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The effectiveness of Lean Manufacturing Audits in driving improvements in operational performance

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THE EFFECTIVENESS OF LEAN MANUFACTURING AUDITS IN DRIVING IMPROVEMENTS IN OPERATIONAL PERFORMANCE

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A research reported submitted to the faculty of engineering and the built environment, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science in Engineering

Johannesburg 2009

Declaration

I declare that this research report is my own work and is being submitted for the degree of Master of Science in Engineering at the University of the Witwatersrand, Johannesburg. It has not been submitted to any university or academic institution for any reason prior to this submission.

Signed 

This the **5th** Day of **October** in the year **2009**

Abstract

In recent years companies have made increased use of Lean Manufacturing audits to measure the degree of Lean Manufacturing implementation within their organizations. Thereafter, a gap analysis highlights areas for improvement, which leads to increased Operational Performance. This approach may be flawed. The audit may measure Lean Manufacturing characteristics that are not beneficial or the Lean Manufacturing audit may be inaccurate due to auditor bias or inadequate scope. The result is frustration and a lack of belief in the effectiveness of Lean Manufacturing as a competitive strategy. This study tests the hypothesis that "Lean Manufacturing audits drive improvements in Operational Performance."

A sample company comprising sixty four organizations operating in a job shop and Batch operations management environment is used as a case study. The organizations manufacture and service high value added products for heavy industry. The Lean Manufacturing audit developed to assess the effectiveness of Lean Manufacturing audits in driving Operational Performance uses Lean Manufacturing characteristics commonly used in previous research. These characteristics include policy deployment, standardized work, visual management and housekeeping, quick changeover techniques, total preventative maintenance, continuous improvement, error proofing, cultural awareness, material control and level production. Commonly used Operational Performance measures such as On-Time-Delivery, Inventory turns and Direct Labour Utilization are used to assess Operational Performance. A range of independent auditors were used to gather data on the extent of implementation of Lean Manufacturing and Operational Performance measures.

Structural Equation Modelling is used to relate the results of the Lean Manufacturing audits to Operational Performance. This is the first known paper to use Structural Equation Modelling in measuring the extent of implementation of Lean Manufacturing to Operational Performance.

Lean Manufacturing audit results have a significant correlation to Operational Performance but with a high degree of variation in Operational Performance not accounted for by the results of the Lean Manufacturing audit. This variation is caused by the inadequate scope of the audit relative to Operational Performance measures as well as auditor bias. Lean Manufacturing audits are effective in driving improvements in Operational Performance provided that the scope of the audit is expanded to include office functions, supplier networks and customer and branch distribution networks. A recommended audit framework is suggested in this research.

A large scale study of a number of different companies should be conducted to verify the results of this research using the audit framework developed.

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Table of Contents

Declaration ..... **i**
Abstract ..... **ii**
Acknowledgements ..... **iii**
Table of Contents ..... **iv**
List of figures ..... **vii**
List of tables ..... **viii**
List of abbreviations ..... **ix**
1 Introduction **1**
1.1 Background 1
1.1.1 The origins and development of Lean Manufacturing 2
1.1.2 Lean Manufacturing characteristics 2
1.1.3 Operational Performance measures 3
1.1.4 Relationship between Operational Performance and Lean Manufacturing 4
1.2 Statement of the problem 4
1.3 Formulating the research question into a hypothesis: 4
1.4 Research objectives 5
1.5 Research context 5
1.6 Definition of terms 5
1.6.1 Company 5
1.6.2 Organization 5
1.6.3 Operation 5
1.6.4 Operational Performance 6
1.6.5 Operational Performance measures 6
1.6.6 Lean Manufacturing 6
1.6.7 Lean Manufacturing Characteristic 6
1.6.8 Lean Manufacturing audit 6
1.7 Delimitations of data 6
1.8 Research report overview 6
2 Literature review **8**
2.1 Introduction 8
2.2 Types of operations management environments 8
2.3 Research defining Lean Manufacturing characteristics 9
2.4 Research defining Operational Performance measures 13
2.5 Research linking Lean Manufacturing with Operational Performance 17
2.6 Lean Manufacturing audits 18
2.7 Relevance of this study 20
2.8 Conclusion 20

3 Research methodology 22
3.1 Introduction 22
3.2 Theoretical foundation 22
3.3 Research Design 22
3.4 Data collection method 23
3.5 Implementation 23
3.5.1 Population selection 23
3.5.2 Sample selection 23
3.5.3 Questionnaire design and scale selection 24
3.6 Data analysis 26
3.6.1 Pre-analysis 30
3.6.2 Data screening 32
3.6.3 Assessment of the measurement model 34
3.6.4 Assessment of structural model 37
3.7 Conclusion 39
4 Results 41
4.1 Pre-analysis 41
4.1.1 Defining the measurement model 41
4.1.2 Determining sample size adequacy 42
4.1.3 Structural model 43
4.2 Data screening 43
4.3 Assessing the measurement model 44
4.3.1 Initial single factor measurement model for Lean Manufacturing 45
4.3.2 Initial single factor measurement model for Operational Performance 46
4.3.3 Full measurement model 47
4.3.4 Reliability and Validity 48
4.4 Assessing the structural model 49
5 Discussion of results 54
5.1 Evaluation of research hypothesis 54
5.2 Assessment of the primary research question 54
5.3 Interpretation of results 54
5.3.1 Using Lean Manufacturing auditing to drive Operational Performance 54
5.3.2 Accounting for unexplained variation in Operational Performance 55
5.3.3 Recommendations for implementing Lean Manufacturing audits 60
5.4 Limitations of this research 63
6 Conclusion 64

6.1 Assessment of the research question 64
6.2 Recommendations for future research 64
7 References 65
Appendix A Lean Manufacturing audit used in this research 69
Appendix B Operational definitions for Operational Performance measures 84
Appendix C SAS Input listing for indicator reliability 93
Appendix D SAS input listing for the single factor measurement model 94
Appendix E SAS input listing for the full factor measurement model 96
Appendix F SAS input listing for the theoretical model 98
Appendix G SAS input listing for the uncorrelated models 100
Appendix H Full recommended Lean Enterprise audit. 103

List of figures

Figure 2.1: Performance measurement model 15
Figure 3.1: Empirical research model in Operations Management 22
Figure 3.2: Process flow for data analysis of research data 29
Figure 3.3: Simplistic two factor measurement model 30
Figure 3.4: Typical 2 factor structural model 32
Figure 3.5: Illustration of Skewness and Kurtosis 34
Figure 4.1: a priori measurement model 41
Figure 4.2: Power analysis graph for current SEM model 42
Figure 4.3: a priori structural model 43
Figure 4.4: Lean Manufacturing Measurement model 45
Figure 4.5: Operational Performance Measurement model 46
Figure 4.6: Full measurement model 47
Figure 4.7: Full structural model 49
Figure 4.8: Full theoretical model 50
Figure 4.9: Structural model results 52
Figure 4.10: Theoretical model results 53
Figure 5.1: Scatter plot for Lean Manufacturing Audit and Operational Performance 55

List of tables

Table 2.1: Operations Management environments 8
Table 2.2: Research on Lean Manufacturing characteristics 9
Table 2.3: Frequently measured Lean Manufacturing characteristics in the literature 10
Table 2.4: Strength of Lean Manufacturing characteristics as linking to Lean Manufacturing 11
Table 2.5: Definition of Lean Manufacturing characteristics used in this research 12
Table 2.6: Review of performance measurement frameworks 14
Table 2.7: Literature on Operational Performance measures and TQM, JIT or Lean Manufacturing 15
Table 2.8: Operational Performance measures defined in the literature 16
Table 2.9: Strength of Operational Performance measures linking to Operational Performance 17
Table 2.10: Research linking Lean Manufacturing to Operational Performance 17
Table 2.11: Lean characteristics audited in Lean Manufacturing audits found in the literature 18
Table 2.12: Assessment of Lean Manufacturing audits found in the literature 19
Table 3.1: Summary statistics on organization types 24
Table 3.2: Summary statistics on organization region and size 24
Table 3.3: Summary statistics on organization operation and type 24
Table 3.4: Lean Manufacturing characteristics defined in the Lean Manufacturing audit 24
Table 3.5: Example of Lean audit question 25
Table 3.6: Scale definition of Lean Manufacturing audit questionnaire 25
Table 3.7: Operational Performance measures 26
Table 3.8: OTD scoring table 26
Table 3.9: Direct Labour Efficiency scoring table 26
Table 3.10: Inventory turns scoring table 26
Table 3.11: Output table for indicator reliability 33
Table 3.12: Ideal fit criteria 35
Table 3.13: Typical output for reliability analysis 36
Table 3.14: Table illustrating convergent and discriminate validity 37
Table 3.15: Illustration of Parsimony indices results 39
Table 4.1: Model identification 41
Table 4.2: Cronbach α reliabilities for indicator variables 43
Table 4.3: Pearson correlation coefficients for all MV's 44
Table 4.4: Goodness of fit test results for initial single factor measurement model 45
Table 4.5: Results for modified single factor measurement model 46
Table 4.6: Goodness of fit results for full measurement model 47
Table 4.7: Reliability assessment for the measurement model 48
Table 4.8: Validity assessment of measurement model 49
Table 4.9: Results for the full theoretical model 50
Table 4.10: Parsimony ratio's for the theoretical and structural model 51
Table 4.11: Standardized path coefficients for theoretical model 52
Table 4.12: Error variance for Operational Performance 53
Table 5.1: Summary statistics for sample on organization types in quadrant four 56
Table 5.2: Summary statistics for sample on organization region and size in quadrant four 56
Table 5.3: Summary statistics for sample on organization operation and type in quadrant four 57
Table 5.4: Evaluation of Lean Manufacturing Audit 61
Table 5.5: Features of a recommended Lean audit framework 62

List of abbreviations

D	Disturbance Term
df	Degrees of Freedom
EP	Error Proofing
IMVP	International Motor Vehicle Program
ISO	International Standards Organization
JIT	Just-In-Time
LV	Latent Variable
ME	Measurement Error
MIT	Massachusetts Institute of Technology
MV	Manifest Variable
PNFI	Parsimonious fit index
PR	Parsimony ratio
QC	Quick Changeover
RNFI	Relative normed fit index
RPFI	Relative parsimony fit index
RPR	Relative parsimony ratio
R^2	Reliability coefficient
SAS	Statistical Application Software
SEM	Structural Equation Modeling
TPM	Total Productive Maintenance
TQM	Total Quality Management

1 Introduction

1.1 Background

Process improvement initiatives aimed at bringing about large scale sustainable change have frequently been employed by companies wishing to gain a competitive position in the market place. There are at least fifty recent Operations Management research papers specifically relating business performance to the degree of implementation of a process improvement initiative. These are backed up by numerous business books advocating the use of a certain process improvement initiative to improve competitiveness. Example initiatives include Lean Manufacturing, Six Sigma Total Quality Management, Agile Manufacturing, Business Process Reengineering and management by Theory of Constraints. A working paper written for the Massachusetts Institute of Technology's (MIT) Lean Aerospace Initiative provides a comprehensive assessment of each of these process improvement initiatives in terms their effectiveness, use and shared features with other initiatives. The main conclusion is that Lean Manufacturing provides by far the most compelling Intellectual architecture for the various systemic change initiatives (Bozdogan, 2006).

The main reason for the superiority of Lean Manufacturing over other change initiatives is that Lean Manufacturing encompasses a unified, mutually-reinforcing, set of enterprise-wide principles at all levels, linking the board room to the factory floor and providing an end-to-end view of all enterprise operations spanning a defined enterprise's entire value stream (Bozdogan, 2006). Lean Manufacturing takes a more simplistic approach to problem solving and does not rely on an array of complex statistical tools to be effective. Lean Manufacturing has shown an ability to incorporate new techniques and adapt to current process improvement requirements (Bicheno, 2004). Because of these characteristics, Lean Manufacturing is able to find common ground with a wider array of people.

The central problem facing manufacturing organizations that decide to adopt Lean Manufacturing as a chosen process improvement model is how to measure the extent of implementation of Lean Manufacturing within their organization and how to link the implementation of Lean Manufacturing to Operational Performance that will justify capital spent on these initiatives. One method is to audit the implementation of Lean Manufacturing practices within an organization through a structured audit. The audit is a questionnaire and consists of questions purposely structured around what is constituted as Lean Manufacturing best practice. The results of the audit provide a gap analysis between where an organization currently is and where it needs to be in order to be considered world class in terms of Lean Manufacturing (Kobayashi, 1995).

Lean Manufacturing audits are popular because they provide a structured approach to measure the implementation of the same set of Lean Manufacturing best practice characteristics across a range of organizations, often operating in similar operations management environments. Organizations can compare Lean Manufacturing audit scores and use each other as benchmarks to improve (Kobayashi, 1995).

The problem with using a Lean Manufacturing audit to drive world class performance is that the audit assumes that implementing the range of Lean characteristics audited will mean that the organization has world class Operational Performance. An organization with a high score for a Lean Manufacturing audit should have good Operational Performance measures and vice versa. This however assumes that the Lean Manufacturing characteristics used within the audit are beneficial to the organization being audited. Furthermore the audit is susceptible to auditing error in the form of auditor bias (Shah & Ward, 2007).

This research addresses the question of whether using a Lean Manufacturing audit framework is effective in driving Operational Performance. This is done by assessing whether organizations that show a strong degree of implementation of Lean Manufacturing characteristics, as measured through an audit, show good Operational Performance measures.

The research uses data from implementation of Lean Manufacturing in one specific company operating Job shop and Batch manufacturing environments as a case study.

1.1.1 The origins and development of Lean Manufacturing

The term "Lean" Manufacturing was first coined by MIT researchers benchmarking the differences between Western and Japanese automobile manufacturing under the International Motor Vehicle Program (IMVP) (Holweg, 2006). The IMVP was initiated in the early 1980's and involved the benchmarking of over seventy automobile manufacturing plants across the globe. The book 'The machine that changed the World' resulting from the study was published in 1990. It introduced the world to the concepts of Lean Manufacturing (Holweg, 2006).

In his paper on the "Genealogy of Lean production", Holweg explains that the core elements of Lean Manufacturing stem from the evolution of the Toyota Production System. This was a system that evolved from humble beginnings in 1950 to produce stable evolutionary learning capability (Fujimoto, 1999). Its successes include the adoption of continuous improvement teams and development, Just-In-Time parts supply, single piece flow, quick changeover times, standardized work, built in quality, level production, visual controls and preventative maintenance (Liker, 2005).

The diffusion of Lean Manufacturing concepts into widespread manufacturing circles occurred after the publication of the book 'Lean Thinking' by Wolmack and Jones in 1994. Both researchers had participated extensively in the IMVP study as well as the publication of 'The machine that changed the world'. The last decade has seen the implementation of Lean Manufacturing grow beyond manufacturing and into service and product development industries (McManus, 2005) .

The main difficulty in using Lean Manufacturing across a range of manufacturing and related manufacturing service industries is that although the concepts of Lean Manufacturing remain the same, particular Lean Manufacturing characteristics and Operational Performance measures may change. Attempting to apply specific Lean Manufacturing characteristics in an environment where they have little effect and where implementation is not correctly linked to Operational Performance may cause an organization to loose faith in the strength of Lean Manufacturing as a process improvement framework. Understanding what Lean characteristics to implement and how to implement them in order to drive Operational Performance is crucial to the success of using Lean Manufacturing in a wider array of operations management environments (Shah & Ward, 2007).

1.1.2 Lean Manufacturing characteristics

Lean Manufacturing focuses either on conceptual philosophy or practical management techniques and characteristics (Shah & Ward, 2007). The latter provides the basis of Lean Manufacturing audits.

The concept of "Lean" has been broadly defined as follows: "Lean production is an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability" (Shah & Ward, 2007). The above definition of Lean Manufacturing does not indicate any characteristics that can be defined and measured.

Shah and Ward, in their study on measures of Lean production suggest ten underlying Lean Manufacturing characteristics. These are supplier development, pull systems, continuous flow, quick changeover, preventative maintenance, statistical process control, employee involvement, process control and customer involvement (Shah & Ward, 2002). Mann suggests the same set of

characteristics but expands process control to measure standard work, process definition and focus, visual controls, cultural awareness and evidence of daily accountability (Mann, 2005). He also divides the employee involvement characteristic into continuous improvement and the ability of the organization to perform root cause problem solving. A supplier development scorecard developed by Lockheed Martin focuses on the same characteristics above but includes transparency of the organization (visibility on value stream mapping out the process in the organization), Lean product development and leadership (Lockheed Martin, 2006).

Clearly defining Lean Manufacturing characteristics, their cultural effect, the business scope of implementation and the Operational Performance measures they impact make measuring the link between Lean Manufacturing and Operational Performance difficult. This is especially true for organizations adopting Lean Manufacturing in operating environments that are dissimilar to those in which Lean Manufacturing was developed, such as the automotive industry. Furthermore a blind focus on specific Lean Manufacturing characteristics may lead companies away from industry specific best practice that is not covered in any predefined and detailed Lean Manufacturing characteristic. Such practices may include the focus on supply chain pipeline inventories or retail and distribution networks (Schonberger, 2008).

The use of Lean Manufacturing as a process improvement framework across a wide array of operating environments highlights the importance of measuring the implementation of defined Lean Manufacturing characteristics and determining their link to Operational Performance.

1.1.3 Operational Performance measures

There are three groups interested in assessing the performance of an organization; they are external stakeholders, internal stakeholders and the customer. External stakeholders may include public investors. Internal stakeholders include group level management and employees. Customers include those with a vested interest in buying a firm's product or service based on its cost, delivery and quality. External stakeholders look for the following characteristics: operating profit, return on invested capital, financial stock turns. Internal stakeholders look for cost of quality, On-Time-Delivery, lead time, direct labour efficiency, lost time injury rate, order book and price-cost ratio (Mahidhar, 2005).

A balanced scorecard combines Internal and External stakeholder characteristics with customer characteristics and includes characteristics for employee training and retention (Abdel-Maksoud, Dugdale, & Luther, 2005). External stakeholders looking for investment potential may narrow these characteristics to financial characteristics such as Price Earnings ratio, Operating profit and financial stock turns. This enables them to calculate the value of a multitude of organizations using a key set of agreed and standard performance characteristics (York & Miree, 2004). Contextual factors, such as the increasing importance of environmental management are starting to play a role. Customers looking to deal with the organization as a supply partner may focus on environmental compliance, quality compliance, corporate compliance and safety in addition to cost, quality and delivery performance characteristics. Standard measurement systems such as ISO14000 environmental compliance and ISO9001:2008 quality compliance and ISO18000 safety management provide standards to measure these characteristics.

Within the scope of this research, Operational Performance measures that have a strong link to Operational Performance relating to Lean Manufacturing literature are defined.

1.1.4 Relationship between Operational Performance and Lean Manufacturing

The success of any Lean Manufacturing implementation and sustainment is dependent upon a performance measurement system that combines a set of consistent characteristics with relationships that link those characteristics and enterprise level stakeholder value characteristics (Operational Performance measures) (Mahidhar, 2005). In essence, organizations manage what they measure.

From the standpoint of an internal stakeholder, it is important to know that the capital invested in Lean Manufacturing will produce improvements in Operational Performance measures. The link between Lean Manufacturing and Operational Performance must be clear.

Although there is widely published literature relating Lean Manufacturing to Operational Performance (Womack, Jones, & Roos, 1990) the literature does not mention specific Lean Manufacturing characteristics or only relates industry specific characteristics (such as the automotive industry) to Operational Performance. There has been extensive research linking other process improvement frameworks, such as Total Quality Management and Just-In-Time, to Operational Performance (Chonga & Rundusb, 2003), (Cua, McKone, & Schroeder, 2001). The characteristics of these process improvement frameworks, although sharing many common characteristics with Lean Manufacturing differ from Lean Manufacturing in other characteristics. There exists little research on linking the implementation of specific Lean Manufacturing characteristics to Operational Performance (Fullerton & Wempe, 2009).

This research addresses the above shortcoming by assessing the effectiveness of using Lean Manufacturing audits, based on popular Lean Manufacturing characteristics, to measure and improve Operational Performance.

1.2 Statement of the problem

The central research problem of this thesis can be summarized in the following question:

Do organization's that exhibit strong implementation of Lean Manufacturing characteristics, as measured through a structured audit framework, also exhibit strong Operational Performance measures?

To answer this question the concepts of *"Lean Manufacturing"* and *"Operational Performance"* must be clearly defined and measured. Lean Manufacturing audits are comprised of categories that measure the implementation of defined Lean Manufacturing characteristics. Is it possible for organizations to exhibit good Operational Performance while scoring low in an audit of Lean Manufacturing characteristics and if so, does this indicate that the characteristics are poorly defined or measured? Implicitly this research asks the following:

Are Lean measurement and performance auditing frameworks effective in driving Operational Performance improvements?

1.3 Formulating the research question into a hypothesis:

The above research question or "Statement of the problem" is reformulated into the following research hypothesis which can be tested using statistical analysis:

H_1: There exists a positive correlation between the results of a Lean Manufacturing audit and Operational Performance

1.4 Research objectives

The research objective is to quantitatively test the hypothesis that "There exists a positive correlation between the results of a Lean Manufacturing audit and Operational Performance" using the following steps:

1. Define the characteristics of Lean Manufacturing and Operational Performance from those commonly used in previous research
2. Define the Lean Manufacturing audit from the most common and relevant Lean Manufacturing characteristics defined above
3. Define the research model to be used for testing the research hypothesis
4. Use the developed research model to measure the correlation between Lean Manufacturing audit results and Operational Performance in a case study company operating in Job shop and Batch operations management environment.

1.5 Research context

This research is inspired by the author's personal experience in Lean Manufacturing transformations and the use of Lean Manufacturing audits to measure the extent of implementation of Lean Manufacturing in an organization. Resistance to these audits has been encountered from those who were not convinced that improving Lean Manufacturing characteristics, as measured through a Lean Manufacturing audit, is effective in driving Operational Performance. Criticisms include:

1. The Lean Manufacturing audits are not applicable to certain operations management environments
2. The audit is too subjective
3. The audit is too rigid to recognise improvement taken outside of the measuring framework

1.6 Definition of terms

The following section provides a brief explanation of the main terms used in this research:

1.6.1 Company

A "Company", is an independent legal and financial entity that operates in the open market to satisfy customers, external shareholders and internal shareholders. A company has a defined, vision, mission and values. These values form a specific culture. One company may consist of a many organizations, operating under various divisions.

1.6.2 Organization

An "Organization" is an individual manufacturing or service operation. The operation has its own identity, management, independent control structure, inputs and outputs but operates as part of a group of similar organizations within one company (Knod & Schonberger, 2001).

1.6.3 Operation

An "Operation" is the task or set of tasks a group of individuals perform to turn an input into a value added output. It refers to both something that is small in scale, such as casting or machining an item

as well as something that is large and complex, such as the set of interrelated activities used to manage and improve an organization (Knod & Schonberger, 2001).

1.6.4 Operational Performance

"Operational Performance" is the effectiveness of an organization in converting inputs into outputs (Knod & Schonberger, 2001).

1.6.5 Operational Performance measures

An "Operational Performance measure" is a measurable indicator of good Operational Performance.

1.6.6 Lean Manufacturing

"Lean Manufacturing" is an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability (Shah and Ward, 2007). Lean Manufacturing is a term used to describe an improvement model that has actively sought to reduce the time from order input through to cash input of the operation by eliminating wasteful activities in that operation.

1.6.7 Lean Manufacturing Characteristic

A "Lean Manufacturing characteristic" is a managing principal or desirable approach which helps implement Lean Manufacturing

1.6.8 Lean Manufacturing audit

A Lean Manufacturing audit is a structured measurement framework that measures the implementation of popular Lean Manufacturing characteristics within an organization. The audit has a scope, management method and a questionnaire structure.

1.7 Delimitations of data

The research data is limited to a case study of one company, consisting of sixty four organizations that use the same Lean Manufacturing audit framework in measuring the extent of implementation of Lean Manufacturing. This company manages a comprehensive Lean process improvement framework. The organizations are located in thirteen different countries. The organizations provide products related to the nuclear industry, the petroleum industry and the minerals processing industry and operate in Job shop and Batch operations management environments. Each organization contains one or more of the following core operations: casting, machining, elastomer products production, warehousing and integrated assembly.

The names of the organizations involved in the study remain undisclosed for confidentiality reasons.

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1.8 Research report overview

Chapter one provides an introduction to this research, the background, the research problem, research question and the hypothesis. It provides the overall research setting.

Chapter two presents a review of relevant literature related to Lean Manufacturing, its key characteristics, its effect on Operational Performance and common Lean Manufacturing audits.

Chapter three provides details on the research model used in this research, its applicability to research in operations management and this research.

Chapter four details the results of this research, including detailed outcomes and assumptions.

Chapter five provides a discussion of the results in relation to the research question. Contextual factors that help explain and evaluate the research are presented along with recommendations for Lean Manufacturing audit frameworks.

Chapter six provides a conclusion of the results of this research and recommendations for further research.

2 Literature review

2.1 Introduction

2.2 Types of operations management environments

For both manufacturing and service industries there are five different operations management environments. These are Project, Job, Batch, Repetitive and Continuous. Each environment is defined by unique process, volume and variety characteristics. Table 2.1 illustrates the various operations management environments (Knod & Schonberger, 2001).

Table 2.1: Operations Management environments

Process Overview **Volume** **Variety/Flexibility**	**Functional** **Lowest (one item)** **Highest**	**Functional** **Very Low** **Highest**	**Mixed** **Moderate** **Moderate**	**Product** **High** **Low**	**Product** **Highest** **Lowest**
Project	Construction ERP implementation R&D effort				
Job		Tool & Die Shop Service centre			
Batch			Heavy equipment Cement mixing		
Repetitive				Auto assembly Licence processing	
Continuous					Steel mill Brewery Chemical plant

Lean Manufacturing evolved in repetitive operations management environments, specifically the automotive industry (Holweg, 2006). Repetitive operations management environments are defined by low variety of products. Equipment is mostly purpose built and operators trained on specific narrow applications. Operations focus on the entire product flow rather than a discrete set of operations (Knod & Schonberger, 2001). Lean Manufacturing characteristics such as standardized work, error proofing, value stream mapping, kanban system and Heijunka evolved in this environment and proved successful at increasing the productivity, delivery, quality and cost of products made in this operations management environment (Womack, Jones, & Roos, 1990).

Lean Manufacturing has moved beyond repetitive manufacturing and into other operations management environments, such as Job shop and Batch operations.

Job shop environments are characterised by low volumes and a high degree of variety. There are many jobs in various stages of completion. Operations management in this environment can become chaotic as an organization in this environment requires a high degree of flexibility of employees and equipment. Management tends to focus on departments and their problems rather than on a job (Knod & Schonberger, 2001). Since jobs are non-standard and equipment or facilities are not dedicated, applying specific Lean Manufacturing characteristics, as developed in repetitive environments, requires a degree of lateral thinking.

Batch operations management environments are similar to job shop environments but with less variety, higher volumes and more standard products. Product outputs are a regular mix of familiar items and occasional on request jobs. Batch processing shares some of the difficulties of job

operations but the familiarity with the output mix reduces many of the surprises faced by job operations management environments (Knod & Schonberger, 2001). Implementing Lean Manufacturing characteristics in these environments may be easier than in job operations but may still require a degree of lateral thinking when assessing the feasibility of implementing Lean Manufacturing characteristics borrowed directly from repetitive operations management environments.

2.3 Research defining Lean Manufacturing characteristics

There is a wide variety of literature available on the concepts Lean Manufacturing. Lean Manufacturing is described from either a philosophical approach (Womack & Jones, 1996) or from the practical perspective of a set of managing principles and characteristics (Shah & Ward, 2007). This research focuses on the latter approach. Table 2.2 lists recent research focusing on defining Lean Manufacturing characteristics.

Table 2.2: Research on Lean Manufacturing characteristics

Literature source	Publication	Operations Management Environment (primary focus)				
		Project	Job	Batch	Repetitive	Continuous
Published Books	(Bicheno, 2004)		X	X	X	
	(Mann, 2005)		X	X	X	
	(Kobayashi, 1995)		X	X	X	
	(Fujimoto, 1999)				X	
	(Liker, 2004)				X	
	(Schonberger, 2008)		X	X	X	X
Primary Journal Publications	(Lockheed Martin, 2006)		X	X	X	
	(Shah & Ward, 2007)		X	X	X	
Supporting Journal Publications	(Amasaka, 2002)		X	X	X	
	(Li, Rao, Ragu-Nathan, & Ragu-Nathan, 2005)		X	X	X	
	(Sakakibara, Flynn, & Schroeder, 1993)		X	X	X	
	(B Flynn, 1995)		X	X	X	
	(Flynn, Schroeder, & Sakakibara, 1995)		X	X	X	
	(Sakakibara S. , Flynn, Schroeder, & Morris, 1997)		X	X	X	
	(Koufteros, Vonderembse, & Doll, 1998)		X	X	X	
	(Koufteros & M Vonderembse., 1998)		X	X	X	
	(Dow, Samson, & Ford, 1999)		X	X	X	X
	(McKone & Weiss, 1999)		X	X	X	
	(Cua, McKone, & Schroeder, 2001)		X	X	X	
	(Ahmad, Schroeder, & Sinha, 2003)			X	X	
	(Shah & Ward, 2002)			X	X	
	(Liker, 2005)				X	

Note: All research publications are exclusive to the manufacturing and associated support industries

In comparing Lean Manufacturing characteristics used in various research studies the following problems are encountered:

1. A characteristic used in one publication may have evolved over time to conceptualize a different characteristic. An example is Total Productive Maintenance (TPM). TPM was

originally listed as a sub set of the Just-In-Time (JIT) characteristic. Now it has evolved to become its own characteristic (Shah & Ward, 2007).

2. A characteristic defined in one publication is defined differently in another publication.
3. A characteristic listed in one publication is defined as two or more characteristic in a different publication

The difficulty in clearly defining and standardizing on Lean Manufacturing characteristics indicate that the conceptual and operational space around Lean Manufacturing is under-developed (Shah & Ward, 2007). In order to resolve this issue Table 2.3 lists all key Lean Manufacturing characteristics frequently mentioned in the literature. The table identifies whether the research publications clearly identify the characteristic as a measurable characteristic or as a latent characteristic that was measured by something different in the publication. Table 2.3 further indicates which research publications measure the defined characteristic using two separate measures or whether the two characteristics have been combined into one measure in the publication

Table 2.3: Frequently measured Lean Manufacturing characteristics in the literature

Lean Manufacturing characteristic	Publication									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Goal alignment /Policy deployment	A		C	A		A	A			A
Visual management & housekeeping	A		A	A	A	A	A		A	A
Continuous improvement/waste reduction	A		A	A	A	A	A	C	A	A
Cultural awareness	A	B	B	B		A	A	C	A	A
Standardized work	A	A	A	A		C	A		A	A
Flexible operations / layouts	A		A	A	A	C	A		A	A
Error proofing	A		A	C		C	A		A	A
Focus on reducing variability / statistical process control	A		A	C	C	C	A	A		A
Design for simplicity / manufacture	A		A	B	A		A		A	
Focus on quick changeover /total flow time	A		A	C		A	A	A	A	A
Total Productive Maintenance	A		A	C	A	A	A	A	A	A
JIT/Pull systems	A		A	A	C	C	A	A	A	A
Levelling / Heijunka	A		A	A	A	A	A	C	A	A
Customer involvement	B		B	B	A	A		A		
Value network/supplier focus	B		A	A	A	A		A		

Use of advanced technology				C		A	
Daily accountability	C	A		A		B	
Process focus	C	A	A	A		A	B	C
A: Used a measurable characteristic in publication **B: Used as a latent characteristic in publication** **C: Combined with another characteristic in publication to define a combined measurable characteristic**							
1: (Bicheno, 2004) **2: (Mann, 2005)** **3: (Schonberger, 2008)** **4: (Liker, 2005)** **5: (Goodson, 2002)** **6: (Kobayashi, 1995)** **7: (Lockheed Martin, 2006)** **8: (Shah & Ward, 2007)** **9: (Fujimoto, 1999)** **10: Lean Manufacturing characteristics used in the Lean Manufacturing audit assessed in this research**							

Table 2.3 implicitly illustrates the strength of each Lean Manufacturing characteristic as a measurable variable of Lean Manufacturing. Those characteristics that have been used as a direct measure across multiple publications link strongly to the construct of Lean Manufacturing. Those characteristics that have only been directly measured in relatively few publications, have been combined with other characteristics or have been defined as underlying constructs of other measurable characteristics show that their link to Lean Manufacturing is weaker. This is because across multiple publications on Lean Manufacturing characteristics, relatively few agree on the direct measure of the characteristic.

Using Table 2.3 and the above argument, Table 2.4 illustrates the strength of a Lean Manufacturing characteristic in being a direct measure for Lean Manufacturing in publications that review practical management tools and practices of Lean Manufacturing.

Table 2.4: Strength of Lean Manufacturing characteristics as linking to Lean Manufacturing

Lean Manufacturing characteristic	**Link to Lean Manufacturing**			**Used in this study as a Lean Manufacturing characteristic**
	Strong	**Medium**	**Weak**	
Goal alignment /Policy deployment		x		YES
Visual management & housekeeping	x			YES
Continuous improvement/waste reduction	x			YES
Cultural awareness		x		YES
Standardized work	x			YES
Flexible operations / layouts	x			YES
Error proofing		x		YES
Focus on reducing variability / statistical process control		x		
Design for simplicity / manufacture		x		
Focus on quick changeover /total flow time	x			YES
Total Productive Maintenance	x			YES
JIT/Pull systems	x			YES
Levelling / Heijunka	x			YES
Customer involvement			x	
Value network/supplier focus		x		
Use of advanced technology			x	
Daily accountability			x	
Process focus		x		
Note: The link is determined by the number of "A" symbols for each characteristic in Table 2.3 **Strong: 6 or more A's** **Medium: 4 – 6 A's** **Weak: Less than 4 A's**				

Table 2.4 illustrates that the Lean Manufacturing audit assessed in this research includes all characteristics that are strongly linked to Lean Manufacturing and only two characteristic out of the seven that are moderately linked to Lean Manufacturing.

In order for each characteristic to be understood Table 2.5 provides a definition of each characteristic used in this research as well as its defining sub characteristics (Bicheno, 2004).

