize performance, the vast majority of companies conduct research to decide how best to implement methodologies such as manufacturing, six sigma, and so on lean. Lean manufacturing is based on a concept that facilitates reducing both waste and cost (**Womack et al., 1990**), whereas six sigma focuses on eliminating defects in services and products (**Breyfogle, 1999**). A literature review reveals that, from a philosophical perspective, lean manufacturing differs from six sigma. Both aim to continuously improve quality to satisfy the final customer (George, 2002; Taghizadegan, 2006; Näslund, 2008). Furthermore, implementing both together appears to produce exemplary improvements in efficiency (**Breyfogle, 1999; George, 2003; Arnheiter and Maleyeff, 2005; Gamal Aboelmaged, 2010; Antony, 2011; Snee, 2010**).

To test this hypothesis, empirical data were collected to verify and identify how lean manufacturing and six sigma affect the performance of French industrial companies. The research results reveal that 27.3% of companies implement both lean manufacturing and six sigma, 60.6% implement only lean manufacturing, and a minority use a limited set of tools from both. Thus, 72.7% of French industrials do not combine SS and lean manufacturing. Companies that implement lean manufacturing and omit six sigma obtain only mediocre improvements to their quality of service, although implementing lean manufacturing without six sigma creates problems that cannot be resolved statistically by lean manufacturing (**George, 2002**). Conversely, implementing six sigma without lean manufacturing can lead to long cycle times or increased waste, because lean tools support the SS methodology (**Shah et al., 2008**). Thus, the present work assesses best methods for improving the performance of French industrial companies. To determine whether differences exist between these three categories of companies, this study investigates how company performance outcome by using the analytic hierarchy process (AHP), which was developed by Saaty in 1980 as an objective method to analyze choices for solving complicated problems. This work focuses on how company performance relates to the methods implemented. The AHP model is used to rank the relative priorities in decision-making based on three criteria: financial performance, operational performance, and innovation performance. The AHP is used because it has been applied to many business and industrial decision-making processes and it provides a method to choose between several alternative solutions to complex problems (**Triantaphyllou and Mann, 1995**). The AHP is a measurement theory relying on pairwise comparisons and the judgments of experts for compiling a priority scale. Essentially, the AHP model involves constructing a hierarchy of problems and their interactions, comparing the attributes of choices, and then prioritizing solutions (Saaty, 2008). This work is based on two surveys: The first survey identifies items that influence the type quality of the implemented methods used, whereas the second survey is an AHP questionnaire used to identify the relative weight of three criteria and 12 subcriteria. The AHP process was used in this

work for two reasons: First, our sample consists of three categories: companies that implemented lean manufacturing and six sigma, companies that implemented lean manufacturing only, and companies that implemented only certain lean manufacturing and SS tools. Second, a literature review indicates that implementing both lean manufacturing and six sigma instead of only one of these leads to better performance. This begs the question of whether French industrial companies that implement both lean manufacturing and SS enjoy better quality, increased profits, reduced costs, and superior productivity relative to other companies. Therefore, the overall purpose of this study is to prioritize methods for these three categories of companies to maximize cost, quality, customer satisfaction (Alhuraish et al., 2016d). This research investigates not only the impacts of lean manufacturing and six sigma implementation, but also the influence of the implementation method based on the type of industry (Alhuraish et al., 2016b).

This chapter is organized as follows: Section 1 introduces the topic, the research strategy, and the research objective. Section 2 presents an overview of AHP in general and as a tool for implementing lean manufacturing and six sigma. The AHP model is discussed in Section 3. Finally, Section 4 contains the conclusion and presents plans for future research. Table C presents a summary of chapter 6.

Table C Summary of chapter 6

Problem	Objective	Result
Finding the cause of the eight variables (improve productivity, improve quality, reduce time, decrease inventory, etc) on the impact of implementing lean manufacturing only that show high mean score result compared to companies implemented both methods lean manufacturing and six sigma. This is because; a review of literature indicates that methods lean manufacturing and six sigma leads to significant benefits in increasing companies performance. Therefore, do French companies that implementing lean manufacturing and six sigma achieve improvements in quality, increase profit, reduced cost, and productivity as reported in the literature relative to other companies that implemented lean manufacturing only or using limited lean six sigma tools?	This research seeks in this chapter two objectives. Firstly, to identify the status of the 12 variables on the impact of implementing lean manufacturing and six sigma such as improve productivity, decrease inventory compared to companies implemented lean manufacturing only and companies implemented limited tools of lean and six sigma. Secondly, to identify the most efficient methodologies of lean manufacturing and six sigma within various industries based on three criteria. These criteria are financial, operational and innovation performance.	The study results show that companies implementing both methods were more effective than implemented either lean manufacturing only or use limited tools of lean six sigma across operational and financial performance. While companies that used limited tools of lean six sigma gain minimal performance improvements. The results illustrated that automobile industries are the most effectiveness of innovation and operational and financial performance followed by service and electronics industry. Moreover, this study shows struggle of lean manufacturing and/or six sigma implementation with transportation and health industry.

6.2. Overview Analytic Hierarchy Process

According to Saaty AHP model, when making decisions, individuals and businesses are confronted with options and requirement from which to choose. As for requirements or criteria, there are typically diverse levels of importance. Alternatives on the other hand are heavily dependent on an individual's preferred options for specific requirements or criteria, and in order

to prioritize the selection criteria, it is necessary to measure specific weights representative of the comparative significance of the specific pairings (Saaty, 2008). A final priorities ration scale is then organized illustrating alternatives in order of ranking.

The AHP model is a multi-criteria model that is compatible with many complex decision-making scenarios (Ramanathan, 2001). The AHP process was developed to aid in making decisions on the basis that good decisions require having a good idea of what consequences can flow from choices. It is necessary to be in a position to judge is desirable or predictable (Saaty, 2007). AHP is founded on the belief that in order to make sound decisions, people knowledge and experience is just as important as the data relied on (Vargas, 1990). In decision-making, the AHP model has been found to be particularly useful where members of the group are striving to reach an agreement or to voice their own opinions, thus individual opinions can be amalgamated in a variety of ways. Specifically, AHP can amalgamate individual opinions and individual priorities. By taking this approach, all opinions can be weighed with equal significance for prioritizing the soundest decision (Forman and Peniwati, 1998). The Analytic hierarchy process is based on measurement theory for quantifying or establishing requirements founded on decision theory in resolving problems (Vargas, 1990). However, literature review provides few case studies of the AHP model application to the implementation of lean and six sigma methodologies. The AHP model can be effectively used in the implementation of lean and six sigma methodologies. For example, Hassan (2013) conducted a case study on the main contributors of waste. The results of the study revealed that AHP can be successfully used to identify and resolve the main factors attributed to organizational waste (Hassan, 2013). AHP was able to identify the primary waste sources and in doing so aided in the successful implementation of lean and six sigma (Hasan, 2013). Su and Chou (2008) investigated the benefits and risk criteria for the six sigma project selection. The study first began with the creation of important six sigma projects and then applied AHP for evaluating the benefits of the projects and a failure mode effects analysis for evaluating the risks associated with the project. By taking this approach, the research study was able to identify ways in which six sigma project risks and benefits can be prioritized (Su and Chou, 2008). There is also support in the literature on six sigma for the use of AHP for improving decision-making in specific manufacturing operations and for improving product quality and reducing related costs (Azzabi, et al., 2009). Hu, et al., (2008) developed a multi-objective model for selecting projects in the manufacturing sector. The study found that this model is useful for implementing lean and six sigma. Moreover, AHP is consistent with six sigma management systems because six sigma focuses on the elimination of defect and continuous improvement (Banuelas and Antony, 2003). The AHP has been applied to many business and industrial decision-making processes as it allows for a more specific way to choose solutions to complex problems where several alternative solutions are available (Triantaphyllou and Mann, 1995). Thus AHP process can be used for helping in making project decisions and planning (Banuelas and Antony, 2003)

6.3. AHP used for best or optimal methods

6.3.1. Evaluation companies performance based on optimal method

The purpose of this study is to evaluate the performance of three categories of companies: Category (A) represents companies that have implemented lean manufacturing and six sigma; category (B) represents companies that have implemented lean manufacturing only, and category (C) represents companies that only use limited LSS tools. To use AHP to select the most effective method for French industry as a whole, an AHP model is constructed and applied. The Super Decisions software was used to apply the AHP model (www.superdecisions.com).

Step 1: Defining the criteria and subcriteria

After discussions with quality experts, the impact of implementing lean manufacturing and six sigma was prepared based on 12 items, such as reduced cost, improved quality, reduced lead time, environment safety, etc. The analysis contains two phases: in the first phase, the impact of implementation is determined based on the type of operational methods used. This was done by using questionnaires to collect empirical data. The second phase includes constructing the criteria from an extract of the measurement of business performance table developed by **Atkinson and Brander-Brown (2001)**. Additionally, to assure that the criteria was appropriate, expert researchers in quality systems verified that the criteria are clear and suitable. The result is 12 items grouped into three criteria: (i) financial performance, (ii) operational performance, and (iii) innovation performance.

The first survey was done by using a Likert-type scale presented in a categorical manner designed to measure value. Survey participants were asked to respond to survey questions with a number from 1 to 5 indicating (1) extremely ineffective or disagree to (5) extremely effective or agree. results indicate that, of these companies, nine implement lean manufacturing and six sigma, 20 implement lean manufacturing only, and four implement a limited of tools from LM and SS tools (although they did not describe them as LM and SS methods within their organization). The consistency of the questionnaire was verified by analyzing its reliability (**Nunnally, 1978**). Cronbach's alpha for all the items gives a reliability coefficient of 0.902. As shown in Table 6.1, Cronbach's alpha for the subcriteria of financial performance, operational performance, and innovation performance is 0.790, 0.827, and 0.915, which indicates that the questionnaire is consistent.

Table 6.1 The results of Cronbach's alpha

Criteria	SubCriteria	Cronbach's Alpha
Financial performance	Increase profit	0.790
	Reduce cost	
Operational performance	Improve quality	0.827
	Reduces variation	
	Improves productivity	
	Reduces Lead-time	
	Increase Customer satisfaction	
	Creates safety environment	
	Decreases Inventory	
Innovation performance	Suggestions from the employees	0.915
	Involves employees	
	Reduce turnover rate	

Step 2: Developing hierarchy

In this section, the hierarchical structure for selecting the best method is developed. The performance is evaluated based on the four levels shown in Figure 1, which are objectives, criteria, subcriteria, and alternatives. The first level contains the basic objective of choosing the best or optimal methods. The second level contains the three important criteria of financial performance, operational performance, and innovation performance. The third level contains the 12 most important subcriteria: increase profits, reduce costs, improve quality, decrease inventory, improve productivity, reduce lead times, reduce variation, satisfy customer, safeguard the environment, involve employees, reduce turnover rate, and gather employee suggestions.

The last level contains three alternatives A, B, and C implemented by these different methods within French industrial companies. Alternatives A, B, and C are evaluated to select the most effective methods.

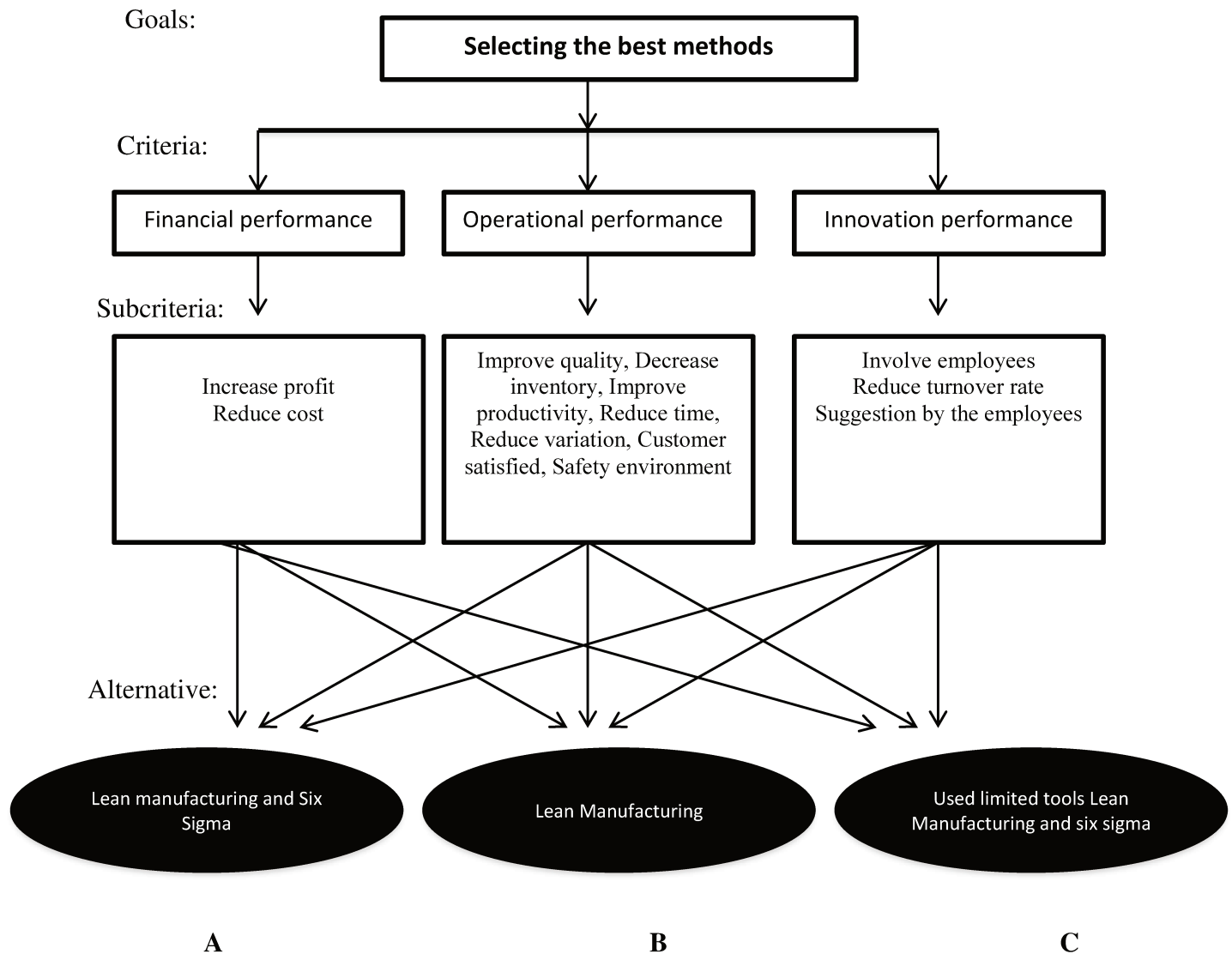


Figure 6.1: Hierarchical structure decision

Step 3: Establish the Pair wise Comparison Matrix

This study used four evaluators that are working in research development of system engineering and expertise of quality to evaluate the criteria and subcriteria. The respondents were asked to identify the effectiveness of each criterion and subcriteria of implementing quality system by using a nine point scale, in order to get pairwise comparison judgments. The purpose of the study has explained in detail to each expert and in turn, they were requested to perform ratings. In order to make an organized decision for generating priorities, the following steps should be adopted:

1. The problem should be defined and the information desired should be determined.
2. A hierarchal structure of the decision should be compiled with the decision objective at the top, the broad objectives, and the criteria influencing subsequent factors/intermediate level to the lowest level/alternatives.
3. Establish a set of pairwise matrices, let us assuming $C_1, C_2 \dots C_n$ the number of criteria or subcriteria; $n = 1, 2 \dots n$; where n_j are the numbers of elements of the comparison matrix; $f(x) = \sum_{i=1}^n \sum_{j=1}^n$. Comparisons are scaled indicative of the

strength of importance or dominance of one factor over another in terms of the criterion set for comparisons. Saaty (2008) implied a 9 points Likert scale for ranking the comparative importance of the criteria and subcriteria. The Likert scale ranks the degree of comparative importance in a graduated scale from equal, moderate, strong, very strong to extreme. The AHP pairwise comparison scale is shown in Table 6.2.