Table 2.5: Definition of Lean Manufacturing characteristics used in this research

Lean Manufacturing characteristic	Conceptual definition	Sub Characteristics and features
Policy Deployment	The process of aligning the strategic goals of an organization with all lower level activities. Objectives and Targets are cascaded down through the organization so that recourses and personal are aligned. Regular review of lower level projects that support organizational objectives are conducted.	▪ Hoshin-Kanri plan ▪ Policy deployment Matrix ▪ Individual & departmental goals linked to organization objectives ▪ Regular review process ▪ All projects have defined targets and link back to organization objectives
Cultural Awareness	The ability of all individuals in organization to understand how their job contributes to the objectives of the organization and to work in cross-functional teams to solve organization wide issues.	▪ Personal development programmes linked to organization objectives ▪ Tier 1, 2 and 3 level regular meetings ▪ Regular cross functional development and communication
Visual management & housekeeping	All operational activity areas (factory floor, offices, storage locations etc) are defined, neat and ordered. There is a place for everything and everything in its place. Operational management and improvement measurement metrics are clearly visible to all, easy to manage and easy to interpret. Control of metrics reporting is done from the ground up.	▪ Formal 5S program in place for office and factory areas ▪ Clear focus on the identification and ordering of all operational areas ▪ Easy to see up to date and relevant white board charts, simple display charts, colour coded signals etc replace computer accessed reports and metrics
Standardized Work	There is a standardized way of conducting each process. The standard is published, and improved in a structured manner. There is a standardized way of reporting, daily management and area control from operators to senior management	▪ Standard Operating procedures (SOP's) are developed, published and readily available in all areas ▪ Non manufacturing operations are standardized ▪ Leader standard work and checklists are developed ▪ There is evidence of a continuous improvement process for standard work
Flexible Operations	Equipment and labour is flexible enough to adapt to changes in customer demand without major disruptions to the supply chain. There is a strong process focus	▪ Equipment is right sized and movable ▪ Cellular manufacturing cells, pulse line cells, small value stream specific work centres etc are in use and can be rebalanced depending on demand. Equipment is not grouped in large disjointed work centres ▪ Operators and supervisors are cross functionally trained and flexible to rotate into different jobs. Pay grade is by number of cross functional skills required
Continuous Improvement	Employees are involved in continuous improvement of processes and cross functional systems. Employees are empowered to get involved and make change. Improvements are typically small, ongoing and managed by cross functional teams	▪ QC Circles ▪ Ideas programmes ▪ Cross functional team celebrations for projects ▪ Record of teams and improvements ▪ Formal kaizen programme in place
Error proofing	Top causes for defects in quality, cost, delivery or safety are systematically identified by employees and cross functional teams work to ensure that these defects cannot happen. There is strong process control	▪ Error proofing awareness ▪ Poke Yoke and Jidoka devices ▪ Tracking and charting of serious safety, quality, cost and delivery defects and potential defects ▪ Celebration of defects that have been eliminated

Quick Changeover	The ability of an organization to adapt to customer demand by producing in small lot sizes rather than large batch runs. Economic order quantities are not accepted and rather batch sizes are determined by the mix of customer demand and work is done to reduce set-up times between batches so as to increase machine effectiveness.	▪ Single Minute Exchange of Die programmes in use ▪ Machine effectiveness tracked ▪ Focus is on reducing batch sizes as much as possible ▪ Single piece flow programmes or practices are in use
Total Productive Maintenance	Key equipment and machinery is available when required. Availability and downtime is measured and analyzed to improve equipment effectiveness. Operators and professional maintenance teams work together to prevent unexpected breakdowns	▪ Downtime is measured and analysed for improvement ▪ Machine effectiveness is typically reported in terms of overall equipment effectiveness (OEE). ▪ Operators perform daily standard checks on machines and all key maintenance actions are planned, displayed and monitored for closeout
Material Control	Material is pulled from the customer through the supply chain using Just-In-Time / Pull system techniques. Inventory is divided into runner's repeaters and strangers. Running inventory is closely monitored throughout the supply chain and stocked in the right quantity so as to ensure 100% availability and short lead times for delivery	▪ A pull system (also known as a kanban system) is used to control the production of new parts and assemblies. ▪ Parts/assemblies are only made when required ▪ There is joint inventory planning across the supply chain for all key running parts ▪ There is an effort to reduce repeaters and strangers and turn them into running parts ▪ There is clear evidence of a controlled re-order process through the supply chain using kanban signals
Level production	Customer demand is levelled based on medium term planned supply capacity. Orders are sequenced and split so as to not overload the manufacturing system through demand spikes. There is a steady beat to the supply chain. On a second level, different orders types are supplied in mixes so as to prevent any long runs of one type of part/assembly and to ensure that at any one time there is availability of all common parts and assemblies	▪ TAKT time is calculated and used in the production process ▪ Total Actual Cycle Time (TACT) is used as a measure of capacity of each operation ▪ TAKT time is compared to TACT on a regular basis to assess demand and capacity balance ▪ Operations are re-balanced and adjusted to cater for a decrease or increase in TAKT time

2.4 Research defining Operational Performance measures

Operational Performance measures have been defined and measured in a wide variety of literature. Some publications that mention Operational Performance measures further mention Lean Manufacturing while others do not. This research focuses on Operational Performance measures that are specifically mentioned in publications relating to Lean Manufacturing.

As with Lean Manufacturing, Operational Performance is defined by literature focusing on a philosophical approach and literature dealing with practical techniques and management tools. The philosophical approach characterizes the performance measurement framework and the scope of measures involved. Table 2.6 illustrates various recent performance measurement models (Mahidhar, 2005).

Table 2.6: Review of performance measurement frameworks

Performance Measurement Framework	Key features	Reporting covers:	Strengths	Weaknesses
Strategic measurement and reporting technique (SMART)	▪ Uses performance pyramid to cascade down company gaols through the organization ▪ Tries to align lower level goals to higher level objectives	▪ Employees ▪ Customers ▪ Stakeholders	▪ Integrates strategic objectives with Operational Performance measures. ▪ Aggregates financial and nonfinancial measures across various functions and business units.	▪ Does not capture measures with respect to all stakeholder values ▪ Does not provide any mechanism to identify causal relationships between measures across functions or levels. ▪ Does not explicitly integrate the concept of continuous improvement. ▪ May promote local optimization due to functional approach
The Balanced Score card	▪ Looks at financial perspective – how do our shareholders view us ▪ Looks at internal business perspective – what must we excel at ▪ Looks at customer perspectives – how do our customers view us ▪ Innovation – how can we continue to improve	▪ Employees ▪ Customers ▪ Stakeholders ▪ Learning and growth	▪ Scorecard approach to integrate strategic, operational, and financial measures. ▪ Focus on linkages and strategy maps ▪ Most widely accepted	▪ The linkages between the measures are presumed and unidirectional. ▪ Explicitly focuses on customers but leaves other stakeholders implicit. ▪ No deployment system that breaks high-level goals down to the sub process level.
European Foundation for Quality Management	▪ Consist of enablers and results ▪ Looks at Consistency of purpose ▪ Results orientation ▪ Management by processes and facts ▪ Policy deployment process	▪ Employees ▪ Customers ▪ Stakeholders ▪ Community	▪ Contains self assessment tests ▪ Focuses not only on the results, like the balanced scorecard, but also on the drivers of success	▪ Enterprise performance management is broader than quality management. ▪ Loosely defined framework with no supporting process of implementation.
The Performance prism	▪ Who are our stakeholders and what do they want? ▪ What strategies are needed to address these needs ▪ What processes do we need to execute this strategy ▪ What capabilities do we need to perform our processes ▪ What do we expect from our stakeholders in return	▪ Employees ▪ Customers ▪ Stakeholders ▪ Community	▪ Has a much more comprehensive view of different stakeholders (e.g. investors, customers, employees, regulators and suppliers) than other frameworks. ▪ Provides visual map causal relationship map of measures for individual stakeholders.	▪ It offers little about how the causal relationships between the performance measures are going to be realized. ▪ There is little or no consideration is given to the existing systems that companies may have in place.

In addition to the type of performance measurement framework in use, Figure 2.1 illustrates a recommended performance measurement development framework (Mahidhar, 2005).

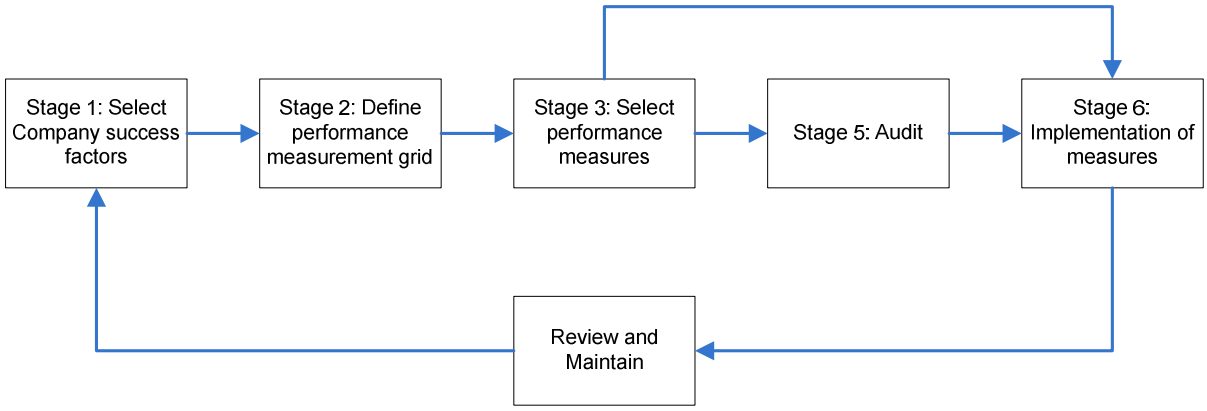

Figure 2.1: Performance measurement model

The purpose of Table 2.6 and Figure 2.1 is to highlight the fact that Operational Performance measures are not developed in isolation and that their effect on company success factors must be determined before implementation.

Operational Performance measures relating solely to finance such as revenue, profit, earnings per share, return on sales etc are seldom mentioned in Lean Manufacturing studies. Traditional management accounting systems are not conducive to highlighting the benefits of Lean Manufacturing to an organization (Schonberger, 2008). The use of non financial manufacturing performance measures acts as a mediator between Lean Manufacturing and financial performance (Fullerton & Wempe, 2009).

Table 2.7 provides a list of recent publications defining Operational Performance measures and that also mention process improvement either in the form of TQM, JIT or Lean Manufacturing.

Table 2.7: Literature on Operational Performance measures and TQM, JIT or Lean Manufacturing

Literature source	Publication	Operations Management Environment (primary focus)				
		Project	Job	Batch	Repetitive	Continuous
Published Books	(Fujimoto, 1999)			X	X	
	(Womack, Jones, & Roos, 1990)				X	
	(Knod & Schonberger, 2001)	X	X	X	X	X
	(Ortiz, 2008)		X	X	X	
	(Schonberger, 2008)	X	X	X	X	X
	(Bicheno, 2004)		X	X	X	
Primary Journal Publications	(Abdel-Maksoud, Dugdale, & Luther, 2005)		X	X	X	
	(Cua, McKone, & Schroeder, 2001)		X	X	X	
	(Flynn, Schroeder, & Sakakibara, 1995)		X	X	X	
	(Forker, 1997)		X	X	X	
	(Fullerton & Wempe, 2009)		X	X	X	X
	(Koufteros, Vonderembse, & Doll, 1998)		X	X	X	
	(Mahidhar, 2005)		X	X	X	
	(Schonberger, 2006)				X	
	(Shah & Ward, 2002)		X	X	X	
	(York & Miree, 2004)		X	X	X	X
	(Samson & Terziovski, 1999)		X	X	X	X

From the research in Table 2.7, Table 2.8 illustrates key Operational Performance measurements and the number of publications that refer to them.

Table 2.8: Operational Performance measures defined in the literature

Operational Performance characteristic	Publication																
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
On-Time-Delivery	A		A		A	A	A					B				A	A
Inventory Turns		A	A	A	A			A				B	A				A
Unit cost	A		A		A		A					B	A				
Direct Labour Utilization & Productivity (hours/unit)	A		A	A	A	A						B	A			A	A
Lead time	A	A	A		A						B	B	A				
Customer satisfaction			A		A	A						B				A	
Defects as a % of Volume (First pass yield)		A	A	A	A	A		A				B	A				
Warranty claims as a % of Sales			A	A		A		A				B					
Cost of Quality			A		A			A				B		A			
Specific Quality index	A						A	A	A			B				A	
Manufacturing cycle time														A			
Manufacturing space (area/unit/period)		A	A	A	A												
Travel distance (distance/period)			A	A													
Volume flexibility							A										
Return on Sales								A		A		B			A		
Revenue								A							A		
Profit								A							A		
Market share															A		

A: Used a measurable characteristic in publication
B: Used as a latent characteristic in publication
C: Combined with another characteristic in publication to define a combined measurable characteristic

1: (Fujimoto, 1999)
2: (Womack, Jones, & Roos, 1990)
3:(Knod & Schonberger, 2001)
4: (Ortiz, 2008)
5: (Bicheno, 2004)
6: (Abdel-Maksoud, Dugdale, & Luther, 2005)
7:(Cua, McKone, & Schroeder, 2001)
8:(Flynn, Schroeder, & Sakakibara, 1995)
9:(Forker, 1997)
10:(Fullerton & Wempe, 2009)
11:(Koufteros, Vonderembse, & Doll, 1998)
12:(Mahidhar, 2005)
13:(Schonberger, 2006)
14:(Shah & Ward, 2002)
15:(York & Miree, 2004)
16:(Samson & Terziovski, 1999)
17: Operational Performance measures assessed in this research

Table 2.9 uses the data from Table 2.8 to relate the strength of various Operational Performance measures used in the literature to Operational Performance.

Table 2.9: Strength of Operational Performance measures linking to Operational Performance

Operational Performance measure	Link to Operational Performance			Used in this study as an Operational Performance measure
	Strong	Medium	Weak	
On-Time-Delivery	X			YES
Inventory Turns	X			YES
Unit cost		X		
Direct Labour Utilization & Productivity (hours/unit)	X			YES
Lead time		X		
Customer satisfaction		X		
Defects as a % of Volume (First pass yield)	X			
Warranty claims as a % of Sales		X		
Cost of Quality		X		
Specific Quality index		X		
Manufacturing cycle time			X	
Manufacturing space (area/unit/period)		X		
Travel distance (distance/period)			X	
Volume flexibility			X	
Return on Sales			X	
Revenue			X	
Profit			X	
Market share			X	
Note: The link is determined by the number of "A" symbols for each characteristic in Table 2.3 **Strong: 6 or more A's** **Medium: 4 – 6 A's** **Weak: Less than 4 A's**				

Table 2.9 illustrates that the Operational Performance measures used in this study are strongly linked in Lean Manufacturing literature to Operational Performance.

2.5 Research linking Lean Manufacturing with Operational Performance

Table 2.10 illustrates research specifically addressing the link between Lean Manufacturing and Operational Performance.

Table 2.10: Research linking Lean Manufacturing to Operational Performance

Publication	Operations Management Environment					Conclusion
	Project	Job	Batch	Repetitive	Continuous	
(Womack, Jones, & Roos, 1990)				X		▪ Lean Manufacturing does improve Operational Performance as measured by unit cost, specific quality index, lead time and productivity. The scope of research covers multiple automotive manufacturing plants in different countries and companies. Higher level definitions of Lean characteristics are defined. Philosophy is well defined.
(Fullerton & Wempe, 2009)		X	X	X	X	▪ The implementation of Lean Manufacturing links to mixed if not poor financial results in organizations if Non Financial Performance Measures (NFPM) are not implemented. NFPM helps bridge the link between Lean Manufacturing and the effect on financial performance. A cross functional survey of organizations in different industries and operations management environments is used to gather data.
(Shah & Ward, 2002)		X	X	X		▪ The implementation of Lean Manufacturing does contribute substantially to Operational Performance. Lean Manufacturing is defined through four "Bundles" of best practice. Specific Lean characteristics are defined but are used as secondary measures within each best practice bundle. Plant size does positively impact on the relationship between Lean Manufacturing and Operational Performance. Data from *Industry week's*

					census of manufacturers is used in this research.
(Schonberger, 2008)	X	X	X	X	▪ The implementation of Lean Manufacturing, referred to as the "Lean core" does improve Operational Performance as measured by the rate of increase of inventory turns over a period. However, implementation of practices outside the "Lean Core" contributed significantly to Operational Performance. Practices were specific to operations management environment and industry. Lean Manufacturing characteristics comprising the "Lean Core" and other characteristics outside the "Lean core" are defined. Financial data from thousands of publically listed companies is used in the research.
(Mahidhar, 2005)	X	X	X		▪ The implementation of Lean Manufacturing without the use of structured performance measures will not drive changes in Operational Performance if the structure of the performance measurement framework is not well understood. The measurement framework must consist of well defined enterprise level stakeholder measures, links that map casual relationships between measures across multiple levels and a uniform set of consistent measures within the framework. Implementing this framework will show that Implementing Lean Manufacturing improves Operational Performance. Conclusion is similar to (Fullerton & Wempe, 2009). A case study of one organization implementing Lean Manufacturing in the aerospace industry is used as a data source for the research.

Table 2.10 highlights that a positive relationship between the implementation of Lean Manufacturing and Operational Performance exists. This is implicitly supported by the wealth of literature on Lean Manufacturing (Bicheno, 2009). Nevertheless the research needs to determine whether the use of a Lean Manufacturing audit framework of commonly used Lean Manufacturing characteristics is beneficial to driving Operational Performance. There are a few examples of Lean Manufacturing audit frameworks in the literature which will be discussed in the next section.

2.6 Lean Manufacturing audits

Table 2.11 and Table 2.12 provide a list of Lean Manufacturing audits used in the literature. Table 2.11 provides details on the Lean characteristics measured for each audit framework and Table 2.12 provides specific details on each audit.

Table 2.11: Lean characteristics audited in Lean Manufacturing audits found in the literature

Audit publication	Lean Manufacturing characteristics audited	
(Lockheed Martin, 2006)	▪ Leadership ▪ Transparency ▪ Lean product development ▪ Continuous improvement	▪ Process focus ▪ Just-In-Time Pull systems ▪ Process control ▪ Standardized work
(Kobayashi, 1995)	▪ Cleaning and organizing ▪ Rationalizing the system ▪ Improvement team activities ▪ Reducing inventory ▪ Quick changeover technology ▪ Manufacturing Value Analysis ▪ Zero Monitor Manufacturing ▪ Coupled Manufacturing ▪ Maintaining equipment ▪ Time control and commitment ▪ Leading technology and site technology	▪ Quality assurance ▪ Developing Your Suppliers ▪ Eliminating Waste ▪ Empowering workers ▪ Skill versatility ▪ Production scheduling ▪ Efficiency Control ▪ Using microprocessors ▪ Conservation of energy and Materials
(Goodson, 2002)	▪ Customer satisfaction	▪ Inventory management

	▪ Safety, Environmental, Cleanliness, Order ▪ Visual management ▪ Scheduling/Heijunka ▪ Flow and space	▪ Teamwork and motivation ▪ Condition and Maintenance ▪ Management of complexity ▪ Supplier focus ▪ Commitment to quality
(Shah & Ward, 2007)	▪ Supplier involvement ▪ Supplier Pull systems ▪ Supplier development ▪ Customer involvement ▪ Pull systems	▪ Flow ▪ Setup reduction ▪ Total Productive Maintenance ▪ Statistical Process Control ▪ Employee involvement
(Mann, 2005)	▪ Leader standard work ▪ Visual control - manufacturing ▪ Visual control – support ▪ Daily accountability process	▪ Root cause problem solving ▪ Process improvement ▪ Disciplined adherence to process ▪ Process definition

Table 2.12: Assessment of Lean Manufacturing audits found in the literature

Audit publication	Number of Lean Manufacturing characteristics audited	Assessment type*	Characteristic scoring method	Average number of individual questions per factor	Audit features
(Lockheed Martin, 2006)	7	2	Each question has a minimum score of 0 and a maximum score of 4 in units of 1	3	▪ Contains a list of "enablers" that are prerequisites for the development of the Lean factor. Contains recommended improvement actions. Results are audited on an audit radar
(Kobayashi, 1995)	20	1	Each characteristic has a minimum level of 0 and a maximum level of 5, in units of 1	N/A	▪ Contains recommended improvement actions. The idea is to progressively increase each level for each characteristic. Results are reported on an audit radar.
(Goodson, 2002)	11	1	Minimum score of 1 and maximum score of 11, in units of 2	N/A	▪ Audit also includes a separate 20 question "yes/no" style audit for quick assessment of plant, independent of categories. Results are totalled into one final score.
(Shah & Ward, 2007)	10	2	Each question has a minimum score of 0 and maximum of 1, measured as a % in units of 0.01	4	▪ Each category is measured as an average of each audit question within that category. No weighting is given. Results are reported on an audit radar
(Mann, 2005)	8	2	Each question spread across 4 Levels. Scoring method is at discretion of auditor but aggregating scores for each characteristic is recommended	7	▪ The audit focuses on specifically on Lean management practices. These differ from the traditional Lean characteristics in that the focus on the management of Lean systems. Results are reported on an audit radar

Note: Assessment type:
Type 1: Characteristics are measured by broad perception on a predefined scale
Type 2: Characteristics are measured by accumulation of points scored on various subsets of the factor. These subsets may be sub-categories or individual questions

Each of the Lean Manufacturing audits listed in Table 2.11 share the same basic features.

1. They each divide Lean Manufacturing into a set number of characteristics, typically 7 – 20.
2. A rating system to measure the extent of implementation of each Lean characteristic is used.
3. The rating system for each Lean characteristic is either directly measured by broad perception or measured through the accumulation or average of scores given for individual questions or sub categories.

The audits provide a measure of where an organization currently is in terms of a particular Lean Manufacturing characteristic and what it needs to do in order to attain the highest rating for that characteristic; a gap analysis of what needs to be improved in order to attain Lean Manufacturing best practice.

Various definitions are used for Lean Manufacturing characteristics in the above audits and thus the audits will give different results when assessing the degree of implementation of Lean Manufacturing in the same organization. These differences suggest that Lean Manufacturing audits inaccurately assess the implementation of Lean Manufacturing in an organization. Inaccurate assessments would jeopardize the successful implementation of Lean Manufacturing.

2.7 Relevance of this study

Research has shown that Lean Manufacturing does link to Operational Performance for a variety of operations management environments. This fact is not in question. The question is whether it is useful to use popular Lean Manufacturing characteristics to construct a Lean Manufacturing audit and use the results of the audit to Implement Lean Manufacturing that links to Operational Performance improvements through the implementation of those characteristics. To date there is no known study that addresses this specific question. Furthermore no known study exists which uses Structural Equation Modelling to compare the extent of implementation of Lean Manufacturing to Operational Performance.

The indication for an organization wishing to implement Lean Manufacturing and measure its progress through the use of a published audit is that there is no certainty that the Lean characteristics defined in the audit are truly reflective of best practice within that industry or operations management environment. This can create confusion and frustration. Furthermore if the results of the Lean Manufacturing audit do not correlate to Operational Performance, the organization may lose buy-in to Lean Manufacturing as a process improvement framework that drives Operational Performance improvement.

This research addresses the effectiveness of using a Lean Manufacturing audit to drive Operational Performance improvements using a case study of Lean audit results for a sample of sixty four organizations operating under a single company.

2.8 Conclusion

A literature survey has shown that in operations management environments Lean Manufacturing characteristics have been developed and defined. This is of practical value to those seeking to understand the tools and characteristics of Lean Manufacturing as opposed to the principals and philosophy. There are certain Lean characteristics that are commonly defined and measured across literature. Because of this they are seen as being strongly linked to the concept of Lean

Manufacturing. There are other characteristics that are only defined in a few publications and are seen as being weakly related to Lean Manufacturing. This research uses an audit framework that has all of its characteristics either strongly linked or moderately linked to Lean Manufacturing.

There are also Operational Performance measures associated with Lean Manufacturing. These measures are either strongly linked to Operational Performance relating to Lean Manufacturing or weakly linked. This is based on the number of publications on Lean Manufacturing and Operational Performance that mention those measures. This research uses Operational Performance measures that are strongly linked to Operational Performance relating to Lean Manufacturing.

Despite the wide variety of literature on Lean Manufacturing there are relatively few studies that focus on the link between Lean Manufacturing and Operational Performance. Those that do research the link between Lean Manufacturing and Operational Performance are focused on a single industry or define Lean characteristics differently to other studies that focus on the link between Lean Manufacturing and Operational Performance. There is a wide variety of literature relating the link between TQM, JIT and Operational Performance for all operations management environments but both TQM and JIT share different characteristics and approaches to Lean Manufacturing, despite being the process improvement forerunners from which Lean Manufacturing evolved (Holweg, 2006). The studies that do focus on the link between Lean Manufacturing and Operational Performance share the conclusion that Lean Manufacturing does improve Operational Performance provided the Operational Performance measurement framework is correct. Such frameworks include the use of non financial performance measures.

Research also provides examples of Lean Manufacturing audits to be used by organizations wishing to implement Lean Manufacturing. These auditing frameworks share the common purpose of measuring the current state of implementation of specific Lean Manufacturing characteristics and indicating where organizations must improve in order to be considered best in class for implementing Lean Manufacturing.

To date no research has addressed the question of whether it is useful to use a Lean Manufacturing audits, consisting of popular Lean Manufacturing characteristics, to drive Operational Performance improvements. This research addresses this question by using a defined research methodology to assess data from sixty four organizations assessed using a structured Lean Manufacturing audit and compare their audit results to their Operational Performance measures. The results provide insight into whether or not it is effective to use Lean Manufacturing audits to drive Operational Performance improvement and provide recommendations for those wishing to implement Lean Manufacturing.

3 Research methodology

3.1 Introduction

This research follows the research model outlined in "Empirical Research Methods in Operations Management" (Flynn, Sakakibara, Schroeder, Bates, & Flynn, 1990). The recommended research model follows a six step approach to researching and presenting results (see Figure 3.1).

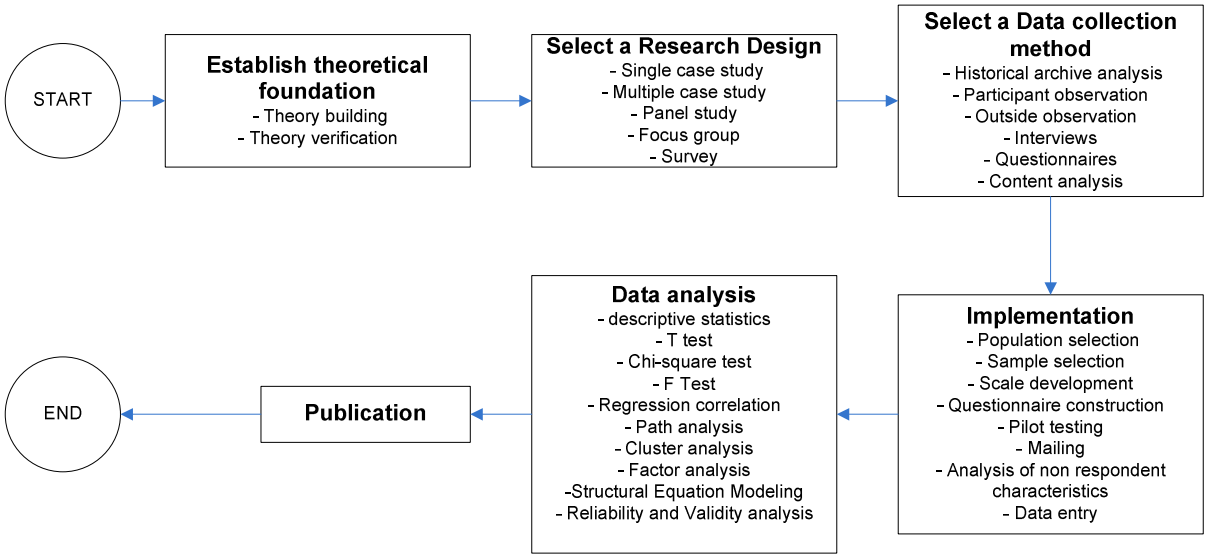

Figure 3.1: Empirical research model in Operations Management

3.2 Theoretical foundation

The research question in this research is:

Is there a positive correlation between the results of a Lean Manufacturing audit and Operational Performance?

The corresponding research hypothesis is as follows:

H_1 *: There exists a positive correlation between the results of a Lean Manufacturing audit and Operational Performance*

The corresponding null hypothesis is:

H_o *: There exists no correlation between the results of a Lean Manufacturing audit and Operational Performance*

The theory verification relating to the research question has been addressed in Chapter two

3.3 Research Design

The research design selected for this research is a combination of a multiple case study and an independent survey.

Data for this research is gathered through access to a database containing Lean Manufacturing audit scores reflecting the extent of implementation of Lean Manufacturing characteristics within a company comprising sixty four organizations operating in job shop and batch operations management environments. The database also contains Operational Performance measures from each organization. A survey would have provided the same information and as a result the study is additionally considered a survey in terms of research design.

Due to the low sample size (sixty four organizations) and because the database represents organizations of a similar type operating as part of one company, there is a risk that the results are too homogenous to be generally applicable. For this reason data relating to audit feedback is included into this research. This aspect represents a multiple case study. The multiple case study data is used to reinforce outcomes from the survey.

3.4 Data collection method

The data collection method selected is that of content analysis and outside observation.

Each organization is audited annually on the extent of implementation of Lean Manufacturing characteristics by pairs of independent, outside auditors using a structured Lean Manufacturing audit. The audit is based on a Lean Manufacturing best practice questionnaire that measures the extent of implementation of Lean Manufacturing across eleven defined Lean Manufacturing characteristics. In total the questionnaire covers seventy eight independent questions.

Data on Operational Performance of the organization is also gathered, and a report on the highlights and improvement points for each organization gathered during the audit is compiled.

3.5 Implementation

3.5.1 Population selection

The population for this research is confined to organizations operating job shop and batch environments in heavy industry. Every organization in the population is a part of the same company. The organization is the observation to be measured. The organization in this research is defined as a manufacturing operation or equivalent manufacturing related service operation. This is advantageous to the applicability of the research because although Lean Manufacturing is a strategic company wide approach many of its benefits occur at a manufacturing operations level (Flynn, Sakakibara, Schroeder, Bates, & Flynn, 1990). Typical output products and services from the population include mineral processing equipment, oil, gas and power processing equipment and repair and renovation services for common processing equipment relating to the minerals, oil & gas and nuclear & power industries.

3.5.2 Sample selection

Because this research focuses on a case study of one company, the sample is equivalent to the population. Table 3.1 through to Table 3.3 indicates the breakdown of the sample data into type of customer market (oil & gas, minerals and power & nuclear), type of organization (manufacturing or service), region, size and operations (casting, machining etc).

Table 3.1: Summary statistics on organization types

Type of market	Organization type		*Total*
	Manufacturing	Service	
Minerals equipment	25%	22%	**48%**
Oil & gas equipment	5%	19%	**22%**
Power & nuclear equipment	8%	21%	**29%**
Total	**38%**	**62%**	**100%**
Sample size: 64			

Table 3.2: Summary statistics on organization region and size

Region	Organization Size*			*Total*
	Small	**Medium**	**Large**	
North America	14%	16%	7%	**36%**
South America	3%	0%	2%	**5%**
Europe	9%	16%	5%	**29%**
Africa	0%	0%	3%	**3%**
Middle East	0%	5%	0%	**5%**
Asia	3%	7%	2%	**12%**
Australia	2%	5%	2%	**9%**
Total	**31%**	**48%**	**21%**	**100%**
Sample size: 58**				
***Note: Organization size is based on number of employees. Small = less than 50 employees, Medium = less than 200 employees, Large = greater than 200 employees** ****Sample size is 59 not 64 as 5 plants have insufficient published data to add to table**				

Table 3.3: Summary statistics on organization operation and type

Operation	Organization type		*Total*
	Manufacturing	**Service**	
Casting	2%	0%	**2%**
Machining	13%	14%	**27%**
Elastomer moulding	3%	0%	**3%**
Fabrication	4%	1%	**5%**
Assembly	13%	18%	**31%**
Warehousing & logistics	13%	18%	**31%**
Total	**49%**	**51%**	**100%**
Sample size: 58*			
***Sample size is 59 not 64 as 5 plants have insufficient published data to add to table**			

3.5.3 Questionnaire design and scale selection

The Lean Manufacturing audit questionnaire contains eleven Lean Manufacturing characteristics. Each characteristic has a number of questions relating to that characteristic. Table 3.4 provides a summary of the characteristics and number of questions.

Table 3.4: Lean Manufacturing characteristics defined in the Lean Manufacturing audit

Lean Manufacturing characteristic	Code	No of individual questions
Policy Deployment	LM01_PD	7
Cultural Awareness	LM02_CA	7
Visual management & housekeeping	LM03_VMH	8
Standardized Work	LM04_SW	8
Flexible Operations	LM05_FO	7
Continuous Improvement	LM06_CI	7
Error proofing	LM07_EP	8
Quick Changeover	LM08_QC	8
Total Productive Maintenance	LM09_TPM	6
Material Control	LM10_MC	6
Level production	LM11_LP	6
Total		***78***

Each question in the Lean Manufacturing audit questionnaire guides the auditor in terms of whom to ask the question to, where to look for evidence relating to the question and the type of improvement actions that would be evident should the answer show full implementation of the details of the question. The full audit questionnaire is available in Appendix A. Table 3.5 illustrates a typical Lean Manufacturing question contained in the audit questionnaire.

Table 3.5: Example of Lean audit question

Q#	Characteristic	Where to audit	How to audit	Whom to ask	Questions	Audit Score 0-4	Standard Improvement Actions & Expected practice
38	Error Proofing	shopfloor	walk around, observe	- observe - ask employees	Workers have been trained in the principles and methods of error proofing within the production process. There is a structured and regular analysis of production defects and identification of error proofing opportunities.		Train personnel on Poka Yoke (error proofing). Set up a team, for example Training and Continuous Improvement Team, or teams to review defects with view to install Poka Yoke to repeat concerns. It can be demonstrated that opportunities for error proofing have been studied (e.g. new process / product risks, analysis of quality performance and root causes), and error proofing actions defined and progress tracked.

The scale used to evaluate each question is a horizontal numeric scale. The scale ranges in intervals of 1 from 0 to 4. Table 3.6 illustrates the scale system in use for the Lean Manufacturing audit questionnaire. This scale is true for all Lean Manufacturing characteristics with the exception of Policy Deployment (LM01_PD). For Policy Deployment the questionnaire contains a separate guide for each of the seven questions assessing the implementation of Policy Deployment. The guide details levels, ranging from zero to four, for each question. Each level has a description of characteristics that are needed in order to score a specific level for a specific question. Details of the Policy Deployment guide of the Lean Manufacturing audit are given in Appendix A.

Table 3.6: Scale definition of Lean Manufacturing audit questionnaire

Scale No	Interpretation
0	No implementation evident at all
1	Question has been implemented in at least 25% of operations
2	Question has been implemented in at least 50% of operations
3	Question has been implemented in at least 75% of operations
4	Question is fully implemented in all operations, without exception

Details of the Operational Performance measures are converted into a numeric scale ranging from one to eight. Each Operational Performance measure has only one question related to it and the scale from one to eight is nonlinear. Table 3.7 provides a summary of the Operational Performance measures. Table 3.8, Table 3.9 and Table 3.10 give details of the scales used for the three Operational Performance measures.

Table 3.7: Operational Performance measures

Operational Performance characteristic	Code	No of individual questions
Inventory Turns	OP01_IT	1
Direct Labour Efficiency	OP02_DLE	1
On-Time-Delivery	OP03_OTD	1
Total		***3***

Table 3.8: OTD scoring table

Average Monthly OTD (%) in the last 6 months	Score
98% or higher`	8
95 – 97 %	7
91 – 95 %	6
86 – 90 %	5
81 – 85 %	4
71 – 80 %	3
61 – 70 %	2
51 – 60 %	1
< 50 %	0

Table 3.9: Direct Labour Efficiency scoring table

Average Plant Direct Labour Utilisation (%) in the last 6 months	Score
>90%	8
86 – 90 %	6
76 – 85 %	4
61 – 75 %	2
<60%	0

Table 3.10: Inventory turns scoring table

Number of inventory turns > = group target over last 8 months	Score
8	8
7	7
6	6
5	5
4	4
3	3
2	2
1	1
0	0

Details on the operational definitions for each Operational Performance measure are contained in Appendix B.