Table 6.2 The AHP pairwise comparison scale

Intensity of weight	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objectives
3	Weak/moderate importance of one over another	Experience and judgment slightly favoured one activity over another
5	Essential or strong importance	Experience and judgment strongly favour one activity over another
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
9	Absolute importance	The evidence favouring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values between the two adjacent scale values	Used to represent compromise between the priorities listed above
Reciprocals of above non-zero numbers		If activity i has one of the above non-zero numbers assigned to it when compared to activity j, then j has the reciprocal value when compared with I

Source: Saaty, 1980

4. The matrix for pairwise comparison illustrate on the follow matrix

$$5. A = \begin{bmatrix} & C_1 & C_2 & \dots & \dots & \dots & C_n \\ C_1 & A_{11} & A_{12} & \dots & \dots & \dots & A_{1j} \\ C_2 & A_{21} & A_{22} & \dots & \dots & \dots & A_{2j} \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ C_n & A_{n1} & A_{n2} & \dots & \dots & \dots & A_{nj} \end{bmatrix}$$

6. Sum the value in each comparison matrix $f(x) = A_{11} + A_{21} + A_{31} \dots + A_{n1}$; then divide each elements in the matrix by the total to generate to normalized relative weight

$$c_{ij} = \frac{c_{ij}}{\sum_{i=1}^n c_{ij}}$$

$$X_{ij} = \frac{C_{ij}}{\sum_{i=1}^n C_{ij}}$$

7. At the next level, the priorities derived from the pairwise comparisons are utilized for weighing the priorities.

$$W_{ij} = \frac{\sum_{j=1}^n X_{ij}}{n}$$

In order to identify the effective method, a survey was administered to four experts from Laboratory for Research in System Engineering to determine the relative effectiveness of each criteria and subcriteria within Likert scale from 1 to 9.

Step 4: Synthesis of Priorities

A completely consistent matrix was developed for each evaluator of all criteria and subcriteria. The synthesis of all these criteria measurements priority and calculating the Eigen value provides final priority scale. Priority weights for each of the criterion were calculated by creating a pair wise comparison matrix for criteria and subcriteria. A majority of the evaluator indicated the highest priority to the criteria of financial performance followed by operational performance, and innovation performance. The priority weights of the second level criteria (the impact of quality practices on company performance) is presented in Table 6.3. In the next step, maximum Eigen value (λ_{max}) was calculated. λ_{max} is used in calculating the consistency ratio. The consistency ratio was performed to check the consistency of this decision acceptably or not acceptably.

Table 6.3 Priority weights for criteria

Criteria (Level 1)	Evaluator 1	Evaluator 2	Evaluator 3	Evaluator 4
Financial performance	0.5841	0.333	0.7927	0.6144
Operational performance	0.2318	0.333	0.1312	0.2683
Innovation performance	0.1840	0.333	0.0760	0.1177
Consistency Ration (CR)	0.0515	0.06852	0.0208	0.0175

For checking whether the weights are correctly assigned pursuant to expert reasoning, the consistency ratios are computed for measuring the consistency. It requires two phases: first calculation of the max eigenvalue (λ_{max}), second calculation the random index using the below formula where random index is given in the below Table 6.4:

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

Table 6.4 Random consistency index (RI)

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Then, subsequently random index is given, in calculating the consistency ratio, the consistency

index was divided into a random index using the below formula:

$$CR = \frac{CI}{RI}$$

Results show that the consistency ratios for the comparison matrix per evaluator are ≤ 0.1 . Thus, the four evaluators from the completed questionnaires indicate acceptable consistency. The results indicate that the experts' opinions are vastly similar. Calculations conducted based on the strength of each experts' opinion were 1/4.

Table 6.5 Overall priority weights for criteria

Criteria	Overall priority	Ranking
Financial performance	$1/4*0.5841+1/4*0.7927+1/4*0.6144+1/4*0.333=0.5810$	1
Operational performance	0.2410	2
Innovation performance	0.1776	3

The results are delineated in Table 6.5. Consequently, the effect of the order of priorities according to their occurrence, following the determination of the effect of the impact strength of each individual decision, shows the highest priority to financial performance (0.5810), followed by operational performance (0.2410) and innovation (0.1776). In the next step, subcriteria were evaluated.

Evaluator 1 indicated a highest priority for increasing profits, a subcriterion under the financial criteria. This was followed by customer satisfaction subcriterion under operation criteria, and involved employees subcriterion under innovation criteria. The remaining rankings that follow are shown in Table 6.6.

Table 6.6 Priority weights for criteria & subcriteria for evaluator 1

Criteria	Weights	SubCriteria	Weight	Rank	CR
Financial performance	0.5841	Increase profit	0.526	1	0.000
		Reduce cost	0.473	2	
Operational performance	0.2318	Customer satisfied	0.257	1	0.0471
		Decrease inventory	0.251	2	
		Improve quality	0.184	3	
		Improve productivity	0.11	4	
		Reduce variation	0.05	7	
		Reduce lead time	0.06	6	
Innovation performance	0.1840	Safety environment	0.08	5	0.0515
		Involve employees	0.499	1	
		Reduce turnover rate	0.396	2	
		Suggestion by the employees	0.104	3	

Evaluator 2 indicated equal priority to increases profit and reduced cost subcriterion under the criteria of financial criteria, the highest priority for customer satisfaction subcriterion under operation criteria, and involved employees subcriterion under innovation criteria. The complete results for evaluator 2 are shown in Table 6.7

Table 6.7. Priority weights for criteria & subcriteria for evaluator 2

Criteria	Weights	Subcriteria	Weight	Rank	CR
Financial performance	0.333	Increase profit	0.500	1	0.000
		Reduce cost	0.500	1	
Operational performance	0.333	Customer satisfied	0.183	1	0.072
		Decrease inventory	0.140	4	
		Improve quality	0.182	2	
		Improve productivity	0.125	5	
		Reduce variation	0.174	3	
		Reduce lead time	0.115	6	
		Safety environment	0.076	7	
Innovation performance	0.333	Involve employees	0.412	1	0.051
		Reduce turnover rate	0.327	2	
		Suggestion by the employees	0.259	3	

Similar to Evaluator 1, Evaluator 3 indicated highest priority to increased profit subcriterion under the financial criteria, followed by customer satisfaction subcriterion under operation criteria, and involved employees subcriterion under innovation criteria. Complete results are shown Table 6.8.

Table 6.8. Priority weights for criteria & subcriteria for evaluator 3

Criteria	Weights	SubCriteria	Weight	Rank	CR
Financial performance	0.7927	Increase profit	0.750	1	0.000
		Reduce cost	0.250	2	
Operational performance	0.1312	Customer satisfied	0.234	1	0.097
		Decrease inventory	0.086	6	
		Improve quality	0.193	3	
		Improve productivity	0.113	4	
		Reduce variation	0.222	2	
		Reduce lead time	0.099	5	
		Safety environment	0.044	7	
Innovation performance	0.0760	Involve employees	0.333	1	0.000
		Reduce turnover rate	0.333	1	
		Suggestion by the employees	0.333	1	

Finally, evaluator 4 also indicated highest priority to increased profit subcriterion under financial criteria, followed by customer satisfaction subcriterion under operation criteria, and involved employees' subcriterion under innovation criteria. For complete results see Table 6.9.

Table 6.9 Priority weights for criteria & subcriteria scale for evaluator 4

Criteria	Weights	Subcriteria	Weight	Rank	CR
Financial performance	0.6144	Increase profit	0.608	1	0.000
		Reduce cost	0.391	2	
Operational performance	0.2683	Customer satisfied	0.225	2	0.056
		Decrease inventory	0.118	4	
		Improve quality	0.236	1	
		Improve productivity	0.136	3	
		Reduce variation	0.099	6	
		Reduce lead time	0.109	5	
		Safety environment	0.077	7	
Innovation performance	0.11722	Involve employees	0.450	1	0.006
		Reduce turnover rate	0.059	3	
		Suggestion by the employees	0.490	2	

As demonstrated in Table 6.10, the overall weight for the financial performance criteria, the weight obtained for the subcriteria are as follow: increased profit (0.596) and reduced cost (0.403). While the overall weight under operational performance criteria are as follows: customer satisfied (0.224), decrease inventory (0.148), improved quality (0.198), reduced variation (0.136), improved productivity (0.121), reduced lead time (0.095), and the creation safety environment (0.069). Finally, last criteria of innovation criteria (0.177), the subcriteria are order of involved employees (0.423), followed by suggestion from the employees (0.296) and reduced turn overrate (0.278).

Table 6.10 overall priority weight of criteria & subcriteria

Criteria	Overall Weights	SubCriteria	Overall Weights	Rank
Financial performance	0.5810	Increase profit	0.596	1
		Reduce cost	0.403	2
Operational performance	0.2410	Customer satisfied	0.224	1
		Decrease inventory	0.148	3
		Improve quality	0.198	2
		Improve productivity	0.121	5
		Reduce variation	0.136	4
		Reduce lead time	0.095	6
		Safety environment	0.069	7
Innovation performance	0.1776	Involve employees	0.423	1
		Reduce turnover rate	0.278	2
		Suggestion by the employees	0.296	3

Step 5: The global comparative score for each category

Firstly, descriptive statistics were used in analyzing and interpreting the survey results. Companies were categorized also into three groups commensurate with their implementation methods as a means of analyzing the participants in financial and operation and innovation performance outcome variables. In this regard, A=Companies implemented lean manufacturing and six sigma, B=Companies implemented lean Manufacturing, and C=Companies have not

reported implementing lean or six sigma method, even though these companies have been implementing many of the lean manufacturing and six sigma practices. In order to verify whether there are significant difference respondent by groups on the impact on the operational performance, Kruskal Wallis test was used. The results of the Kruskal Wallis test indicated that there were no statistically ($p\text{-value} > 0.05$) significant differences existing between the three groups in terms of improved quality and reduced cost except reduce turnover rate. Therefore, with the exception of reduced turnover rates there are no significant differences between three groups. In other words, according to the results of the Kruskal Wallis test, all French companies had similar performance outcomes when implementing and practicing lean manufacturing and six sigma except for the reduced turnover rate, indicating reduced turnover rate are different among three category across performance outcomes. Observation reflected for the impact on the operational performance, it is clear that they gained various benefits of performing lean and six sigma, but the level of advantage varies among organizations. Remark exposed in Table 6.11 suggest that French companies implementing lean manufacturing and six sigma achieved better mean performance levels than French companies that implemented only lean manufacturing and companies that implemented only lean manufacturing and six sigma tools in terms of increased profit (4.12), improved quality (4.63), reduced variation (4.25) and reduced cost (4.50). These average scores reveal that companies implementing lean and six sigma achieve greater benefits along several important variables indicative of efficiency and quality, relative to other companies choosing only to implement either lean manufacturing or utilize lean and six sigma alone

Table 6.11 Comparing companies performances among three groups

Companies implemented lean manufacturing and six sigma		Companies implemented lean manufacturing		Companies using the tools but not referring as lean and six sigma methods with their organizations		Kruskal Wallis test (P-Value)
Benefit	Mean	Benefit	Mean	Benefit	Mean	Asymp. Sig
Increase profit	4.12	Increase profit	3.90	Increase profit	3.25	0.207
Improve quality	4.63	Improve quality	4.19	Improve quality	4.00	0.062
Reduces variation	4.25	Reduces variation	3.95	Reduces variation	3.75	0.422
Reduces cost	4.50	Reduces cost	4.00	Reduces cost	3.75	0.276
Improves productivity	4.13	Improves productivity	4.38	Improves productivity	3.50	0.505
Reduces Lead-time	4.13	Reduces Lead-time	4.33	Reduces Lead-time	3.50	0.252
Increases suggestions from the employees	3.50	Increases suggestions from the employees	3.90	Increases suggestions from the employees	2.75	0.092
Involves employees	3.63	Involves employees	4.00	Involves employees	2.75	0.061
Increase Customer satisfaction	3.50	Increase Customer satisfaction	4.10	Increase Customer satisfaction	3.75	0.227
Decreases Inventory	3.13	Decreases Inventory	4.24	Decreases Inventory	3.75	0.113
Reduce turnover rate	2.88	Reduce turnover rate	2.95	Reduce turnover rate	2.00	0.041*
Creates safety environment	2.88	Creates safety environment	3.48	Creates safety environment	2.50	0.165

It could therefore be determined that companies improve efficiency, quality and performance when using a combination of lean manufacturing and six sigma methodologies. While companies that implemented lean manufacturing achieved better performance such as improved productivity (4.38), reduced lead-time (4.33), increased customer satisfaction (4.10), improved employee involvement (4.00) and suggestions (3.90) and at the same time created a safer environment (4.10) within the organization. These results are remarkable because the combination of lean and six sigma produced greater efficiency and effectiveness through improving process speed, reducing recycled time, added value among other improvements based on the literature review. Therefore, we do more analysis in each of these variable by using Analytic Hierarchy Process. Figure 6.2 was established as a means of only providing an overview of the 3 performance outcomes categories through the implementation of lean manufacturing and/or six sigma.

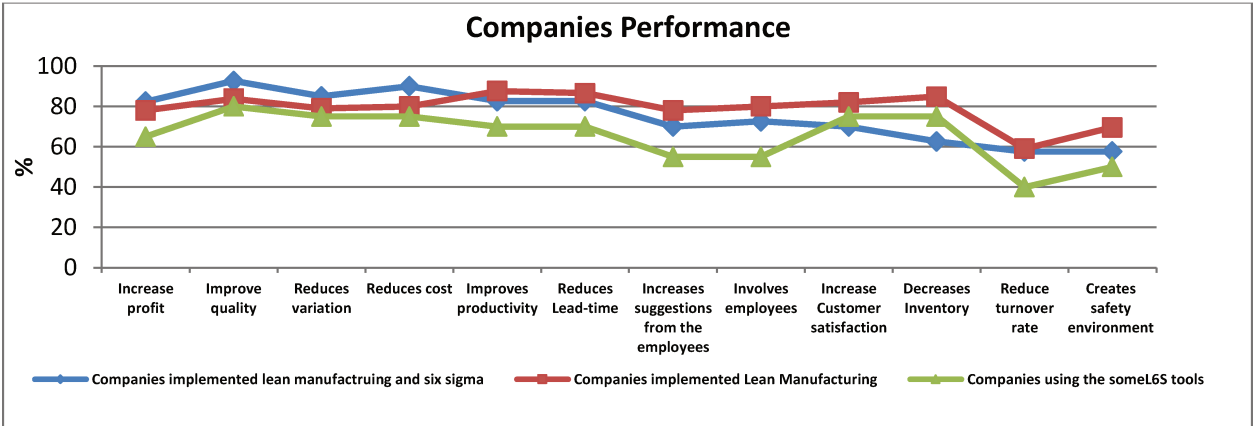


Figure 6.2: Performance Outcomes for Lean Manufacturing, Six Sigma.

Moreover, from the Figure 6.3 to Figure 6.14 demonstrate the measurement of performance outcome such as increase profit, reduce cost, improve quality etc, among three (A, B, C) categories and therefore to display the effective of each category through the implementation of lean manufacturing, six sigma.

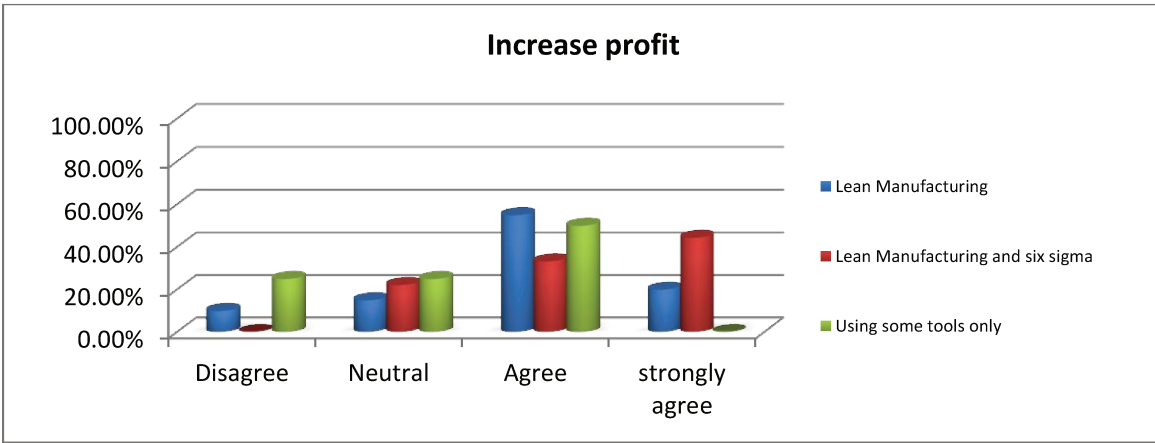


Figure 6.3: Frequency the response enterprises among three categories for increase profit

As illustrated in the above Figure 6.3 most of the enterprises that had implemented lean manufacturing and six sigma (44%) strongly agree and (33.3%) agree that there is an increase in profits. For companies implementing lean manufacturing only, fewer (20%) strongly agree and

more agree (55%). Meanwhile for companies using limited tools of lean manufacturing and six sigma, 50% agree that there is an increase in profits. It was observed based on the responding enterprises, that companies implementing both methods of lean manufacturing and six sigma, there was more agreement that there are increased profits compared to the other category in terms of increased profits.

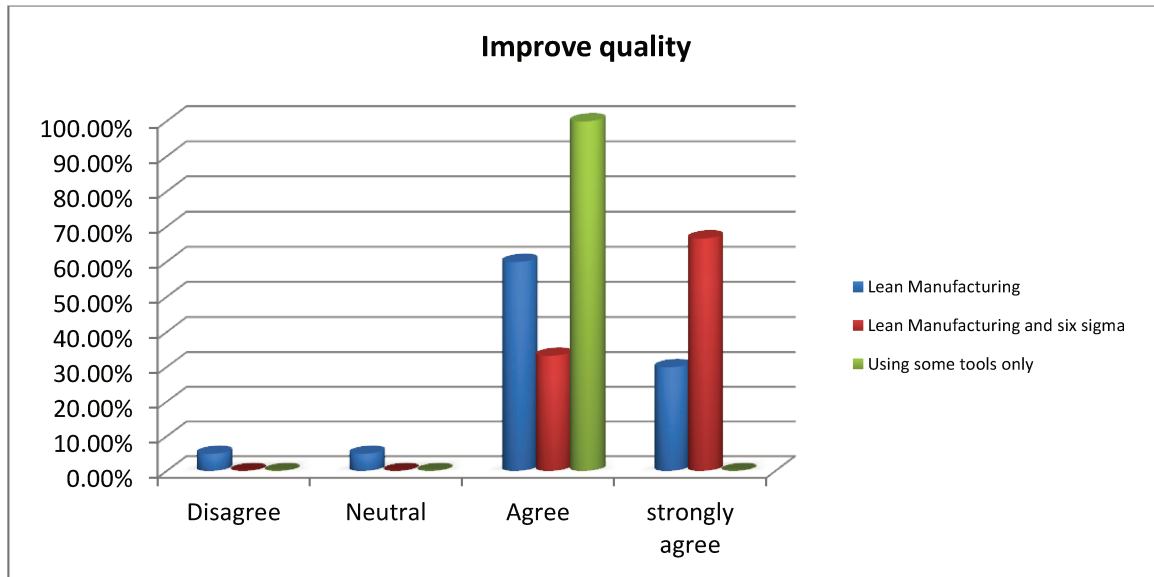


Figure 6.4: Frequency the response enterprises among three category for improve quality.

As shown in figure 6.4, most of the enterprises that had implemented lean manufacturing and six sigma (66.7%) strongly agree and (33.3%) agree that there was improved quality. For companies implementing lean manufacturing only (30%) strongly agree and (60%) agreed. For companies using limited tools of lean manufacturing and six sigma 100% agree on improved quality. It was observed based on the responding enterprises that most companies implementing both methods of lean manufacturing and six sigma strongly agree that there is improved quality compared to the other category (B, C) where some companies did not agree improved quality.

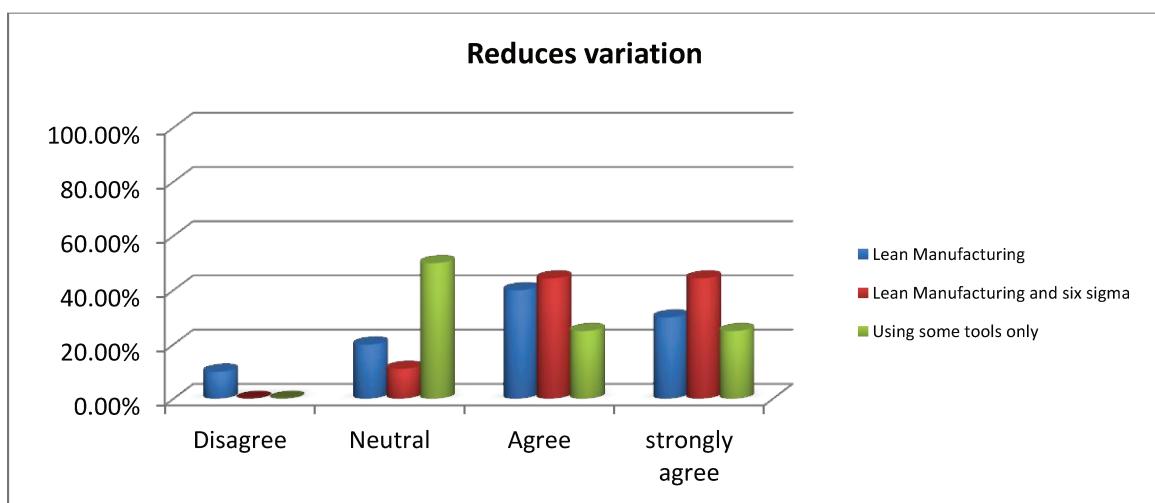


Figure 6.5: Frequency the response enterprises among three categories for reduce variation.

As demonstrated in Figure 6.5, the clear status is that most of the enterprises that had implemented lean manufacturing and six sigma highly agree (88.8%) that there is reduced variation compared to other companies, that either implemented lean manufacturing (70%) or implemented limited tools of lean six sigma (50%).

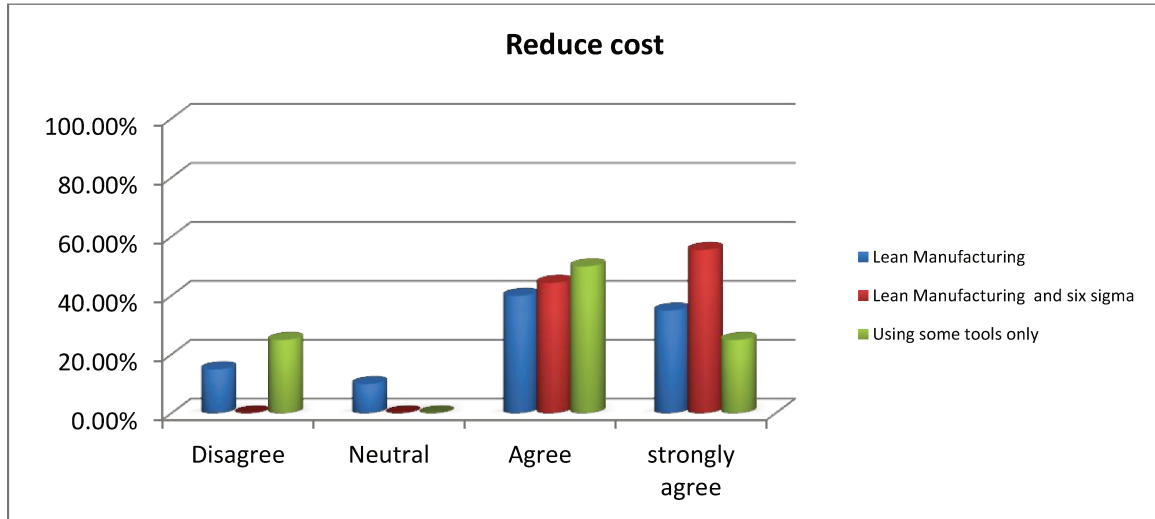


Figure 6.6: Frequency the response enterprises among three categories for reduce cost.

As shown in Figure 6.6 most of the enterprises that had implemented lean manufacturing and six sigma (55.60%) strongly agree and (44.4%) agree in reduced cost. Whereas companies implementing lean manufacturing, only 25% strongly agree and 50% agree, while companies using limited tools of lean manufacturing and six sigma 25% strongly agree and 50% agree that there is reduced cost. The status of reduced cost as was observed within three categories (A, B, C) reveals that there is moderate to more extensive agreement of reducing cost through implementing lean manufacturing and six sigma compared to companies that practiced lean manufacturing only or used limited lean six sigma tools.

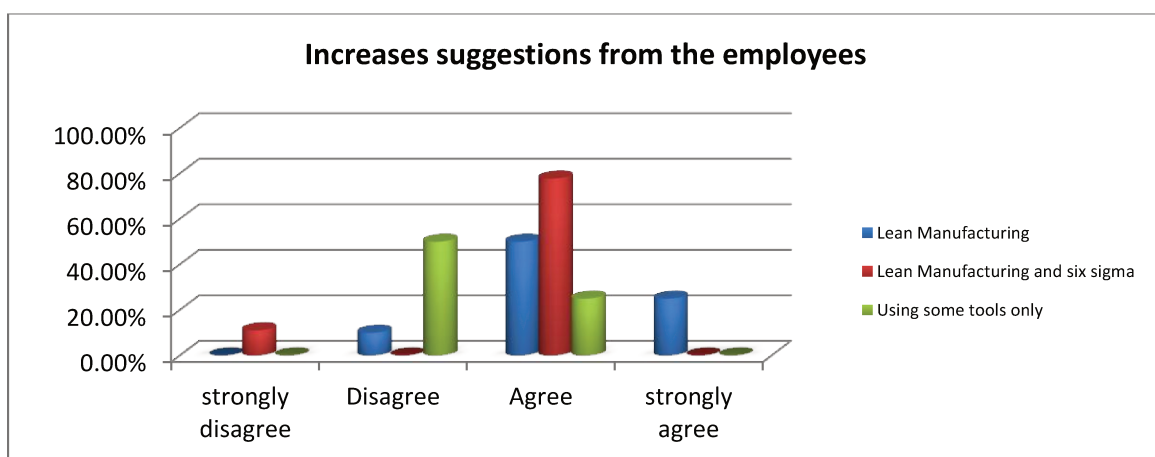


Figure 6.7: Frequency the response enterprises among three category for suggestion from the employees.

Involvement and suggestion of the employees are complemented each other, and we asked that these two factors, in order to determine whether employees had job satisfaction and contributed to performance within the organization in terms of implementing lean manufacturing and/or six

sigma, employees participation/involvement and suggestions were measured. Results show in Figure 6.7 moderate to extensive agreement by employee in the implementation of lean manufacturing and/or six sigma with exception to these companies that practicing or using only limited lean six sigma tools. Consequently, it can be inferring that implementing and practicing lean and six sigma results in higher job satisfaction and the company in turn, seeks and achieves continuous improvement.

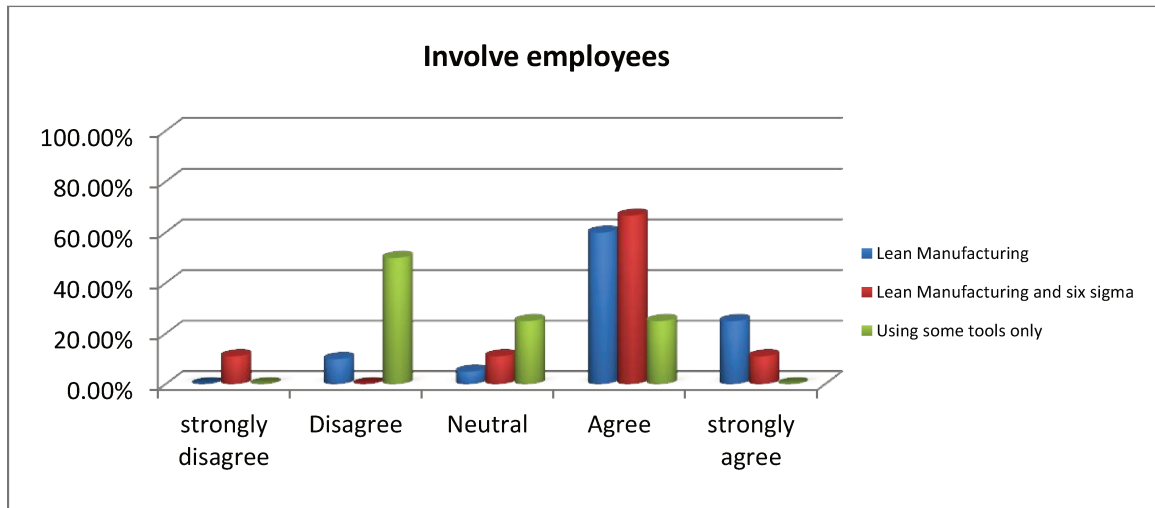


Figure 6.8: Frequency the response enterprises among three categories for involve employees.

Figure 6.8 shows the status of involved employees within three categories (A, B, C). It shows weakly to extensive agreement in involved employees resulting from implementing lean manufacturing and/ or six sigma. While companies using limited tools illustrates more extensive disagreement on employee's involvement (50%). Therefore, it can be concluding that implementing lean manufacturing and six sigma results support to create more suggestion and involvement between the employs.