The data from each audit is uploaded into a central database and controlled by a master administrator, who performs an analysis on the integrity of the data. The audits are administered electronically and are constructed in such a way as to prevent the input of data scales that are not predefined on the audit. The audit also does not allow for missing data.

3.6 Data analysis

The data analysis technique chosen for this research is Structural Equation Modelling (SEM).

SEM is a technique that is able to specify, estimate and evaluate models of linear relationships among a set of observed variables in terms of a generally smaller number of unobserved variables (Shah & Goldstein, 2006). SEM models contain observed variables (referred to as Manifest Variables

or MV's for short) and unobserved variables (also known as underlying latent variables or LV's for short). LV's are hypothetical constructs that cannot be directly measured (Shah & Goldstein, 2006). Multiple MV's will represent an underlying LV.

SEM models represent an a priori hypothesis about a pattern of linear relationships among a set of MV's and their LV's. The objective when using SEM is to determine the model validity rather than to find a new model.

SEM has become attractive to operations management research as it is able to find unobserved latent variables from observed measurement variables and it is furthermore able to detail the strength of relationships between measurement and latent variables and among latent variables. This approach is advantageous for operations management research, which often tries to find or verify relationships between underlying constructs from a given set of observed measurements in an environment that is not easy to measure and observe mechanistically. (Shah & Goldstein, 2006). This is similar to the Lean Manufacturing audit in which Lean Manufacturing characteristics are measured so as to quantify the underlying degree of implementation of Lean Manufacturing. This is the first known study to use SEM in reference to Lean Manufacturing and its impact on Operational Performance.

This research uses the combined approaches suggested in "Use of structural modelling in operations management" (Shah & Goldstein, 2006) and "Structural Equation Modelling in Practice: A review and recommended two step approach" (Anderson & Gerbing, 1988). Both approaches recommend a two step approach to SEM.

In the first step the measurement model is defined by taking the theoretical a priori model, overlaying the data onto the model and assessing what is left over. If the data fits the measurement model perfectly (a so called ideal fit) then there should be no residuals left over and goodness of fit tests should indicate a high degree of fit. In reality it is difficult to obtain an ideal fit and the process of defining the measurement model is iterative in that the researcher adds and deletes MV's, LV's and casual relationships between the two until the measurement model approaches an ideal fit without significantly compromising the theoretical a priori model .

The second step is to define the structural model, which measures the relationships between LV's. Since most operations management research is based around ascertaining relationships between hypothetical constructs such as Lean Manufacturing and Operational Performance, the structural model is the model that is of interest. For simple relationships, there is no iterative process in assessing the structural model and the results of the model, usually the strength of the path relationships between various LV's are used to draw conclusions from the research. The full model, known as the theoretical model, is a combination of the structural and measurement models.

The two step approach described above differs in detail, depending on which data analysis package is used. This research uses the Statistical Analysis Software (SAS) package to do all data analysis. For this approach detail data analysis has been conducted along the guidelines suggested by "A Step by step approach to using SAS for Factor Analysis and Structural Equation Modelling" (Hatcher, 1994).

The data analysis follows the following basic steps:

- Pre Analysis
- Data screening
- Assessing the measurement model
- Assessing the structural model

Figure 3.2 provides the overall process flow for the data analysis.

Data analysis was conducted using Statistical Application Software (SAS) version 9.1. The programming algorithms contained in this research are unique to SAS

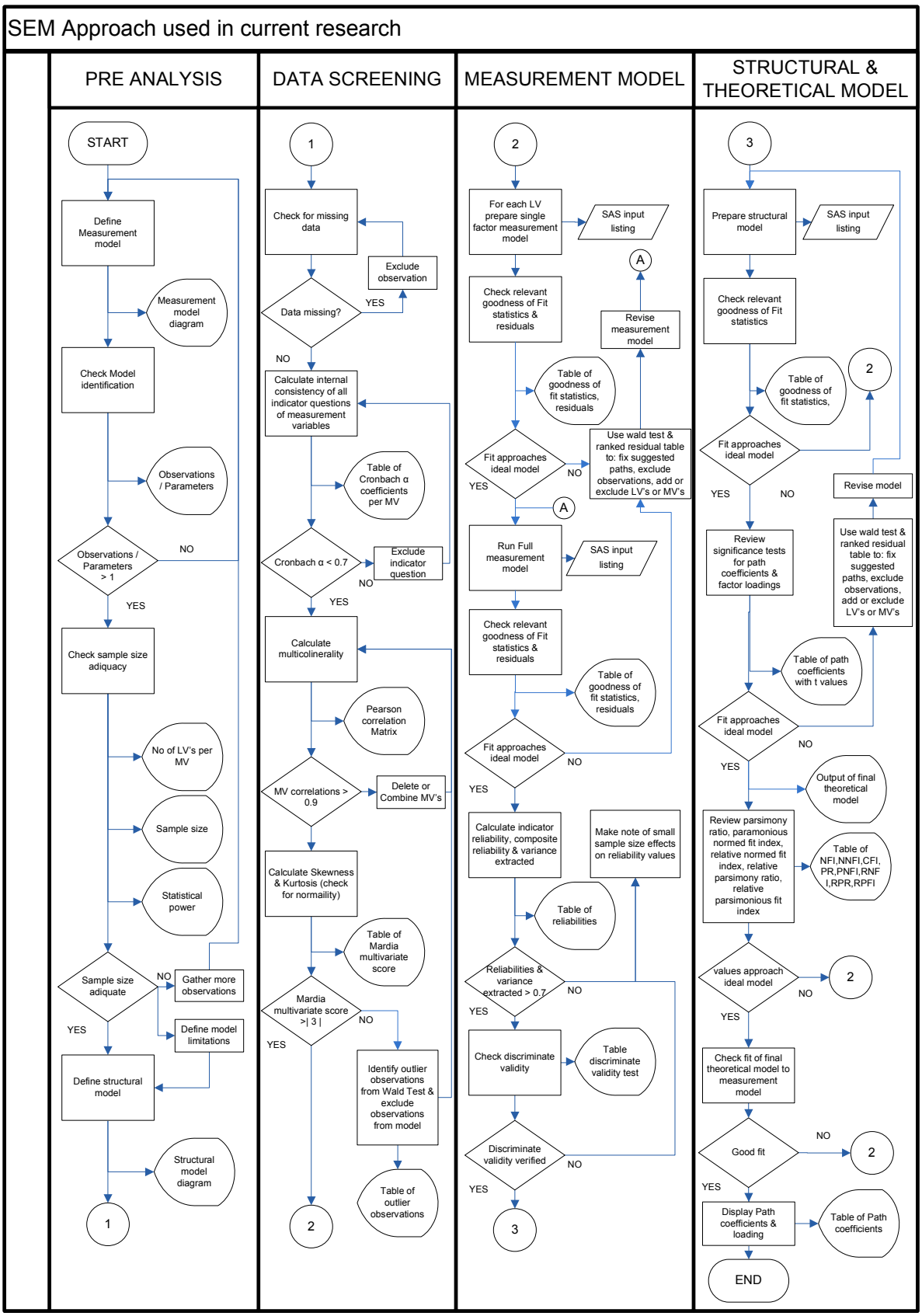

Figure 3.2: Process flow for data analysis of research data

3.6.1 Pre-analysis

3.6.1.1 Defining the measurement model

The pre-analysis consists of defining the scope of the research model. The first step is defining the a priori measurement model. Figure 3.3 illustrates a simplistic two factor measurement model, similar to the model used in this research.

For measurement models no directional relationship between factors is defined and they are allowed to co-vary (as indicated by the double headed arrow between LV's). An LV will have an effect on an MV, which is why the single headed arrows point out from the LV to the MV's. Measurement errors (ME's) also have an effect on MV's. The strength of the relationship between an LV and an MV is denoted by a path coefficient ($L_{(MVX)(LVY)}$).

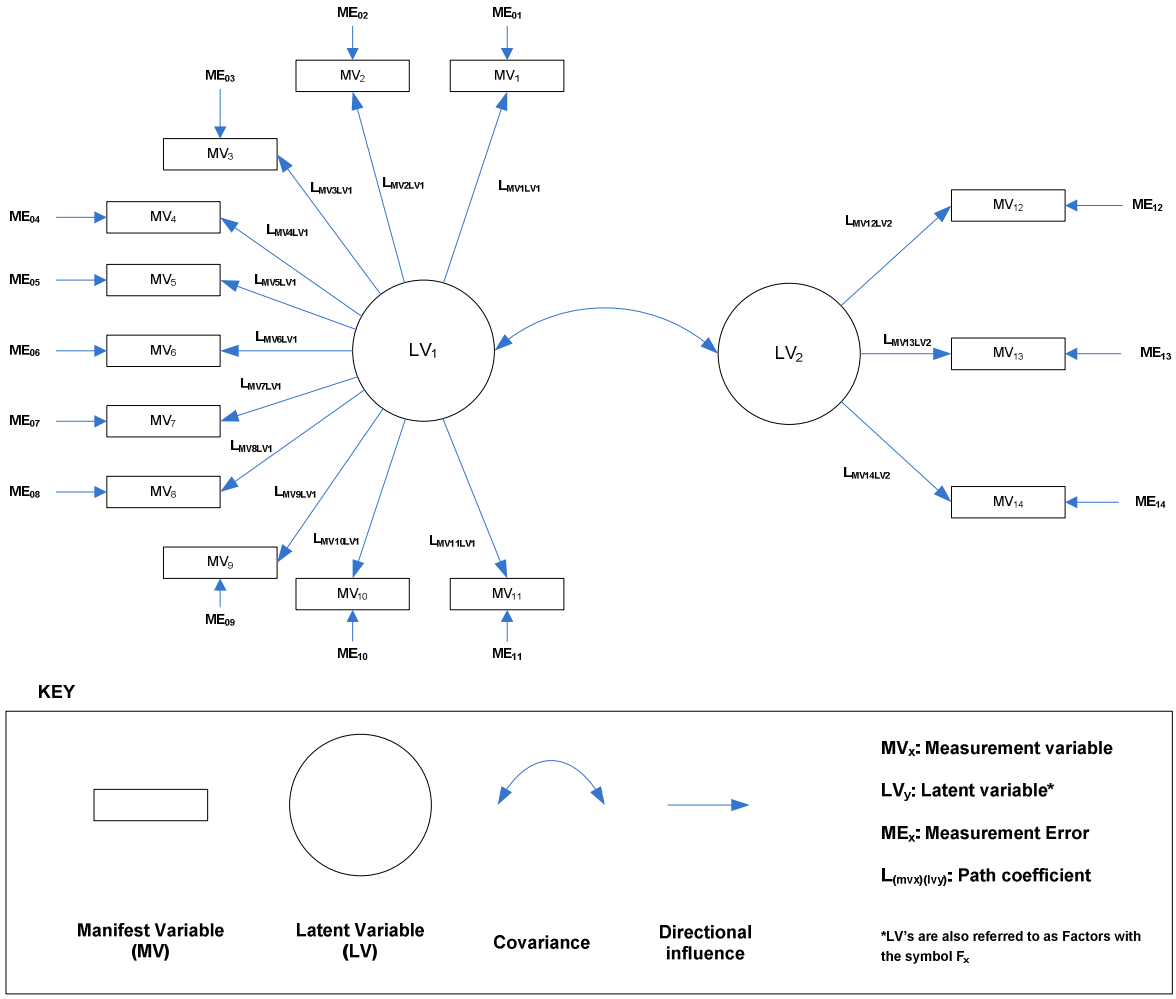

Figure 3.3: Simplistic two factor measurement model

The measurement model in Figure 3.3 is described in terms of structural equations. A typical listing is given in Equation 3.1

$$MV_x = L_{mvxlvy} \times LV_y + E_x \qquad (3.1)$$

After the measurement model has been formulated, the model needs to be defined i.e. analyzed if the equation set has a unique solution. Model identification is determined by dividing the number of observations by the number of parameters. The resultant ratio must be greater than or equal to one.

The number of observations is given by equation 3.2 (Shah & Goldstein, 2006)

$$Observations = \frac{v(v+1)}{2} \qquad (3.2)$$

Where v is the number of MV's contained in the measurement model. The definition of the term *Observations* as used in equation 3.2 is specific to equation 3.2 and is not to be confused with the general meaning of *observations* in this research, which is taken to mean the data gathered from a particular organization.

The number of parameters is defined by the number of directional influence paths and covariance's of latent variables, measurement error terms and factor loadings (Shah & Goldstein, 2006). The model identification criterion is given in Equation 3.3

$$Model\ Identification\ Criterion = \frac{Observations}{Paramaters} \geq 1 \qquad (3.3)$$

3.6.1.2 Determining sample size adequacy

Once the model identification has been assessed the next step is to determine whether the sample size is adequate. SEM models used in Operations Management research up until 2006 have had average sample size of two hundred and two observations with a maximum of eight hundred and forty observations and a minimum of fifty two observations (Shah & Goldstein, 2006). Sample size has a significant impact on the reliability of parameter estimates and model fit. Smaller sample sizes are generally characterized by parameter estimates with low reliability, greater bias in goodness of fit tests and RMSEA fit statistics and greater uncertainty in future replication (Shah & Goldstein, 2006).

There is no blanket limit on the minimum sample size to use because the reliability of results is also dependant on the number of MV's per LV as well as the sample size to parameter ratio. SEM models used in Operations Management research up until 2006 have had an average of 4.1 MV's per LV with a low of one. Shah and Goldstein determined that the average sample size to parameter ratio is 7.4 with a low of 1.6. Generally the reliability of results may be an issue if the sample size to parameter ratio is less than five (Shah & Goldstein, 2006).

An important test for determining sample adequacy is power analysis; a technique for determining the minimum sample size needed to ensure reliability of results. The use of power analysis minimizes the chance of making a type one error, i.e. rejecting the null hypothesis based on a sample when in fact it is accepted for a population (Montgomery, Runger, & Hubele, 2004). A statistical power of 0.8 or above is acceptable for ensuring a sample size is representative and reliable (Shah & Goldstein, 2006). Estimating the required sample size for SEM models is done via SEM sample size algorithms written for SAS. These sample size algorithms are based on research into sample determination for covariance structure modeling (MacCallum, Browne, & Sugawara, 1996).

3.6.1.3 *Defining the structural model*

The purpose of the structural model is to define not the shape of the model (as in the case of the measurement model) but rather the relationship between LV's in the measurement model. Figure 3.4 illustrates a typical two factor structural model.

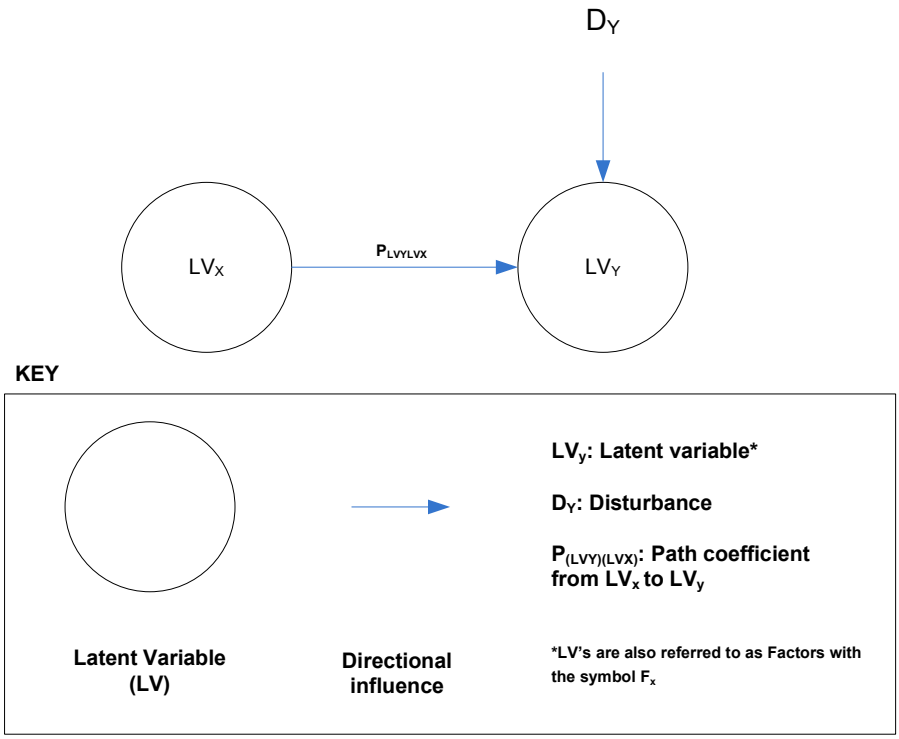

Figure 3.4: Typical 2 factor structural model

As with the measurement model, the structural model is described in terms of linear equations. Equation 3.4 gives a generic example of a linear equation describing the structural model.

$$LV_Y = P_{LVYLVX} \times LV_X + D_Y \qquad (3.4)$$

The LV's in the structural model are either endogenous or exogenous. Endogenous LV's are the result of exogenous LV's and conversely exogenous LV's cause endogenous LV's. The description is analogous to independent (exogenous) and dependant (endogenous) variables in simple linear regression (Hatcher, 1994). A path coefficient P_{LVYLVX} describes the strength of the directional relationship from an LV to another LV. The path coefficient is of ultimate interest as it reports the strength of relationships between LV's (hypothetical constructs) in a research model. A disturbance term (D_Y) describes the measurement error that may affect the structural model. This measurement error arises from factors that cannot be accounted for by the research model.

3.6.2 Data screening

Before any core analysis can be performed the sample data needs to be screened to identify and control for the effect caused by outliers, missing data or data that is non-normal.

There is a wide array of techniques used to handle data with missing items. Because the data collection method used in this research is of the form of independent auditors and the questionnaire design does not allow for missing data, the data set does not contain any missing data. Thus there is no need to use missing data techniques in this analysis.

The next step is to calculate the internal consistency of all indicator variables used to define the MV's. In this research the MV's are categorised into two types: single measurements and multiple measurements.

Since the indicator variables load onto MV's and MV's load onto LV's it could be argued that the measurement model is a second order model. However, for the purposes of this research it is decided to use the average response values from the indicator variables to construct the value for the MV in cases where multiple indicator variables load onto a MV. This approach simplifies the analysis without compromising the measurement model. This approach is possible because:

1. The indicator variables, in the form of Lean Manufacturing audit questions, are measured on a standardized numeric scale. This enables their scores to be aggregated for a specific MV. The average value becomes the response value for the MV.
2. Each MV has been clearly defined in the Lean Manufacturing audit questionnaire, making the structure between indicator variables and MV's clear.

In order to adopt the above approach it is necessary to confirm that all seventy eight indicator variables measure their underlying MV's. This is known as discriminate validity. Each indicator measures only the MV that it was designed to measure. Cronbach's α was used as a measure of reliability for the validity test. The rejection criterion was set at 0.7 (Hatcher, 1994). The reliability of the seventy eight indicator variables is measured using the PROC CALIS algorithm in SAS, with the ALPHA option selected. A full listing of the input program is contained in Appendix C. This analysis produces a table similar to Table 3.11. An "OK" - for all Manifest variables in Table 3.11 indicates that all seventy eight questions used by the Lean Manufacturing audit act as reliable measures of the underlying Lean Manufacturing characteristic or MV.

Table 3.11: Output table for indicator reliability

Manifest variable	No of indicators	Minimum indicator Cronbach's α (standardized variables)	Result (OK /NOK)*
LM01_PD	7		
LM02_CA	7		
LM03_VMH	8		
LM04_SW	8		
LM05_FO	7		
LM06_CI	7		
LM07_EP	8		
LM08_QC	8		
LM09_TPM	6		
LM10_MC	6		
LM11_LP	6		
***Note: A result of "OK" is only given if the minimum of all indicator Cronbach's α is > 0.7. This shows that the set of indicator variables reliably loads onto the Manifest variable**			

Multicollinearity occurs when two or more MV's correlate with each other to such a degree that they can practically be combined into a single MV. A correlation coefficient of 0.9 or greater has been defined as indicating Multicollinearity (Hatcher, 1994). Multicollinearity can be assessed by calculating a correlation matrix for all MV's. Pearson correlations are used to assess Multicollinearity using the PROC CORR algorithm in SAS. The standardized output of the SAS algorithm produces a correlation table for all MV's. If any correlation between two MV's is greater than 0.9 it is flagged.

SEM analysis requires that the data sample is normal. Kurtosis and skewness (refer to Figure 3.5) are used to measure the normality of the data.

Kurtosis measures the spread of data relative to a normal distribution and it looks at the standard deviation of a data set. A low standard deviation indicates data that mostly falls into a specific range. This could mean that the range intervals are too broadly defined, such that all responses fall into it, or that the sample data contains lots of non response values. A high degree of kurtosis indicates that the data is unsuitable for statistical analysis. Absolute values of kurtosis above 2.0 indicate non-normal data (Hatcher, 1994).

Skewness measures the deviation of the data median relative to its mean (Hatcher, 1994). The measure reflects how the data is distributed relative to a normal distribution, which is centred symmetrically. Absolute values of skewness above 2.0 indicate non-normal data (Hatcher, 1994).

In general non-normality can be assessed in SAS using Mardia's *Normalized* multivariate score. If the value of the score is above 3.0, then the data is assumed to be non-normal (Lee, 2009).

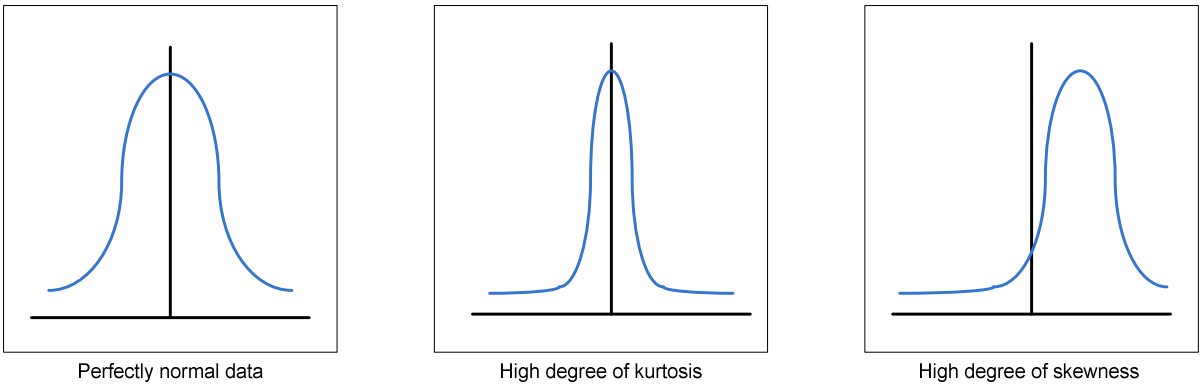

Figure 3.5: Illustration of Skewness and Kurtosis

Kurtosis, skewness and Mardia's *Normalized* multivariate score are calculated using PROCA CALIS in SAS.

The PROC CALIS algorithm in SAS is used to determine if any outlying observations are causing non-normality. Observations containing outliers are excluded from the analysis as illustrated in Figure 3.2.

3.6.3 Assessment of the measurement model

An iterative process is followed in which MV's LV's and their path coefficients are specified until the measurement model provides a solution which best fits the data.

The first step in assessing the measurement model is to determine whether or not MV's measure their LV's i.e. show that the MV's show discriminate validity (Lee, 2009). To do this it is necessary to construct a single LV model for each LV using PROC CALIS in SAS. This model is referred to as a single factor model.

In order for a single factor model to be considered representative of the data it must fit the criteria outlined in Table 3.12 (Hatcher, 1994) (Shah & Goldstein, 2006).

Table 3.12: Ideal fit criteria

Category	Measure	Ideal value
Descriptive statistics	Mardia's *Normalized* multivariate score	<3*
Goodness of fit statistics	*p* value	>0.05
	chi-square / *df* ratio	<2
	Comparative fit index (CFI)	>0.9
	Non normed fit index (NNFI)	>0.9
	Normed fit index (NFI)	>0.9
	Root Mean Square Error of Approximation (RMSEA)	<0.1
Path coefficients	*t* value**	>1.96
Residuals between data and measurement model	Ranked normalized residuals	<=2
***Note: Value based on (Lee, 2009) **Note: use of the t test is dependant on a large sample size. For small sample sizes the test is not meaningful.**		

The measures contained in Table 3.12 are standard outputs for PROC CALIS. If each single LV model satisfies the criteria contained in Table 3.12 then the full measurement model can be constructed.

Satisfying all the ideal fit criteria given in Table 3.12 is very difficult for most models (Hatcher, 1994). Thus most research focuses only on using common indicators such as RMSEA and chi-square /*df* ratio to determine model fit (Shah & Goldstein, 2006). Some models have been deemed acceptable having failed this reduced criteria set. Successful measurement models may deviate by the criteria by up to 15% (Lee, 2009). In general the criteria in Table 3.12 give a robust guide for an ideal fit.

If the full measurement model satisfies the ideal fit criteria then the next step is to calculate the overall reliabilities and validities of all LV's and MV's. This is done through the calculation of four separate indicators (Hatcher, 1994):

- Indicator reliability
- Composite reliability
- Variance extracted
- Convergent and discriminant validity

3.6.3.1 Indicator reliability

Indicator reliability is defined as the square of the correlation between a LV and a MV. The reliability indicates the percentage of variation in a MV that is explained by a LV (Hatcher, 1994). The PROC CALIS algorithm in SAS outputs indicator reliabilities as standard outputs labelled as R^2 values.

3.6.3.2 Composite reliability

Composite reliability measures the internal consistency of all MV's in measuring a given LV. It is similar to Cronbach's α for measuring multi item scales (Hatcher, 1994). Composite reliability can be calculated using equation 3.5

$$Composite\ reliability = \frac{(\sum L_i)^2}{(\sum L_i)^2 + \sum Var(E_i)} \qquad (3.5)$$

Where

L_i = *The standardized loadings for that LV*

$Var(E_i)$ = *The error variances associated with the individual indicator variables*

3.6.3.3 Variance extracted estimate

The variance extracted estimate is defined as the amount of variance that is captured by a LV in relation to the amount of variance due to measurement error. Equation 3.6 illustrates the calculation for variance extracted:

$$Variance\ extracted\ estimate = \frac{\sum L_i{}^2}{\sum L_i{}^2 + \sum Var(E_i)} \qquad (3.6)$$

3.6.3.4 Convergent and discriminant validity

Convergent validity is demonstrated if all MV's of a LV are strongly correlated. This indicates they are measuring the same underlying construct. Convergent validity is assessed using the significance of the t values for each path coefficient between MV's and their LV's (Hatcher, 1994).

Discriminant validity is measured by comparing the unconstrained measurement model (a measurement model in which all LV's are allowed to co-vary) and the constrained measurement model (a model in which all factors are set to one). The unconstrained model is the standard measurement model. Discriminant validity is determined by calculating the difference in the chi-square values for each model calculated using the PROC CALIS algorithm in SAS. If the chi-square value of constrained model minus the unconstrained model is significantly positive (indicating the chi-square value for the unconstrained model is lower than that of the constrained model), then discriminant validity is demonstrated. This is because the results indicate that an unconstrained model (measurement model) fits the data better than an artificially constrained model and thus does not measure anything it was not supposed to measure (Hatcher, 1994).

3.6.3.5 Interpreting reliability and validity results

The results for reliability are displayed in a table similar to Table 3.13. Reliability and variance extracted estimate values that are close to one are considered ideal.

Table 3.13: Typical output for reliability analysis

LV and MV's	**Standardized loading**	***t* value**	**reliability**	**Variance extracted estimate**
Ideal vale	-	>1.96	>0.7	>0.7
LV_x			**CR_x**	**$LVES_x$**
MV_x	SL_x	t_x	R_x^2	VES_x
MV_{x+1}	SL_{x+1}	t_{x+1}	$R_{x+1}{}^2$	VES_{x+1}

For reliability and Variance Extracted Estimates, values that are close to one are considered ideal.

Convergent validity is demonstrated if all measured t values are significant (Hatcher, 1994); greater than 1.96 is assumed significant as shown. Discriminant validity is demonstrated if the difference in chi-square value of the constrained model minus the unconstrained model is significantly positive.

The convergent and discriminant validity test formats are summarized in Table 3.14.

Table 3.14: Table illustrating convergent and discriminate validity

Characteristic	Measure	Ideal value	Measured value
Convergent validity	Minimum of all measured *t* values	>1.96	
Discriminant validity	chi-square of unconstrained model – chi-square of constrained model	>0	

3.6.4 Assessment of structural model

Assessment of the structural model undergoes the same basic procedure as that of the measurement model; only the emphasis is on the directional influences between exogenous and endogenous LV's.

The structural model needs to satisfy the criteria listed in Table 3.12. If the model does not satisfy the criteria in Table 3.12 then the relationships between LV's must be reviewed and in some instances either allowed to co-vary or to be severed (Lee, 2009).

If the structural model satisfies the criteria in Table 3.12 it has in effect become the final theoretical model. The measurement aspect of this model specifies the relationship between LV's and MV's while the structural aspect of this model specifies the relationship between LV's.

3.6.4.1 Reviewing parsimony indices

It is desirable for the final theoretical model to describe the theoretical relationships between LV's as simplistically as possible i.e. the theoretical model should contain the minimum number of covariance relationships and directional influence paths as is needed to describe the theory. Additional paths and covariance relationships complicate the model. This is referred to as parsimony (Hatcher, 1994) and is an important aspect in reviewing the final theoretical model. There are two indices that describe parsimony for the theoretical model and three that describe parsimony for the structural model only. The indices are as follows:

- Theoretical model
  - Parsimony ratio (PR)
  - Parsimonious fit index (PNFI)
- Structural model only
  - Relative normed fit index (RNFI)
  - Relative parsimony ratio (RPR)
  - Relative parsimony fit index (RPFI)

Parsimony ratio (PR)

The parsimony ratio is calculated using equation 3.7.

$$PR = \frac{df_J}{df_0} \qquad (3.7)$$

Where

df_J = Degrees of freedom for the model being studied

df_0=Degrees of freedom for the null model

df_j is a standard output of the final model analysis in SAS. df_0 is also an output of SAS and is shown in the same table where df_j is displayed. The closer the PR is to one the better the parsimony of the model.

Parsimonious fit index (PNFI)

The parsimonious fit index (PNFI) combines the PR with the normed fit index (a required criterion listed in Table 3.12). The combined index measures both the fit of the model as well as its parsimony. The purpose of the index is to ensure that neither the PR nor NFI are increased at the expense of the other. The PNFI is calculated using equation 3.8

$$PNFI = PR \times NFI \qquad (3.8)$$

Relative normed fit index (RNFI)

In cases where the measurement model consists of a large number of MV's relative to LV's and the structural model consists of relatively few LV's, the theoretical model (which is a combination of the two) is likely to display goodness of fit statistics in Table 3.12 that are heavily influenced by the measurement model. This is because there are so many more directional influences in the measurement model compared to the structural model. The risk of this is that the theoretical model may display favourable goodness of fit statistics even though the structural portion of the model (which is of interest to research) is not specified correctly. The relative normed fit index (RNFI) addresses this issue. The RNFI determines the fit of just the structural portion of the model as given by equation 3.9.

$$RNFI = \frac{F_u - F_j}{F_u - F_m - (df_j - df_m)} \qquad (3.9)$$

Where

F_u = model chi-square for the uncorrelated variables model

F_j = model chi-square for the theoretical model

F_m = model chi-square for the measurement model

df_m = Degrees of freedom for the measurement model

The RNFI should be greater than 0.9 and as close to 1.0 as possible (Hatcher, 1994).

Relative parsimonious ratio (RPR)

The relative parsimonious ratio (RPR) as given in equation 3.10 is the measure of parsimony accounted for by the structural model alone.

$$RPR = \frac{df_j - df_m}{df_u - df_m} \qquad (3.10)$$

Where

df_u=Degrees of freedom for the null model

The closer this ratio is to one the better.

Relative parsimonious fit index (RPFI)

The relative parsimonious fit index as given in equation 3.11 provides information about the fit for just the structural portion of the model.

$$RPFI = RNFI\ X\ RPR \qquad (3.11)$$

The closer the RPFI is to one, the better.

Reviewing parsimonious indices results

The indices are best viewed in a table such as Table 3.15.

Table 3.15: Illustration of Parsimony indices results

Item	Model	Theoretical model							Structural Model		
		chi-square	df	NFI	NNFI	CFI	PR	PNFI	RNFI	RPR	RPFI
M_o	Null model				-	-	-	-	-	-	-
M_u	Uncorrelated model										
M_t	Theoretical model										
M_m	Measurement model										

Note: NFI = Normed Fit Index; NNFI = Non Normed Fit Index; CFI = Comparative Fit Index; PR = Parsimony Ratio; PNFI = Parsimonious Normed Fit Index; RNFI = Relative Normed Fit Index; RPR = Relative Parsimony Ratio; RPFI = Relative Parsimonious Fit Index

3.6.4.2 Reviewing fit of theoretical model to measurement model

The process of reviewing the fit between the theoretical model and the measurement model is the final step in verifying the validity of the theoretical model. Some indication of fit will have arisen from Table 3.15. The final measurement of fit can be determined by performing a chi-square difference test on the theoretical model to the measurement model. A lack of significant difference between the two models proves that the theoretical model accounts for both the relationships between LV's and MV's and among LV's. Equation 3.12 and 3.13 are used to calculate the chi-square difference test

$$Chi - square\ difference = M_t - M_m \qquad (3.12)$$

$$Degree\ of\ freedom\ difference = df_t - df_m \qquad (3.13)$$

The critical value of chi-square for the calculated degrees of the freedom at a *p* value less than 0.001 is available in statistics reference tables (Montgomery, Runger, & Hubele, 2004). If the value of the chi-square difference tests exceeds the critical value then the theoretical model is not properly specified.

3.7 Conclusion

The research methodology presents a structured approach to addressing the research problem using well defined operations research techniques. The research design is a combination of a survey and multiple case studies due to the fact that a Lean Manufacturing audit questionnaire has been used to gather data in conjunction with feedback of organization Lean implementation in the form of a report. The audit questionnaire is administered by external auditors for each organisation.

The population of organizations undergoing the analysis is confined to heavy industry located in a multiple countries and serving at least three different markets. The organizations operate in job

shop and batch operations management environments. A significant number of organizations operate as service and repair centres. The organizations all form part of one company.

The Lean Manufacturing audit is conducted using a horizontal numeric scale to indicate the degree of implementation of a specific Lean Manufacturing question. The Lean Manufacturing audit questionnaire measures seventy eight individual questions that are linked to eleven Lean Manufacturing characteristics. The Lean Manufacturing audit questionnaire also gathers data on four key Operational Performance measures. The nature of the audit ensures that there is no missing data.

Structural Equation Modelling (SEM) is used to determine the relationship between Lean Manufacturing implementation and Operation Performance characteristics due to its strength in measuring the relationship between hypothetical constructs based on measurements from directly observable indicators. Its growing use in operations management research also contributes to the selection of this form of analysis. The analysis consists of a two step approach of first defining the measurement model and then assessing the structural model. The measurement model assesses the degree to which the research data supports a given relationship between observable variables (also known as Manifest Variables or MV's) and hypothetical constructs (also known as Latent Variables or LV's). The structural model assesses the relationship among LV's. Together the two models combine to form the theoretical model. The theoretical model must satisfy a range of criteria if it is to represent that data used in the research.

The process of specifying and re-specifying both the measurement model and the final model is iterative and eventually results in a theoretical model that supports that data and the research question. If the theoretical model does not support the research question then the null hypothesis must be accepted.