Figure 6.9: Frequency the response enterprises among three categories for customer satisfaction

Figure 6.9 shows the status of increased customer satisfaction within three categories (A, B, C). It shows weakly to extensive agreement in customer satisfaction through implementing lean manufacturing and/ or six sigma while companies that practicing lean or using limited lean six

sigma tools moderate agreement in customer satisfaction.

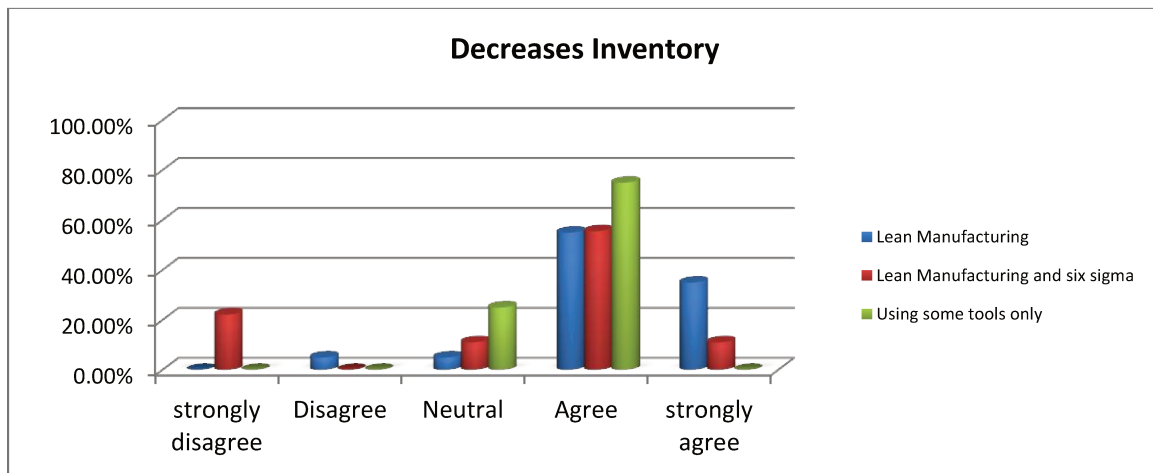


Figure 6.10: Frequency the response enterprises among three categories for decrease inventory.

Figure 6.10 shows that most of the enterprises that had implemented lean manufacturing and six sigma (66.70%) agree that there is decreased inventory, while companies implementing lean manufacturing only, (90%) agree that there is decreased inventory. Where companies using limited tools of lean manufacturing and six sigma (75%) agree in decreased inventory. It was observed based on the responding enterprises that companies implementing lean manufacturing have more agreement in decreased inventory compared to the other categories (A, C) against decreased inventory.

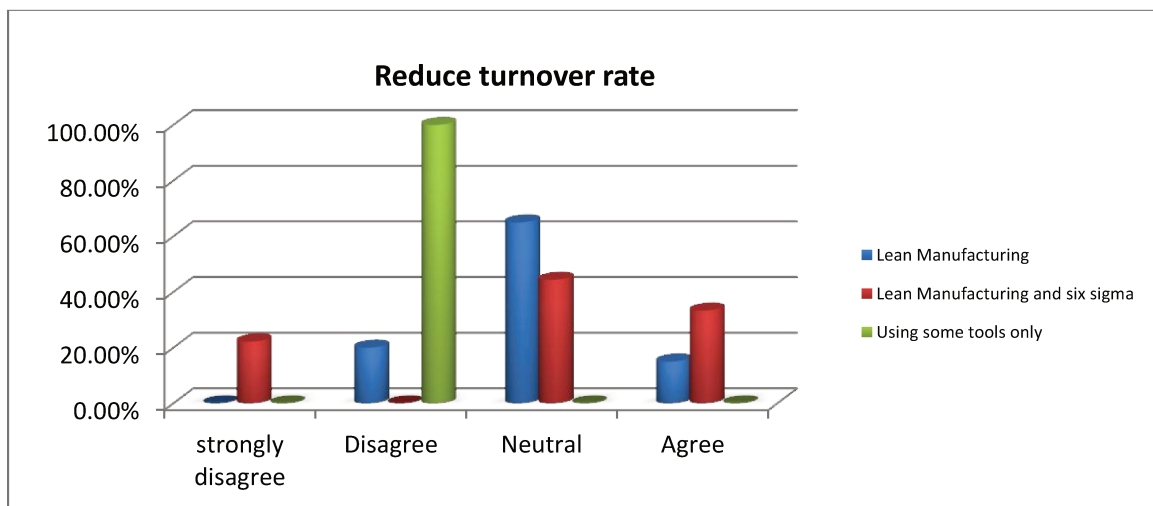


Figure 6.11: Frequency the response enterprises among three categories for Reduce turnover rate

As shown in the Figure 6.11 most of the enterprises that had implemented lean manufacturing and/or six sigma have more negative impact in reduced turnover rate compared to companies using the limited tools. Companies implementing lean manufacturing and six sigma perceived only (15%) agree and (44.4%) neutral to reduced turnover rate, where companies implementing lean manufacturing only (15%) strongly agree and (65%) neutral to reduce turnover rate, while companies using limited tools of lean manufacturing and six sigma that (100%) disagree, it seems more disagreement to reduced turnover rate. Therefore, it was observed that the status of reduced

turnover rates within three categories show moderate to more extensive agreement in reduced turnover rates through implementing lean manufacturing and six sigma or lean manufacturing only compared to companies that practiced used limited lean six sigma tools (C).

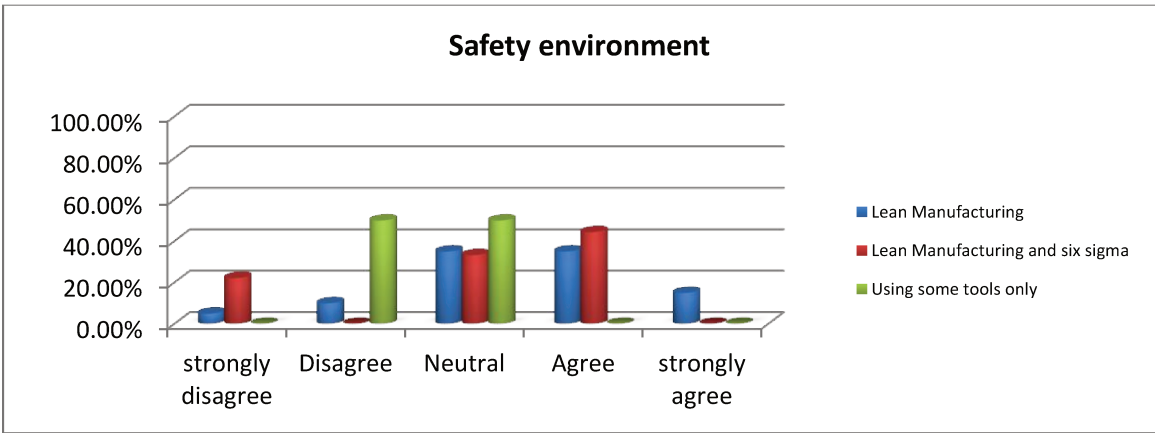


Figure 6.12: Frequency the response enterprises among three categories for creates safety environment

Figure 6.12 shows the status of improve safety with the enterprises within three category (A, B, C). It shows weakly agreement (50%) of improve safety with the enterprises that using the limited of lean six sigma, where companies implementing lean manufacturing and/ or six sigma are moderate to extensive agreement increase safety environment within the enterprises.

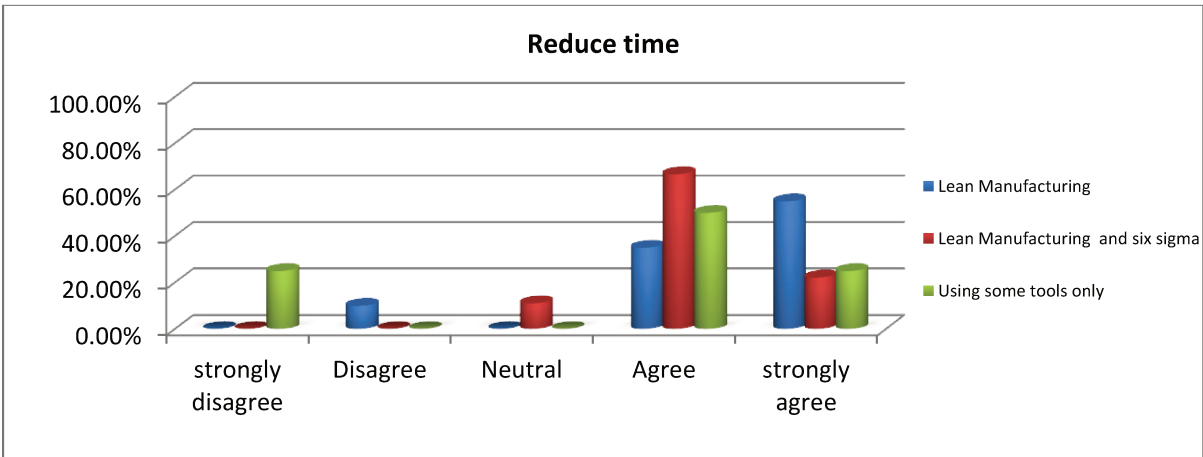


Figure 6.13: Frequency the response enterprises among three categories for reducing time

As shown in Figure 6.13, most of the enterprises that had implemented lean manufacturing and six sigma (22.20%) strongly agree and (66.0%) agree that there was reduce time. For companies implementing lean manufacturing (55%) strongly agree and (35%) agreed. For companies using limited tools of lean manufacturing and six sigma (22%) strongly agree and (50%) agree on reduce time. It was observed based on the responding enterprises that most companies implementing both methods of lean manufacturing and/or six sigma more strongly agreement in reducing time compared to the other category (B, C) where some companies did disagree in reducing time.

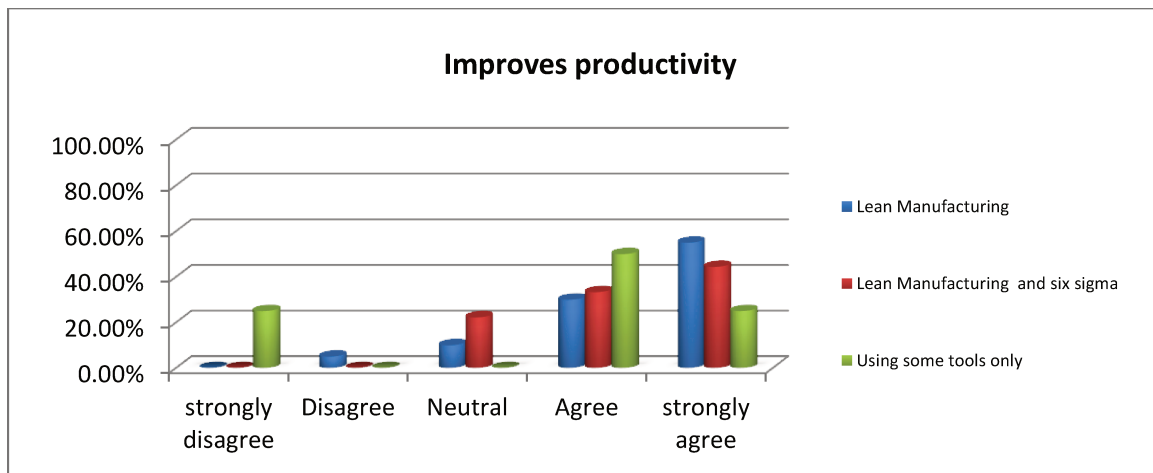


Figure 6.14: Frequency the response enterprises among three categories for improve productivity

Figure 6.14 shows the status of improve productivity with the enterprises within three categories (A, B, C). It shows moderate agreement of improve productivity with the enterprises that using the limited of lean six sigma, where companies implementing lean manufacturing and/ or six sigma are moderate to extensive agreement in productivity within the enterprises. Most of the enterprises that had implemented lean manufacturing and/or six sigma have more likely to get positive impact in improve productivity compared to companies using the limited tools.

However, we propose a simplified approach to investigating the optimal method via the interpretation of the mode result. The simplified approach is weighting the alternatives for three different categories (A, B, C) with support from box blots for providing a clear overview of the status of financial, operational, and innovation performance.

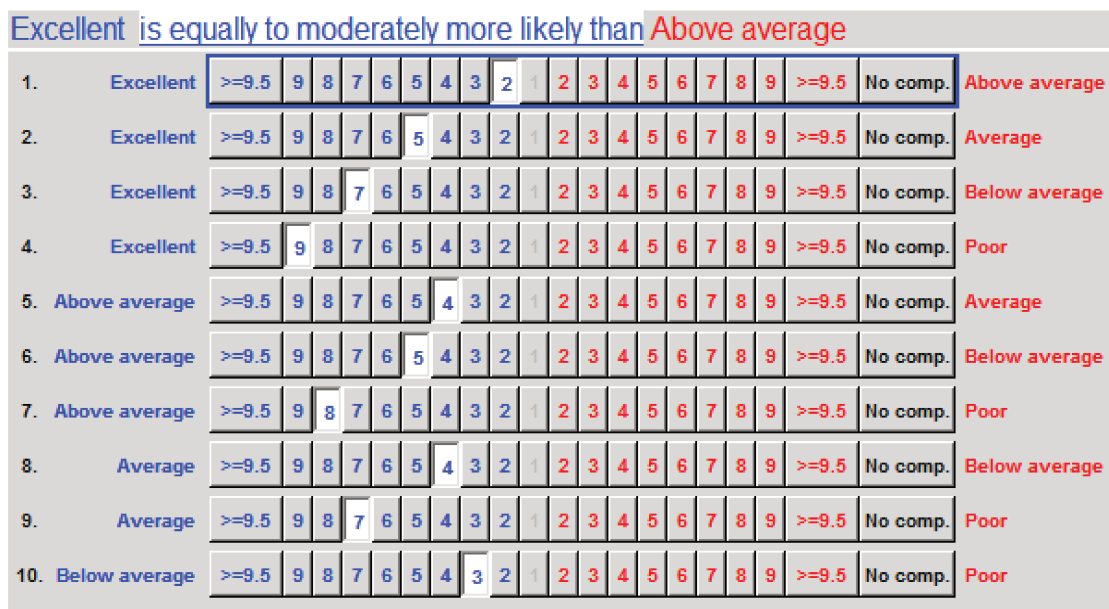


Figure 6.15: Prioritize the ratings words Excellent, above average, average, below average, poor

We used a rating score by “super decision” software for evaluating the alternative method using five category words such as excellent, above average, average, below average and poor. A

pairwise comparison matrix was created for dealing with a situational AHP problem. A pairwise comparison by super decision rating score performed. Therefore, we identified the Prioritizing of the rating category as shown in Figure 6.15. For example, comparing excellent and above average, logically, excellent is more effective than above average. Therefore, we estimate excellent is 2 times more important or effective than above average and so on, for the other comparison category (www.superdecisions.com).