The next chapter deals with the results of the analysis on the research data.

4 Results

4.1 Pre-analysis

4.1.1 Defining the measurement model

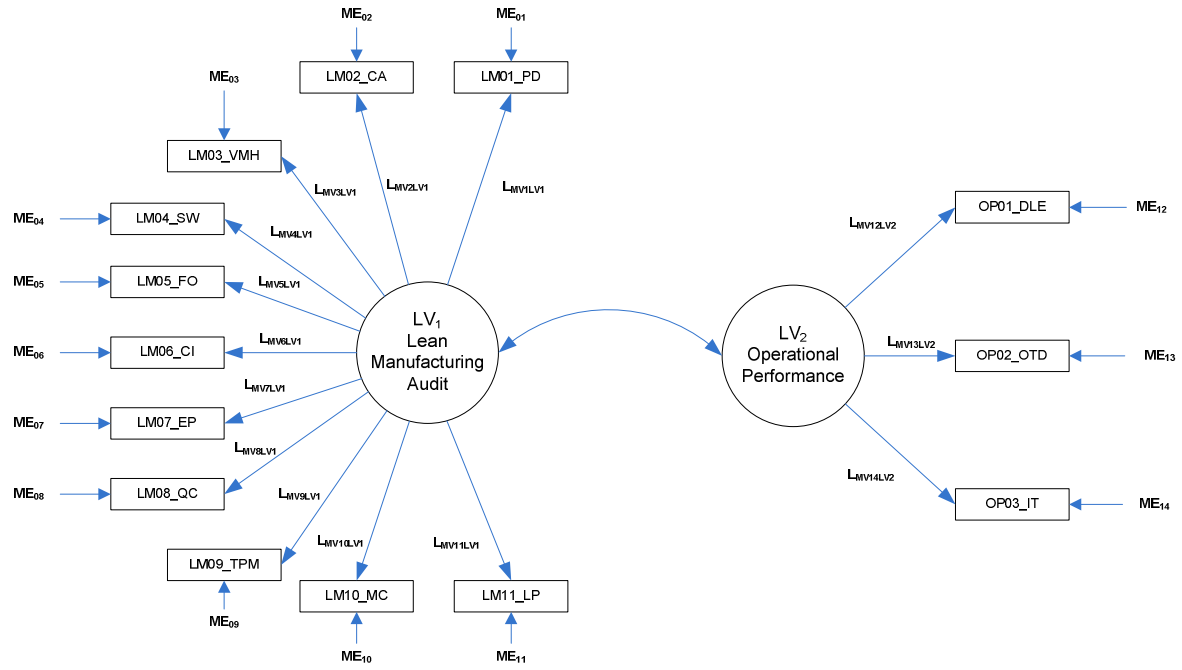

Figure 4.1: a priori measurement model

Figure 4.1 illustrates the measurement model hypothesised in this research. The Lean Manufacturing audit consists of eleven distinct Lean Manufacturing characteristics. These are Policy Deployment, Cultural Awareness, Visual Management & Housekeeping, Standardized Work, Flexible Operations, Continuous Improvement, Error Proofing, Quick Changeover, Total Productive Maintenance, Material Control and Level Production. These characteristics are all features of the underlying latent construct, which is the Lean Manufacturing audit. The Lean Manufacturing audit co-varies with the second latent construct, which is Operational Performance. This construct manifests itself in three measurable variables. These are On-Time-Delivery, Direct Labour Efficiency and Inventory turns.

Table 4.1 illustrates that the measurement model is safely over identified.

Table 4.1: Model identification

Model	No. Of observations	No. of parameters	Model Identification ratio	Result
A priori measurement model	105	29	3.62	Over identified

4.1.2 Determining sample size adequacy

Figure 4.2 illustrates that for the type of SEM models used in this research, the required sample size needed to ensure an adequate statistical power of 0.8 is over ninety seven with an RMSEA fit of 0.1 as criteria for accepting H_o. Since the actual sample size is sixty four, the power analysis suggests that the sample size may be inadequate. Increasing the RMSEA criteria to 0.12 will ensure that the sample size is adequate for the research. The higher RMSEA value decreases the goodness of fit accuracy required by the model to the data. However, certain SEM research has had RMSEA acceptance criteria up to 0.13 (Shah & Goldstein, 2006).

The sample size in this research is low compared to typical SEM research, which has an average sample size two hundred and two (Shah & Goldstein, 2006) . This means that the sample size will affect the reliability of the fit statistics. The sample size used in this research is not the lowest encountered for SEM in Operations Management research. This number is fifty three (Shah & Goldstein, 2006). The degrees of freedom of fifty (*df*) chosen in Figure 4.2 are done so based on pilot tests of SEM measurement models in this research.

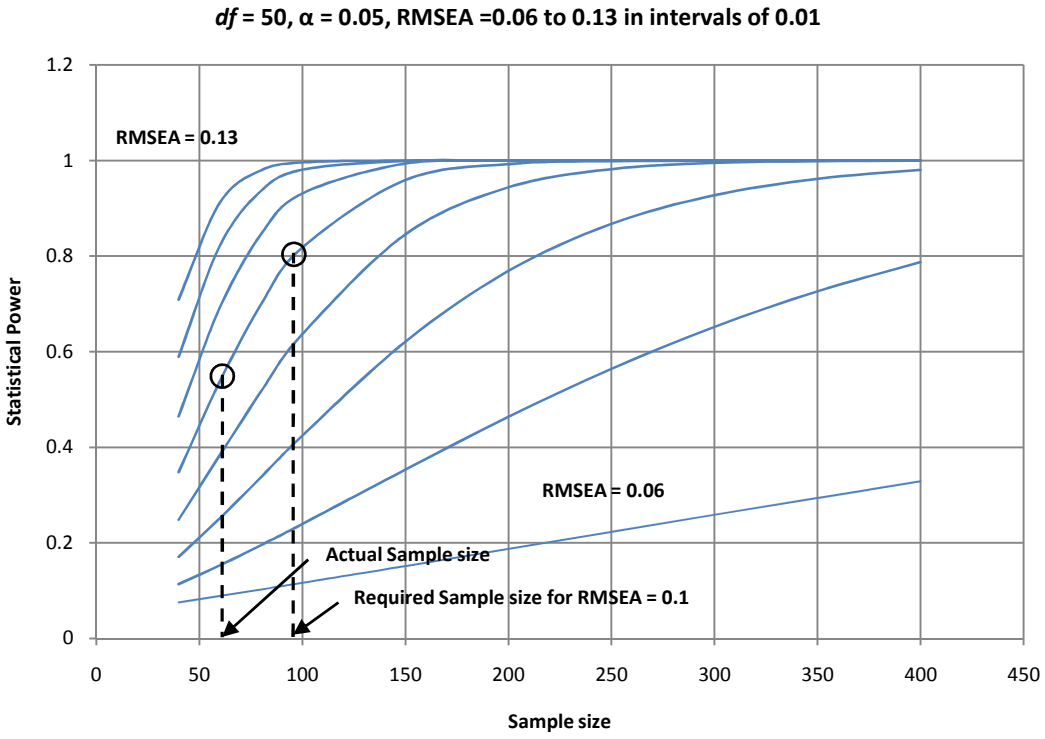

Figure 4.2: Power analysis graph for current SEM model

The average number of MV's loading on an LV is 7. This is above the recommended value (Shah & Goldstein, 2006) and compensates to a degree for the low sample size. The sample size to parameter ratio is 2.1, which is below the average value of 7.4 used in SEM research models.

The results of Figure 4.2 (low sample size) and the below average sample size to parameter ratio indicate that the results may not be reliable. However, the sample size used contains more than the minimum sample size used in SEM research found in the literature (Shah & Goldstein, 2006). This indicates that while the small sample size raises questions about the validity of the results, they can still be used for meaningful interpretation.

4.1.3 Structural model

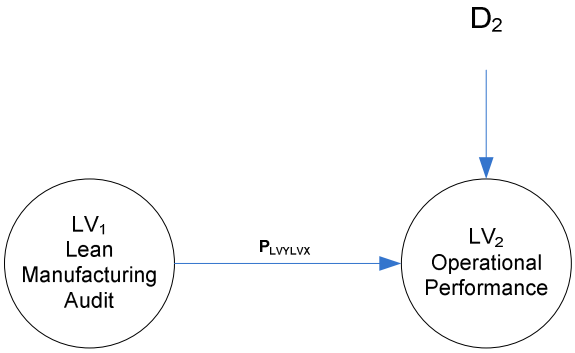

Figure 4.3: a priori structural model

Figure 4.3 illustrates the a priori structural model used in this research. The Lean Manufacturing audit is hypothesised to directionally influence Operational Performance. The Lean Manufacturing audit is the exogenous variable that has an influence on the endogenous variable, which is Operational Performance. There is a disturbance term to account for measurement error.

4.2 Data screening

Table 4.2 indicates that all seventy eight questions used as individual indicators in the Lean Manufacturing audit, have minimum indicator standardized Cronbach's α values of greater than 0.7. All eleven Lean Manufacturing characteristics have measurements that are reliable in describing the characteristic.

Table 4.2: Cronbach α reliabilities for indicator variables

Manifest variable	No of indicators	Minimum indicator Cronbach's α (standardized variables)	Result (OK /NOK)*
LM01_PD	7	0.927	OK
LM02_CA	7	0.868	OK
LM03_VMH	8	0.889	OK
LM04_SW	8	0.888	OK
LM05_FO	7	0.844	OK
LM06_CI	7	0.877	OK
LM07_EP	8	0.913	OK
LM08_QC	8	0.935	OK
LM09_TPM	6	0.856	OK
LM10_MC	6	0.882	OK
LM11_LP	6	0.910	OK
***Note: A result of "OK" is only given if the minimum of all indicator Cronbach's α is > 0.7. This shows that the set of indicator variables reliably loads onto the Manifest variable**			

Table 4.3 lists the multicolinearity between all Lean Manufacturing characteristics and Operational Performance measures. Two Pairs of MV's have values greater than the recommended maximum value of 0.9 indicating a degree of multicolinearity between Continuous Improvement (LM06_CI) and Cultural Awareness (LM02_CA) and between Error proofing (LM07_EP) and Quick changeover (LM08_QC). These characteristics were not combined as their multicolinearity values, despite being higher than 0.9, did not cause any problems for the measurement model.

Table 4.3: Pearson correlation coefficients for all MV's

	LM01_PD	LM02_CA	LM03_VMH	LM04_SW	LM05_FO	LM06_CI	LM07_EP	LM08_QC	LM09_TPM	LM10_MC	LM11_LP	OP01_DLE	OP02_OTD	OP03_IT
LM01_PD	1.000													
LM02_CA	0.729	1.000												
LM03_VMH	0.641	0.845	1.000											
LM04_SW	0.551	0.803	0.786	1.000										
LM05_FO	0.459	0.740	0.727	0.781	1.000									
LM06_CI	0.643	0.904	0.857	0.828	0.754	1.000								
LM07_EP	0.528	0.620	0.579	0.711	0.698	0.652	1.000							
LM08_QC	0.515	0.671	0.647	0.776	0.784	0.719	0.918	1.000						
LM09_TPM	0.619	0.756	0.766	0.813	0.680	0.761	0.805	0.847	1.000					
LM10_MC	0.431	0.690	0.678	0.805	0.867	0.728	0.779	0.849	0.775	1.000				
LM11_LP	0.418	0.624	0.612	0.793	0.749	0.667	0.742	0.836	0.770	0.836	1.000			
OP01_DLE	0.369	0.340	0.347	0.340	0.330	0.417	0.172	0.253	0.249	0.240	0.318	1.000		
OP02_OTD	0.306	0.220	0.303	0.114	0.229	0.171	0.143	0.060	0.118	0.170	0.123	0.143	1.000	
OP03_IT	0.290	0.258	0.306	0.143	0.154	0.227	0.134	0.143	0.214	0.151	0.129	0.202	0.360	1.000

4.3 Assessing the measurement model

The measurement model presented in Figure 4.1 contains only two LV's in comparison to four LV's typical in operations management research using SEM (Shah & Goldstein, 2006). The number of MV's is typical of operations management research models using SEM but load onto only two LV's, one exogenous and one endogenous.

The first process in defining the model is to assess the model structure of each LV.

4.3.1 Initial single factor measurement model for Lean Manufacturing

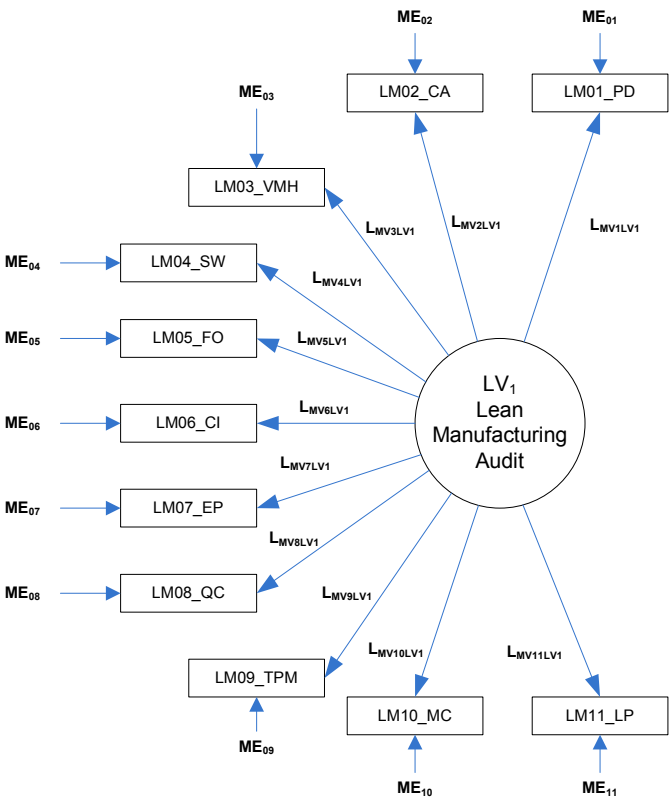

Figure 4.4: Lean Manufacturing Measurement model

Figure 4.4 depicts the single factor measurement model for Lean Manufacturing. Table 4.4 illustrates the first iteration goodness of fit between the measurement model in Figure 4.4 and the data. Appendix E contains the full SAS listing used to create the single factor measurement model.

Table 4.4: Goodness of fit test results for initial single factor measurement model

Category	Measure	Ideal value	Result	Comment
Descriptive statistics	Mardia's *Normalized* multivariate score	<3	3.499	NOK
Goodness of fit statistics	*p* value	>0.05	<0.001	NOK
	chi-square / *df* ratio	<2	4.79	NOK
	Comparative fit index (CFI)	>0.9	0.805	NOK
	Non normed fit index (NNFI)	>0.9	0.756	NOK
	Normed fit index (NFI)	>0.9	0.769	NOK
	Root Mean Square Error of Approximation (RMSEA)	<0.1	0.247	NOK
Path coefficients	Min *t* value	>1.96	6.47	OK
Residuals between data and measurement model	Ranked normalized residuals	<=2	1.35	OK

Seven out of nine criteria are not met.

Outliers in the data were removed using the Wald modification indices outputted by the PROC CALIS algorithm in SAS and the majority of error terms were allowed to co-vary i.e. it was assumed that the error terms related to the MV's are caused by the same thing. The modified SAS listing is presented in Appendix E and gives an output listed in Table 4.5.

Table 4.5: Results for modified single factor measurement model

Category	Measure	Ideal value	Result	Comment
Descriptive statistics	Mardia's *Normalized* multivariate score	<3	1.983	OK
Goodness of fit statistics	*p* value	>0.05	0.143	OK
	chi-square / *df* ratio	<2	1.345	OK
	Comparative fit index (CFI)	>0.9	0.993	OK
	Non normed fit index (NNFI)	>0.9	0.979	OK
	Normed fit index (NFI)	>0.9	0.973	OK
	Root Mean Square Error of Approximation (RMSEA)	<0.1	0.077	OK
Path coefficients	*t* value	>1.96	6.092	OK
Residuals between data and measurement model	Ranked normalized residuals	<=2	0.510	OK

The much improved fit to the data is shown in Table 4.5. All nine criteria are acceptable – validating that the single factor measurement model for Lean Manufacturing is representative of the data.

4.3.2 Initial single factor measurement model for Operational Performance

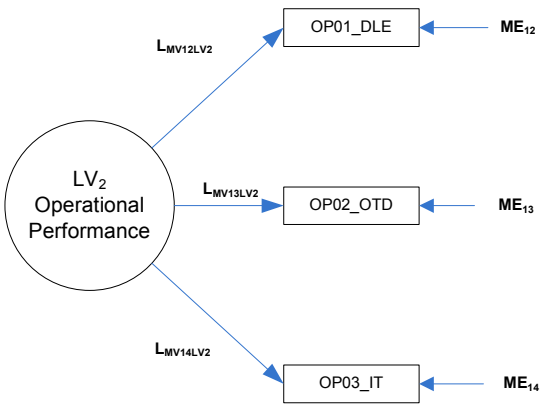

Figure 4.5: Operational Performance Measurement model

Figure 4.5 illustrates the single factor measurement model for Operational Performance. The model has three MV's loading onto one LV and each MV is measured directly as part of the Lean Manufacturing audit (as opposed to being the sum of individual questions used to make up the MV). Due to the relative simplicity of the model it is unnecessary to apply the ideal fit criteria as was done with the single factor measurement model for Lean Manufacturing and instead assess the full Measurement model.

4.3.3 Full measurement model

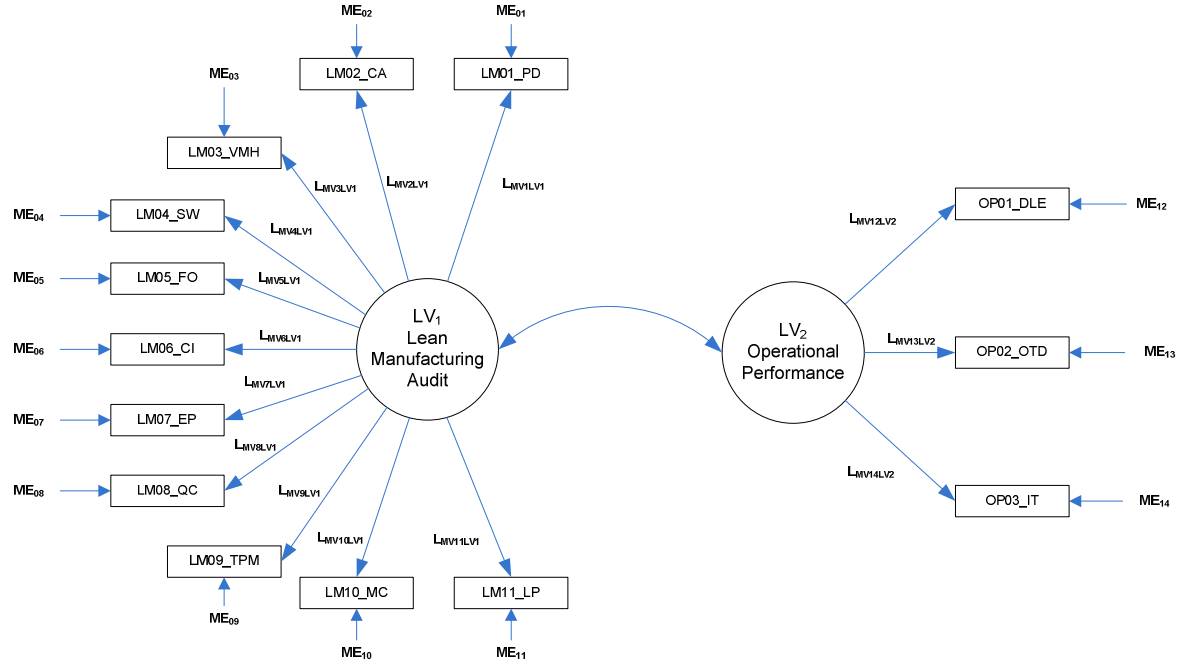

Figure 4.6: Full measurement model

Figure 4.6 illustrates the full measurement model used to construct the relationship between each Lean Manufacturing characteristic used in the Lean Manufacturing audit, the Lean Manufacturing audit's relationship with Operational Performance and the relationship between Operational Performance and the measures it manifests itself in. For the measurement model the relationship between the Lean Manufacturing audit and Operational Performance is allowed to co-vary. The full SAS listing used to model Figure 4.6 is contained Appendix F. Table 4.6 lists the results of the goodness of fit between the measurement model in Figure 4.6 and the modified data set used in the goodness of fit criteria in Table 4.5.

Table 4.6: Goodness of fit results for full measurement model

Category	Measure	Ideal value	Result	Comment
Descriptive statistics	Mardia's *Normalized* multivariate score	<3	0.824	OK
Goodness of fit statistics	*p* value	>0.05	0.117	OK
	chi-square / *df* ratio	<2	1.242	OK
	Comparative fit index (CFI)	>0.9	0.987	OK
	Non normed fit index (NNFI)	>0.9	0.976	OK
	Normed fit index (NFI)	>0.9	0.938	OK
	Root Mean Square Error of Approximation (RMSEA)	<0.1	0.065	OK
Path coefficients	*t* value	>1.96	2.143	OK
Residuals between data and measurement model	Ranked normalized residuals	<=2	1.710	OK

The results indicate a good fit with all nine criteria passing the acceptance test.

4.3.4 Reliability and Validity

Table 4.7: Reliability assessment for the measurement model

LV and MV's	Standardized loading	*t* value	reliability	Variance extracted estimate	Result
Ideal vale	-	>1.96	>0.7	>0.7	
Lean Manufacturing Audit			**0.969**	**0.740**	**OK**
LM01_PD	0.634	6.113	0.403	0.598	
LM02_CA	0.815	9.700	0.664	0.336	
LM03_VMH	0.860	10.705	0.740	0.260	
LM04_SW	0.960	13.705	0.921	0.079	
LM05_FO	0.868	10.730	0.754	0.246	
LM06_CI	0.856	10.860	0.732	0.268	
LM07_EP	0.823	9.702	0.677	0.323	
LM08_QC	0.909	12.656	0.826	0.174	
LM09_TPM	0.942	13.021	0.888	0.112	
LM10_MC	0.894	11.773	0.800	0.200	
LM11_LP	0.881	11.443	0.776	0.224	
Operational Performance			**0.559**	**0.300**	**NOK**
OP01_DLE	0.646	3.801	0.417	0.583	
OP02_OTD	0.472	2.889	0.223	0.777	
OP03_IT	0.513	3.166	0.263	0.737	

Table 4.7 lists the results for indicator and composite reliabilities of the path coefficients predicted by the measurement model. Also listed are the standardized loadings and t values used to calculate the reliabilities and variance extracted estimates. For the latent variable, Lean Manufacturing audit, the path coefficients reliably load onto the latent variable, with the exception of Policy Deployment (LM01_PD), which has a low loading coefficient of 0.634 and a low reliability of 0.403. Error proofing (LM06_EP) also has a low reliability value of 0.677. Overall, for the construct of the Lean Manufacturing audit, the data shows that the measurement model is reliable, as measured by a composite reliability score of 0.969. The amount of variation explained by the Lean Manufacturing audit is also above acceptable limits (0.740). The reliability of the latent construct of the Operational Performance is below the acceptable limit at 0.559. All manifest variables show weak standardized loadings onto the latent variable of Operational Performance, indicator reliabilities are below acceptable levels. Only 30% of the variation in Operational Performance measures can be explained by the structure of the latent variable, Operational Performance. The rest of the variation is measurement error. This potentially points to a large specification error in the structural model and practically indicates that the reliability of the Operational Performance measures may be questionable. This issue is assessed in the Chapter five.

The validity assessment of the model is illustrated in Table 4.8. The minimum measured t value of all the indicators is 2.889, which is higher than the recommended value of 1.96 needed to demonstrate

convergent validity. This proves the model presented in Figure 4.6 measures everything it was intended to measure. Discriminant validity of the measurement model is proven in Table 4.8, which shows that the constrained model has a significantly better fit to the data than the unconstrained model – indicating that it does not measure anything it was not meant to measure.

Table 4.8: Validity assessment of measurement model

Characteristic	Measure	Ideal value	Measured value	Result
Convergent validity	Minimum of all measured *t* values	>1.96	2.889	OK
Discriminant validity	chi-square of unconstrained model – chi-square of contained model	>0	663.138	OK
Degree of freedom for test (α = 0,05)	df of unconstrained model – df of contained model	>0	26	OK
	Critical chi-square value at df = 26, α = 0.05	>48.290	663.138	OK

4.4 Assessing the structural model

The structural model presented in Figure 4.7 represents the model of interest. The Lean Manufacturing audit has a directional influence on Operational Performance. A disturbance term is added to account for variation in Operational Performance not accounted for by the Lean Manufacturing audit.

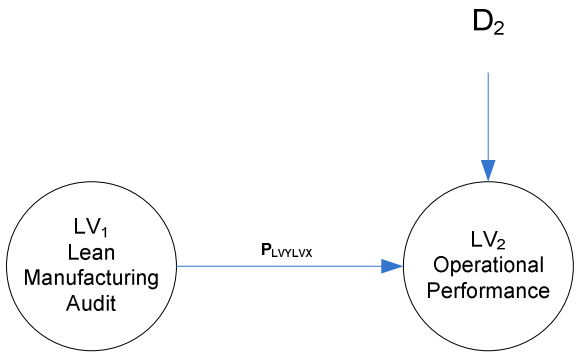

Figure 4.7: Full structural model

In order to model the structural model it is necessary to model the theoretical model. This is the final model of interest and combines both the measurement and structural portions of the model. The rules for modelling the theoretical model involve fixing one of the path coefficients between MV's and LV's at the value of one for each LV and allowing only the exogenous LV's to co-vary (Hatcher, 1994). Figure 4.8 illustrates the full theoretical model. The full SAS listing used to create the structural model is given in Appendix G.

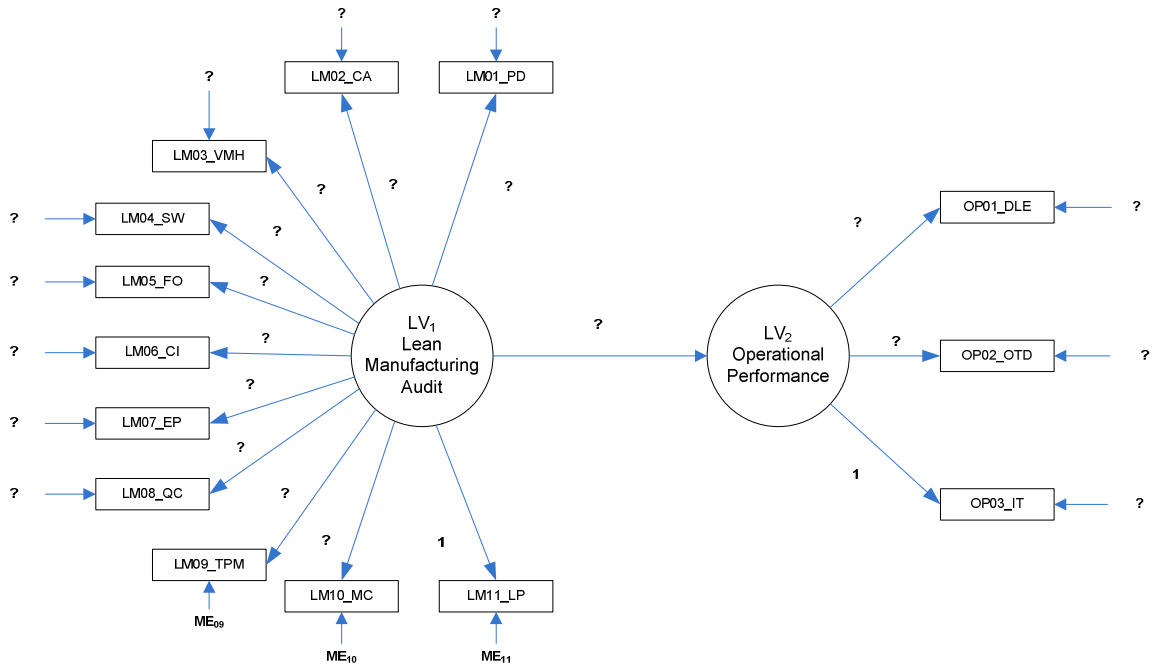

Figure 4.8: Full theoretical model

Table 4.9 lists the results for the theoretical model. Because the measurement model contains only two LV's the results obtained by the theoretical model should be identical. This is because of the principal of equivalent models (Marcoulides & Schumacker, 2001). The results listed in Table 4.4 indicate that this model is identical measurement model.

Table 4.9: Results for the full theoretical model

Category	Measure	Ideal value	Result	Comment
Descriptive statistics	Mardia's *Normalized* multivariate score	<3	0.824	OK
Goodness of fit statistics	*p* value	>0.05	0.117	OK
	chi-square / *df* ratio	<2	1.242	OK
	Comparative fit index (CFI)	>0.9	0.987	OK
	Non normed fit index (NNFI)	>0.9	0.976	OK
	Normed fit index (NFI)	>0.9	0.938	OK
	Root Mean Square Error of Approximation (RMSEA)	<0.1	0.065	OK
Path coefficients	*t* value	>1.96	2.143	OK
Residuals between data and measurement model	Ranked normalized residuals	<=2	1.710	OK

The parsimony ratios for theoretical and structural models are listed in Table 4.10. The full SAS program listing used to create the uncorrelated model is given in Appendix G.

Table 4.10: Parsimony ratio's for the theoretical and structural model

Item	Model	Theoretical model							Structural Model		
		Chi-square	df	NFI	NNFI	CFI	PR	PNFI	RNFI	RPR	RPFI
M_o	Null model	1006.5	91	0	-	-	-	-	-	-	-
M_u	Uncorrelated model	282.868	77	0.719	0.734	0.783	0.850	0.610	0	1	0
M_t	Theoretical model	62.101	50	0.938	0.976	0.983	0.550	0.520	1	0	0
M_m	Measurement model	62.101	50	0.938	0.976	0.983	0.550	0.520	1	0	0

Note: NFI = Normed Fit Index; NNFI = Non Normed Fit Index; CFI = Comparative Fit Index; PR = Parsimony Ratio; PNFI = Parsimonious Normed Fit Index; RNFI = Relative Normed Fit Index; RPR = Relative Parsimony Ratio; RPFI = Relative Parsimonious Fit Index

The parsimony ratio (PR) listed in Table 4.10 for the theoretical model is 0.520, which is less than that of the uncorrelated model at 0.850, indicating that the theoretical model is more complex than the uncorrelated model. This is due to the addition in the theoretical and full measurement model of allowing the error terms to co-vary. The Parsimonious Fit Index (PNFI) for the theoretical model is 0.610, which is higher than the uncorrelated model at 0.520. This indicates that the theoretical model does provide a better fit than the uncorrelated model with respect to the Normed Fit Index. The RNFI shows that the structural portion of the model provides a good fit to the data and is above the recommended minimum value of 0.9. The RPR and RPFI are both 0, indicating that the structural model is identical to the theoretical model and the measurement model. There is only one path between latent variables and thus the RPR and RPFI are 0 for the theoretical and structural model. Overall Table 4.10 indicates that:

1. The theoretical model is more complex than a simple uncorrelated model
2. The theoretical model, with all the paths specified, provides a better fit to the data then a simple uncorrelated model
3. Because of the principle of two factor LV model equivalency the measurement model and theoretical model are identical.

The standardized path coefficients are listed in Table 4.11.

Table 4.11: Standardized path coefficients for theoretical model

MV	Path coefficient	LV	Error
LM01_PD	0.634	LM	0.773
LM02_CA	0.815	LM	0.580
LM03_VMH	0.860	LM	0.510
LM04_SW	0.960	LM	0.281
LM05_FO	0.868	LM	0.496
LM06_CI	0.856	LM	0.518
LM07_EP	0.823	LM	0.569
LM08_QC	0.909	LM	0.417
LM09_TPM	0.942	LM	0.335
LM10_MC	0.894	LM	0.448
LM11_LP	0.881	LM	0.473
OP01_DLE	0.646	OP	0.764
OP02_OTD	0.472	OP	0.882
OP03_IT	0.513	OP	0.858
LM	**0.457**	**OP**	**0.889**

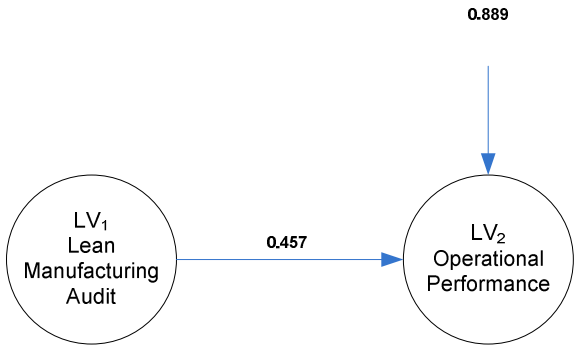

Figure 4.9: Structural model results

Figure 4.9 illustrates the results of the structural model. The path coefficient between the Lean Manufacturing audit and Operational Performance is significant with a medium correlation at 0.457. This indicates that Lean Manufacturing audit results are significantly correlated to Operational Performance. The disturbance term is calculated at 0.889 indicating that significant random noise and factors other than the Lean manufacturing audit result affect Operational Performance. This is consistent with the results in Table 4.8 and Table 4.10, which show that there is a significant amount of variance in measures relating to Operational Performance that are not accounted for by the model.

Of primary interest in the model is not the disturbance, which only indicates a large amount of variance, but the actual reliability coefficient between the LV of Lean Manufacturing audit and Operational Performance. Table 4.12 illustrates that the reliability coefficient is 0.209. Thus just over 79% of the variance in Operational Performance cannot be explained by the Lean Manufacturing

audit. This result is also determined by dividing the error variance in Table 4.12 by the Total variance.