Step 6: Evaluation of the method on the basis of three criteria

While the data were measured on an ordinal scale, we used the mode to synthesize opinions in three categories (A, B, C). These ordinal numbers actually meant to the respondents, and derive judgment-based priorities effective for them. We estimated companies (A, B, C) results by their mode as shown in below Table 6.12. The interpretation of the answers of the mode score rating was constructed from excellent to poor. The order of weight was considered as follows: excellent was coded as **5**, above average was coded as **4** and average was coded as **3**, below average was coded as **2**, and poor was coded as **1**. Consequently, we rated alternatives with respect to each category A, B, C based on the mode results.

Table 6.12 Alternatives with respect to each category A, B, C

Performance measurement		Lean manufacturing and six sigma (A)			Lean manufacturing (B)			Used limited tools only (C)		
	Impact Measure	Min	Max	Mode	Min	Max	Mode	Min	Max	Mode
Financial	Increase profit	3	5	5	2	5	4	2	4	4
	Reduce cost	4	5	5	2	5	4	2	5	4
Operational	Reduces variation	3	5	4	2	5	4	3	5	3
	Improve quality	4	5	5	2	5	4	4	4	4
	Improves productivity	3	5	5	2	5	5	1	5	4
	Reduces Lead-time	3	5	4	2	5	5	1	5	4
	Safety environment	1	4	4	1	5	3	1	3	2
	Increase Customer satisfaction	1	5	5	2	5	5	3	4	4
	Decreases Inventory	1	5	4	2	5	4	3	4	4
Innovation	Suggestions by employees	1	4	4	2	5	4	2	4	2
	Reduce turnover rate	1	4	3	2	4	3	2	2	2
	Involves employees	1	5	4	2	5	4	2	4	2

A. Financial Performance

The rating score for each of these categories with respect to profit and reduced cost were established and overall priority score for each category were presented in the Table 6.13. As for under financial performance, the results indicate that the priority weight category A = companies implemented lean manufacturing and six sigma are the highest priority or most effective having, score of 0.4294 compared to other categories B (0.2852) and C (0.2852).

Table 6.13 The weight of the alternative for financial performance

Methodology	Priority weight	Increase profit	Reduce cost
Lean manufacturing and six sigma	0.4294	Excellent	Excellent
Lean manufacturing	0.2852	Above average	Above average
Using some tools only	0.2852	Above average	Above average

The graph in Figure 6.16 shows the priorities with respect to financial performance for each of the categories. Moreover, to compare the distribution of the 3 categories, a box plot was conducted (See Figure 6.17). A Box plot can obviously show the effectiveness of the data of the overall value emphasizing that implementing lean manufacturing and six sigma have significant outcomes in financial performance.

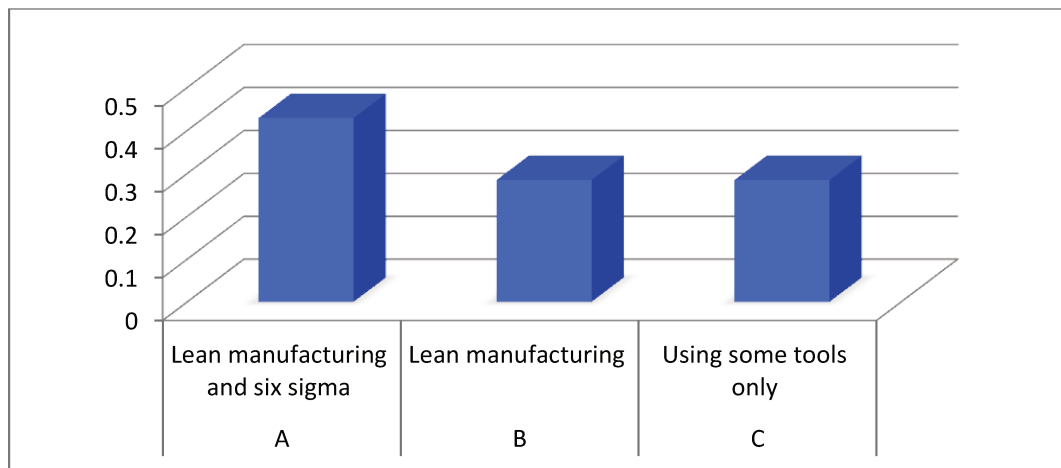


Figure 6.16: Priorities on Financial performance for each category (A, B, C).

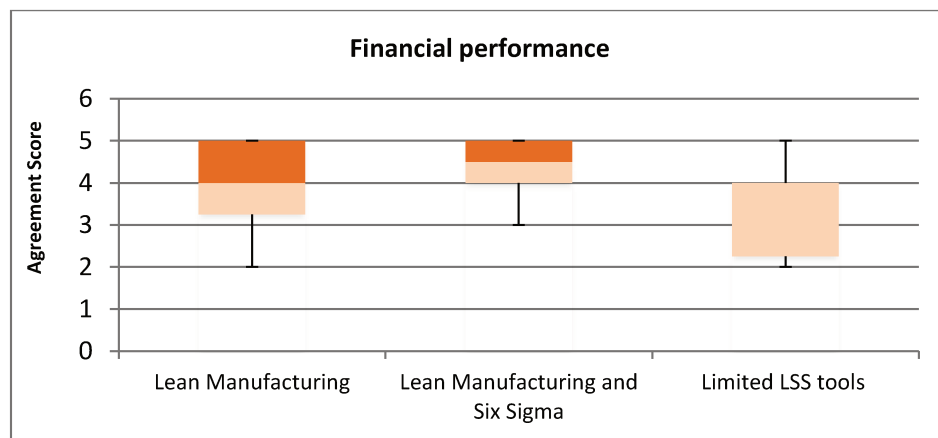


Figure 6.17: Box plot of the overall value for financial performance

Fifty percent of the companies implementing both methods almost strongly agree that they benefit financially, the data shows less variability and the interquartile range equals 2. While companies using lean manufacturing only, achieve less agreement that they benefit in financial performance (the interquartile range equals 3).

Also, boxplot graphics indicate that the variability of the companies that use limited lean and six sigma is huge (data value ranges from 2 to 5). These results are consistent with findings in the literature. Bhasin and Burcher (2006) indicated that it is more beneficial to implement a varies

of the lean tools as opposed to implementing just one or two random tools. The results of this study confirm that implementing limited lean as well as six sigma tools can hinder a firm ability to improve its financial performance.

B. Operational Performance

The general goal was the selection of the best method based on the most effective method among A, B and C relative to the operational performance criteria. A pairwise comparison by super decision rating score was used. The results indicate that A= companies that implemented lean manufacturing and six sigma used ideal methods with a score of 0.3812 as shown in Table 6.14. The bar charts Priorities weight are presented in Figure 6.18.

Table 6.14 The weight of the alternative for operational performance

Methodology	Priority weight	Customer satisfied	Decrease inventory	Improve quality	Improve productivity	Reduce variation	Reduce time	Safety environment
Lean manufacturing and six sigma	0.3812	Above average	Above average	Excellent	Excellent	Excellent	Above average	Excellent
Lean manufacturing	0.3570	Excellent	Above average	Above average	Excellent	Above average	Excellent	Above average
Using tools only	0.2633	Above average	Above average	Above average	Above average	Average	Above average	Below average

Priorities weight on operational performance for companies (A) that implemented lean manufacturing and six sigma yielded the highest priority. Companies that implemented lean manufacturing (0.3570) show a higher priority compared to companies that used limited tools of lean and six sigma (0.2633). Companies using some lean and six sigma tools show they have lowest effectiveness under operational performance. However, it was interesting to observe in the results that a majority of expertise evaluations concluded that satisfied customers, a sub-criteria under operational performance, is the maximum priority weight (0.225) and therefore an important influence in quality goals. However, findings indicate that companies that implemented both methods lean and six sigma obtained higher priority weight (0.381) and their performance outcomes were above average. Meanwhile companies that implemented lean manufacturing obtained a slightly lower priority weight (0.357), although they were still perceived as excellent. Regardless, the AHP result reveals that companies implementing both lean and six sigma together still obtained the highest priority weight for selecting the best method for operational performance, although companies implementing lean manufacturing only, excelled. It can therefore be inferred from these findings that companies that implement lean manufacturing and six sigma together can expect to see more improvements in operational performance.

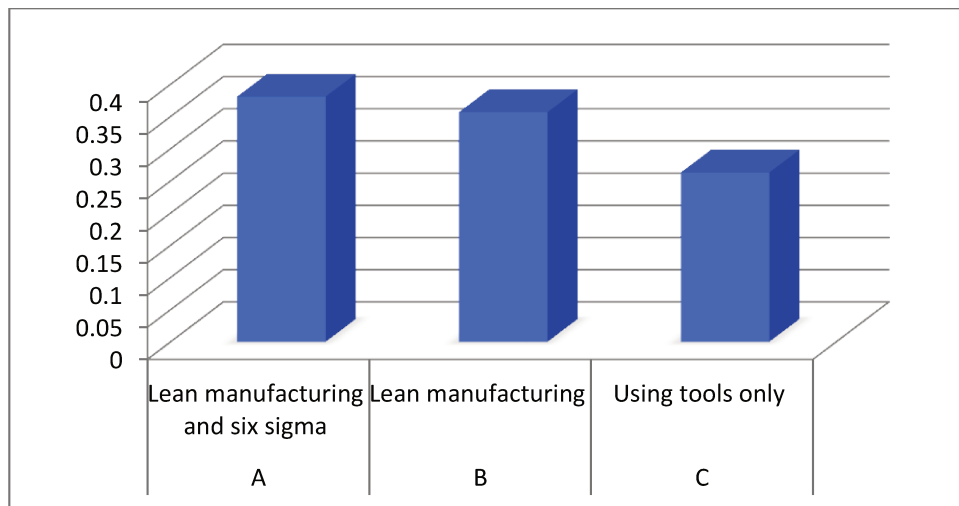


Figure 6.18: Priorities weight on operational performance for each category (A, B, C).

In Figure 6.19, the box plot shows status agreement scores across operational performance such as improved quality; improved productivity etc., at three different categories. It showed seventy five percent of agreement value lies between 4 to 5 for companies that implemented lean manufacturing only and companies implementing both methods. Whereas, companies using limited tools have fifty percent value lying between 3 to 4. It can also be interpreted via the box plot that implementing limited tools of lean six sigma, is moderate supportive of increasing operational performance.

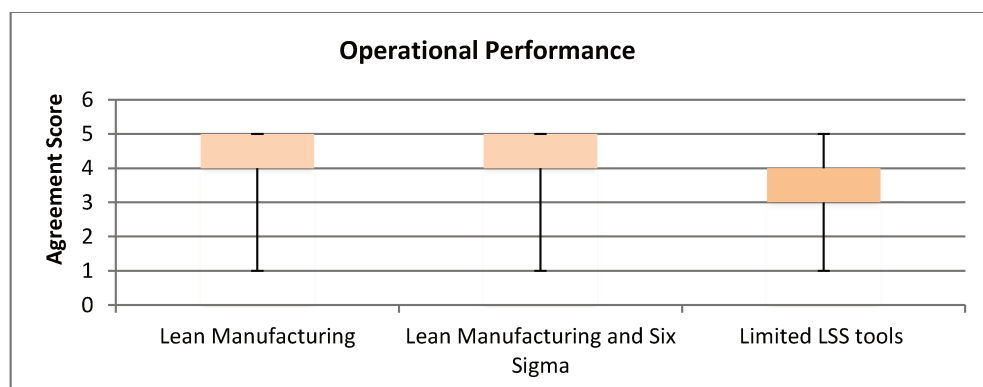


Figure 6.19: Box plot of the overall data value under operational performance

C. Innovation performance

The top methods with the most effectiveness among A, B, and C with respect to the innovation performance criteria were selected. The results indicate that categories A and B which are companies implementing lean Manufacturing and six sigma and also the companies implementing lean manufacturing have equal priority as shown in Table 6.15. Therefore the results can be interpreted to mean that these subcriteria can be achieved by implementing one of these methods for innovation performance. Companies using the limited tools of lean manufacturing and six sigma have the lowest priority as shown below in the figure 6.20 of bar chart and the Priorities for different categories are illustrated as well. Companies using the limited tools of lean manufacturing and six sigma get above average under reduce turnover rate, inferred from these findings that these companies can expect to see less negative impact to reduce

turnover compared to companies implementing lean Manufacturing and six sigma and also the companies implementing lean manufacturing only.

Table 6.15 The weight of the alternative for innovation performance

Methodology	Priority weight	Involve employees	Reduce turn over	Suggestion from the employees
Lean manufacturing and six sigma	0.4016	Above average	Average	Above average
Lean manufacturing	0.4016	Above average	Average	Above average
Using some tools only	0.1967	Below average	Above average	Below average

Figure 6.20 shows that based on the result of AHP, companies that implemented lean manufacturing and six sigma together and lean manufacturing only have equal levels of the priority weight (0.4016) of effectiveness in innovation performance. Yet Box plot of the overall value also shows that implementing lean manufacturing and six sigma have more variability in the data score compared to companies that deploy lean manufacturing only. Specifically, the data value ranges from 1 to 5 as shown in Figure 6.21, and there is less data variability, with data values ranging from 2 to 5 in companies that implemented lean manufacturing only. However, it can be interpreted from AHP and the box plot results that implemented lean manufacturing and/or six sigma shows approximately more support for increases in companies performance for innovation performance. Where companies used limited tools show weak supportive for innovation improvements.

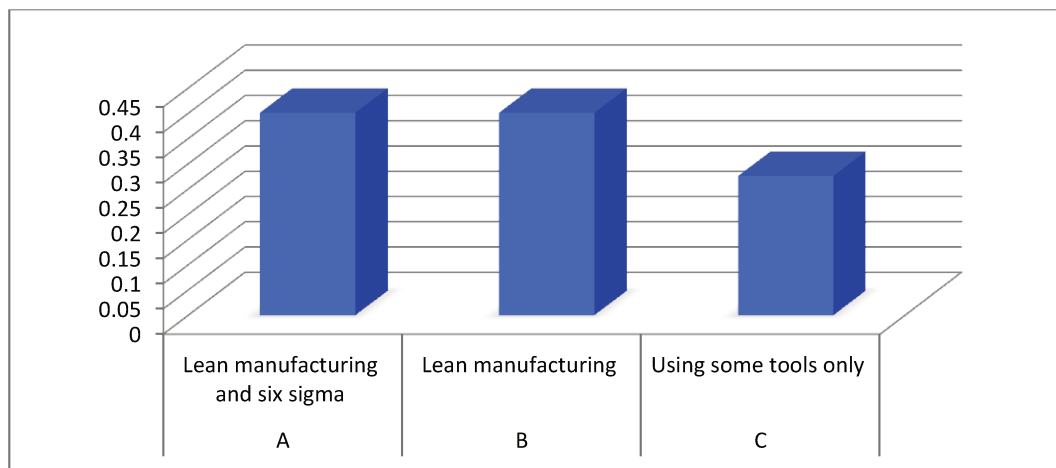


Figure 6.20: Priorities weight on innovation performance for each category (A, B, C)

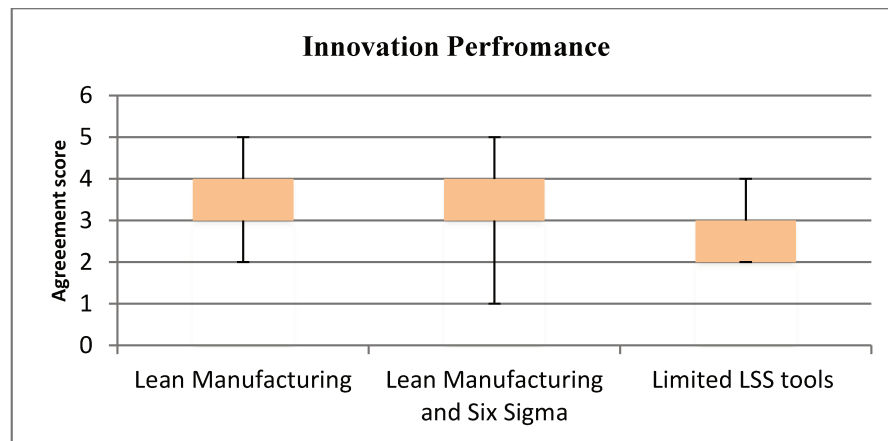


Figure 6.21: Box plot of the overall value under innovation performance

Based on the results showed the companies that had implemented lean manufacturing and/or six sigma methodologies have more positive impacts in terms of suggestion and involvement of the employs, compared to companies using the limited LSS tools.

However, Previous paired comparisons show that “excellent” is perceived to be better than “above average,” and so on. Reasonably, in this case, the AHP estimate for reducing turnover rate is contrary to the ordinal scale, therefore “strongly agree” implies poor performance, so it gets a lower priority weight for the companies that implement LM and/or SS (their mode is 3). Finally, companies that used limited LSS tools obtain a mode of 2, implying “above average.” Therefore, companies that had implemented lean manufacturing and/or six sigma methodologies have more negative impacts in reduced turnover rate, compared to companies using the limited tools. However, the results indicate that (A & B) companies implementing lean manufacturing and/or six sigma have equally priority weight (0.4016), therefore it can interpret that these subcriteria such as suggestion from the employees, involvement of the employees that can achieved identical result by implemented either lean manufacturing or both methods under innovation performance. On the other hand, companies using limited tools (have the lowest priority) show weak support for innovation improvements.

6.3.2. Evaluation companies performance based on type of industry

This research additionally evaluated the performance based on the type of the industry. The hierarchical structure decision for selecting the best industry that has developed as shown in the Figure 6.22. A similar criterion was followed for identifying the best industry. Various types of industries participated in this study. These industries are (30.3%) ten companies from the electronics industry, (21.2%) seven companies from the automotive industry, (12.1%) four companies from the health industry, (6.1%) two companies from the transportation industry, (18.2%) six companies from the service and (12.1%) four companies from other industry such as energy, oil, gas and aerospace industry. We evaluated each type of industry against financial, operational and innovation performance (Alhuraish et al., 2016b). We used the mode as well to synthesize opinions for various industries as shown in Table 6.1

Table 6.16 Alternatives with respect to industries

Measure Impact	Electronics Mode	Automobile Mode	Health Mode	Service Mode	Transport Mode	Other industries Mode
Increase profit	4	5	4	5	2	4
Reduces cost	5	4	4	4	2	4
Reduces variation	3	5	4	4	2	4
Improve quality	4	5	4	4	2	5
Improves productivity	5	4	4	4	2	5
Reduces Lead-time	5	4	4	5	2	4
Creates safety environment	3	4	4	3	1	3
Decreases Inventory	4	4	4	4	2	4
Increase Customer satisfaction	4	4	4	5	2	4
Involves employees	4	4	2	4	2	4
Reduce turnover rate	3	3	2	3	2	3
Increases suggestions from the employees	4	4	4	4	2	4

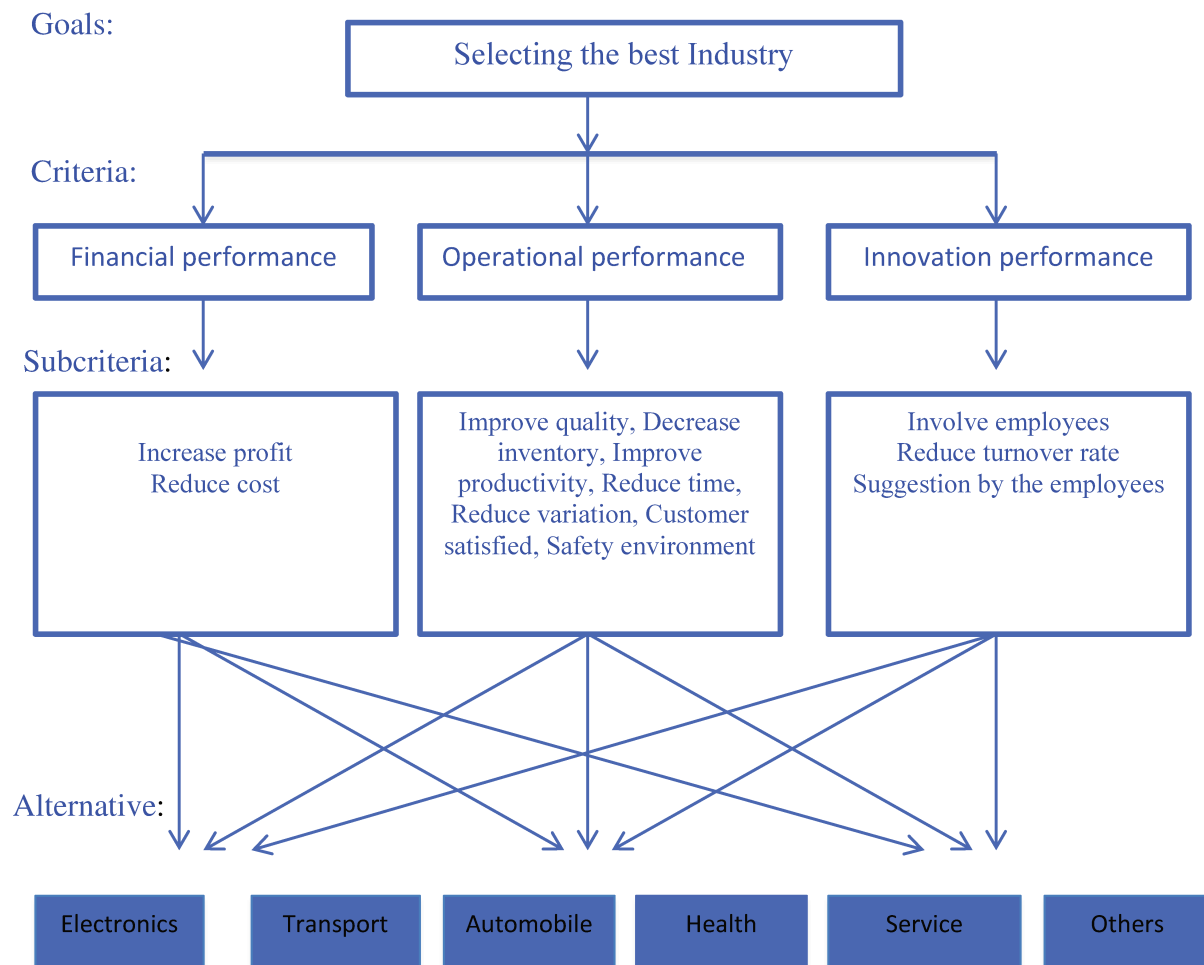


Figure 6.22. Hierarchical structure decision

Step 6: Evaluation of the best industry on the basis of three criteria

A. Financial performance

The rating score for each of these industries with respect to financial performance were established and overall priority weight score for each industry were presented in the Table 6.17. The results indicate that the priority weight for automobile and service industries are the highest priority or most effective having, score of 0.2170 compared to electronics industries (0.2007), health industries (0.1667), transportation (0.0317) and other industries (0.1667).

Table 6.17. The weight of the alternative for financial performance based on industry

Type of industries	Priority weight	Increase profit	Reduce cost
Electronics industry	0.2007	Above average	Excellent
Automobile industry	0.2170	Excellent	Above average
Health industry	0.1667	Above average	Above average
Service industry	0.2170	Excellent	Above average
Transportation	0.0317	Below average	Below average
Other industry	0.1667	Above average	Above average

Figure 6.23 shows that companies vary in their benefits from industry to industry. The automobile industry shows high agreement 56.20% and 43.80% strongly agree with no disagreement on their companies in terms of increased financial performance. The service industry followed with a 58.30% strongly agreeing and 25.00% agreeing and one company in the service industry disagreed that their company experienced improved in financial performance. It was also found out that Automobile and service industry emphasized what was previously illustrated by AHP resulted that these industries are the effective across financial performance. Although electronic industry showed a 44.40% agreement and a 27.80% strong agreement, 27.80% were neutral. The health industry showed 16.70% agrees and 12.50% strongly agree, but there was a 25.00% disagreement. On the other hand, the transportation sector showed 100% disagreement with their company across financial performance. The results showed that the transport industry does not agree at all to increase financial performance. However, the automobile industry shows greatest agreement followed by the service industry and the electronics industry in terms of increase financial performance. Therefore, it seems these industry gain more benefit of implementing lean manufacturing and/or six sigma compared to other industry such as transportation and health industry.

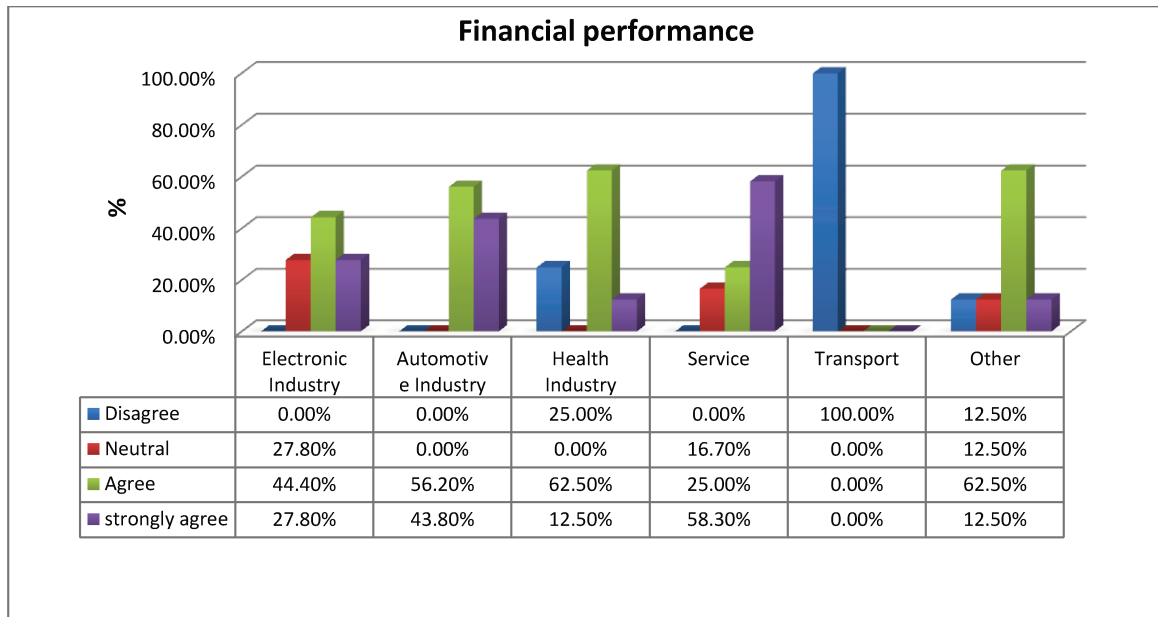


Figure 6.23: Percentage of agreement status on financial performance by industry

B. Operational performance

Prioritizing the various industries were evaluated against operational criterion to select the optimal most effective industries. For this purpose rating score for each of industry with respect to improve quality, reduce time, reduce variation, improve productivity were performed and priority weights for each industry were calculated. The results indicate that the highest priority weight for automobile industries (0.2088) and followed by other industries (0.2008) and service industry (0.2008), Health industry (0.1784), electronics industry (0.1782) and transportation industries have the lowest priority as shown in Table 6.18. Figure 6.24 illustrates, the automotive industry shows the greatest agreement that their company achieves improved operational performance with only 1.60% disagreeing, 0.00% strongly disagreeing, 51.60% agreeing and 37.50% strongly agreeing. The other industry show the second greatest agreement and no companies in other industries strongly disagreed with this perception and only 3.10% disagreed with 15.60% remaining neutral followed by service industries with 37.50% agreeing and 43.80% strongly agreeing that their companies faced improved operational performance. The health industry also had a strong showing in terms of agreeing that their companies achieved operational performance improvement.

Table 6.18 The weight of the alternative for operational performance based on industry

Type of industry	Priority weight	Customer satisfied	Decrease inventory	Improve quality	Improve productivity	Reduce variation	Reduce time	Safety environment
Electronics industry	0.1782	Above average	Above average	Above average	Above average	Average	Above average	Above average
Automobile industry	0.2088	Above average	Above average	Excellent	Excellent	Excellent	Excellent	Average
Health industry	0.1784	Above average	Above average	Above average	Above average	Above average	Above average	Above average
Service industry	0.2008	Excellent	Above average	Above average	Above average	Above average	Excellent	Average
Transportation	0.0327	Below Average	Below Average	Below Average	Below Average	Below Average	Below Average	Poor
Other industry	0.2008	Above average	Above average	Excellent	Excellent	Above average	Above average	Average

On the other hand, the results show that the transport industry has higher percentage of disagreement 56.20%. However, the automobile and other industry shows most agreement followed by electronic, service, health and transportation industry

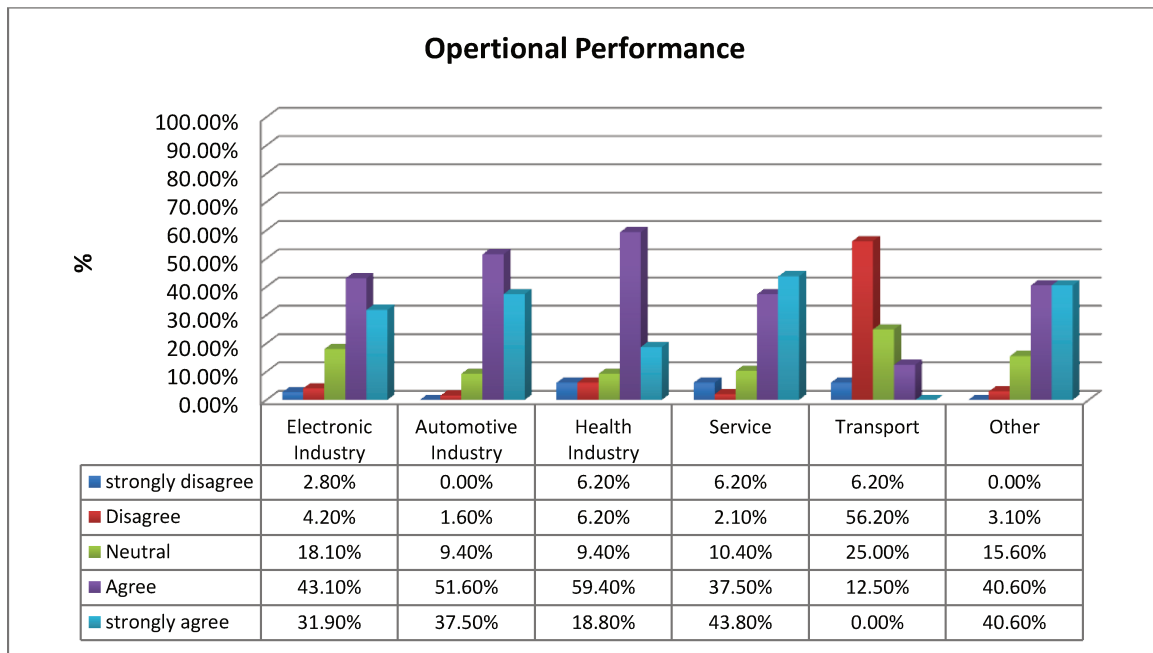


Figure 6.24: Percentage of agreement status on Operational performance by industry

C. Innovation performance

The most effective industries under innovation performance criteria were executed. The results indicate that various industries such as electronics, automobile, service and other industries have equal priority. Therefore, the results can be interpreted to mean that these subcriteria can be achieved by various industries for innovation performance. While health and transportation industries have the lowest priority against innovation performance. On the other hand, it showed advantage of health and transportation industries that that have less negative impact in terms of reduce turnover rate compared to other industries that have highest priority weight for reduce

turnover rate under innovation performance (Above average). These industries are electronics, automobile, service and other industries.