Table 4.12: Error variance for Operational Performance

LV	Error Variance	Total Variance	R-Square
OP	0.479	0.605	0.209

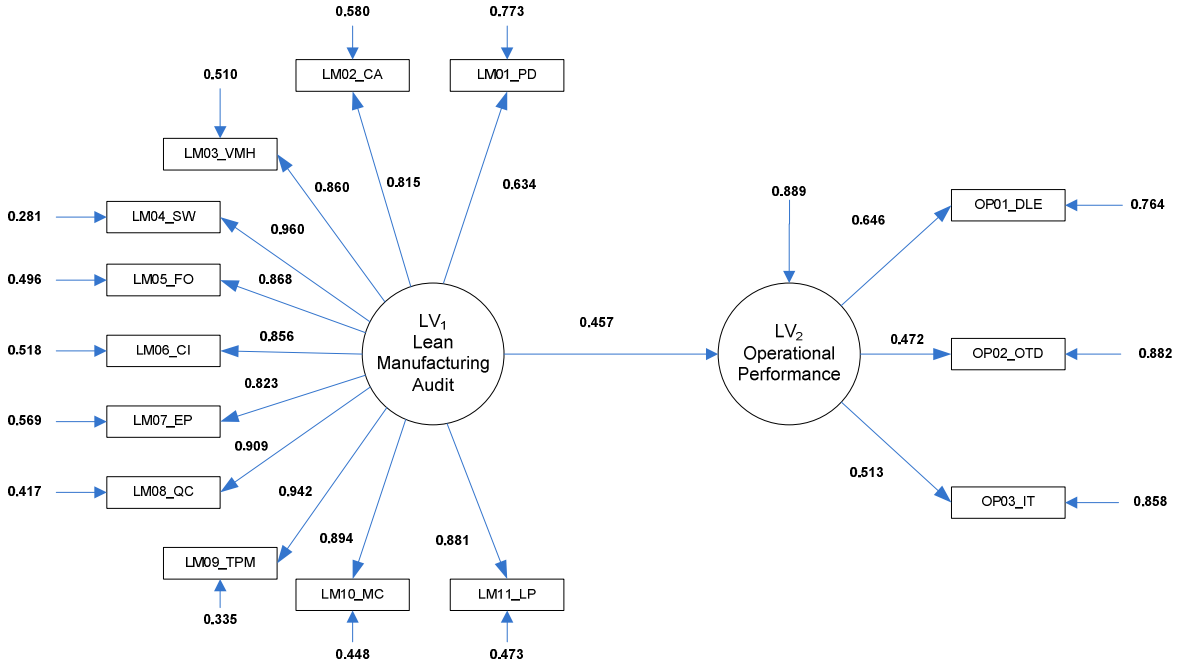

Figure 4.10: Theoretical model results

Figure 4.10 shows the path coefficients for the full theoretical model. All the Lean characteristics measured during the Lean Manufacturing Audit are strongly linked as reliable characteristics for the audit with the exception of Policy Deployment (LM01_PD), which has a standardized path coefficient of 0.634. The measures for Operational Performance are less reliable. All measures for Operational Performance do not load onto the LV of Operational Performance with a value greater than 0.646. This indicates a significant amount of variation in Operational Performance not accounted for by the model, which in confirmed by the R^2 value of 0.209 in Table 4.12.

5 Discussion of results

5.1 Evaluation of research hypothesis

The research hypothesis of this research thesis is as follows:

There exists a positive correlation between the results of a Lean Manufacturing audit and Operational Performance

Figure 4.9 shows that there is a positive correlation (0.457) between the results of a Lean Manufacturing audit and Operational Performance. The probability of obtaining such a result in a sample in which there was no correlation is less than 0.001, as listed in Table 4.9. Thus the null hypothesis is rejected.

There is a large disturbance term (D =0.883) acting on Operational Performance. This indicates that despite the acceptance of the research hypothesis, there is a large amount of variation in Operational Performance that cannot be accounted for by the Lean Manufacturing audit results. This is confirmed by the low R^2 value of 0.209 listed in Table 2.12.

Figure 4.10 also shows that Policy Deployment (LM01_PD) does not load strongly onto the latent construct of the Lean Manufacturing audit. The standardized loading path coefficient value given is 0.634. The rest of the standardized path coefficient values for MV's loading onto the Lean Manufacturing audit are all above 0.8. This means that Policy Deployment is less representative as a manifestation of the Lean Manufacturing audit than the other ten Lean Manufacturing characteristics. An explanation for this is interpretive error. Appendix A contains the full audit questionnaire used to compile the data. In the questionnaire Policy deployment is the only characteristic that is defined and measured on a separate sheet using a different scoring methodology (See section 3.5.3). Because of this there is more of a chance for interpretative error during the Lean Manufacturing audit.

5.2 Assessment of the primary research question

The primary research question is stated as follows:

Is there a positive correlation between the results of a Lean Manufacturing audit and Operational Performance?

The answer is yes. Organizations that have strong Lean Manufacturing audit results also have good Operational Performance measures. However, for the population of organizations used in the data there is a large amount of variation in Operational Performance that is not explained by the results of the Lean Manufacturing audit alone.

5.3 Interpretation of results

5.3.1 Using Lean Manufacturing auditing to drive Operational Performance

The positive correlation of 0.457 between the results of a Lean Manufacturing audit and Operational Performance has shown that poor Lean Manufacturing audit results correlate to poor Operational Performance measures. Similarly good Lean Manufacturing audit results correlate to good Operational Performance measures. By making the assumption that the organizations in the population had poor Operational Performance results before the implementation of the audit it

strongly suggests that the gap analysis provided by the Lean Manufacturing audit has been successful in driving Operational Performance.

The results indicate that a significant correlation between the two but also a large amount of variation in Operational Performance that is not related to the results of the Lean Manufacturing audit. This variation has to do with factors that are not defined in the research model.

5.3.2 Accounting for unexplained variation in Operational Performance

The low R^2 value of 0.209 listed in Table 4.12 indicates that there is a significant amount of variation in Operational Performance that is not explained.

To better understand this variation a scatter plot of the sum of Lean Manufacturing audit scores and the Sum of Operational Performance scores for all sample organizations is given in Figure 5.1. The same observations identified in the SEM analysis as outliers have been excluded from the scatter plot in order to directly compare the scatter plot with the results of the SEM analysis.

If Organizations have truly implemented the Lean Manufacturing characteristics as measured by the Lean Manufacturing audit then their individual scores for each question would be high. Summing all these individual scores would result in a high overall summated score. Similarly organizations that have strong individual Operational Performance measures would show up as having a high overall Operational Performance score. The scatter plot in Figure 5.1 has been divided into four equal quadrants.

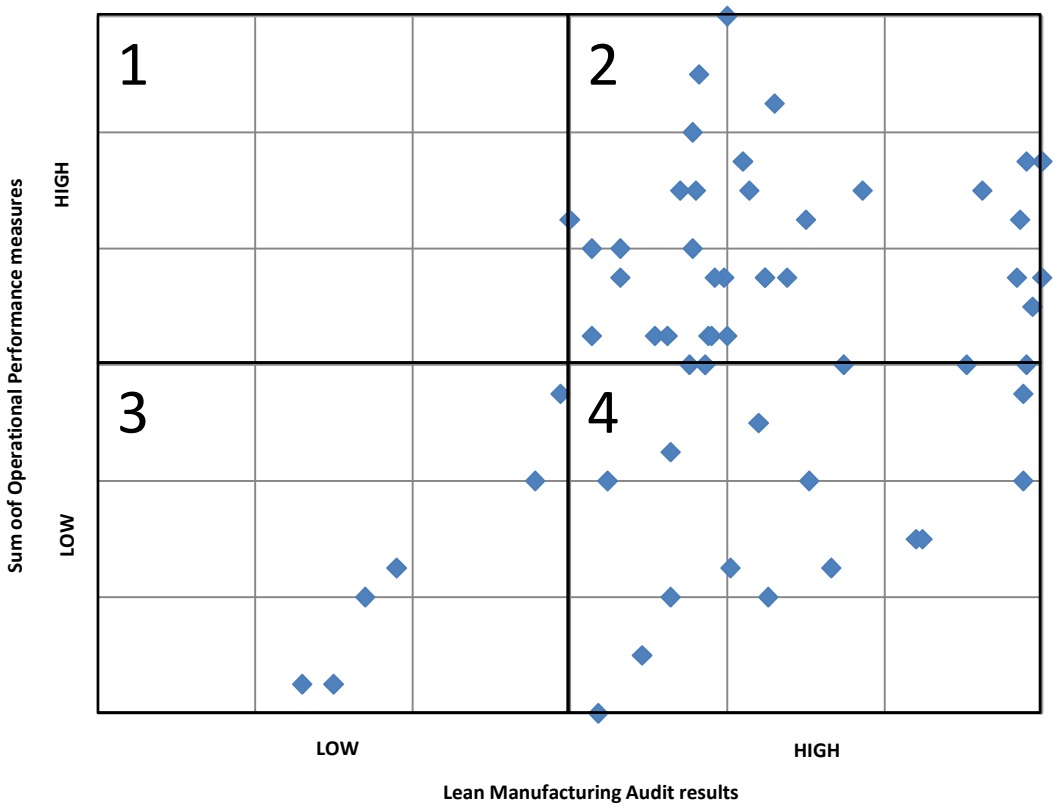

Figure 5.1: Scatter plot for Lean Manufacturing Audit and Operational Performance

Figure 5.1 illustrates the summated results of the Lean Manufacturing Audit and the summated score for Operational Performance. Individual observations that fall into quadrant three and two, are compliant with the findings of this research. Organizations that have low Lean Manufacturing audit results have low Operational Performance Measures and Organizations that have high Lean Manufacturing audit results have high Operational Performance Measures. Of interest in this research is accounting for the observations in quadrants one and four.

There are no observations that fall into quadrant one. In other words there are no organizations that have low Lean Manufacturing audit results and high Operational Performance Measures. Practically this means that no organization in the population measured has been able to achieve good Operational Performance measures with a low degree of Lean implementation.

At least 28% of the observations fall into quadrant four. This means that at least 28% of the population measured have implemented Lean Manufacturing (as indicated by the high results of the audit) yet failed to produce high results in Operational Performance. This 28% is the main contributor to the low R^2 value in the SEM results. There are two theories for why observations fall into quadrant four. There are listed as follows:

- Error caused by Lean Manufacturing audit bias
- Error caused by audit scope

In order to understand the nature of the sample of the population falling into quadrant four, summary statistics have been produced in Table 5.1 to Table 5.3.

Table 5.1: Summary statistics for sample on organization types in quadrant four

Type of market	**Organization type**		***Total***
	Manufacturing	Service	
Minerals equipment	50%	0%	**50%**
Oil & gas equipment	36%	4%	**40%**
Power & nuclear equipment	0%	10%	**10%**
Total	**86%**	**14%**	**100%**
Sample size: 16			

Table 5.2: Summary statistics for sample on organization region and size in quadrant four

Region	**Organization Size***			***Total***
	Small	**Medium**	**Large**	
North America	6%	20%	20%	**46%**
South America	0%	0%	0%	**0%**
Europe	10%	10%	8%	**28%**
Africa	0%	0%	16%	**16%**
Middle East	0%	0%	0%	**0%**
Asia	4%	6%	0%	**10%**
Australia	0%	0%	0%	**0%**
Total	**20%**	**36%**	**44%**	**100%**
Sample size: 16**				

***Note: Organization size is based on number of employees. Small = less than 50 employees, Medium = less than 200 employees, Large = greater than 200 employees**

****Sample size is 59 not 64 as 6 plants have insufficient published data to add to table**

Table 5.3: Summary statistics for sample on organization operation and type in quadrant four

Operation	Organization type		*Total*
	Manufacturing	Service	
Casting	4%	0%	**4%**
Machining	22%	2%	**24%**
Elastomer moulding	4%	0%	**4%**
Fabrication	6%	0%	**6%**
Assembly	24%	6%	**30%**
Warehousing & logistics	26%	6%	**32%**
Total	**86%**	**14%**	**100%**
Sample size: 16*			
***Sample size is 59 not 64 as 6 plants have insufficient published data to add to table**			

Table 5.1 indicates that the sample data in quadrant four is made up of 86% manufacturing organizations. Table 5.2 indicates that 80% of organizations in quadrant four are either medium or large organizations and 46% of all organizations are located in North America. There are no significant findings from Table 5.3

5.3.2.1 Error caused by Lean Manufacturing audit bias

This research does not contain data specific to each independent auditor. All that is known is that

- A group of auditors audited specific organizations using the standard Lean Manufacturing audit
- This group was split into region specific auditors who audited each organization in pairs. Each auditor in the pair contributed to the single list of scores reflected in the organization Lean Manufacturing audit
- No one single auditor audited a significant amount of organizations within the population
- Auditors receive training on the audit and how to interpret questions before each audit is conducted

No data in the Lean Manufacturing audit result are available for different sets of auditors who have audited the same organization at the same time. Thus a gauge repeatability and reliability study cannot be conducted to determine the effect of auditing error on organization results. The significance of auditing error is low because audits were conducted by randomly assigned auditors within each region. No one auditor audited a large percentage of organizations.

The variation in Operational Performance due to geographic location (and the possibility of one or two biased auditors in that region) does not appear to be significant because of the same argument listed above. Results from audit feedback of organizations located in North America and falling into quadrant four reveal that no one auditor had an influential role in auditing these organizations. Of the seven organizations located in North America and falling into quadrant four, there were at least thirteen auditors auditing them and only one organization had less than two auditors per audit.

Another type of audit bias is in the form of Interpretative error. This has to do with the relevancy of specific questions relating to a Lean Manufacturing characteristic as applied in a certain operations environment. Two examples are Total Productive Maintenance (TPM) and Quick Changeover (QC). Both characteristics have been identified as essential to the characteristic of Material Control and

Levelling (Bicheno, 2009). However, for organizations primarily involved in warehousing, distribution and assembly, with little manufacturing equipment on site, the applicability of characteristic, as outlined in specific audit questions is queried. Organizations with operations limited to warehousing distribution and assembly do not have large manufacturing equipment with set up times etc. These centres have material handling equipment, packaging operations and basic hand tools for assembly. Although the essence of TPM, which is to ensure key processes are available when needed, is valid, the characteristic nature of TPM, as defined through specific questions contained in the Lean Manufacturing audit, is difficult to interpret in warehousing, distribution and assembly environments.

Assessment of the Lean Manufacturing audit feedback presentations for Organizations primarily involved in warehousing, distribution and assembly have focused on the use of TPM for hand held equipment and test equipment. With the exception of certain test equipment, the benefit of performing daily rigorous checks and measuring downtime on low cost hand held equipment is questionable. The daily checks are certainly valid as is noting reasons for failure. However should such equipment fail it is replaced instantaneously by a backup on site, meaning that availability of processes will not suffer.

Quick changeover in such operations is another example. In warehousing, distribution and assembly operations, hand held tools are easily multitasked to a variety of operations and in batch and job shop environments, equipment is assembled not in purpose built lines, but in flexible assembly stations. Manpower and equipment are often deployed to work on different products without any need to perform adjustments or set-ups.

For various operations management environments auditors are trained to think laterally about the applicability of a specific question contained in the Lean Manufacturing audit to the operations management environment being audited. This question forms parts of a Lean characteristic being audited. Auditors are asked to understand the intention of the characteristic and interpret the questions in the Lean Manufacturing audit in the context of the operation being assessed. This interpretation may lead to variation in the Lean Manufacturing audit results. By over specifying a question, its applicability for various operations management environments is reduced and consequently the results obtained through the question are in fact less reliable. Interpretive error may thus add to the variation between Lean Manufacturing audit results and Operational Performance.

A true assessment on the effect of auditor bias on the Lean Manufacturing audits can only be conducted through a gauge reliability and repeatability study.

5.3.2.2 Error caused by audit scope

Table 5.3 indicates that 86% of organizations falling into quadrant four are manufacturing organizations. Within these organizations the scope of the Lean Manufacturing audit is confined to shop floor operational activities. These include the operations listed in Table 5.3.

The scope does not include the supplier networks and branch distribution networks required to support the end customer. The audit focuses specifically on what is known as the "Lean core", which are best practices that have been developed from shop floor operations. (Schonberger, 2008)

The Operational Performance measures, as defined in this research, are strongly related to the customer and include all activities required to flow products from suppliers through to the customers. These include pipeline inventories, management of distribution networks, management of supplier networks and management of the office based order process and any engineering activity involved (especially for batch and job shop operations management environments). It has been recognized that most of the waste elimination opportunities relate to the management of pipeline inventories between organizations (Schonberger, 2008).

There is a difference in scope between the Operational Performance Measures and the scope of the Lean Manufacturing audit. This is evident in the definition of the Operational Performance measures as listed in Appendix B. Manufacturing organizations are most likely to be affected by this difference in scope because they have a higher percentage of activities involving supplier and customer logistics management. The only exceptions to this are organizations that are highly vertically integrated. Of the 16 observations in Table 5.3, none display full vertical integration of all operations. Table 5.2 also indicates that 80% of the organizations in quadrant four are either medium or large. These organizations are large because they act as supply hubs to various service centres and typically include office environments required to support the logistics networks and order process. The processes needed to support the distribution networks are not part of the scope of the Lean Manufacturing audit. Of all the audit feedback presentations for the manufacturing organizations, none made explicit reference to the management of pipeline inventories, logistics networks or office based order processes. Only activities with specific connection to the shop floor were mentioned. For example, the Lean Characteristic of Levelling is important in the management of order processes and supplier capacity yet all feedback presentations mentioning levelling only referred to examples of levelling implemented in local machine centres or assembly stations at shop floor level as opposed to at plant or supplier network level. To further add to this point, the Pearson correlation coefficients between Lean Manufacturing Characteristics and Operational Performance measures listed in Table 4.3 shows that the correlations between the Operational Performance measure of Inventory turns and the Lean Manufacturing Characteristics of Level Production and Material Control are both less than 0.2. Both Lean Manufacturing Characteristics encompass Just-In-time systems, which are proven systems for increasing inventory turns (Schonberger, 2008).

It can be argued that the mismatch in scope between the Operational Performance measures and the Lean Manufacturing audit accounts for significant variation in Operational Performance.

5.3.3 Recommendations for implementing Lean Manufacturing audits

The results indicate that Lean Manufacturing audits do correlate to Operational Performance measures and can thus be used to drive Operational Performance provided the assumption of causality is made. However, the results indicate that there is a large variance in Operational Performance that is not accounted for by the Lean Manufacturing audit. Table 5.4 lists the advantages and disadvantages of the current Lean audit process.

Table 5.4: Evaluation of Lean Manufacturing Audit

Advantages	Disadvantages
• Audit structure is well developed, with many independent auditors to minimise auditor bias • Auditor are well trained before auditing and must be qualified to audit • Lean Manufacturing audit covers all Lean Characteristics popularly defined in open source literature • Audits are regular, occurring annually • History does exist for Lean Manufacturing audits and Operational Performance measures	• The scope of the audit does not cover many aspects relating to the Operational Performance Measures, such as supplier and customer logistics networks and management. Office based order processes and support processes common in Batch and Job shop operations management environments are also not defined in the audit scope • The specific nature of the questions contained in the audit lead to interpretative error when applied to different organizational environments. • There is no system to identify outlying organizations and question audit results or Operational Performance measures • There is no comprehensive system to track and assess trends in Lean Manufacturing audit results and Operational Performance measures

Analysis of similar audits found in the literature (see Table 2.12) reveals that they share the same disadvantages as found in Table 5.4. The mismatch in scope between Operational Performance and the Lean Manufacturing audit leads to disappointment as audit results do not translate to Operational Performance. Furthermore the specific nature of the questions contained in the audit leads to interpretative error.

In a system whereby the audits are mandatory and linked to performance bonuses, the risk is that the characteristics in the Lean Manufacturing audit are implemented for the sole purpose of increasing the Lean Manufacturing audit results and not to improve Operational Performance. Examples of this contained in feedback from the Lean Manufacturing audits for the population of organizations include the use of error proofing devices on non-key equipment (such as dust bins) and the application of Quick changeover and Total Productive Maintenance characteristics to equipment that will not provide immediate benefit to Operational Performance measures (such as hand drills).

The results indicate that the structure of the audit, the audit scope, the audit frequency and the audit method influence the effectiveness of the audit to drive Operational Performance.

Based on this research Table 5.5 outlines the recommended features of a Lean audit framework used to drive Operational Performance and to decrease the amount of unexplained variation in Operational Performance.

The concept of the recommended audit is that it is used to audit the entire enterprise and not only the shop floor or manufacturing operations. The audit title may be changed from Lean Manufacturing Audit to Lean Enterprise audit. There are four scopes in the audit. These scopes represent the focus area at which the characteristic has been implemented. These are defined as manufacturing operations, office environments, supplier associations and customer and branch distribution networks. Each scope contains four levels. The levels represent the degree of implementation of the Lean characteristic. Audits are conducted annually and audit results are managed statistically to identify and manage outliers. Table 5.5 contains the details of the recommended audit. The full recommended audit is contained in Appendix H.

Table 5.5: Features of a recommended Lean audit framework

Feature	Specification	Comments
Audit frequency	Once per annum, organizations that are defined at being outliers have an audit at least twice per annum	Audits are conducted annually and the results entered into a consolidated database. Organizations that exhibit unusual results or that are defined as having little or no improvement from the previous year may be subject to a further midyear audit to follow up on their progress and plans.
Audit method	Independent auditors are used. Auditors are employees of the company but from different organizations. There are enough trained auditors to minimise audit bias	By having a large pool of internally trained auditors a company can minimise the effect of auditor bias.
Audit scope	The scope of the audit is measured on four separate categories. Each category deals with a different scope of the organization. For each category there are four levels of implementation for the Lean characteristic. Each level has defined features.	The scope in contained in four categories. For each category the degree of Lean implementation of the Lean characteristic is split into four levels. Each level has defined features.
Lean Characteristics	The Lean characteristics are essentially the same as used in the audit assed in this research. The Lean characteristic of "Error proofing" is chained to "Process control" to broaden the definition and the Lean characteristic of "Flexible Operations" is chained to "Process focus" for the same reason. To this set, the Lean characteristics of "Design for simplicity" and "Specific best practice" are included. The Lean characteristic of "Policy deployment" is set to measure not only the Policy deployment process but the actual projects against their Targets.	The Lean characteristics assessed in this research are all defined as popular Lean characteristics in previous research studies. The Lean characteristic of "Design for Simplicity" is included to cater for engineering processes. The Lean characteristic of "Specific best practice" is used to include any best practices that are unique to the company and found to be beneficial to all organizations, regardless of structure. The Lean characteristic of "Policy Deployment" is modified to include the actual results against Policy Deployment targets. Since Policy Deployment is used as the main driver for improvement it is the one document that is key to controlling the alignment and priority of all improvements.
Audit Format	The audit is less specific. Individual questions are replaced by features used to attain levels of implementation for each Lean Characteristic in each category. This is similar to the 20 keys audit. (Kobayashi, 1995). Each audit includes a comprehensive feedback presentation.	By making the audit less specific, there is less room for interpretive error and frustration brought about by trying to increase the Lean audit results through implementing a specific question that does not increase the Operational Performance measures for a certain environment. The general nature of the question allows organizations the flexibility to show how they have adapted the characteristic to their environment
Audit management	Audits are administered through a Company Lean manager. If one organization (such as a service or repair centre) falls under the wing of a regional hub, than it is the hub that is audited as "the organization" and not the branch or service centre in isolation. The results are collated in a central database along with Operational Performance measures.	Audits are performed at a higher level so that the audit scopes can be covered. Audit results are assed statistically to identify outlying organizations and those organizations are required to provide evidence as to why their Lean audit results do not correlate to the in limits values for the audit sample. These organizations may be subject to midyear audits. Auditor bias is managed annually through a selection of sample audit checks. These confirmation audits are used to assess gauge reliability and repeatability of the auditors. Massive variations are investigated for root causes with the aim of decreasing auditor bias through standardization.
Operational Performance	Inventory turns along with an inventory turns rating system (see (Schonberger, 2008) is used to asses Operational Performance. The rating system is used to grade an organization based on whether it is improving its inventory turns or getting worse. On-Time-Delivery, as measured by the customer is also used. A quality index is added to the list of measures. A customer satisfaction survey (formally developed and standardized across the group) is also used as a measure	The Lean measures of quality, cost and delivery are measured. A formal customer satisfaction survey is used to understand customer's thinking towards the organization and its ability to provide products and services. Inventory turns and an inventory turns rating is used as an overall measure of the effectiveness of the organization in converting orders into cash inputs. On-Time-Delivery and quality are used to ensure internal focus on these metrics. Both measures have defined operational definitions.

5.4 Limitations of this research

This research has shown that there is a significant positive correlation between the results of a Lean Manufacturing audit and Operational Performance. This means that the implementation of Lean Manufacturing characteristics, as measured under the audit do correlate to Operational Performance. Organizations that have not implemented those characteristics have poor Operational Performance and vice versa. The limitation in this research is that it must assume causality in order to clearly state that the Lean Manufacturing audits are effective in driving Operational Performance. Data on the Operational Performance measures of each organization prior to the Implementation of Lean Manufacturing is not available to support this assumption because this research involves a cross sectional and not longitudinal study. However, there are two factors that can support this assumption.

1. Previous research studies have proven the causality of Lean Manufacturing and Operational Performance (Table 2.10)
2. No organizations in the population measured exhibited high Operational Performance and low Lean Implementation (See Figure 5.1), This implies that in order to score high in Operational Performance the organizations need to have high results of the Lean Manufacturing audit.

Thus it can be stated with fair certainty that the Lean audits are effective in driving Operational Performance but that there are large variations in Operational Performance unaccounted for by the audit.

Another limitation of this research is its low sample size of sixty four observations. This has the effect of decreasing the statistical reliability of the results. All sample size indicators pointed to the fact that the sample size was around sixty four to thirty one percent below ideal values. Furthermore the homogenous nature of this research towards the Lean Manufacturing audit framework as measured and developed by one company and applied to multiple organizations may affect the generalization of the results. The fact that the Lean audit used in this research uses popular Lean characteristics and is similar to other audits found in the literature suggests that the results are applicable.

6 Conclusion

6.1 Assessment of the research question

The central research question is: Are Lean Manufacturing audits effective in driving improvements in Operational Performance.

This research has shown that Lean Manufacturing Audits are effective in driving improvements in Operational Performance provided the audit covers popular Lean Manufacturing characteristics used in previous research studies and that the scope of the audit is well defined to include all aspects of the organization, such as manufacturing operations, office environments, supplier associations and customer and branch distribution networks. This scope will reduce any variation in Operational Performance that cannot be accounted for by the audit. Furthermore audit results should be managed statistically to query and investigate outlying organizations. Finally there should be a multiple array of trained auditors and a gauge reliability and repeatability study should be done to assess for auditor bias. The audits should be conducted annually with a comprehensive feedback presentation accompanying each audit in order to identify opportunities for improvement and share best practice. This is, after all, the fundamental reason for auditing.

6.2 Recommendations for future research

This research uses data from a limited sample, operating in a homogenous population environment. Although the depth of the research and the research design (which is a combination of a survey and multiple case study) compensates somewhat for this, there is scope for more detailed research in order to verify the above conclusion. Specifically this research recommends the following:

1. The recommended Lean Enterprise audit resulting from this research (Listed in Appendix H) should be sent out as a self administered audit to a sample of publically listed, large scale Manufacturing companies from different industry sectors in order to understand the degree of Lean Implementation in their organizations. The target respondents should be at a level high enough in the company to report on Lean implementation for the four scopes listed in the recommended audit.
2. For each company that received an audit, their inventory turns rating (as detailed by Schonberger (Schonberger, 2006)) should be gathered from publically listed annual reports. This is to be used as the basis of determining Operational Performance due to its effectiveness of independently measuring Operational Performance for a large sample of different companies (Schonberger, 2008) . An alternative to this would be to administer a second “customer satisfaction” survey to the key customers of the sample organizations in order to gather their data on the Operational Performance of the target companies.
3. The results of the self administered survey should be compared to the results of Operational Performance data using Structural Equation Modelling to verify that the structure of the audit is reflective of the data and to assess the correlation between the two.
4. The results of the above should provide a large scale assessment of the conclusions of this research.

This research has provided a foundation to implement, manage and measure the implementation of Lean characteristics within an organization as well as assess their effectiveness in driving Operational Performance

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Appendix A **Lean Manufacturing audit used in this research**

Q#	Characteristic	Where to audit	How to audit	Whom to ask	Questions	Standard Improvement Actions & Expected practice
PD1	Policy Deployment	Policy Deployment	use PD Assessment	all functions, complete plant	Company objectives – development, content and communication	see Policy Deployment Assessment document
PD2	Policy Deployment	Policy Deployment	use PD Assessment	all functions, complete plant	The scope of implementation	see Policy Deployment Assessment document
PD3	Policy Deployment	Policy Deployment	use PD Assessment	all functions, complete plant	Participation	see Policy Deployment Assessment document
PD4	Policy Deployment	Policy Deployment	use PD Assessment	all functions, complete plant	Objectives metrics and targets	see Policy Deployment Assessment document
PD5	Policy Deployment	Policy Deployment	use PD Assessment	all functions, complete plant	Improvement projects breakthrough level	see Policy Deployment Assessment document
PD6	Policy Deployment	Policy Deployment	use PD Assessment	all functions, complete plant	Ownership; alignment; resourcing	see Policy Deployment Assessment document
PD7	Policy Deployment	Policy Deployment	use PD Assessment	all functions, complete plant	Progress tracking	see Policy Deployment Assessment document
1	Cultural Awareness	shopfloor	ask for last 2 dates	- 2-3 employees random - 2-3 managers	Plant Management communicates with production workers regarding employee satisfaction within the workplace and organizational objectives at least twice per year.	Introduce twice year communication process that explains progress against the company objectives. Explain the current health of the business and the relative market situation, NPI, Health & Safety, Environmental, Developments and Quality status.
2	Cultural Awareness	shopfloor	ask	2-3 employees random	Employees are able to describe the company goals and how their job contributes to the achievement of those goals.	Employees have annual objectives set and agreed that are used as a basis for PDP or appraisal, the review of progress provides focus on importance of their role and how they interplay with the department and company objectives.
3	Cultural Awareness	shopfloor	ask for evidence	look into upstream workers, not QA	There is a formal process for production workers to regularly receive feedback on problems detected in downstream processes. e.g. At assembly and at the customer.	Set up daily/weekly reviews of quality issues within the plant and on site by incorporating quality as a standard agenda item in cell or workshop meetings, involve, as appropriate, representative from upstream/downstream processes.
4	Cultural Awareness	shopfloor	ask for evidence	production area employees	There is a formal process in place that provides production workers with the opportunity to work in teams to address production performance, quality, or safety issues.	Introduce cell or workshop activities that enable cross-functional improvements in Safety, QCD, (Quality, Cost, Delivery.) Use WPS 3C's, Pareto and/or problem analysis. Publish results and progress at cell meetings.

5	Cultural Awareness	shopfloor	ask for evidence	production area employees	Production workers understand and can use common key performance indicators and data to monitor and improve production processes.	Machine shops and key process equipment (test rigs, paint plant etc) should be using OEE as a measure of improvement OR key element(s) of OEE - downtime, efficiency and/or quality and any other related measure. Performance and Availability rates should be known. Assembly shops should be aware of Quality, Delivery and performance. All employees should be aware of HS&E statistics.
6	Cultural Awareness	shopfloor	ask for last couple of problems	production area employees	When problems in the production process occur, they are detected immediately and formal investigation process started within 1 hour of the first occurrence.	Set up a formal system of problem analysis (e.g, 5 Why's, 3C's, Pareto, Cause & Effect, 8D…) and empower production teams to resolve concerns (this may call cross functional support) Analysis starts within the first hour of the concern being raised.
7	Cultural Awareness	shopfloor	- ask for last couple of visits - senior management is known to the workforce	production area employees	Production engineers and support staff, routinely go to the spot of a problem in the production area to assess the actual situation and talk to production workers.	Align support department personnel in order that they have cell responsibility. Teach Production Engineers and support staff that observation techniques and direct 2-way communication in the area is frequently the first step to ensuring the production operatives concerns are correctly identified and understood.
8	Visual Management & Housekeeping	shopfloor	walk around, just observe	no discussion, first impressions are positive, first 20 secs	The plant, including manufacturing offices, is generally clear of all unnecessary materials or scrap and passageways are clear of obstructions.	A formal 5S or equivalent housekeeping process should be in place and enforced to provide a safe, efficient environment for production activities. 1S (WPS) has been completed and maintained.
9	Visual Management & Housekeeping	shopfloor	walk around, just observe	no discussion	Lines on the floor clearly distinguish work areas, paths, and material handling isles. Signs clearly identify production, inventory staging, and material drop areas, including manufacturing offices, as applicable.	Create visually an environment where the workshop is self explanatory as to what, and where data. 2S (WPS) has been completed and maintained.
10	Visual Management & Housekeeping	shopfloor	ask for evidence, e.g memo, SOP, cLeaning equipment	employees: - since when - how often - how long	All employees are considerate of housekeeping (including manufacturing offices) and operators consider daily “cLean-up & put away” activities part of their job.	SOP's should exist and be published for daily routine procedures for house keeping during the end of shift or change over.

11	Visual Management & Housekeeping	shopfloor	walk around, and observe	ask for demonstration	There is "a place for everything and everything in it's place"; every container, tool and equipment rack is clearly labelled and easily accessible to the user. People using tools, parts, fixtures, quality gauges, etc. know where to find them.	Action to achieve 2S (WPS) is completed and a "30 second" rule (common use items can be retrieved in 30 seconds, or as agreed by plant management, at the work station) is applied. Evidence is noted that the process is adhered to.
12	Visual Management & Housekeeping	shopfloor	walk around, just observe	no discussion	Updated display boards containing relevant information and KPIs required to maintain smooth flow of information and material throughout the plant, for example safety, schedule, operation and production data, quality problems and countermeasure information	Establish standard format cell or workshop information boards that display the data sets and they are current, known to workers within the cell. These should be used as the basis of daily cell meetings. Some data may be electronically stored however all operators must be able to access on their own.
13	Visual Management & Housekeeping	shopfloor	walk around, just observe, check the dates against declared frequency	operators - when feedback is done, frequency, by whom how, to quote last few sessions	Display boards are updated frequently for each cell, work area or process. Operators get regular feedback on the teams overall production performance.	Set up minimum weekly updates and minimum weekly reviews with teams. Daily (frequent) Standup Meetings are established and maintained.
14	Visual Management & Housekeeping	shopfloor	walk around, and observe	ask for checksheets	Check sheets that describe and track the top defects are posted and kept up to date at each workstation. Data is used to drive continuous improvements.	Set up tally charts, measle charts, Pareto, SPC, attribute charts or Process Control charts…as appropriate at the work place. (May be a cell quality buy off area if specialist equipment is required to check attributes.) Use 3Cs or similar to record, prioritise and drive continuous improvement.
15	Visual Management & Housekeeping	shopfloor	ask for evidence, couple of places	operators	There is good, effective communication between consecutive production shifts in the plant.	Set up a formal process of communication for the various shifts to handover communications. This can be Electronic, written, diagrammatic or verbal, unsocial hours workers should be asked for feedback on effectiveness.
16	Standardised Work	shopfloor	ask for evidence, couple of SOPs	couple of areas	A Standard Operating Procedure (SOP) has been developed and used to train operators for production processes to prevent recurrence of Quality-Delivery-Safety problems.	Write SOPs to a standard format and use a basis for training, practice maintenance and problem solving and improvements. SOPs should be readily available, controlled, approved.
17	Standardised Work	shopfloor	walk around, just observe	no discussion	Every production process has the Standard Operating Procedure posted within view or readily accessible by the worker performing	Develop SOPs for all operations including material handling. Electronic filing is permissible if all production operative can access the database on their own.

					the process.	
18	Standardised Work	Planning, after shopfloor	evidence	Planning	Each production process has been designed to be completed within a standard cycle time that is based on the Takt time for a given part or work activity. Each production process is designed and scheduled to complete within required lead time, which is based on the rate of demand, and to prevent overload or waiting.	Balance all operations to Takt time or a weighted Takt time. Only Tool room and Development activities are non-Takt driven.
19	Standardised Work	shopfloor	evidence	operators	Operators provide input and are involved in the process of job design and standardization.	Cross-functional team makes input into the cells or work place design. "Cardboard" Engineering is used extensively by the team to determine where and how materials should flow in and out of the cell and workplace layout.
20	Standardised Work	shopfloor	evidence	operators	Frequently repeated, non-production operations in the plant are standardized such as changeover processes, quality checks, equipment and perishable tool checks, etc.	Create SOPs and check sheets and make them readily available for the operations described.
21	Standardised Work	shopfloor	evidence	no discussion	Standard Operating Procedures are time dated and show what and when improvements have been made to the process.	Document and provide revision history.
22	Standardised Work	shopfloor	evidence	internal auditors, e.g. QA, supervision…	Standard Operating Procedures throughout the plant are regularly audited for completeness and adherence by production workers.	Set up self-audit of SOPs that are a regular part of the operator, Team Leader, Supervisor role. If operator / team leader / supervisor or manager has a concern that the SOP is incorrect, there is a structured system in place to immediately capture and resolve that issue within agreed timescale. There is an audit process in place regularly used by the management, to ensure adherence to the SOPs.
23	Standardised Work	shopfloor	evidence	production area employees	Operators individually perform their processes according to the process sheets or Standard Operating Procedure and make few method or technique errors.	Set up system to record method and technique errors on attribute charts for analysis. Support for training only withdrawn when zero errors are detected. Method changes may be prompted from this analysis.