Table 6.19 The weight of the alternative for innovation performance

Type of industry	Priority weight	Involve employees	Reduce turn over	Suggestion from the employees
Electronics industry	0.1900	Above average	Average	Above average
Automobile industry	0.1900	Above average	Average	Above average
Health industry	0.1468	Below average	Above average	Above average
Service industry	0.1900	Above average	Average	Above average
Transportation	0.0930	Below average	Above average	Below average
Other industry	0.1900	Above average	Average	Above average

Two factors were tested under innovation performance: increased employee suggestions and increased involvement of employees. Figure 6.25 reveals that the automotive industry with 87.50% together with other industries had the highest agreement on their company showing increased employee suggestions and involvement. Other industries however edged out the automotive industry with 12.50% also strongly agreeing that their companies showed increased employee suggestions and involvement. While the health, electronic and service industries scored relatively well, the transport industry showed no agreement that their companies experienced increased employee suggestions and involvement.

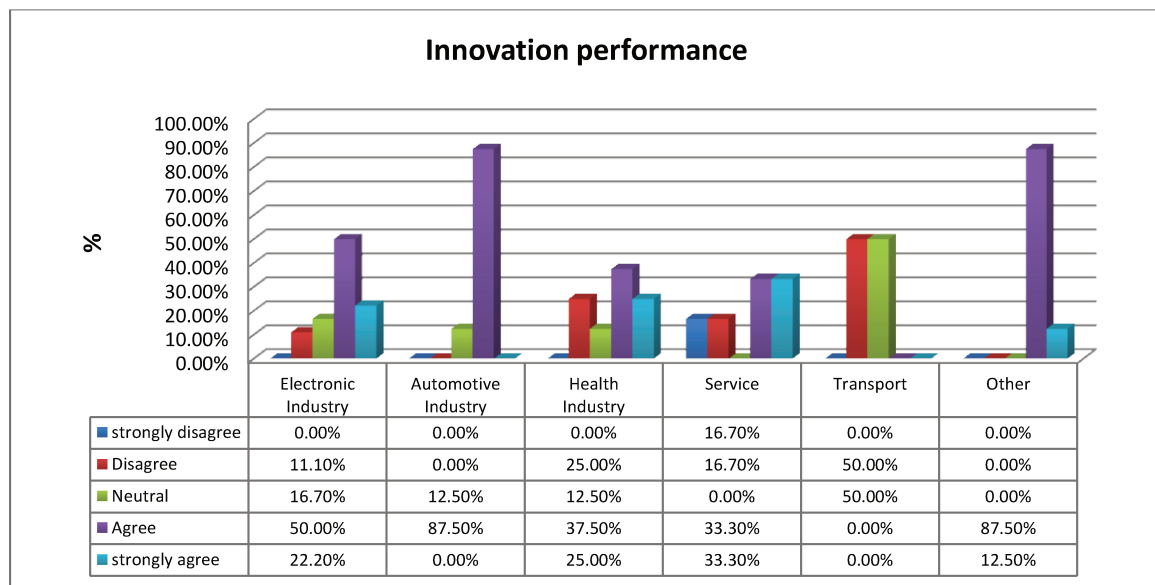


Figure 6.25: Percentage of agreement status on innovation performance by industry

With respect to innovation performance a further factor was tested: reduced turnover rates. The transportation industry, which scored more favorably in on reduced turnover rates. The transportation industry was 100% in disagreement that their companies did not experience reduced turnover rates. However the remaining industry did not score very well on this category on reduce turnover rate under innovation performance. The Automotive industry scored worst than all industries with 37.50% agreeing that their companies experienced reduced turnover rates. The electronic industry was second with 22.20% agreeing and the service industry was third with

16.50% agreeing. The health industry was equally and totally divided between disagreement and neutral. Other industries were more disproportionate with 25.00% disagreement and 75.00% neutral. However, based on the result that seem that the transportation and health industry shows more positive impact compared to automobile, electronic, service and other industry against reduce turnover rate. AHP supported this result as well. The results are illustrated in Figure 6.26.

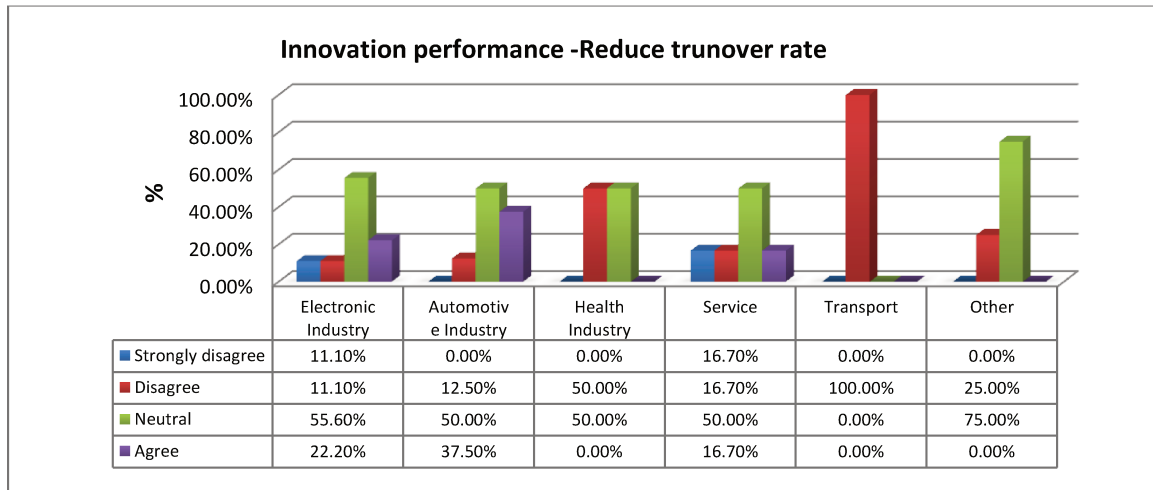


Figure 6.26: Percentages for Reduced Turnover by industry

This research investigates the extent to which specific industries have implemented lean manufacturing only, lean manufacturing and six sigma or limited lean six sigma tools as shown in Table 6.20. In investigating the implementation of these methods, this research determines the impact of each method on each industry financial, operational and innovative performance. The AHP was used to identify which industries have an advantage through the implementation of a specific method. We ranked the best industry based on the result that attained from AHP for each criterion. Below Table presents the ranking effective from 1 to 4. It shows that the respondent companies were comprised of 77.8% electronics industry with lean manufacturing implementation alone, and 22% with lean manufacturing and six sigma implementation. The results illustrated that the first priority weight in terms of effectiveness is innovation and the second priority weight in terms of effectiveness are financial and operational performance. However, the electronics industries are less effective in operational and financial performance compared to other industries such as automobile and other industry. However, it appears that implementing of lean manufacturing and/or six sigma with electronics industry needs to improve their operational performance. Fifty percent of respondent companies in the automobile industry implemented lean manufacturing only with 37% implementing lean manufacturing and six sigma and 12.5% implementing limited tools of lean manufacturing and six sigma. Results as demonstrated that financial, operational and innovation performance was the most effective with the first priority weight for all the three criteria for automobile industries. As expected these companies achieved the highest effectiveness in increased company performance. Specifically, the automobile industry achieved the highest (37.5%) among the companies that practiced both method lean manufacturing and six sigma compared to other industries. It would therefore appear that implementing lean manufacturing and/ or six sigma in this industry is more effective for performance outcomes.

Table 6.20 Measure the impacts of methodology implementation on various industries

Method	N	Electronic	Automotive	Health	Service	Transport	Other
Lean	Count	7	4	1	4	2	2
Manufacturing	%	77.8%	50.0%	25.0%	66.7%	100.0%	50.0%
Lean	Count	2	3	1	1	0	2
Manufacturing and six sigma	%	22.2%	37.5%	25.0%	16.7%	0.0%	50.0%
Used limited tools lean six sigma	Count	0	1	2	1	0	0
	%	0.0%	12.5%	50.0%	16.7%	0.0%	0.0%
	Count	9	8	4	6	2	4
Total	%	100	100	100	100	100	100
Rank the impact by AHP		Electronics	Automotive	Health	Service	Transport	Other
Financial performance		2	1	3	1	4	3
Operational performance		2	1	2	1	3	1
Innovation performance		1	1	2	1	3	1

Rank AHP results; 1= First priority effectiveness or highest priority; 2= Second priority effectiveness; 3= Third priority effectiveness; 4= Fourth priority effectiveness.

In the service industry, 66.7% of the companies implemented lean manufacturing, 16.7% implemented lean and six sigma and 16.7% implemented limited lean and six sigma tools. Even so, the service industry companies showed remarkable performance outcomes. It seems lean implementation is working well with their organization. Thus further research involving more detail can help to identify why the most effective methodologies for financial, operational and innovation performance outcomes as majorities of these companies implemented lean manufacturing only. The results reveals that 25% of companies in the health industry implemented lean manufacturing, another 25% implemented lean manufacturing and six sigma and the remaining 50% implemented limited lean and six sigma tools. Results demonstrate moderate effectiveness in financial and operational performance. It therefore appears that moderate effectiveness is related to difficulties associated with implementing lean manufacturing and six sigma within the health industry. Furthermore, it shows that companies in other industries are comprised of 50% that implemented lean manufacturing only and 50% that implemented lean manufacturing and six sigma. Results indicate that the greatest effectiveness occurs in operational performance with little advantages for financial performance since it is neither the first or second priority weight. It would therefore appear that other industries perform well in operational and innovation compared to their performance outcomes were perceived as third priority weight in terms of financial performance. On the other hand, the transportation industry that was comprised

of a small sample of two companies with 100% implementing lean manufacturing only, did not yield significant performance outcomes. It appears that have difficulty of lean manufacturing implementation with this industry. However, it appears that automobile, service industries as well as the electronics industries, yield effective performance outcomes through the implementation of lean manufacturing and six sigma.

6.4. Conclusion

The results of this case study indicate that using the AHP is advantageous for determining the most effective methods. These results lead to the conclusion that both methods complement each other to increase the financial performance, operational performance, and innovation performance of companies. The box plots presented herein show the distribution of firm performance for the three categories A, B, and C from 25% to 75%. The results indicate clearly that category A is 50%, which indicates a stronger increase in financial performance compared with categories B and C. Additionally, categories A and B generate equivalent results for operational and innovation performance, whereas category C leads to the lowest increase in organizational performance. The AHP results indicate that priority weighting for category A means that companies that implement LM and SS are more likely to increase performance. The results also show that companies that implement either LM only or both LM and SS can achieve similar results for innovation performance. Therefore, companies that implement these methods expect similar impacts on involving employees, gathering employee suggestions, and reducing the turnover rate. In this study, three options existed for companies: (i) implementing LM and SS, (ii) implementing LM only, or (iii) implementing limited tools of LM and SS. The criteria were financial performance, operational performance, and innovation performance. The results indicate a greater influence on all three criteria for companies implementing LM and SS. It showed that companies implementing lean manufacturing and six sigma together can achieve improved performance compared with those using one method alone or using only a limited number of tools from either methodology. However, two important points have been noted. According to the majority of experts, the variable with the greatest influence on operational performance is customer satisfaction. Companies implementing both methodologies achieved the best operational performance, even though their performance outcomes being above average in terms of customer satisfaction, while companies that implemented lean manufacturing alone had lesser operational performance, even though their performance outcomes were perceived as excellent in terms of customer satisfaction. Consequently, superior operational performance can be expected from simultaneous implementation of lean manufacturing and six sigma. Future research should focus on distinguishing the impact of lean manufacturing and six sigma with regard to operational performance. There is a need to understand why the combination of methodologies provides the greatest improvement in operational performance, even though lean manufacturing alone can achieve superior results with regard to customer satisfaction.

General Conclusion and Future research

This thesis focuses on evaluating or estimating the performance of lean manufacturing and six sigma implemented in French industry. These methodologies ensure that an organization achieves superior performance, leading to satisfaction for customers, shareholders, and society. It was found that company size (i.e., SMEs versus large companies) has no effect on the implementation of lean manufacturing and six sigma in terms of financial performance, operational performance and innovation performance. Simultaneous implementation of lean manufacturing and six sigma was found to have no effect on profit. Additionally, it has revealed the absence of any relationship between certification such as ISO 9001 and ISO 14001 and the simultaneous implementation of lean manufacturing and six sigma. Thus, it appears that these certifications have no supportive role with regard to implementing lean manufacturing and six sigma in the same time. Additionally, the results of this research can be interpreted as indicating that companies are facing difficulties in integrating lean manufacturing and six sigma simultaneously owing to several reasons, including lack of knowledge, company culture, finance, and lack of top management commitment. Further research should be conducted into the feasibility of integrating lean manufacturing and six sigma with modified or simplified versions of each methodology. This is necessary since this study indicates that implementing either lean manufacturing or six sigma alone is insufficient to meet the demands of a competitive market. On the other hand, this research revealed both negative and positive aspects of implementing lean manufacturing and/or six sigma. It showed that implementation of lean manufacturing in all departments facilitated greater employee involvement and helped create a safer environment in the enterprise, while implementation of six sigma in all departments improved quality and thereby helped to solve the difficulties usually associated with promotion of organizational change. A majority of papers in the literature have focused on the positive impact of implementing lean manufacturing and six sigma, such as increased profit and improved quality, while this research has illustrated a negative impact within these companies, namely, that implementing lean manufacturing and/or six sigma can reduce turnover rate. Furthermore, lean manufacturing and six sigma tools such as 5S, PDCA, GEMBA, Kanban, DOE, and Takt time were found to help improve company performance. This research has shown the advantages of each of these tools in terms of financial performance, operational performance, and innovation performance. For example, several tools were found to be more helpful in reducing costs in companies that used them compared with companies that did not: Takt time, Poka Yoke, Gemba, VSM, Kanban, and VOC. The limited implementation of statistical tools (six sigma tools) such as DOE, DPMO, DMAIC and regression analysis within French industry was revealed. Additionally, this study has compared the common success factors for implementing lean manufacturing and six sigma, providing additional insight into the success factors for each method. Further research is also needed to further validate some of these factors, such as linking of the respective methods to business strategy or to human resources, education, and training. It is also necessary to understanding why some of these factors show significant differences in level of importance between lean manufacturing and six sigma, since previous studies have shown that these factors are important when choosing whether to implement either lean manufacturing or six sigma, or both together. These factors need to be broken down into sub-factors for future research. Moreover, the AHP model was used in this research to select the

optimal method. It showed that companies implementing lean manufacturing and six sigma together can achieve improved performance compared with those using one method alone or using only a limited number of tools from either methodology. This study also found that implementing lean manufacturing alone is sufficient to improve innovation performance. Thus companies implementing either lean manufacturing alone or lean manufacturing and six sigma together can achieve parallel results in terms of innovation performance. This study investigated which specific industries achieved the best performance outcomes when implementing lean manufacturing and/or six sigma. It showed that automobile industries achieved the best financial, operational, and innovation performance. It was also noted that a majority of service industries implemented lean manufacturing only, but, even so, the service industry companies showed remarkable performance outcomes. It seems that lean manufacturing is working well with these organizations. Further, more detailed research should be able to help elucidate the reasons for this. However, based on the results of this research, it can be concluded that French companies are implementing lean manufacturing and/or six sigma with significant performance outcomes. Informed by the results of this research, French industrial companies should be aware that implementing both lean manufacturing and six sigma significantly improves company performance. Therefore, for optimal results, organizations should consider integrating lean manufacturing and six sigma to reduce waste, improve quality and value, and obtain greater customer satisfaction.