24	Flexible Operations	Audit room, after shopfloor	evidence, training log	production area employees	Operators are given a formal training period before doing a job on their own. Few defects or production slowdowns are attributable to new or inexperienced operators.	It is recognized that this question is more for volume production. However it can be explained how every effort has been made to increase first time pass and protect performance. I.e. There is an induction plan that reduces risks through training.
25	Flexible Operations	Audit room, after shopfloor	evidence	Plant Facilitator	Component and material travel distances have been analyzed and reduced by moving equipment and workstations closer together.	Use either mapping or string diagrams within the work area to reduce the movement. Examples of movement savings can be provided.
26	Flexible Operations	shopfloor	evidence	production area employees	Subassembly or production areas that supply a main production area or cell(s) do not changeover early to build inventory buffers, etc. The production system prevents overproduction in terms of the quantity and/or early production.	Only Pull System requirements in the form of Kanbans trigger batch making requirements. Operations to subsequent assembly areas are controlled by Production Instruction Kanbans and not Priority lists.
27	Flexible Operations	shopfloor	evidence	production area employees	Defective items are immediately detected when they occur in the production process and very seldom pass on to final assembly or to the customer.	Set up quality checks, controlled by the work team and formally set out in the SOPs. Analysis to lead to a check sheet to record important criteria, operators have go/ no go criteria and standard actions to correct.
28	Flexible Operations	shopfloor	evidence	production area employees	Processes and equipment are arranged to facilitate the continuous flow of work through a production area or cell. Work in progress within the factory does not accumulate after the process is complete and machines or equipment do not bottleneck the material flow.	Set up a pull process for controlling WIP to eliminate over-production on previous operations, as set by customer demand.
29	Flexible Operations	shopfloor	training matrix, observe	production area employees	Production operators are multi-process capable, fully trained and able to do the work at each workstation in the production cell or area.	Set up, verify and publish a training matrix for all cell staff.
30	Flexible Operations	shopfloor	observe	no discussion	U-shaped work areas or other appropriate cell layout has been implemented on the shop floor to enable and facilitate one-piece (continuous) flow of material	Set up U shaped cell or process (as per constraints of the site) or flexible manpower straight lines. These are permissible provided they demonstrate that employees can operate between lines.

					through production.	
31	Continuous Improvement	Audit room, after shopfloor	evidence	Plant Facilitator	There is a clearly communicated strategy and designated person for continuous improvement in the plant with the necessary resources, organization , and infrastructure in place to support the improvement process.	Dependent on the size of the plant if full time or not. Responsible person known to all personnel. The person should be able to show the company improvement plan and demonstrate progress of the plan.
32	Continuous Improvement	shopfloor	evidence	- observe - ask employees	There is a formal process in use to obtain ideas and suggestions for improvements from all employees and to recognize their participation.	Set up a suggestion scheme or 3Cs process or other process to record suggestions and improvement ideas.
33	Continuous Improvement	shopfloor	evidence	Plant Facilitator	Employees have been trained in continuous improvement methods and have benefited by, or have participated, in a continuous improvement project.	Records will provide evidence that a minimum of 85% of the employees have been trained on improvement methods and/or been involved in improvement activities longer than 3 days continuous duration per year.
34	Continuous Improvement	shopfloor	evidence	- observe - ask employees	Employees know the seven wastes, and are actively involved in identifying waste in their processes. They are empowered to work to identify, reduce or eliminate waste in the process.	Train every employee to be aware of the 7 wastes and the 2 categories. The number 1 waste and why it is number 1.
35	Continuous Improvement	Audit room, after shopfloor	evidence	Plant Facilitator	Continuous improvement projects are well structured and planned. Improvement actions are recorded and implemented to a planned time scale. Successful projects are recognised and expanded throughout the plant.	Presentation material is available for all activities. Senior management attends feedback and supports the outcome. Process should be WPS or equivalent successful method.

36	Continuous Improvement	shopfloor	evidence	production area employees	Many of the improvements made throughout the plant involve only minor or no capital investment. The improvement process is dominated by small improvements rather than large scale capital investment.	Controlled through the revenue budget in the main. Some allocation of capital for special additional equipment may be acceptable. This question is trying to move towards efficiency of man-machine-process as opposed to automation and pallet line transfer systems, which Lean, believes are inflexible.
37	Continuous Improvement	shopfloor	evidence	production area employees	Standard Operating Procedures are subject to a continuous improvement process that seeks to improve the sequence of steps in the operation, reduce Work in Progress and increase labour and machine utilization.	Set up a plan of improvement activities which deliver improvements to SOPs, WIP, change over and set up, flow, health & safety, quality and empowerment.
38	Error Proofing	shopfloor	walk around, observe	- observe - ask employees	Workers have been trained in the principles and methods of error proofing within the production process. There is a structured and regular analysis of production defects and identification of error proofing opportunities.	Train personnel on Poka Yoke (error proofing). Set up a team, for example Training and Continuous Improvement Team, or teams to review defects with view to install Poka Yoke to repeat concerns. It can be demonstrated that opportunities for error proofing have been studied (e.g. new process / product risks, analysis of quality performance and root causes), and error proofing actions defined and progress tracked.
39	Error Proofing	shopfloor	evidence	- observe - ask employees	Error proofing devices and methods have been implemented or are being developed to assist in elimination of the top production defects for each work area in the plant.	Analysis and Development of Solutions Analysis of top causes of defects in the plant (Pareto charts) is displayed and has resulted in installation of the appropriate error proofing devices. Schedule and control of the testing devices is available and up to date.
40	Error Proofing	shopfloor	evidence	- observe - ask employees	Error proofing devices and methods have been applied to both manual operations and automated process within the plant. Where practical manual processes have been improved using check fixtures, locating devices, poke-yoke methods, in-process check sheets etc. Automated machines are equipped with self inspection technology.	Implementation of Solutions Implement appropriate error proofing devices asking yourself what is that customer does not want and what we need to implement to eliminate the root cause in the process, e.g.: - Simple low maintenance checking (PASSING PLATES) are normal practice as is machine probing - Proving programs on machines

41	Error Proofing	shopfloor	evidence	- observe - ask employees	Error-proofing devices that have been installed are monitored for effectiveness, and kept in good working condition.	Validation and checks Set up a system for testing all devices and scheduling into SOP or daily / weekly work routines. (i.e. part of 5S system)
42	Error Proofing	Audit room, after shopfloor	evidence	- observe - ask employees	A detailed analysis has been conducted on parts, components and processes, to identify design opportunities to eliminate waste and improve productivity.	Error proofing analysis Advanced Quality Planning session are set up to review generic quality issues and evidence of requests to design and design changes have allowed error to be eliminated. Recommended approach is to focus on the process, rather than a project, and use Process and Design FMEA and/or job record/route card.
43	Error Proofing	shopfloor	evidence, observation	- observe - ask employees	Operators will stop the production process when a defective unit is found or when they can not complete their process according to the Standard Operating Procedure.	Stop Errors at source Operators should also be aware of the procedure to alert the team leader or supervisor of the concern.
44	Error Proofing	shopfloor	evidence	production area employees	Manual processes or work tasks have been equipped with mechanical checks to aid human judgment wherever possible.	Remove Human Judgement Gauges, check fixtures and jigs are provided at the earliest operation to check the component. Where possible the check should mark the part to verify it was "good" only! or prevent further operations.
45	Error Proofing	shopfloor	evidence	no discussion	Processes are equipped with call lights, signals or sounds so that workers and machines call for assistance when a problem is encountered.	Andons, cell phones, verbal or any other visual communication etc are acceptable as a means to immediately communicate concerns and reacted to with a sense of urgency.
46	Quick Changeover	shopfloor	evidence, observation	production area employees	Changeovers are scheduled in advance and communicated to all workers on the team. They know the day's changeover schedule. Next job(s) are known well in advance to enable completion of all 'in cycle' job preparation tasks.	The production shop understands changeovers in advance on a planning board or a similar visual process, unless the process is scheduled through a kanban batch making system, in which case the system will control changeover to a set procedure. Changeovers are scheduled to ensure that all required inputs are provided on time, e.g. tooling, programming, material...
47	Quick Changeover	Audit room, after shopfloor	evidence	Plant Facilitator	Quick changeover teams have received training on changeover time reduction procedures and are actively improving changeover methods.	Examples of SMED using WPS SMED sheets are available and activities have achieved sub 10-minute change over in actual terms. (It should be noted that WPS is endeavouring for single-piece flow, and therefore if a changeover takes 5 hours for a batch of 5, as an example, the target time should be 1 hour or better to maintain costs per item. Note: all processes should be dealt with in this manner before achieving 10 minutes changeovers.)

48	Quick Changeover	Audit room, after shopfloor	evidence	Plant Facilitator	Changeover activities have been subject to detailed process analysis techniques such as motion study, time study and video recording of process to identify waste.	Changeover studies Team based activities have been completed and provide examples that are available for verification. Use the WPS to follow a simple but effective method of analysis and improvement.
49	Quick Changeover	shopfloor	evidence	no discussion	Changeover time, both internal and external, is visibly tracked at each workstation where changeovers are performed.	Changeover time tracking WPS SMED sheets are in use, actual times are logged against target and displayed on the machine or in the cell.
50	Quick Changeover	shopfloor	evidence	production area employees	As new changeover procedures are developed, they are standardized and replicated in other areas of the plant.	Standardise and Propagate improvements Evidence of method duplication in other areas is required if duplication/replication is possible, subject to plant layout and size.
51	Quick Changeover	shopfloor	evidence	production area employees	Special tools or equipment have been developed and implemented to reduce the time and labour involved in the changeover process.	Examples of tools/ fixtures or jigs with before and after condition will be expected.
52	Quick Changeover	shopfloor	evidence	production area employees	All of the cutters, fixtures, tools, fasteners, materials, parts, raw stock, lifting equipment. etc. needed for the next production run are prepared in advance to reduce change-over times.	System is set up that identifies part required for the next set up and this is completed whilst the machine is operating on the previous part. i.e. in cycle / internal.
53	Quick Changeover	shopfloor	evidence	no discussion	All dies, fixtures, and changeover tools are stored in a neat, orderly fashion when not in use and are maintained in good working condition.	Tools and equipment storage A "30 second" rule should apply (common use items can be retrieved in 30 seconds, or as agreed by plant management, at the work station) . SOP for maintenance of tooling should be available. These items are laid out in a 2S condition within the working area and an inspection procedure for the condition and maintenance of the equipment is in place.
54	Total Productive Maintenance	shopfloor	evidence	Maintenance	Maintenance team managers and workers have been trained in the basics of Total Productive Maintenance (TPM).	Set up training in the use of WPS TPM training package and OEE (Overall Equipment Effectiveness) measure to generate savings in the 6 big loss areas of machine-dominated processes. Training provided in Downtime, causes of downtime and efficiency / utilization tracking methods.

55	Total Productive Maintenance	shopfloor	evidence, demonstration	production area employees	Machines have all safety guard devices operative. Where appropriate the machine will shut down immediately if defective. (e.g. Safety guards are not disabled or removed. Malfunctioning equipment is not allowed to continue operating in production.)	WPS does not accept any changes to guarding or method that compromises safety or a well-being of our staff or contractors. Interlocks, mechanical, Electrical and Hydraulic (Where applicable are all in good working order and either operate as commissioned or as to a higher level fitted to match current codes of practice).
56	Total Productive Maintenance	shopfloor	evidence	no discussion	Preventive maintenance activity lists are posted in work areas. Each item for action has a planned close out date and is monitored until complete.	Electronic systems are acceptable however persons responsible for carrying out the activity must prove capability to retrieving the instructions. Printouts from electronic systems need to be posted in the cell would be acceptable.
57	Total Productive Maintenance	shopfloor	evidence	no discussion	Accurate and visible maintenance records are kept up to date and posted nearby or are readily available for all production machines.	A system that visually shows overdue maintenance activities must be visible in production areas.
58	Total Productive Maintenance	shopfloor	evidence	Maintenance	Preventive maintenance activities are focused on increasing production utilization and minimizing cycle time variation. (e.g. Work capacity utilization is tracked and cycle time performance is monitored for each machine and is used in maintenance activity planning. The maintenance team is developing from preventive to predictive maintenance capability)	Maintenance is focused on the results of OEE and the TPM targets. Objectives concentrate on minimizing the 6 losses through machine capability and reliability issues. Production is seen as internal customers by maintenance and close liaison with cell management is the norm. Downtime and causes of downtime are tracked. Efficiency (utilization) is also tracked.
59	Total Productive Maintenance	shopfloor	evidence	production area employees	Preventive maintenance responsibilities are defined for both maintenance and production workers. (e.g. Operators are responsible doing routine tasks like checking oil, cLeaning machines, & changing tools.etc)	Set up a system where SOPs are set up to distinguish roles. Training has been provided and tested for competency. Preference is to store SOPs in the cell.
60	Material Control	shopfloor	evidence	no discussion	The production target and actual output per shift, is displayed for each manufacturing cell or process group. The shift production requirement and	Set up a visual system, where: - either through the Heijunka post (if visible to the work team) or - electronically if staff have easy access - or appropriate local visual planning board production output targets and shift

					time scale is also displayed.	length in time are shown.
61	Material Control	Audit room, after shopfloor	evidence	Plant Facilitator	All production managers and supervisors have been trained in the principles and implementation of production material pull systems.	Pull system training WPS Pull System using Production Instructions and Withdrawal Kan Bans is the preferred method. Operating to a known takt time and planned tact.
62	Material Control	shopfloor	evidence	production area employees	Material flow or movement in the plant is dependent on individual pull signals (using recognised WPS pull methods, e.g. kanban, slotting/TAKT…), as parts or materials are used at assembly or dispatched to customer.	Set up production in order that replenishment is through Pull signal or in Engineered to Order product cells through the WPS system of ASN's (Advanced Shipping Notes).
63	Material Control	shopfloor	evidence	production area employees	Downstream processes such as assembly, are pulling material from upstream processes such as production cell or from stock. The upstream production schedules are therefore dependent on downstream usage. Pull system supports smooth flow and prevents overproduction in terms of a quantity (producing unnecessary parts) and/or time (produced parts wait between operations).	Assembly is "KING". And sets the pace of the plant. All other supply areas do not over produce against the pace set by assembly.
64	Material Control	Audit room, after shopfloor	evidence	Planning	Adapting to changes in customer demand requires changing only the production schedule for the "final" line or process activity. There is a system in place that enables change of production schedule in accordance with the customer demand at just one point in the flow, and all other elements of the flow will re-adjust themselves to prevent overproduction	Mainly true to volume configured production plants. However any plant should be able to demonstrate that this rule is applied as near to this flexibility as is possible given the degree of Made to Order. For example, there is a pull system in place that enables change in the most downstream point in the production process.

					and/or waiting.	
65	Material Control	shopfloor	evidence	production area employees	Production supervisors do not produce more parts than the subsequent processes requires, both in terms of quantity and timing.	Through use of SMED, batch size reduction has been successful in reducing the cost of single part batches. This enables this rule to be applied without cost impact.
66	Level Production	Audit room, after shopfloor	evidence	Planning	There is an effort to level production schedules by spreading the monthly work load evenly over the period.	Heijunka has been introduced as normal, an understanding of why Heijunka is so important in the engineer to order environment is embedded in management thinking. Sales and Operations planning process controls the levelling at the earliest stage possible.
67	Level Production	Audit room, after shopfloor	evidence	Planning	Changeover in production are made to support the mix of customer demand requirements and not to support long productions runs, large batches, work in progress inventory buffers, or local emergencies, etc.	The Heijunka of customer demand in component cells is controlled to ensure all customers of the cell receive level delivery. Suppliers of the cell can understand the reasons and benefits of this process.
68	Level Production	shopfloor	evidence	no discussion	TAKT (Time slot), calculated based on customer demand, determines the pace of production in the plant.	Takt time is known at any time of year and the working pattern is reflected to show the takt requirements. Variations in takt sets about a known course of action in manning or hours of work for the period.
69	Level Production	Audit room, after shopfloor	evidence	Planning	The Takt time (customer demand) is used as the basis to determine process cycle times (TACT) and allocate work throughout the production process. The Takt time is compared to cycle times to determine resource needs.	Balanced cells are set up based on the achievement of takt time. A management allowance for changeover time and minor stoppages is normally set depending on the type of business, therefore the total actual cycle time is divided by the number of stations (TACT) and an allowance is added of 5% of high volume and 15% - 20% in an Engineered to order environment. Management need to assess this number and set it in their policies. This is balanced to achieve takt time.

70	Level Production	shopfloor	evidence	production area employees	Processes in production cells or work areas are balanced or levelled so that the difference between cycle times of linked processes is negligible. Comment: waiting time is eliminated or negligible and there is no overproduction	Any cells or processes containing multiple operations should be charted to show the total actual cycle time of each operation against takt. Any variation in the cycle time should be minimised through balancing the work more evenly. The lightest station in terms of workload should always be the last station to allow for quality product.
71	Level Production	Audit room, after shopfloor	evidence	Planning	When material or component demand is increased, production processes are re-balanced or redesigned to reduce the process cycle times to correspond to the new Takt time (the new customer demand).	Generally a measure of takt time set an actual is communicated to the shopfloor team at regular periods (normally after programming the forward load for a specific period or quarter). Kaizen work by the team will endeavour to achieve savings to enable the higher volume to be achieved. The takt / cycle time comparison drive kaizen opportunities. For example is takt is 10.1 and cycle is 10.3 kaizens should focus on reducing the cycle by 0.2 or 0.2+"catchback" time (depending on the nature of the process).

Policy deployment assessment:

For each statement indicate the score that best represents the current working practice within the plant.

Q1 - Objectives – development, content and communication

Practice	Score
Company/facility objectives have not been developed	**0**
Company/facility objectives developed; consist financial objectives mainly	**1**
Company/facility objectives developed; consist non-financial and financial objectives; known to the management	**2**
Company/facility objectives developed and aligned with Divisional objectives; consist non-financial and financial objectives; presented to all employees.	**3**
Company/facility objectives for the current year have been developed, aligned with Divisional objectives, consist non-financial and financial objectives that address Safety, Quality, Delivery, Cost, Development of people and processes, and Management systems; presented to all employees; publicised widely across the company.	**4**

Q2 - Policy Deployment – the scope of implementation

Practice	Score
Policy Deployment matrix does not exist	**0**
Policy Deployment matrix developed at the company level only	**1**
Policy Deployment matrix developed at the company level and all/selected functions	**2**
Policy Deployment matrix developed at the company level and all functions. Selected departmental objectives developed and transferred to PDP for selected employees	**3**
Policy Deployment matrix developed at the company level and all functions. All departmental objectives developed and PD objectives transferred to PDP for all employees	**4**

Q3 - Policy Deployment development – leadership and participation

Practice	Score
Policy Deployment does not exist.	**0**
Policy Deployment developed by the management only	**1**
Policy Deployment developed by the management and selected employees.	**2**
Policy Deployment developed considering feedback from the management, selected employees, last year objectives, budget, resources, alignment across functions / departments and Divisional objectives. Development led by plant MD/GM.	**3**
Policy Deployment developed considering relevant feedback from all internal and external stakeholders: workforce, long-term plan, management, key suppliers, customers…last year objectives, budget, resources, alignment across functions and departments…and Divisional objectives. Development led by plant MD/GM.	**4**

Q4 - Policy Deployment development – objectives metrics and targets

Practice	Score
Policy Deployment does not exist	**0**
Some objectives have relevant metrics, mainly descriptive, some have target dates	**1**
All objectives have one or more relevant metric, some descriptive, some measurable, some target dates	**2**
All objectives have one or more relevant metric, all measurable, some have start, target values and dates	**3**
All objectives have relevant metric(s), all measurable, all have start / target values and target dates	**4**

Q5 - Policy Deployment development – improvement projects 'breakthrough' level

Practice	Score
Policy Deployment does not exist	**0**
All improvement projects are aiming to maintain the current system delivering control of the current working practices and predictable performance results	**1**
Some (approx. half) of improvement projects deliver substantial* change of working practices and performance results	**2**
Most (75%+) of improvement projects deliver substantial* change of working practices and performance results	**3**
All improvement projects deliver substantial* change of working practices and performance results	**4**

*'Substantial change' means expected or achieved improvement rate of relevant KPIs by 30% - 70% or more

Q6 - Policy Deployment development – ownership; alignment; resourcing

Practice	Score
Policy Deployment has not been developed.	**0**
Key improvement projects have defined roles (who leads/responsible, who supports/participates/consulted/facilitates); Resources have not been considered.	**1**
All improvement projects have defined roles (who leads/responsible, who supports/participates/consulted/facilitates); Resources have not been considered.	**2**
All improvement projects have defined roles (who leads/responsible, who supports/participates/consulted/facilitates); Resources have been considered for some projects.	**3**
All improvement projects have defined roles (who leads/responsible, who supports / participates / consulted / facilitates);	**4**

Resources have been planned for all projects against the schedule	

Q7 - Policy Deployment development – progress tracking

Practice	Score
Policy Deployment has not been developed.	**0**
Policy Deployment progress is not structured and is irregular: projects tracking is left to project leaders; progress reviews are not scheduled but when requested by senior management.	**1**
Policy Deployment progress is structured but irregular: each project is tracked using simple report; reviews are not scheduled but happen when requested by management.	**2**
Policy Deployment progress is structured and regular: each project is tracked using simple report; bi-monthly / quarterly reviews by management and project leaders, led by plant MD/GM.	**3**
Policy Deployment progress is structured and regular: each project is tracked using simple report; monthly reviews by senior management and project leaders, led by plant MD/GM.	**4**

Appendix B Operational definitions for Operational Performance measures

Lean Manufacturing Audit Upgrade – Addition of KPIs

KPI Definition, Calculation, Target Setting and Scoring

1. On-Time-Delivery

- Definition and Calculation

Key Guiding Principles:

- On-Time-Delivery is considered from customer's point of view
- We need to maintain integrity and honesty in our decisions. If in doubt, quote assumptions made to make any 'gray' issue transparent.

'Complete Shipment' – consist of:

1. products (hardware)
2. drawings that require customer approval and
3. QA documents required by the customer that need to be delivered to complete a shipment and not hold back full payment, as agreed with the customer.
4.

Note: the above three categories have been initially selected to simplify OTD measurement. All other items that impact customer satisfaction will be taken into account when we establish and run simple and robust OTD measurement and improvement of the above three items.

Purchase Order contains one or more Complete Shipments.

Complete Shipment contains one or more Line Items.

On-Time Delivery in the period (%) =

The number of Complete Shipments delivered satisfactorily on the day agreed and required by the customer divided by the number of Complete Shipments due in the period plus the number of late (not delivered yet or delivered late in the period) Complete Shipments.

* "On Time" complete shipment has a delivery date within 'agreed delivery time window', as agreed with a customer.

An early delivery could be as unacceptable to a customer as a late delivery.

A complete shipment may have unspecified (open) earliest delivery date. In that case a complete shipment can not be 'an early delivery'.

An agreed date with a customer should be a documented agreed date.

If a date is going to change from the original PO and is being driven by customer changes for instance the new date should be documented in an e mail or change order which simplifies any auditing.

Measured to the day agreed and required date by the customer, within 'agreed delivery time window'.

Reported monthly.

Calculation tolerance on agreed dates is +/-0 days.

We can write OTD calculation formula as: OTD (%) = DOT / (DUE + LATE)

OTD = On-Time-Delivery in % for selected period, e.g. one month

DOT = Number of Complete Shipments Delivered on Time in selected period

DUE = Number of Complete Shipments due in the period

LATE = Total number of late Complete Shipments at the time of calculation, e.g. end of month, including complete backlog, but excluding orders already counted in DUE (to prevent double-counting)

The following two numbers, A and B, are reported through Cognos:

A = DOT (see the above formula)

B = DUE + LATE (see the above formula)

OTD (%) Calculation Example

1.	Purchase Order #1	Required date	Actual date	On Time/Late?
1.1.	Complete Shipment	**28-May-2008**	**26-May-2008**	**on time delivered**
1.1.1.	Line Item	28-May-2008	22-May-2008	on time
1.1.2.	Line Item	28-May-2008	20-May-2008	on time
1.1.3.	……	28-May-2008	22-May-2008	on time
1.2.	Complete Shipment	**30-April-2008**	**15-May-2008**	**late delivered**
1.2.1.	Line Item	30-April-2008	25-April-2008	on time
1.2.2.	….	30-April-2008	15-May-2008	late
2.	Purchase Order #2	Required date	Actual date	On Time/Late?
2.1.	Complete Shipment	**18-May-2008**	**20-May-2008**	**late**
2.1.1.	Line Item	18-May-2008	16-May-2008	on time
2.1.2.	Line Item	18-May-2008	20-May-2008	late
2.1.3.	……	18-May-2008	16-May-2008	on time
2.2.	Complete Shipment	**30-July-2008**	**open**	**not due yet**
2.2.1.	Line Item	30-July-2008	15-May-2008	
2.2.2.	….	30-July-2008	open	
3.	Purchase Order #3	Required date	Actual date	On Time/Late?
3.1.	Complete Shipment	**18-March-08**	**not delivered yet**	**late**
3.1.1.	Line Item	18-March-08	16-March-08	on time
3.1.2.	Line Item	18-March-08	not delivered yet	late
3.1.3.	……	18-March-08	16-March-08	on time

Calculation of OTD in May 2008:

- Number of Complete Shipments delivered on time: 1 (#1.1.)

- Number of Complete Shipments due in May-2008: 2 (#1.1. #2.1.)
- Number of late (not delivered yet or delivered late in the period) Complete Shipments. 2 (#3.1. #1.2.)

OTD in May-2008 = 1 / 4 = 25%

- Target Setting and Scoring

Average Monthly OTD (%) in the last 6 months	Score
98% or higher`	8
95 – 97 %	7
91 – 95 %	6
86 – 90 %	5
81 – 85 %	4
71 – 80 %	3
61 – 70 %	2
51 – 60 %	1
< 50 %	0

3. Inventory Turns

- Definition and Calculation – as already defined and monitored at the Group level

Inventory turns = Rolling last 3 months Cost of Goods Sold, annualised

---

Net stock level in the balance book which includes obsolescence

Net stock level includes stock (physical inventory), WIP, inventory obsolescence provision and "Amounts Recoverable on Contracts"

- Target Setting

Target Inventory Turns are set internally against each month for the following year.

The targets are set using Group internal or external benchmark.

Inventory turns targets need to be confirmed by Divisional Managing Director and Divisional MEC Champion.

- Scoring

Observation is done against the last 8 months. One point is scored for each month when inventory turns are either on target or better than target.

4. Direct Labour Utilisation

- Definition and Calculation

Labour Utilisation is calculated for each work order processed through the manufacturing plant.

Labour Utilisation = Standard hours generated* / Direct labour hours attended

Standard hours exclude non-job related time, e.g. waiting, tooling, set-up, re-work, meetings, breakdowns, inspection, programming, material quality problem…

*When standard hours are not available use estimated hours against a job**

**When estimated hours are not available use direct hours charged to a job (paid by the customer)

- Target Setting and Scoring

Average Plant Direct Labour Utilisation (%) in the last 6 months	Score
>90%	8
86 – 90 %	6
76 – 85 %	4
61 – 75 %	2
<60%	0

- Direct Labour Utilisation example

Total attended time

Suppose that there are 30 direct operators in a plant and they have attended 8 hours per day each, 22 days in a given month.

Attended time is measured from operator clocking in to operator clocking out.

Total attended time for this plant equals to 30 x 22 x 8 = 5280 hours

Standard hours

In a given month, those 30 operators have clocked 4000 standard hours in total, for all of their jobs.

Notes:

- if standard hours are not available use estimated hours. If estimated hours are not available use hours charged to the customer.

- standard hours exclude non-value added time, e.g. waiting, tooling, set-up, re-work, meetings, breakdowns, inspection, programming, material quality problem…

Direct Labour Utilisation = Standard hours / Total Attended hours = 4000 / 5280 = 75.5%

“4000” and “5280” are reported through Cognos

Note:

Direct Labour Utilisation = Efficiency x Effectiveness

where,

- Efficiency = Standard hours / Actual hours (this presents how efficient we were against our estimate, hours quoted/charged to the customer)

- Effectiveness = Actual hours / Attended hours (this presents what percentage of attended time was spent on jobs)

On-Time-Delivery – Frequently Asked Questions and Answers

Questions

Q1: An order is contracted to ship in July. However the order ships in June. In which month does it count as a shipment before or on time. In which month is it considered a "due" order?

Q2: How should we treat 'inter-companies trading', i.e. deliveries to other companies?

Q3: As we deliver projects does OTD apply to us? – Yes.

Q4: OTD is scored only once in the Lean Assessment. Is OTD double weighted when calculating Overall Lean Score?**: Yes**

Q5: We can not set delivery date for the castings as their quality is unpredictable. Should we include castings in OTD?

Q6: In order to meet 100% OTD we will have to increase our stock size because there are 2-3 % of rejects in every delivery. That is not Lean as inventory is a waste. How do we achieve 100% OTD with no extra cost to the business?

Q7: We have a high incidence of a client placing an order and then asking for a partial delivery. When the balance of the order is complete we have great difficulty getting him to collect the balance or even acknowledging any e-mails or faxes. The reason appears that the client has satisfied his urgent requirement to keep the rig in operation, does not immediately require the balance of the material and is so busy fighting operational fires your requests are completely ignored as not important at the time.

How do we manage this situation?

Q8: The customer has a contract in place with an external contractor which currently accounts for high percentage of our business. The majority of the contractor's orders cover material to be repaired or manufactured to support customer operations and the contractor requests normally have the following delivery request:

A) Breakdown

B) Emergency

C) Rush emergency

D) Top emergency

E) Hot taxi emergency (the customer's truck waits in the yard to re-load and take it back)

How to manage this situation?

Q9: We measure OTD Pump Units 32.4% and OTD Spares 73.13%, this is what we report in Cognos, how do we combine these?

- Total Pump orders on the books is 450 @ OTD of 32.4%=306 items late

- Spares would be over 5000 items on the books of which OTD @ 73.13%=1344 items late.

- Therefore 5450 items (complete shipments) required, 1650 late = 69.72% OTD

It makes no sense to add 73.13% & 32.4% and divide by 2=52.76%.

Equally the 306 pump units late could have a value of $20 million where as the 1344 spares could have a value of $100k.

Could you please clarify?

Q10: How to record early shipments?

If a delivery is early, do we count it the month it ships or in the month it is due to ship?

Q11: What is monthly OTD in the example below and what is reported through Cognos?

100 items are due to ship this month, comprised of items (a) and (b), as follows:

(a) 80 items originally due this month and

(b) 20 late items from previous months that are scheduled for production and delivery into current month

By the end of this month the following items have been delivered:

- 70 of the 80 items (a), so 10 items (a) remain open from this month

- 12 of the 20 items (b) from previous months, so 8 remain open from previous months

Answers

A1: When considering On-Time-Delivery always start from the following Guiding Principles:

- On-Time-Delivery is considered from customer's point of view

- We need to maintain integrity and honesty in our decisions

Our long term objective is to achieve 100% Just-In-Time deliveries, which means that every single order is received by our customers complete and within agreed 'delivery window'.

If the order is contracted to be shipped in July that gives 'delivery window' between 01-July and 31-July. If that order is shipped in June than it is outside its delivery window and it is <u>not on time</u>, it is 'early'.

This order should be reported in July, counted in as 'DUE' in denominator*, but <u>not</u> counted in numerator*.

**In the fraction A/B, A is the numerator, B is the denominator.*

Practically, this order has the same effect on July OTD whether it is 'late' or 'early'.

Note: this order can be counted in as 'delivered on time' in June, providing that the customer has agreed to move delivery date from July to June and <u>the way we have received that agreement</u> meets OTD Guiding Principles.

A2: Internal customers (deliveries to other companies) should be treated the same way as deliveries to external customers and need to be added to the overall OTD statistics.

A3: On-Time-Delivery applies to every single business activity. Time is one common factor for any business process and task.

A4: Yes, OTD is scored once but it is double weighted in the overall Lean Score calculation.

A5: Every single delivery (whether service or product) needs to have agreed delivery date or schedule. Use structured problem solving, e.g. 8D, to understand and eliminate causes of your casting quality problems.

A6: In order to achieve full customer satisfaction and eliminate or reduce waste you need to take the following two actions:

1. Containment action – the objective is to immediately protect the customer, for example, by 100% inspection, or temporarily increase stock by adding 'safety stock' which cover for expected rejects, or another solution…
2. Preventive action – use structured problem solving to identify and eliminate root causes of rejects, fix the process to achieve near 100% 'right fist time' and reduce 'safety stock'.

Note: Preventive action needs to be completed, not just containment actions

A7: OTD Guiding Principles are:

- Look into OTD from the customer point of view

- Maintain our integrity, honesty and credibility

The main objective of OTD metric is to improve customer satisfaction and service level, by establishing where we truly are, identify, prioritise and drive improvements and achieve OTD improvement trend.

As described in the question, the OTD measurement problem is an outcome / reflection of the issues related to the flow of work.

Recommended action is to properly examine this value stream, for example by using VSA.

The fact that this is 'a high incidence' is excellent opportunity because this implies existence of consistent customer need and relevant flow.

It appears that there are two independent streams:

#1 - 'urgent' flow

#2 - 'standard replenishment' flow

VSA will show those

Possible solution is to separate those two flows (although they have the same start / trigger point). Think about this like a patient calling 999 for an urgent attention, and once in the hospital asking for some standard tests where timing is not that important.

VSA will help better understanding of customer needs and material / information flow.

Also use structured problem solving to identify real root causes and corrective / preventive actions. It is critical that improvements are led and driven by someone who understands how VSA and problem solving work, believes that those will help and someone who has authority to make necessary changes.

Maintain regular dialogue with the customer.

A8: This is an operational issue. You need to report OTD in accordance with the KPi Definition.

It is an excellent opportunity to use VSA, starting by categorising customers and their needs, identifying streams....(for example already quoted A, B,....E are the customer needs categories, which may require the same or separate streams).

A9: When in doubt, always start from the Guiding Principles of OTD definition, as follows:

- On-Time-Delivery is considered from customer’s point of view

- We need to maintain integrity and honesty in our decisions

Our long term objective is to achieve 100% Just-In-Time deliveries, which means that every single order is received by our customers complete and within agreed ‘delivery window’.

In accordance with those principles and assuming that you had 5450 shipments in July (either due or overdue), out of which 1650 shipped on time, your July OTD is 69%.

This OTD calculation assumes that you had 5450 complete shipments, not line items, as one complete shipment may contain one or more line items.

OTD calculation is based on complete shipments delivered on time, regardless of their monetary value.

Although, from our point of view pumps are seen as high value, from the customer point of view , a spare part which could be worth just few dollars might be critical to keep customer's operation running.

A10:

If an early (and complete) shipment is accepted by the customer than it is counted as 'on time' in the period when shipped, otherwise it can not be counted as 'on time'.

If the customer does not want early shipment or has not authorized change of delivery date than this is counted as 'due' but not as 'on time' in the period of original delivery date.

Examples:

Original due date: 12-Nov-2008

Actual shipment date:13-Oct-2008

Customer accepted*: yes

New due date: 13-Oct-2008

OTD calculation: OTD (%) = DOT / (DUE + LATE), count this order in 'DOT' and in 'DUE', report in October 2008

Original due date: 12-Nov-2008

Actual shipment date: 13-Oct-2008

Customer accepted*: **no**

New due date: no change

OTD calculation: OTD (%) = DOT / (DUE + LATE), count this order in 'DUE' only, report in November 2008

*when considering On-Time-Delivery always start from the Guiding Principles:

- On-Time-Delivery is considered from customer's point of view

- We need to maintain integrity and honesty

A11:

The formula to calculate OTD is as follows (ref: page 2 of this document):

OTD = On-Time-Delivery in % for selected period, e.g. one month

DOT = Number of Complete Shipments Delivered on Time in selected period

DUE = Number of Complete Shipments due in the period

LATE = Total number of late Complete Shipments at the time of calculation, e.g. end of month, including complete backlog, but excluding orders already counted in DUE (to prevent double-counting)

The following two numbers, A and B, are reported through Cognos:

A = DOT (see the above formula)

B = DUE + LATE (see the above formula)

OTD = 70

DUE = 80

LATE = 20

OTD = 70 /(80+20) = 70%

The following two numbers (A and B) are reported through Cognos:

A = DOT = 70

B = DUE + LATE = 100

Notes:

- Only 80 items is DUE this month because DUE does not refer to how many scheduled for production, but scheduled to be delivered this month as agreed with the customer.
  OTD is not an internal measure!

- All of items (b), i.e. all 20, are LATE and remain late unless new delivery dates have been agreed with the customer

- 12 items that were produced on-time against internal schedule can not count as ‘on time’, (see Guiding Principle #1) although they look on time from production point of view when measured against internal plan. Internal due dates are irrelevant, what only matter are customer agreed dates.

How to achieve and sustain relatively good OTD: Internal examples

How to achieve and sustain relatively good OTD – key points

1. Levelling daily production each month and levelling hours of load to capacity each week

2. Daily Heijunka loading.

3. Strength is spare parts delivery

4. Casting supplier (next door) attend daily production meeting and Customer go to the foundry daily to confirm the plans

Note: Pumps delivery is not that good, to correct this they are focussing on front end process with VSM with sales orders and VSM with engineering

Appendix C **SAS Input listing for indicator reliability**

```
PROC CORR DATA = MSC.INPUT_DATA_4_RAW ALPHA;
VAR PD1-PD7;
RUN;
PROC CORR DATA = MSC.INPUT_DATA_4_RAW ALPHA;
VAR CA1-CA7;
RUN;
PROC CORR DATA = MSC.INPUT_DATA_4_RAW ALPHA;
VAR VMH1-VMH8;
RUN;
PROC CORR DATA = MSC.INPUT_DATA_4_RAW ALPHA;
VAR SW1-SW8;
RUN;
PROC CORR DATA = MSC.INPUT_DATA_4_RAW ALPHA;
VAR FO1-FO7;
RUN;
PROC CORR DATA = MSC.INPUT_DATA_4_RAW ALPHA;
VAR CI1-CI7;
RUN;
PROC CORR DATA = MSC.INPUT_DATA_4_RAW ALPHA;
VAR EP1-EP8;
RUN;
PROC CORR DATA = MSC.INPUT_DATA_4_RAW ALPHA;
VAR QC1-QC8;
RUN;
PROC CORR DATA = MSC.INPUT_DATA_4_RAW ALPHA;
VAR TPM1-TPM6;
RUN;
PROC CORR DATA = MSC.INPUT_DATA_4_RAW ALPHA;
VAR MC1-MC6;
RUN;
PROC CORR DATA = MSC.INPUT_DATA_4_RAW ALPHA;
VAR LP1-LP6;
RUN;
```

Appendix D **SAS input listing for the single factor measurement model**

Single factor Measurement Model revision 1

```
DATA STORAGE_DATA;
SET MSC.INPUT_DATA_4_RAW;

V1      =  (PD1+PD2+PD3+PD4+PD5+PD6+PD7)/7;
V2      =  (CA1+CA2+CA3+CA4+CA5+CA6+CA7)/7;
V3      =  (VMH1+VMH2+VMH3+VMH4+VMH5+VMH6+VMH7+VMH8)/8;
V4      =  (SW1+SW2+SW3+SW4+SW5+SW6+SW7+SW8)/8;
V5      =  (FO1+FO2+FO3+FO4+FO5+FO6+FO7)/7;
V6      =  (CI1+CI2+CI3+CI4+CI5+CI6+CI7)/7;
V7      =  (EP1+EP2+EP3+EP4+EP5+EP6+EP7+EP8)/8;
V8      =  (QC1+QC2+QC3+QC4+QC5+QC6+QC7+QC8)/8;
V9      =  (PM+TPM2+TPM3+TPM4+TPM5+TPM6)/6;
V10      = (MC1+MC2+MC3+MC4+MC5+MC6)/6;
V11      = (LP1+LP2+LP3+LP4+LP5+LP6)/6;
V12 = KPI2/2;
V13 = KPI3/2;
V14 = KPI4/2;
RUN;
PROC CALIS COV DATA = STORAGE_DATA KURTOSIS METHOD = ML PALL RESIDUAL=NORM TECH = NR;
LINEQS

        V1 = LV1F1 F1 + E1,
        V2 = LV2F1 F1 + E2,
        V3 = LV3F1 F1 + E3,
        V4 = LV4F1 F1 + E4,
        V5 = LV5F1 F1 + E5,
        V6 = LV6F1 F1 + E6,
        V7 = LV7F1 F1 + E7,
        V8 = LV8F1 F1 + E8,
        V9 = LV9F1 F1 + E9,
        V10 = LV10F1 F1 + E10,
        V11 =     F1 F1 + E11;

               /*V12 = LV12F2 F2 + E12,
               V13 = LV13F2 F2 + E13,
               V14 =        F2 + E14;*/

STD
        F1= VARF1,
        E1-E11= VARE2-VARE11;

VAR     V1-V11;
RUN;
```

Single factor Measurement Model revision 2

```
DATA STORAGE_DATA;
SET MSC.INPUT_DATA_4_RAW;

V1      =  (PD1+PD2+PD3+PD4+PD5+PD6+PD7)/7;
V2      =  (CA1+CA2+CA3+CA4+CA5+CA6+CA7)/7;
V3      =  (VMH1+VMH2+VMH3+VMH4+VMH5+VMH6+VMH7+VMH8)/8;
V4      =  (SW1+SW2+SW3+SW4+SW5+SW6+SW7+SW8)/8;
V5      =  (FO1+FO2+FO3+FO4+FO5+FO6+FO7)/7;
V6      =  (CI1+CI2+CI3+CI4+CI5+CI6+CI7)/7;
V7      =  (EP1+EP2+EP3+EP4+EP5+EP6+EP7+EP8)/8;
V8      =  (QC1+QC2+QC3+QC4+QC5+QC6+QC7+QC8)/8;
V9      =  (PM+TPM2+TPM3+TPM4+TPM5+TPM6)/6;
V10      = (MC1+MC2+MC3+MC4+MC5+MC6)/6;
V11      = (LP1+LP2+LP3+LP4+LP5+LP6)/6;
V12 = KPI2/2;
V13 = KPI3/2;
V14 = KPI4/2;
IF _N_=63 THEN DELETE;
IF _N_=35 THEN DELETE;
IF _N_=32 THEN DELETE;
IF _N_=8 THEN DELETE;
```

```
RUN;
PROC CALIS COV DATA = STORAGE_DATA KURTOSIS METHOD = ML PALL RESIDUAL=NORM TECH = NR;
LINEQS

        V1 = LV1F1 F1 + E1,
        V2 = LV2F1 F1 + E2,
        V3 = LV3F1 F1 + E3,
        V4 = LV4F1 F1 + E4,
        V5 = LV5F1 F1 + E5,
        V6 = LV6F1 F1 + E6,
        V7 = LV7F1 F1 + E7,
        V8 = LV8F1 F1 + E8,
        V9 = LV9F1 F1 + E9,
        V10 = LV10F1 F1 + E10,
        V11 =     F1 F1 + E11;

               /*V12 = LV12F2 F2 + E12,
               V13 = LV13F2 F2 + E13,
               V14 =        F2 + E14;*/

STD
        F1= VARF1,
        E1-E11= VARE2-VARE11;

COV
               E8 E7 = CE8E7,
               E2 E1 = CE2E1,
               E11 E1 = CE11E1,
               E6 E2 = CE6E2,
               E3 E2 = CE3E2,
               E6 E3 = CE6E3,
               E11 E3 = CE11E3,
               E9 E5 = CE9E5,
               E10 E5 = CE10E5,
               E11 E10 =CE11E10,
               E10 E3 = CE10E3,

               E9 E4 = CE9E4,
               E10 E1 = CE10E1,
               E7 E1 = CE7E1,
               E6 E1 = CE6E1,
               E8 E4 = CE8E4,
               E9 E8 = CE9E8,
               E10 E9 = CE10E9,
               E8 E1 = CE8E1,
               E4 E3 = CE4E3,
               E5 E2 = CE5E2,
               E3 E1 = CE3E1,
               E9 E7 = CE9E7,
               E4 E2 = CE4E2,
               E7 E4 = CE7E4;

VAR     V1-V11;
RUN;
```

Appendix E SAS input listing for the full factor measurement model

Measurement Model

```
DATA STORAGE_DATA;
SET MSC.INPUT_DATA_4_RAW;

V1      =  (PD1+PD2+PD3+PD4+PD5+PD6+PD7)/7;
V2      =  (CA1+CA2+CA3+CA4+CA5+CA6+CA7)/7;
V3      =  (VMH1+VMH2+VMH3+VMH4+VMH5+VMH6+VMH7+VMH8)/8;
V4      =  (SW1+SW2+SW3+SW4+SW5+SW6+SW7+SW8)/8;
V5      =  (FO1+FO2+FO3+FO4+FO5+FO6+FO7)/7;
V6      =  (CI1+CI2+CI3+CI4+CI5+CI6+CI7)/7;
V7      =  (EP1+EP2+EP3+EP4+EP5+EP6+EP7+EP8)/8;
V8      =  (QC1+QC2+QC3+QC4+QC5+QC6+QC7+QC8)/8;
V9      =  (PM+TPM2+TPM3+TPM4+TPM5+TPM6)/6;
V10      = (MC1+MC2+MC3+MC4+MC5+MC6)/6;
V11      = (LP1+LP2+LP3+LP4+LP5+LP6)/6;
V12 = KPI2/2;
V13 = KPI3/2;
V14 = KPI4/2;
IF _N_=63 THEN DELETE;
IF _N_=35 THEN DELETE;
IF _N_=32 THEN DELETE;
IF _N_=8 THEN DELETE;
RUN;
PROC CALIS COV DATA = STORAGE_DATA KURTOSIS METHOD = ML PALL RESIDUAL=NORM TECH = NR;
LINEQS

        V1 = LV1F1 F1 + E1,
        V2 = LV2F1 F1 + E2,
        V3 = LV3F1 F1 + E3,
        V4 = LV4F1 F1 + E4,
        V5 = LV5F1 F1 + E5,
        V6 = LV6F1 F1 + E6,
        V7 = LV7F1 F1 + E7,
        V8 = LV8F1 F1 + E8,
        V9 = LV9F1 F1 + E9,
        V10 = LV10F1 F1 + E10,
        V11 = LV11F1 F1 + E11,
        V12 = LV12F2 F2 + E12,
        V13 = LV13F2 F2 + E13,
         V14 =LV14F2 F2 + E14;

STD
        F1-F2= VARF1 - VARF2,
        E1-E14= VARE1-VARE14;

COV
                F1 F2 = CF1F2,

                E8 E7 = CE8E7,
                E2 E1 = CE2E1,
                E11 E1 = CE11E1,
                E6 E2 = CE6E2,
                E3 E2 = CE3E2,
                E6 E3 = CE6E3,
                E11 E3 = CE11E3,
                E9 E5 = CE9E5,
                E10 E5 = CE10E5,
                E11 E10 =CE11E10,
                E10 E3 = CE10E3,
                E9 E4 = CE9E4,
                E10 E1 = CE10E1,
                E7 E1 = CE7E1,
                E6 E1 = CE6E1,
                E8 E4 = CE8E4,
                E9 E8 = CE9E8,
                E10 E9 = CE10E9,
                E8 E1 = CE8E1,
                E4 E3 = CE4E3,
                E5 E2 = CE5E2,
                E3 E1 = CE3E1,
                E9 E7 = CE9E7,
```

```
                E4 E2 = CE4E2,
                E7 E4 = CE7E4;

VAR     V1-V14;
RUN;
```

Appendix F SAS input listing for the theoretical model

Theoretical model

```
DATA STORAGE_DATA;
SET MSC.INPUT_DATA_4_RAW;

V1      =  (PD1+PD2+PD3+PD4+PD5+PD6+PD7)/7;
V2      =  (CA1+CA2+CA3+CA4+CA5+CA6+CA7)/7;
V3      =  (VMH1+VMH2+VMH3+VMH4+VMH5+VMH6+VMH7+VMH8)/8;
V4      =  (SW1+SW2+SW3+SW4+SW5+SW6+SW7+SW8)/8;
V5      =  (FO1+FO2+FO3+FO4+FO5+FO6+FO7)/7;
V6      =  (CI1+CI2+CI3+CI4+CI5+CI6+CI7)/7;
V7      =  (EP1+EP2+EP3+EP4+EP5+EP6+EP7+EP8)/8;
V8      =  (QC1+QC2+QC3+QC4+QC5+QC6+QC7+QC8)/8;
V9      =  (PM+TPM2+TPM3+TPM4+TPM5+TPM6)/6;
V10      = (MC1+MC2+MC3+MC4+MC5+MC6)/6;
V11      = (LP1+LP2+LP3+LP4+LP5+LP6)/6;
V12 = KPI2/2;
V13 = KPI3/2;
V14 = KPI4/2;
IF _N_=63 THEN DELETE;
IF _N_=35 THEN DELETE;
IF _N_=32 THEN DELETE;
IF _N_=8 THEN DELETE;
RUN;

PROC CALIS COV DATA = STORAGE_DATA KURTOSIS METHOD = ML PALL RESIDUAL=NORM TECH = NR;
LINEQS

        V1 = LV1F1 F1 + E1,
        V2 = LV2F1 F1 + E2,
        V3 = LV3F1 F1 + E3,
        V4 = LV4F1 F1 + E4,
        V5 = LV5F1 F1 + E5,
        V6 = LV6F1 F1 + E6,
        V7 = LV7F1 F1 + E7,
        V8 = LV8F1 F1 + E8,
        V9 = LV9F1 F1 + E9,
        V10 = LV10F1 F1 + E10,
        V11 =     F1 F1 + E11,

       V12 = LV12F2 F2 + E12,
       V13 = LV13F2 F2 + E13,
       V14 =        F2 + E14,
       F2 = PV15F1 F1 + D1;

STD
        F1= VARF1,
        E1-E14= VARE1-VARE14,
               D1 = VARD1;

COV
               /*F1 F2 = CF1F2*/

               E8 E7 = CE8E7,
               E2 E1 = CE2E1,
               E11 E1 = CE11E1,
               E6 E2 = CE6E2,
               E3 E2 = CE3E2,
               E6 E3 = CE6E3,
               E11 E3 = CE11E3,
               E9 E5 = CE9E5,
               E10 E5 = CE10E5,
               E11 E10 =CE11E10,
               E10 E3 = CE10E3,
               E9 E4 = CE9E4,
               E10 E1 = CE10E1,
               E7 E1 = CE7E1,
               E6 E1 = CE6E1,
               E8 E4 = CE8E4,
               E9 E8 = CE9E8,
               E10 E9 = CE10E9,
               E8 E1 = CE8E1,
               E4 E3 = CE4E3,
```

```
                E5 E2 = CE5E2,
                E3 E1 = CE3E1,
                E9 E7 = CE9E7,
                E4 E2 = CE4E2,
                E7 E4 = CE7E4;

VAR     V1-V14;
RUN;
```

Appendix G SAS input listing for the uncorrelated models

Uncorrelated model

```
DATA STORAGE_DATA;
SET MSC.INPUT_DATA_4_RAW;

V1      =  (PD1+PD2+PD3+PD4+PD5+PD6+PD7)/7;
V2      =  (CA1+CA2+CA3+CA4+CA5+CA6+CA7)/7;
V3      =  (VMH1+VMH2+VMH3+VMH4+VMH5+VMH6+VMH7+VMH8)/8;
V4      =  (SW1+SW2+SW3+SW4+SW5+SW6+SW7+SW8)/8;
V5      =  (FO1+FO2+FO3+FO4+FO5+FO6+FO7)/7;
V6      =  (CI1+CI2+CI3+CI4+CI5+CI6+CI7)/7;
V7      =  (EP1+EP2+EP3+EP4+EP5+EP6+EP7+EP8)/8;
V8      =  (QC1+QC2+QC3+QC4+QC5+QC6+QC7+QC8)/8;
V9      =  (PM+TPM2+TPM3+TPM4+TPM5+TPM6)/6;
V10      = (MC1+MC2+MC3+MC4+MC5+MC6)/6;
V11      = (LP1+LP2+LP3+LP4+LP5+LP6)/6;
V12 = KPI2/2;
V13 = KPI3/2;
V14 = KPI4/2;
IF _N_=63 THEN DELETE;
IF _N_=35 THEN DELETE;
IF _N_=32 THEN DELETE;
IF _N_=8 THEN DELETE;
RUN;
PROC CALIS COV DATA = STORAGE_DATA KURTOSIS METHOD = ML PALL RESIDUAL=NORM TECH = NR;
LINEQS

        V1 = LV1F1 F1 + E1,
        V2 = LV2F1 F1 + E2,
        V3 = LV3F1 F1 + E3,
        V4 = LV4F1 F1 + E4,
        V5 = LV5F1 F1 + E5,
        V6 = LV6F1 F1 + E6,
        V7 = LV7F1 F1 + E7,
        V8 = LV8F1 F1 + E8,
        V9 = LV9F1 F1 + E9,
        V10 = LV10F1 F1 + E10,
        V11 = LV11F1 F1 + E11,

               V12 = LV12F2 F2 + E12,
               V13 = LV13F2 F2 + E13,
               V14 = LV14F2 F2 + E14;

STD
        F1-F2= 1,
        E1-E14= VARE1-VARE14;

COV
               F1 F2 = 0,

               E8 E7 = 0,
               E2 E1 = 0,
               E11 E1 = 0,
               E6 E2 = 0,
               E3 E2 = 0,
               E6 E3 = 0,
               E11 E3 = 0,
               E9 E5 = 0,
               E10 E5 = 0,
               E11 E10 = 0,
               E10 E3 = 0,
               E9 E4 = 0,
               E10 E1 = 0,
               E7 E1 = 0,
               E6 E1 = 0,
               E8 E4 = 0,
               E9 E8 = 0,
               E10 E9 = 0,
               E8 E1 = 0,
               E4 E3 = 0,
               E5 E2 = 0,
               E3 E1 = 0,
               E9 E7 = 0,
```

```
                E4 E2 = 0,
                E7 E4 = 0;

VAR     V1-V14;
RUN;
```

Validity model

```
DATA STORAGE_DATA;
SET MSC.INPUT_DATA_4_RAW;

V1      =  (PD1+PD2+PD3+PD4+PD5+PD6+PD7)/7;
V2      =  (CA1+CA2+CA3+CA4+CA5+CA6+CA7)/7;
V3      =  (VMH1+VMH2+VMH3+VMH4+VMH5+VMH6+VMH7+VMH8)/8;
V4      =  (SW1+SW2+SW3+SW4+SW5+SW6+SW7+SW8)/8;
V5      =  (FO1+FO2+FO3+FO4+FO5+FO6+FO7)/7;
V6      =  (CI1+CI2+CI3+CI4+CI5+CI6+CI7)/7;
V7      =  (EP1+EP2+EP3+EP4+EP5+EP6+EP7+EP8)/8;
V8      =  (QC1+QC2+QC3+QC4+QC5+QC6+QC7+QC8)/8;
V9      =  (PM+TPM2+TPM3+TPM4+TPM5+TPM6)/6;
V10      = (MC1+MC2+MC3+MC4+MC5+MC6)/6;
V11      = (LP1+LP2+LP3+LP4+LP5+LP6)/6;
V12 = KPI2/2;
V13 = KPI3/2;
V14 = KPI4/2;
IF _N_=63 THEN DELETE;
IF _N_=35 THEN DELETE;
IF _N_=32 THEN DELETE;
IF _N_=8 THEN DELETE;
RUN;
PROC CALIS COV DATA = STORAGE_DATA KURTOSIS METHOD = ML PALL RESIDUAL=NORM TECH = NR;
LINEQS

        V1 = LV1F1 F1 + E1,
        V2 = LV2F1 F1 + E2,
        V3 = LV3F1 F1 + E3,
        V4 = LV4F1 F1 + E4,
        V5 = LV5F1 F1 + E5,
        V6 = LV6F1 F1 + E6,
        V7 = LV7F1 F1 + E7,
        V8 = LV8F1 F1 + E8,
        V9 = LV9F1 F1 + E9,
        V10 = LV10F1 F1 + E10,
        V11 = LV11F1 F1 + E11,

                V12 = LV12F2 F2 + E12,
                V13 = LV13F2 F2 + E13,
                V14 = LV14F2 F2 + E14;

STD
        F1-F2=  VARF1 - VARF2,
        E1-E14= VARE1-VARE14;

COV
                F1 F2 = 1,

                E8 E7 = 1,
                E2 E1 = 1,
                E11 E1 = 1,
                E6 E2 = 1,
                E3 E2 = 1,
                E6 E3 = 1,
                E11 E3 = 1,
                E9 E5 = 1,
                E10 E5 = 1,
                E11 E10 =1,
                E10 E3 = 1,
                E9 E4 = 1,
                E10 E1 = 1,
                E7 E1 = 1,
                E6 E1 = 1,
                E8 E4 = 1,
                E9 E8 = 1,
                E10 E9 = 1,
                E8 E1 = 1,
                E4 E3 = 1,
```

```
                E5 E2 = 1,
                E3 E1 = 1,
                E9 E7 = 1,
                E4 E2 = 1,
                E7 E4 = 1;

VAR     V1-V14;
RUN;
```

Appendix H **Full recommended Lean Enterprise audit.**

Scope 1: Manufacturing Operations

Lean Characteristic	Level 1	Level 2	Level 3	Level 4
Policy Deployment	No policy deployment process exists. Management goals are isolated and consist mainly of financial measures. Senior Management alone decides on goals and workforce has little understanding of Organization objectives for the year	A formal policy deployment process exists but is confined to senior management. an Organization Policy Deployment Matrix exits. Organization targets consist of a few non financial measures. No recourse allocation has been done on targets and projects. Policy deployment process is contained within senior management only and not cascaded down to lower functions. There is no Policy Deployment Tracking in place	Policy Deployment (PD) is well structured and has been cascaded down to departmental and individual manager objectives. Departments track and review PD projects and targets regularly. Departmental projects, targets and tracking is displayed at departmental and individual level. Owners of Projects as well as those who support are well defined and all projects have specific, measurable, achievable, realistic and time based (SMART) objectives.	Policy deployment is well structured and well entrenched with at least two years of consecutive Policy Deployment matrices available for review. All employees are able to contribute to selecting the Organization objectives, targets and projects. All projects and targets are SMART and the effectiveness of an organization in achieving its Policy deployment Objectives of Prior years can be shown. PD Matrices are well published and tracking documents are well understood and displayed throughout the organization. Organization objectives can be linked to individual objectives. Tracking is structured, regular and linked to performance bonuses and salary increases of employees. The PD process is the key driver for all major improvement over and above any other source.
Cultural Awereness	Shop floor Employees are not aware of the company objectives and how their job contributes to those objectives. There are no standardized daily meetings for various operational levels (Shop floor and Middle management). There are no regular cross functional meetings at shop floor or management level to measure and improve processes. Departments are typically inward looking and isolated. Departmental measures are inward looking and isolated. There is no opportunity for employees to get involved in regular cross functional problem solving. Employees are unsure of other departments or their role in the organization.	There are regular daily meetings for shop floor employees. Employees are aware of company objectives but are unsure as to how they contribute to those objectives. Middle management meets regularly to solve cross functional issues but meetings lack a standard structure and there is little evidence of accountability arising from the meetings. Senior management does not often visit the shop floor or interact with employees to learn their frustrations. Employees are aware of other departments and their personal but do not have the opportunity to work with other departments to solve cross functional problems. Departmental structures and incentives are still inward looking and do not consider incentives for cross cooperation.	Daily meetings are a part of the culture. Employees understand company objectives and how they contribute to those objectives. Regular middle management meetings are held to solve cross functional problems. The meetings are structured with actions and responsibilities assigned. Senior management regularly visits the shop floor but do not often interact with employees or stop to understand the management of a certain area. Employees have informal opportunities to work in cross functional teams to solve problems. Departmental structures and incentives include the objective of working cross functionally.	Standardized accountability meetings are a part of the culture. There is a clear, traceable process of daily accountability from standardized meetings shop floor level, through standardized, cross functional, middle management meetings and up to regular (at least weekly) standardized senior manager meetings. This daily accountability process is clearly entrenched and in place. Employees have a clear understanding of the company objectives, the status of the company against those objectives and their role in achieving those objectives. Senior managers regularly visit the shop floor to solve problems and provide support. There is an entrenched process in place for senior managers

				to review an area, question its management and improvement, and provide feedback to area employees. Departments are structured along value streams with the sole objective of providing cross functional support.
Visual Management and housekeeping	First impressions of the shop floor are of disorder and chaos. There is no identification of territory, no visual way to understand how the territory is being managed and no visual way to understand how it is being improved. The floor is cluttered and it is hard to move about.	There is evidence that clutter has been removed from the shop floor and only parts needed are on the floor. Basic team communication boards are in place with graphs that show actual performance against target. Walkways and isles are demarcated and generally clear of waste. There are signs identifying the area and operators are involved in the daily housekeeping process	The shop floor is neat, identified and ordered. There is a visual display of how the area is managed (tracking charts etc) and being improved (tally charts showing defects etc). The area team is identified and there is a clear green area for all main visual boards, showing relevant KPI's in a structured manor (typically with heading like quality, cost, delivery, improvements, the team etc). A formal 5S program is in place and the area is neat, with demarcations for tools, equipment and WIP. Tools are ordered through the use of Shadow boards or a similar process of identifying them. The area is generally well lit and well kept (equipment, floors, workbenches etc all shine and look well maintained)	A formal 5S program has been in place for at least one year. All area's have green areas with well kept and up to date KPI boards showing clear visual management of the area in terms of quality, cost and delivery. Shop floor personal are responsible for updating and maintaining the green area. Work cells or stations have mini communication boards to display local signals (Job cards, tally charting of local problems, area status etc). There is a place for everything and everything is in its place. It is clear on first impressions that the shop floor is well identified, well ordered, well lit and clean. The shop floor is has a clear method of showing how it is managed and a clear method for showing improvements.

Standardized work	There is no evidence of standardized work anywhere on the shop floor. Work instructions may exist but they are outdated, dormant and mostly used for ISO compliance. Operators and supervisors mostly follow their own method of working. On the Job skills are typically gained informally through loose mentorships with experienced operators.	Standardized work templates and Standard Operating Procedures (SOP) have been developed. These are largely up to date and kept active nearby workstations or cells. When starting a new Job Operators will use the SOP to receive training through the facilitation of a fully trained Operator. SOP's cover key tasks only and not out of production work such as changeovers, housekeeping and emergency escalation procedures. In-production work related SOP's do not contain standard cycle times. There is no system to regularly audit and update SOP's. SOP's show little evidence of revision and improvement.	SOP's have been developed, are up to date and show an active revision history. SOP's have been developed for out of production tasks. Operators and Supervisors alike use the SOP's as a basis for training and improvement. It is well understood that standardized methods are the only way for producing sustainable improvement. Standard times have been applied to key production SOP's. The concept of Standardized work has also been developed for Supervisors and Managers, who known what standard tasks they must complete daily and what standardized work they need to complete. Training Matrices linked to SOP's are clearly in use	The process of developing, publishing and revising SOP's is fully entrenched. Every key production and non production related process has an SOP developed for it. The quality of the SOP's is such that they are clear to understand, have standard times (for key production processes) and show who must do what by when. The management infrastructure for SOP's can link their creation and revision management to higher level process flows and ultimately to key business processes. The concept of standardized work is fully entrenched. Supervisors and Managers alike can all show their standard tasks for the day and there is a process to ensure that Leader standard work is being followed. Training matrices are in active use with development actions and timing for those not yet trained on key SOP's.
Process focus	Equipment and work centers are arranged around process villages (clusters of similar equipment). There is a "one man on machine" mentality in place. The workforce is largely specialized and inflexible. Large equipment is run under the philosophy of economic order quantity. Little or no work has been done to reduce material and component travel distances. The path of a product from the start or a value adding process to the end is chaotic and linked with various lengths of queue time and non standard WIP. Operations focus is largely results centered, with little or no focus on the process itself. Crises management and expediting are usual norms for pushing material through the process	There has been some work done on dismantling process villages and trialing out manufacturing cells aligned to value streams. A "product process" analysis has been done to identify and group products by family and it identify runner, repeater and stranger products within each product family. A few Large, multipurpose, centralized pieces of equipment have been replaced by smaller, cheaper, simpler "right sized" single purpose pieces of equipment arranged in a cell. Basic mapping has been done on component and material travel distances and basic opportunities implemented to align the processes to product family value streams. Operator training matrices are in use and Operator remuneration is based on multi skilling rather than specializing. Targets are still results focused but there is some work done on identifying daily issues affecting overall results.	There is substantial evidence that where possible, process villages have been realigned to product value streams and work cells have been implemented. There is strong focus on reducing material and component waiting and traveling distances. The amount of WIP on the shop floor can be shown to have dramatically reduced through the introduction of smaller right sized equipment and the use of Standard In Process Stocks (SIPS). Where movement of large equipment is not feasible (such as large presses, foundry equipment etc) It can be shown that every effort has been made to group the equipment by Value stream and ensure that there is a process for managing the product variety through each piece of equipment by using a combination of Heijunka and SIPSs. Results based graphs have been replaced by tracking charts that show actual performance against process target as well as	Process villages have been completely realigned to product value streams. Departmental structures show the use of value stream leaders, assigned to manage the flow of a product for a practical set of operations through the value stream. Equipment is by en large, mobile and flexible compared to industry standards. Value stream specific work cells have largely replaced any form of process village. Extensive work has been done on managing clusters of large, immovable equipment through the use of "focused factories" within the cluster of equipment that are dedicated to value streams. SIPS's have become the standard form of WIP in the shop floor and the TAKT time is known for each value stream across all process. All Operators are effectively multitasked or are in the process of being multi task capable. It can be shown that travel distance, waiting time and WIP are continuously reduced. Management of

			reasons for exceptional performance or low performance. Operators show a large degree of cross functionality.	the value stream is process focused with daily variances against TAKT time recorded and acted upon for improvements. Process variance against TAKT time is the main method of value stream management
Continuous Improvement	There is no evidence of a culture of continuous improvement. Improvements are typically handled by specialists working in isolation from employees or by management teams through the use of meeting minutes and direct instruction. There is no continuous improvement process or resources assigned to the organization.	A resource has been assigned to the organization (in the form of a lean facilitator) but no kaizen plan exits. Improvements are conducted ad-hoc with no clear link to organization objectives and critical success factors. A few employees have benefited in continuous improvement projects and received training in continuous improvement methods. Projects lack structure and a formal feedback process. Kiazen teams consist of a few regular employees.	There is a formal kaizen program in place managed by a lean facilitator and linked to company objectives and critical success factors. Events are well structured and planned. Management understands the importance of such events and allows scheduled resources to attend. Feedback from events is formally managed through a celebration program and projects are typically displayed on the shop floor using A3 plans or storyboards. A large number of cross functional team members have participated in kiazen programs and received continuous improvement training. Kiazen teams consist of a diverse range of cross functional employees. Management actively supports and monitors feedback from kaizen events.	The culture of kaizen is firmly entrenched in the organization. A formal kiazen plan has been in place for at least 2 years and has shown to link and benefit critical organization success factors. Events are well structured. Employees feel empowered to submit opportunities for improvement (kaizen opportunities) on a regular basis and manage their own cross functional kaizen teams without the support of dedicated lean facilitators. Feedback from events is given regularly to management, who actively drives the process and awards winning kaizen events. Most employees have received regular training on continuous improvement events and have participated in kaizens. The process of evolving is firmly entrenched.

Process control	There is no process control in the facility. Operations management is mainly results based and there is little if no understanding of common cause and special cause variation. Little analysis is done on a shop floor level to identify problems and their root causes. No analysis has been done using FMEA, PPA or other appropriate risk analysis techniques to identify the top 10 risks and develop either mistake proofing or contingency plans as countermeasures.	Basic tally charting and Pareto analysis/ measles charts etc have been developed and are in use to track and identify problems. Analysis and improvement of problems is typically done at a higher level, involving process improvement projects, and not immediately at shop floor. A few employees have undergone process control training (either through six sigma programs or equivalent). The top essential risks are known using FMEA or equivalent methods and either error proofing or contingency planning has been applied. Management is still largely by end of month results.	Tally charting, Pareto analysis etc is in place in most areas to track, Identify and eliminate problems. There is a clear indication that management is process focused and that problems charted and reported on the shop floor are actioned immediately for improvement once there is a clear trend of off target performance rather than being collected for later analysis and improvement. Many error proofing opportunities have been identified and implemented based on shop floor analysis of top safety, quality, cost or delivery performance data and problem charting. A large amount of employees have undergone process control training.	There is a clear culture of process focus within the organization. All key processes are controlled through process control charting (tally charts, Pareto analysis, capability chars etc) as opposed to monthly results management. Out of control processes are actioned immediately for improvement from the shop floor level up through to senior management. There is evidence that most critical processes have undergone analysis to find error proofing opportunities and that error proofing has been implemented and maintained for critical processes.
Quick Changeover	Units are made in large batches to support economic order quantity calculations and management accounting recoveries. There is lots of WIP in and around the organization. There have been little or no Single Minute Exchange of Die (SMED) activities to substantially reduce batch sizes.	The concept of making in smaller lots to improve lead time and flexibility is well understood but SMED activities have not substantially reduce batch sizes. Key teams have received training on quick changeover methods and where no major effort is required, batch sizes have been reduced (eg in warehousing, assembly and order processes).	Batch sizes are small relative to industry standards thanks to work done by quick changeover teams on implementing SMED for key equipment. Planning and scheduling is done to support small batch sizes and equipment is purposely modified to run in fixed, small batch sizes (eg long production lines have been segmented into smaller, more flexible production lines). There is relatively little WIP in and around the organization and where there is WIP, the WIP has been designated into fixed spaces (indicating batch sizing has been taken into account).	Batch sizes are very small relative to industry standards thanks to work done by quick changeover teams on implementing SMED for key equipment. Planning and scheduling is done to support small batch sizes or single piece flow and equipment is purposely modified to run in fixed, small batch sizes (eg long production lines have been segmented into smaller, more flexible production lines). There is hardly any WIP in and around the organization and where there is WIP, the WIP has been designated into fixed spaces (indicating batch sizing has been taken into account). For processes that are closely linked (such as in manufacturing cells etc) single piece flow is clearly evident and this is widespread across the organization.