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APPENDIX

Figure 1. The weight of alternative for financial performance

Super Decisions Ratings			
	Priorities	Increase profit 0.596598	Reduces cost 0.403402
Lean Manufacturing	0.285284	Above average	Above average
Lean and six sigma	0.429433	Excellent	Excellent
Using the Tools	0.285284	Above average	Above average

Here are the overall synthesized priorities for the alternatives. You synthesized from the network Super Decisions Main Window: overall3.sdmod: ratings				
Name	Graphic	Ideals	Normals	Raw
Lean and six sigma		1.000000	0.429433	0.429433
Lean Manufacturing		0.664326	0.285284	0.285284
Using the Tools		0.664326	0.285284	0.285284

Figure 2. The weight of alternative for innovation performance

Super Decisions Ratings				
	Priorities	Involves employees 0.424045	Reduce turnover rate 0.275068	Suggestions from the employees 0.296887
Lean Manufacturing	0.401632	Above average	Average	Above Average
Lean and six sigma	0.401632	Above average	Average	Above Average
Using the Tools	0.196735	Below average	Above average	below Average

Here are the overall synthesized priorities for the alternatives. You synthesized from the network Super Decisions Main Window: overall2.sdmod: ratings				
Name	Graphic	Ideals	Normals	Raw
Lean and six sigma		1.000000	0.401632	0.401632
Lean Manufacturing		1.000000	0.401632	0.401632
Using the Tools		0.489839	0.196735	0.196735

Figure 3. The weight of alternative for operational performance

Super Decisions Ratings									
	Priorities	Totals	Customer satisfaction 0.226035	Decreases Inventory 0.145347	Improve quality 0.199795	Improves productivity 0.122100	Reduce variation 0.137242	Reduce time 0.095860	safety environment 0.069620
Lean Manufacturing	0.357084	0.788425	Excellent	Above average	Above average	Excellent	Above average	Excellent	Average
Lean and six sigma	0.381266	0.841817	Above average	Above average	Excellent	Excellent	Excellent	Above average	Excellent
Using the Tools	0.261650	0.577710	Above average	Above average	Above average	Above average	average	Above average	Below average

Here are the overall synthesized priorities for the alternatives. You synthesized from the network Super Decisions Main Window: overall1.sdmod: ratings				
Name	Graphic	Ideals	Normals	Raw
Lean and six sigma		1.000000	0.381266	0.381266
Lean Manufacturing		0.936575	0.357084	0.357084
Using the Tools		0.686266	0.261650	0.261650

Table1. Box plot for three categories (A, B, C)

Financial performance	Lean Manufacturing	Lean Manufacturing and Six Sigma	Limited LSS tools
Min	2	3	2
Q1	3.25	4	2.25
Median	4	4.5	4
Q3	5	5	4
MAX	5	5	5
Innovation performance	Lean Manufacturing	Lean Manufacturing and Six Sigma	Limited LSS tools
Min	2	1	2
Q1	3	3	2
Median	4	4	2
Q3	4	4	3
MAX	5	5	4
Operational performance	Lean Manufacturing	Lean Manufacturing and Six Sigma	Limited LSS tools
Min	1	1	1
Q1	4	4	3
Median	4	4	4
Q3	5	5	4
MAX	5	5	5

Table 2. Box plot for two categories (lean manufacturing, six sigma)

Success Level	Q1	Q2	Q3
Lean Manufacturing	2	3	4
Six Sigma	1.5	3	3.5

Veuillez répondre à chacune des questions suivantes. Merci.

Quel votre poste actuel au sein de l'entreprise?

1. Chef de projet
2. Responsable Qualité
3. Opération Manager
4. Direction.
5. Consultant
6. Chef de l'entreprise
7. Autres:

Quel est le secteur de votre entreprise ?

1. Electronique
2. Aéronautique
3. Automobile
4. Pharmaceutique / Médical
5. Autres:...

Quel l'âge de l'entreprise ?

1. Moins de 5 ans
2. Entre 5 et 10 ans
3. Entre 10 et 15 ans
4. 15 ans et plus

Quel est le nombre d'employés au sein de votre entreprise ?

1. De 0 à 9 salariés (micro)
2. Du 10 au 49 (petite)
3. De 50 à 249 (moyenne)
4. A partir de 250 et plus (grande)

Votre entreprise possède-t-elle l'une de certifications standards pour la qualité (Ex. ISO, EN900, ...) ?.

1. Oui
2. Non

Si oui, veuillez la préciser :

Quelles Ceintures de Six Sigma avez-vous au sein de votre entreprise ?

1. None
2. Yellow belt
3. Green belt
4. Black belt
5. Master Black belt
6. Champion

Parmi les méthodes suivantes quelles sont celles qui sont dans votre entreprise ?

1. Lean Manufacturing
2. Six sigma

3. Lean Manufacturing et Six Sigma

4. Aucune

Selon vous, quels sont les avantages retirés de la méthode que votre *entreprise a mise en œuvre*?

Avantages	fortement en désaccord	être en désaccord	Pas d'accord Ni d'accord ni en désaccord (Neutre)	se mettre d'accord	Tout à fait d'accord
améliorer la qualité					
Augmenter le profit					
Réduire la variabilité de processus					
Améliorer la productivité					
Réduire le temps de production					
Réduire le coût					
Forte implication des salariés.					
Augmenter les suggestions des salariés					
Augmenter la satisfaction du client					
Diminuer les stocks					
Réduire le taux de turnover					
Créer un environnement de sécurité dans l'entreprise					

Depuis combien d'années votre entreprise a-t-elle implémentée ces méthodes (sélectionnées ci-dessus)?

1. Moins de 3 ans
2. Entre 3 et 6 ans
3. Entre 6 et 9 ans
4. 9 ans et plus

Votre entreprise met-elle en œuvre les méthodes Lean et Six Sigma simultanément ?

1. Oui.
2. Non

Selon vous, quelles sont les raisons de ne pas mettre en œuvre Lean et Six Sigma simultanément ?

1. Finance
2. la culture de l'entreprise

3. Manque de connaissance / savoir-faire
4. Absence de soutien de la direction
5. Autres raisons

Selon vous, quelles sont les raisons de mettre en œuvre Lean et Six Sigma simultanément ?

1. Une amélioration rapide
2. Améliorer la vente
3. Augmenter la satisfaction du client
4. Insuffisance amélioration, si nous mettons séparément en œuvre Lean Manufacturing et Six Sigma

Comment votre entreprise a mis en œuvre la méthode Lean Manufacturing?

Méthode	N'est pas mise en œuvre	Mise en œuvre dans un petit nombre de départements	Mise en œuvre dans quelques départements	Mise en œuvre dans la plupart des départements.	Mise en œuvre dans toute l'entreprise y compris les fournisseurs.
Lean Manufacturing					

Comment votre entreprise a mis en œuvre la méthode Six sigma ?

Méthode	N'est pas mise en œuvre	Mise en œuvre dans un petit nombre de départements	Mise en œuvre dans quelques départements	Mise en œuvre dans la plupart des départements.	Mise en œuvre dans toute l'entreprise y compris les fournisseurs.
Six sigma					

Quelles pratiques sont-elles pertinentes pour votre entreprise ? (Choisissez de 1 -5, tel que 1 : la mise en œuvre et 2 : Mise en œuvre faible et 3 : Mise en œuvre moyenne et 4 : mise en œuvre forte et 5 : la mise en œuvre complète)

Parmi ces différents outils vous pouvez dire quelles pratiques sont-elles pertinentes pour votre entreprise?

Outils	1	2	3	4	5
Système 5S					
équipe Kaizen					
Standardisation du travail					
Maintenance Productive Total					
Takt time					
One piece flow					
Single minute exchange of die					
Cellules en U					
Poka-yoke					
Contrôle visuel.					
Gemba					
Brainstorming					
Value Stream Mapping					

PDCA					
Système Kanban					
Fiches de vérification					
Diagramme de Pareto					
SIPOC					
Plan d'expérience					
Carte de contrôle					
Diagramme d'Ishikawa					
Flow chart					
Voix du consommateur					
Analyse des Modes de Défaillance, de leurs Effets et de leur Criticité					
Défauts Par Million d'Opportunités.					
Analyse de la régression					
DMAIC					

Selon vous, comment estimer le niveau de succès de la méthode mise en œuvre dans votre entreprise?

Méthode	N'est pas mise en œuvre dans l'entreprise.	Succès Faible	Succès Moyen	Succès.	Succès Bien.	Succès Excellent
Lean Manufacturing						
Six sigma						

A votre avis, quel processus une PME devrait suivre pour la mise en œuvre de Lean et Six Sigma

1. Implémenter Lean manufacturing et puis Implémenter six sigma
2. Implémenter six sigma et puis Implémenter lean manufacturing
3. Implémenter Lean manufacturing et Six Sigma simultanément
4. Indifférent
5. Je ne sais pas

A votre avis, Indiquer le degré d'importance de chacun des facteurs qui sont essentiels à la réussite de la mise en œuvre de Lean manufacturing (Choisissez de 1 à 5 en cochant le cas échéant pour chaque facteur en ce qui concerne son, où 1 signifie pas important et cinq désigne facteur critique).

facteur	sans importance	légèrement important	Important	Très important	Critique
Engagement et soutien de la direction de l'entreprise					
Implication et participation des salariés					
Associer la méthode Lean aux fournisseurs.					
Superviser le progrès					
Compétences et l'expertise.					
leadership					
Le changement de la culture de l'entreprise.					
communication					
Éducation et formation.					

équipe Kaizen					
Lier la méthode à la stratégie de l'entreprise.					
Participation de Consultants					
Système de récompense					
Expliquer les outils et les techniques de la méthode Lean qui effectuent emploi dans un bureau qui effectuent des emplois dans la boutique-de-chaussée					
Expliquer les outils et les techniques de la méthode Lean qui effectuent emploi dans un bureau					

Veuillez nous informer de tout autre(s) facteur(s) de succès que vous pensiez très important(s) pour la réussite de la mise en œuvre de Lean manufacturing

Facteurs de succès: méthode six sigma

A votre avis, Indiquer le degré d'importance de chacun des facteurs qui sont essentiels à la réussite de la mise en œuvre de Six sigma (Choisissez de 1 à 5 en cochant le cas échéant pour chaque facteur en ce qui concerne son, où 1 signifie pas important et cinq désigne facteur critique).

facteur	sans importance	légèrement important	Important	très important	Critique
Engagement de la direction et le soutien					
Participation des employés					
La méthode de liaison six sigma aux fournisseurs					
Compétences de gestion de projet					
Compétences et l'expertise					
Priorisation et sélection des projets et leur suivi et supervision					
Le changement culturel					
Belt system					
Éducation et formation.					
Lier Six Sigma aux clients					
Lier la méthode six sigma à la stratégie d'entreprise					
Participation de Consultant					
Système de récompense					
Expliquer les outils et les techniques de la méthode six sigma qui effectuent emploi dans un bureau qui effectuent des emplois dans la boutique-de-					

chaussée.					
Expliquer les outils et les techniques de la méthode six sigma qui effectuent emploi dans un bureau					
Lier Six Sigma aux ressources humaines					

Veuillez nous informer de tout autre(s) facteur(s) de succès que vous pensiez très important(s) pour la réussite de la mise en œuvre de six sigma

Thèse de Doctorat

Ibrahim Alhuraish

Evaluation of the performance of organizations that implemented Lean Manufacturing and Six Sigma methods: Application to French industries

L'évaluation des performances des organisations implémentant les méthodes Lean Manufacturing et Six Sigma : Application aux industries Françaises

Résumé

De nombreuses industries ont mené des recherches en vue de choisir la méthode appropriée afin d'améliorer les résultats, notamment Lean Manufacturing et Six Sigma. Ce travail de thèse s'intéresse principalement à l'influence de l'implémentation de ces méthodes au sein des entreprises françaises, selon trois critères : financier, opérationnel et innovation. Les résultats de nos recherches montrent que les entreprises, appliquant Lean Manufacturing et Six Sigma, sont plus efficaces pour l'amélioration des performances en matières financière et opérationnelle. Par ailleurs, les entreprises qui utilisent juste une partie des pratiques de Lean Manufacturing et/ou de Six Sigma ont montré des améliorations limitées. En ce qui concerne le volet innovation, nous avons montré que l'implémentation de Lean Manufacturing est suffisante pour avoir une amélioration des performances. En outre, nous avons constaté que les pratiques de Lean et Six Sigma, telles que One Piece Flow, Kanban, 5S, etc. contribuent fortement à l'amélioration des performances. Les résultats statistiques montrent également que les facteurs clés, de la réussite de la mise en place de Lean Manufacturing et Six Sigma, peuvent être significativement différents selon la méthode.

Mots clés

Lean Manufacturing, Six Sigma, analyse statistique, Méthodes multi-critères, Analytic Hierarchy Process, évaluation de la performance, les outils de qualité, amélioration continue, ingénierie industrielle.

Abstract

Many industries conduct research in order to decide on the appropriate methodology for delivering optimal performance outcomes such as Lean Manufacturing or Six Sigma. Therefore, this research shows the influence of different categories based on the implementation method against three criteria: financial performance, operational performance and innovation performance. Research results indicate that companies implementing Lean Manufacturing and Six Sigma were more effective in improving company performance across financial and operational dynamics. Additionally, it shows companies who implemented Lean Manufacturing only saw improvements in innovation performance. Moreover, we found that Lean Manufacturing and Six Sigma practices such as One Piece Flow, Kanban, 5S, etc. supported increases in companies' performance. The statistical results also show that the key factors for the success of Lean Manufacturing and Six Sigma implementation could differ depending on the method employed.

Key word

Lean Manufacturing, Six Sigma, statically analysis, Multi criteria decision method, Analytic Hierarchy Process, evaluate the performance, quality tools, continuous improvement, industrial engineering.