Total Productive Maintenance	Process critical equipment availability rates are not known or monitored. There is no analysis of which equipment constitutes key process critical equipment and which equipment constitutes easily repaired or replaced equipment not critical to processes. Unexpected breakdowns of process critical equipment are frequent and maintenance teams are called in for repairs rather than preventative maintenance. There is no preventative maintenance planning.	Key process and maintenance personal have received training on the concepts of Total Productive Maintenance (TPM) and of keeping process equipment available when needed. Availability, Performance and Quality rates for equipment are tracked and known (through the use of Overall Equipment Effectiveness or an equivalent metric) but availability is generally less than 80% per month. Improvement teams are in place to understand key reasons for low availability (downtime, set up time, slow performance, poor quality etc) and to improve availability but as yet little improvements have taken place. When available, Equipment utilization rates are dangerously high (over 95%), leading to long queue times and little reserve capacity for demand fluctuations. Preventive maintenance activities exist for all process critical equipment but do not look like they are strictly followed. There is relatively little operator involvement in monitoring process critical equipment and identifying maintenance needs.	The concept of TPM is well established in the organization. Process critical equipment has been identified and is regularly monitored for availability. Availability of key equipment is over 90% and improvement teams have been in place to measure and improve availability and performance of equipment (using OEE review for example) such that there is a reserve capacity of at least 15% for process critical equipment. Preventative maintenance activities are well defined, known to equipment operators and have close out dates (if busy being performed). Process critical equipment operators are involved in standardized manor for monitoring process critical equipment and identifying maintenance needs.	TPM monitoring and improvement programs have been in place for at least one year. Availability of process critical equipment is over 99% and improvement teams have actively measured and improved availability, performance and quality outputs from process critical equipment (through the use of OEE or an equivalent) to ensure that there is a reserve capacity on the equipment of 20% or more during normal operation of the equipment. The culture of operator involvement in regular equipment checking and standardized reporting is entrenched. Preventative maintenance activities are well structured, available to all and executed to plan (including closeout dates).

Material Control	Material and components are pushed through the production process based on centralized scheduling from planning Electronic movement of inventory through multiple warehouses is used as the signal to re-order or issue out new inventory. Works orders are typically used to control production, value adding operators are also used to fetch and issue parts and material. In line processes typically process whatever they receive with no real focus on order, unless directed so by an outside controller. Inventory is typically centralized. Multiple electronic warehouses are used to contain and control inventory.	Key personal have been trained on the concepts of pull systems in the form of Just-In-Time (JIT) thinking or equivalent. An analysis has been conducted or Type A,B and C inventory (Cost) and Runners Repeaters and Strangers (Volume) to identify inventory suitable for kanban systems, 2-bin systems and make to order parts. 20% of Make to stock A running and B running items have been placed on kanban systems, with the physical movement of the stock signaling an order to replenish the stock from the previous up stream process. For processes that are closely linked, key and consumable "Runner" inventory is available in the form of point of use containers etc. Backflushing is used for selected kanban inventory to control movement and there has been analysis to reduce the number of electronic warehouses in the organization. Basic First-In-First-Out (FIFO) systems are in use to ensure operator adherence to processing the right order of parts. The core process is the organization determines the pace of production and a schedule change in that process does not mean a massive schedule change of all other processes for those few items on kanban (15% of volume). The concept of material handlers has been introduced to help feed and replenish inventory.	Most key personal have been trained on pull systems in the form of Just-In-Time (JIT) thinking or equivalent. Most (80%) of A and B running inventory has been placed on make to stock kanban systems while C running systems have been placed on 2 bin systems. Repeaters have been placed on make to order kanban systems. Importantly the physical movement of the stock generates the signal for replenishment. A large majority of electronic warehouses have been removed and a significant portion of kanban inventory is stored in point of use containers and replenished from the previous processes using manual kanban signals. Material handlers (also known as "Water spiders") are significantly noticeable in their function of replenishing inventory and feeding manufacturing cells, lines etc. The practices of backflushing are in wide use to control inventory from an accounting standpoint. For at least 60% of the organization volume, a change in the core pacemaker process will not mean a massive schedule change of upstream processes. FIFO systems are in widespread use. The use of Standard In Process Stocks (SIPS) has mostly replaced variables amounts of WIP on the shop floor.	All key personal have been trained on pull systems. All A and B running inventory has been placed on make to stock kanban's and all C running inventory has been placed on 2 bin systems. A significant amount of repeater and stranger items have been placed on Make to Order kanban systems. The concept of the physical movement of stock generating the signal for replenishment is well entrenched. Almost all electronic warehouses have been removed in favour of point of use inventory points across the organization divided into value streams. Water spiders are in wide spread use and use structured milk rounds to replenish inventory where applicable. All non value adding processes (such as kitting) have been reviewed and eliminated where feasible. For at least 90% of the volume of the organization volume, a change in the core pacemaker process will not mean a massive schedule change of upstream processes. FIFO systems are in widespread use. The use of Standard in Process Stocks (SIPS) has fully replaced variables amounts of WIP on the shop floor.
Leveling	No understanding of the importance of leveling exists in the organization. There is no control over order demand and manufacturing operations throughout the control to prevent order spikes etc. An excessive amount and variation of WIP and a large variation in overtime requirements etc are evident across the organization	Key managers and personal have been trained and demonstrate an understanding of the principals and benefits of leveling. The key bottleneck operations of the organization have been identified and capacity levels are known. A basic first stage leveling process is in place to ensure that order demand does not exceed normal capacity levels for key bottleneck processes. Excess demand is leveled	For key bottleneck processes leveling is conducted not just in terms of raw capacity for overall products but also in terms of mix for lower level product groups. The level and mix of products for operations feeding and receiving parts or material from bottleneck processes is controlled so that there is always a regular mix of runner, repeater and stranger products flowing through the process. There is a steady beat to	The fundamentals of leveling are firmly entrenched in the organization. All planning is done in terms of TAKT time and TACT time. Operations are often re-balanced and leveled to ensure that TACT times are as close to 90% of TAKT time as possible. Key processes are leveled not just in terms of raw demand but also in terms of product mix. TAKT time is adhered to strictly when controlling the flow of

		into capacity slots.	the plant and for key processes the concepts of TAKT time and Total Actual Cycle Time (TACT) are used to balance capacity and demand.	products through the organization and adherence to TAKT time is done regularly enough to ensure that out of control processes are assessed and improved to bring them back into control
Design for Simplicity	Materials and components have not undergone any analysis to identify design opportunities to simplify their manufacture or cost. Bills of Materials (BOM's) are typically complex with an unusual amount of levels for industry standards. There are an unusually large amount of live part numbers on the organizations system. There is little or no work done on manufacturing operations to reduce the complexity of manufacturing processes or equipment.	There is a regular and structured review of products, Bill or Materials (BOM's) and manufacturing processes to identify design opportunities to reduce manufacturing complexity. BOM's that are older than a certain period are switched off the item master. So far little work has been done on simplifying product manufacture or manufacturing processes.	Regular and structured reviews have resulted in a fair amount of simplification of current product designs (replacement of bolts with clips etc) and manufacturing processes (simpler painting techniques etc). BOM's are regularly reviewed and switched off the item master if older than a specified period	Regular and structured reviews have resulted in a large amount of simplification of current product designs (replacement of bolts with clips etc) and manufacturing processes (simpler painting techniques etc). BOM's are regularly reviewed and switched off the item master if older than a specified period. A comprehensive review of each current product has been conducted to determine if it can be eliminated, combined or reduced in volume.
Specific Best practice	Insert industry or company specific best practice guides here	Insert industry or company specific best practice guides here	Insert industry or company specific best practice guides here	Insert industry or company specific best practice guides here

Scope 2: Office environments supporting manufacturing and distribution operations

Lean Characteristic	Level 1	Level 2	Level 3	Level 4
Policy Deployment	No policy deployment process exists. Management goals are isolated and consist mainly of financial measurements. Senior Management alone decides on goals and the workforce has little understanding of Organization objectives for the year. There is little or no involvement from office functions and office functions have no understanding of the Policy Deployment process	A formal policy deployment process exists but is confined to senior management. An Organization Policy Deployment (PD) Matrix exits. Organization targets consist of a few non financial measures. No recourse allocation has been done on targets and projects. Policy deployment process is contained within senior management only and not cascaded down to lower functions. There is no Policy Deployment Tracking in place. PD Organization Matrices are not published in office areas and office areas have little input into projects listed on the Organization PD Matrix. Most improvement projects are related to Manufacturing Operations.	Policy Deployment (PD) is well structured and has been cascaded down to office departments and individual manager objectives. Office departments track and review PD projects and targets regularly. Departmental projects, targets and tracking are displayed at departmental and individual level. Owners of Projects as well as those who support are well defined and all projects have specific, measurable, achievable, realistic and time based (SMART) objectives. Office projects form a substantial portion of the PD Matrix	Policy deployment is well structured and well entrenched with at least two years of consecutive Policy Deployment matrices available for review. All office employees are able to contribute to selecting the Organization objectives, targets and projects. All office projects and targets are SMART and the effectiveness of office projects in contributing to Policy deployment Objectives of Prior years can be shown. PD Matrices are well published and tracking documents are well understood and displayed throughout office areas. Organization objectives can be linked to individual objectives. Tracking is structured, regular and linked to performance bonuses and salary increases of office employee's employees. The PD process is the key driver for all major improvement over and above any other source. A significant portion of improvement projects have been in office areas.

Cultural Awereness	Office employees are not aware of the organizational objectives and how their job contributes to those objectives. There are no standardized daily meetings for office environments. There are no weekly meetings in place to measure and improve processes. Office participation on organizational cross functional meetings is minimal. Office environments are typically inward looking and isolated. Dl measures are inward looking and isolated. There is no opportunity for office employees to get involved in regular cross functional problem solving. Office employees are unsure of other departments or their role in the organization.	There are regular daily meetings for office employees. Employees are aware of organizational objectives but are unsure as to how they contribute to those objectives or the status of the company relative to the objectives. Middle management meets regularly to solve cross functional issues but office departmental heads do not play an active/ equal role in these meetings compared to manufacturing departments. There is little evidence of accountability arising from the meetings. Office employees have little or no understanding of the structure, management and improvement on the shop floor or interact with employees to learn their frustrations. Office employees are aware of other departments and their personal but do not have the opportunity to work with other departments to solve cross functional problems. Office departments are structured to be inward looking and not to consider incentives for cross cooperation.	Daily office meetings are a part of the culture. Office employees understand organizational objectives and how they contribute to those objectives. Regular middle management meetings are held to solve cross functional problems with active/equal participation from office departments. The meetings are structured with actions and responsibilities assigned. Office employees are aware of the structure, management and improvement of the shop floor and visa versa. Cross functional interaction is minimal though. Office employees have informal opportunities to work in cross functional teams to solve problems. Office departmental structures and incentives include the objective of working cross functionally.	Standardized accountability meetings are a part of the office culture. There is a clear, traceable process of daily accountability from standardized meetings at office level, through standardized, cross functional, middle management meetings and up to regular (at least weekly) standardized senior manager meetings. This daily accountability process is clearly entrenched and in place and office departments actively participate and help lead these meetings. Office employees have a clear understanding of the organization objectives, the status of the organization against those objectives and their role in achieving those objectives. Office employees regularly visit the shop floor to solve problems and provide support. They have a clear understanding of the structure, management and improvement of the shop floor and visa versa. There is an entrenched process in place for senior managers from office environments to review an area, question its management and improvement, and provide feedback to area employees. Departments are structured along value streams with the sole objective of providing cross functional support.
Visual Management and housekeeping	First impressions of office areas are of disorder and chaos. There is no identification of departments, no visual way to understand how departments are being managed and no visual way to understand how departments are being improved. Office floors are cluttered with paperwork and randomly placed desks and it is hard to move about.	There is evidence that unneeded desks, chairs, equipment etc has been removed. Basic departmental communication boards are in place with metrics that measure actual performance against target and highlight problems. Departments and departmental personal are identified. Office personal assist with the daily housekeeping process.	Office area's are neat, identified and ordered. Departmental KPI boards are in place and clearly show how the area is being managed and improved. There is a formal clean desk policy in place and a formal system in place for managing that policy. Departmental staff and their workstation clusters (or offices) are identified.	The first impressions of the office area are of a place that is open, well lit, and well ordered. Office areas are clearly identified, right down to workstation clusters and individual offices. There is a clear, demarcated area to show how a particular department is being managed and what improvements it is making. The departmental team and structure are well identified. The layout of the department is well ordered and makes sense from a process perspective. There is evidence that an Office 5S activity has been conducted. The clean desk policy has been in place for at least 6 months and there

				is evidence that it is well managed. There is clear evidence of standardization of office equipment, desks, chairs etc and employees actively help with housekeeping and improving the layout of an office area to aid with the flow of work.
Standardized work	There is no evidence of standardized procedures to follow in office functions. Departmental process flows are non existent and office workers typically conduct their work according to their own methods. Standardized documents, processes and reporting formats are not widely in use.	Standardized process flows have been developed and standardized documents, forms, procedures are in place. There is little evidence from office employee level to show that standardized procedures are being followed. System related SOP's are in use and freely available for all personal. There is little evidence of improvement and revisions through	Standard process flows are actively in use and have a clear link to standard procedures (SOP's) used by office staff to conduct daily processes as well as development and reporting activities. SOP's are regularly audited and revised as improvements are made and office personal are actively responsible for their auditing and revision. SOP's are easily accessible and used as the standard of training within the office. There is a clear understanding of the importance of standardized work as well as an indication as to who has been trained on what through the use of SOP related training matrices. The basics of Leader standard work is in place.	Standardized process flows are used as the basis to conduct office work and there is a clear link between them, SOP's and key business processes. Auditing and revision of SOP's is frequent and managed through a centralized framework that ensures the creation, merging, and splitting of SOP's is reflected in process flows and key business processes. Office personal actively create and modify SOP's and process flows through a structured process. The concept of standardized work is well entrenched. Supervisors and Managers can show their daily standard work tasks.

Process focus	Departments and office area's are isolated and printing/copying machinery is centralized between offices. No work has been done to understand the flow of operations between workstations. Departmental staff are typically specialized and no cross training has been done.	Office area's have been rearranged to facilitate the flow of work between workstations. Repetitive office functions have been largely grouped by value stream rather than by function (In other words personal have been assigned into value streams). Where one person or a few people process a large variety of information (e.g. contract drawings or invoicing) it can be shown that these people have been grouped into a cluster based on a higher level value stream (e.g. invoicing for customer type A, B etc) or that there is load leveling between the processing of various Job's. (e.g processing invoicing for customer type A in the morning and B in the afternoon with once off customers only done on Friday's etc). Personal have largely been cross trained for repetitive functions. Printing/Faxing and photocopying machines are typically smaller and have been distributed along value streams.	A significant amount of work has been done to align office staff, equipment and reporting along value streams. Office workers are flexible enough such that even though they report into a functional head they are located in a value stream cluster. For example, where feasible, engineering and finance activities have been relocated along value streams rather than by function. Where this is not possible (because of Intellectual Property reasons etc) It can be shown that the flow of work between departments has been assessed and reduced as much as possible and that value stream contact points between departments are well established. There is a significant amount of cross trained employees available to work on a variety of tasks where needed.	Where possible, all office functions have been re-laid out according to value stream. This includes the flow both within a department and between departments as well as the location, complexity and number of printers, faxes (shared recourses) etc. Extensive work has been done on reducing the isolation between departments and where complete value stream re-alignment is not possible it can be shown that there are clear communication channels between departmental value streams. For operations involving a large variety of work and only one person it can be shown that there is extensive leveling of the work based on a repetitive pattern. Most of the workforce is fully cross trained for a variety of departmental activities and a few value stream activities outside of their normal sphere of work.
Continuous Improvement	There is no evidence of a culture of continuous improvement in office environments. Improvements are typically handled by specialists working in isolation from employees or by management teams through the use of meeting minutes and direct instruction. There is no continuous improvement process involving office areas.	A resource assigned to the organization (in the form of a lean facilitator) has conducted a few improvement activities involving office staff but with the focus on manufacturing operations. Office related improvements are conducted ad-hoc with no clear link to organization objectives and critical success factors. A few office employees have benefited in continuous improvement projects and received training in continuous improvement methods. Office projects lack structure and a formal feedback process. Office involvement in kaizen is considered secondary.	Formal kiazen plan's that link to organization success factors clearly involve office environments and kaizen related to reducing the waste in office processes. Kaizen events dedicated to office functions have been conducted and a large number of office workers have received training on kaizen events. Feedback from office kaizens is actively monitored by senior management.	The culture of kaizen for office environments is clearly entrenched. A formal organization kaizen plan has involved office environments for at least a year and a large portion of kaizen projects involve office based processes. Most office workers are trained in continuous improvement methods and feel free to submit opportunities for improvement as well as manage cross functional office kaizen teams for project relating both to the office and to the manufacturing floor. Management actively drives and rewards office based kaizen.

Process control	There is no process control in any office environments. Processes are not well known and Operations management is mainly results based and there is little if no understanding of common cause and special cause variation. Little analysis is done on a shop floor level to identify problems and their root causes. No analysis has been done using FMEA, PPA or other appropriate risk analysis techniques to identify the top 10 risks and develop either mistake proofing or contingency plans as countermeasures.	Basic tally charting and Pareto analysis/ measles charts etc have been developed and are in use to track and identify problems if office areas. Analysis and improvement of problems is typically done at a higher level, involving process improvement projects, and not immediately when a trend is evident. A few employees have undergone process control training (either through six sigma programs or equivalent). The top essential risks office area risks known using FMEA or equivalent methods and either error proofing or contingency planning has been applied. Management is still largely by end of month results.	Tally charting, Pareto analysis etc is in place in most areas to track, Identify and eliminate problems. There is a clear indication that management is process focused and that problems charted and reported by personal are actioned immediately for improvement once there is a clear trend of off target performance rather than being collected for later analysis and improvement. Many error proofing opportunities have been identified and implemented based on shop floor analysis of top safety, quality, cost or delivery performance data and problem charting. A large amount of office employees have undergone process control training.	There is a clear culture of process focus within the office and support areasn. All key processes are controlled through process control charting (tally charts, Pareto analysis, capability chars etc) as opposed to monthly results management. Out of control processes are actioned immediately for improvement from the shop floor level up through to senior management. A large number of people are well skilled in process control management (through six sigma programs or equivalent). There is evidence that most critical processes have undergone analysis to find error proofing opportunities and that error proofing has been implemented and maintained for critical processes.
Quick Changeover	Office tasks are typically performed in large batches (eg order processes, engineering tasks, finance tasks etc). There is no common understanding of the benefits of processing tasks in smaller batches to improve lead time and flexibility. Key office employees have not been introduced to the concepts of quick changeover.	Office employees have been trained on the concepts of quick changeover and where applicable, office teams have received training in SMED activities. “Low hanging fruit” in the form of processes that require little or no effort to reduce batch sizes have had their batch sizes substantially reduced. Daily planning and scheduling of office activities are designed to process items in mixed batches but there are still a large amount of key items that are processed in large batches.	Office employees have been trained on the concepts of quick changeover and where applicable, office teams have received training in SMED activities. A substantial number of office processes have had their batch sizes significantly reduced through quick changeover projects. Daily planning and scheduling is strictly controlled by small batch size thinking.	There is a clear culture of processing tasks in small batches or single piece flow. Almost every key repetitive office process has been assessed for quick changeover and the batch size of processing reduced. There is a clearly entrenched and sustained process of daily scheduling and planning according to small batch sizes or single task flow with methods to ensure small batch sizes or single task flow is being maintained.

Total Productive Maintenance	For office environments process critical equipment (such as key printers, servers, IT systems etc) availability rates are not known or monitored. There is no analysis of which equipment constitutes key process critical equipment and which equipment constitutes easily repaired or replaced equipment not critical to processes. Unexpected breakdowns of process critical equipment are frequent and maintenance teams are called in for repairs rather than preventative maintenance. There is no preventative maintenance planning.	Key process and maintenance personal for office environments have received training on the concepts of Total Productive Maintenance (TPM) and of keeping process equipment available when needed. Availability, Performance and Quality rates for equipment are tracked and known (through the use of Overall Equipment Effectiveness or an equivalent metric) but availability is generally less than 80% per month. Improvement teams are in place to understand key reasons for low availability (downtime, set up time, slow performance, poor quality etc) and to improve availability but as yet little improvements have taken place. When available, Equipment utilization rates are dangerously high (over 95%), leading to long queue and processing times and little reserve capacity for demand fluctuations. Preventive maintenance activities exist for all process critical equipment but do not look like they are strictly followed. There is relatively little operator involvement in monitoring process critical equipment and identifying maintenance needs.	The concept of TPM is well established in office environments. Process critical equipment has been identified and is regularly monitored for availability. Availability of key equipment is over 90% and improvement teams have been in place to measure and improve availability and performance of equipment (using OEE review for example) such that there is a reserve capacity of at least 15% for process critical equipment. Preventative maintenance activities are well defined, known to equipment operators and have close out dates (if busy being performed). Process critical equipment operators are involved in standardized manor for monitoring process critical equipment and identifying maintenance needs.	TPM monitoring and improvement programs have been in place for at least one year in office environments. Availability of process critical equipment is over 99% and improvement teams have actively measured and improved availability, performance and quality outputs from process critical equipment (through the use of OEE or an equivalent) to ensure that there is a reserve capacity on the equipment of 20% or more during normal operation of the equipment. The culture of operator involvement in regular equipment checking and standardized reporting is entrenched. Preventative maintenance activities are well structured, available to all and executed to plan (including closeout dates).
Material Control	Office environments do not support any form of pull system for pulling information and tasks through office process or in support of the rest of the organization. Repetitive tasks and processes are not done in any particular order and are often disjointed from previous operations. A schedule change for a key repetitive operation often means that other operations supporting the key operation have to change their schedules. When interacting with manufacturing operations, daily repetitive instructions sent to manufacturing are centralized.	Office employees have received training in the basics of pull systems. Office operations that interact with manufacturing operations in regular repetitive tasks are at least 50% aligned to the Pull system development in manufacturing operations (in that they let the sequence and manual information generated from physical pull of material flowing through manufacturing determine their task sequence). An analysis has been conducted on running, repeater and stranger processes. For running processes there is a visible means for controlling and pulling	Office environments have been comprehensively assessed to determine where the benefits of a pull system lie. Running tasks have a visible means for controlling WIP and pulling WIP through processes. Only the physical movement of information is used to generate requests or orders for more information and information in comprehensively processed in First In First Out (FIFO) sequence. Office operations that interact with manufacturing operations in regular repetitive tasks are at least 75% aligned to the Pull system development in manufacturing operations (in that they let the	Pull systems have been installed in key areas where the analysis suggest the benefits of pull system are large. Running tasks have a visible means for controlling WIP and pulling WIP through processes and this is widespread. Only the physical movement of information is used to generate requests or orders for more information and information in comprehensively processed in First In First Out (FIFO) sequence. Office operations that interact with manufacturing operations in regular repetitive tasks are at least 100% aligned to the Pull system development in manufacturing operations

		WIP (paperwork or electronic information) through processes. For processes where item completion is signaled by a flag in an electronic system as well as delivery of physical information, only the delivery of physical information triggers the electronic flag.	sequence and manual information generated from physical pull of material flowing through manufacturing determine their task sequence).	(in that they let the sequence and manual information generated from physical pull of material flowing through manufacturing determine their task sequence).
Leveling	There is no leveling of frequently repeated office tasks. Workloads are erratic and often more people are thrown at a problem in order to solve a demand spike or queues of varying length form.	The concepts of leveling are known to office managers. There is a basic review of available man-hours and current demand for repetitive tasks. Excess demand is rescheduled.	Office managers understand the benefits of leveling and making repetitive office tasks easy to control through leveling. There is a detailed review of tasks by type to ensure that they are leveled not just in terms of raw demand but also in terms of task type. Excess demand is leveled and there is an understanding of the use of TAKT time to control the pace of tasks as well as Total Actual Cycle Time (TACT).	Leveling of workloads for repetitive office environments is parts of the regular planning cycle. Tasks are leveled by overall demand and by mix. There is strict adherence to daily TAKT times and processes are rebalanced (by the use of extra recourses etc) if TACT times are over 90% of TAKT times.
Design for Simplicity	Design processes are typically isolated from manufacturing activities. Design engineers do not typically consider current BOM's and part number variety when designing new products. BOM's are complex with an unusual amount of levels for industry standards. Design staff have not undergone any training in design for manufacture, TRIZ or value engineering. Manufacturing processes needed to support designs are considered secondary.	Design and engineering staff have been trained in the concepts of Design for manufacture, TRIZ and Value engineering. There is a regular and structured review of BOM's and products to identify opportunities for simplification. Engineering staff are considerate of using existing BOM's when creating new products and not adding items to the system. Product BOM's are reviewed to ensure that are not unusually complex.	Design and engineering staff have a solid understanding of the concepts of design for simplicity through the use of TRIZ, value engineering and design for manufacture. There has been a fair amount of new and existing product simplification through structured and regular reviews of products. Engineering staff have been instructed to only create new part numbers when there is no alternative. Product designs are reviewed in conjunction with manufacturing teams before sign off and industrialization.	Design and engineering staff have a solid and entrenched understanding of the concepts of design for simplicity through the use of TRIZ, value engineering and design for manufacture. There has been a large amount of new and existing product simplification through structured and regular reviews of products. Engineering staff have been strictly instructed to only create new part numbers when there is no alternative and this goes through a structured review process. Product designs are reviewed in conjunction with manufacturing teams before sign off and industrialization to ensure BOM's are not complex or parts are not costly to manufacture.
Specific Best practice	Insert industry or company specific best practice guides here	Insert industry or company specific best practice guides here	Insert industry or company specific best practice guides here	Insert industry or company specific best practice guides here

Scope 3: Supplier networks

Lean Characteristic	Level 1	Level 2	Level 3	Level 4
Policy Deployment	No supplier involvement in the Policy deployment process. Policy deployment and organizational objectives are inward looking only. There are no projects linked to suppliers.	Few projects listed as part of the Formal Policy deployment deal with supplier activities but these are vague and not specified to supplier. Supplier Management is not aware of the organization's Policy Deployment process and their link to achieving the Policy deployment process.	Projects mentioned in the organization's Policy Deployment process are specific to supplier, scope and objective. Supplier management are aware of the organization's Policy Deployment process and have aligned their internal objectives to the organizations projects and objectives. Project tracking data is shared and recourses are agreed between the supplier and the organization.	The organization's Policy Deployment process has included suppliers for at least two years and supplier involvement in the organization's Policy deployment in entrenched. Supplier key projects are well aligned and tracked to the organization's key projects and objectives. There is evidence of significant achievements in organization objectives through the alignment of the Policy deployment Process with suppliers. The Policy deployment process has been formalised in the supplier's organization.
Cultural Awereness	Suppliers are not aware of the organizational structure, their objectives and how they can contribute to those objectives. There is little interaction with suppliers outside of the purchasing department and suppliers are not commonly known to organizational employees. There is no attempt from the organization to understand the structure, management and improvements taking place at suppliers.	There are regular meetings in place with suppliers and infrequent meetings outside of the purchasing office. Often only key supplier personal visit the organization. Suppliers have an understanding of the organizational objectives but little understanding of how they can contribute to those objectives. Higher level employees understand who the suppliers are and a fair amount of middle managers understand the structure, management and improvements taking place at suppliers.	There are regular meetings in place outside of the purchasing department and supplier personal have the ability to view and understand the organizational daily accountability process. Suppliers are clear on the company objectives and how they contribute to those objectives. Suppliers have some access to company demand and capacity data on request. A fair amount of employees (both office and manufacturing based) understand supplier's structure, management and improvement. Some lower level supplier personal are part of the daily accountability process at the organization.	Supplier involvement in the daily accountability process of the organization is entrenched and understood by all. Selected supplier personal have a permanent presence at the organization with the sole function of sharing demand and capacity data and to solve cross functional problems. Senior management for both the supplier and the organization share a common set of objectives and actively work to build cross functional bridges between the supplier and the organization.

Visual Management and housekeeping	First impressions of a supplier's facility are that of disorder and chaos. For area's that have a direct impact on the organization, there is no identification of territory, no visual way to understand how the territory is being managed and no visual way to understand how it is being improved. The shop floor is cluttered and it is hard to move about for areas that have a direct impact on the organization.	For areas of a supplier's facility that have a direct impact on the organization there is evidence that clutter has been removed from the shop floor of a supplier's facility and only parts needed are on the floor. Basic team communication boards are in place with graphs that show actual performance against target. Walkways and isles are demarcated and generally clear of waste. There are signs identifying the area and operators are involved in the daily housekeeping process	For areas of a supplier's facility that have a direct impact on the organization, the shop floor is neat, identified and ordered. There is a visual display of how the area is managed (tracking charts etc) and being improved (tally charts showing defects etc). The area team is identified and there is a clear green area for all main visual boards, showing relevant KPI's in a structured manor (typically with heading like quality, cost, delivery, improvements, the team etc). A formal 5S program is in place and the area is neat, with demarcations for tools, equipment and WIP. Tools are ordered through the use of Shadow boards or a similar process of identifying them. The area is generally well lit and well kept (equipment, floors, workbenches etc all shine and look well maintained). Some work has been done with the organization on ordering and managing pickup and drop off locations for finished goods etc.	For areas of a supplier's facility that have a direct impact on the organization, a formal 5S program has been in place for at least one year. All area's have green areas with well kept and up to date KPI boards showing clear visual management of the area in terms of quality, cost and delivery. Shop floor personal are responsible for updating and maintaining the green area. Work cells or stations have mini communication boards to display local signals (Job cards, tally charting of local problems, area status etc). There is a place for everything and everything is in its place. It is clear on first impressions that the shop floor is well identified, well ordered, well lit and clean. The shop floor is has a clear method of showing how it is managed and a clear method for showing improvements. Extensive work has been done with the organization on ordering and managing pickup and drop off locations for finished goods etc.
Standardized work	Suppliers to the organization do not follow standardized work for parts, components etc they are adding value to for the organization. Each supplier has its own method when adding value to a particular component or part	The organization has given suppliers standard operating procedures (SOP's) to add value to parts or components. There is little evidence that these SOP's are being followed. Standardized work for inspecting and delivering components has not yet been developed.	The supplier makes active use of SOP's given to it from the organization for adding value to parts or components. There are regular review meetings to ensure that these SOP's are being adhered to. SOP's exist and are in active use for inspection and delivery operations. The supplier has its own method for managing and controlling SOP infrastructure and either has its own method, or has used the organization's method, to develop their own internal SOP's.	The supplier ensures at all times that the SOP's for adding value to a part or components are in use. There is a regular review meeting of SOP's between the supplier and the organization whereby adherence to SOP's are checked and improvements are made both by the supplier and the organization. Supplier teams have an active role in updating SOP's between the supplier and the organization. SOP's are developed and actively revised for delivery and inspection processes. Standard work is in place for key inspection and supplier development team members to ensure that regular standardized tasks between the organization and supplier are taking place.

Process focus	There is no clear strategy for in-sourcing and outsourcing parts or components. Suppliers are selected primarily based on price and suppliers can be used either to supply or to perform value added work on a component (through sub contracting) on short notice. There are a large number of similar suppliers and the flow of products both between suppliers and from suppliers to the organization is chaotic. Supplier facilities are not organized along the organization's products and most resemble Job shops	A strategy for in-sourcing and outsourcing has been developed and suppliers have been rationalized. Changes in supply of a part or product is controlled and only conducted in emergencies. A clear supply chain map has been conducted on the supply of products through suppliers and this map has been converted into a product process map. Some early work has started with suppliers on re-aligning their Job shops into customer specific value streams. Supplier delivery schedules have been arranged and deliveries are made more frequently and evenly spread over the month.	A strategy for in-sourcing and outsourcing has been entrenched for at least 6 months. Suppliers have been fully rationalized and the amount of business they receive is based on supplier scorecard that is reviewed annually and measures not only cost but also quality, delivery and the ability to be part of the development of the organization. Supplier's facilities have been significantly aligned into product value streams and standard buffer stocks (SIPS) are in place for locations between operations within the supply base. Suppliers are managed through a consistent, regular delivery schedule and problems between supplier release and delivery are managed by teams from both the supplier and the organization.	A strategy for in-sourcing and outsourcing has been entrenched for at least 6 months. Suppliers have been rationalized and have formed into a fully co-operative supplier association network. Supplier's facilities have been completely re-organized along product specific value streams and where large immovable equipment is concerned, the capacity of such machines has been dedicated along product value stream with SIPS queues before each machine and a sequenced Heijunka process in place. Supplier delivery and production schedules are monitored by both the organization and the supplier with the emphasis on deliveries based on a TAKT time. Deviation from the TAKT time is investigated and reduced.
Continuous Improvement	Suppliers are not involved in any kaizen activity. Improvements made with suppliers are handled either by process specialists or by regular management teams through meeting minutes etc. Supplier kaizen projects are not part of any kaizen plan.	A few supplier kaizens have been included in the organization's kaizen plan. A small number of supplier based kaizen activities have been conducted involving key personal from the organization and the supplier. Kaizens are not well structured and little feedback is given either to the organization or other suppliers. Relatively few suppliers personal that interact with the organization on a regular basis have participated in continuous improvement training or kaizen events.	Supplier kaizen events feature significantly in the organization's kaizen plan. Supplier based kaizens are well planned, structured and clearly link to the organizations critical success factors. A large amount of supplier personal that interact with the organization on a regular basis have been trained in continuous improvement methods. Feedback from supplier based kiazens is formal and attended by management of both the supplier and of the organization.	Supplier kaizen events have been entrenched in the organization's kaizen plan for over 1 year. Supplier based kaizens are well planned, executed and involve a diverse range of cross functional teams from both the supplier and the organization. Supplier kiazen is actively driven by management of both the supplier and the organization and feedback is formally presented to both teams on a regular basis. Most employees from suppliers that interact with the organization on a regular basis have received training in continuous improvement methods. It can be shown that supplier based kaizens have significantly improved organization critical success factors.

Process control	There is no clear supply chain strategy in place, which is used to drive sustainable processes for development, interaction, delivery from and analysis of suppliers. Orders are made erratically and in-sourcing and outsourcing decisions are made based on short term planning. Communal supplier problems are not assessed or known. No process control techniques have been applied to suppliers to ensure consistency in quality, cost and delivery. There has been no risk analysis done on key supplier processes to identify error proofing opportunities and contingency plans. Key supplier teams have had no exposure to process control techniques.	An overall supply chain strategy exists and is used to drive processes for the development, interaction between, delivery from and analysis of supplier performance. This takes the form of a supplier association forum, supplier scorecards and structured performance reviews. The quality of the processes is not high though and most processes are new to the supplier base. Quality, cost and delivery performance is still inconsistent and there is little structured understating of root causes for supplier variation and programs in place to improve control. A risk analysis has been done on key supplier processes to identify error proofing opportunities and contingency plans but these have not been realized yet. Key supplier teams have been introduced to process control techniques through examples etc.	An overall supply chain strategy exists and is used to drive processes for the development, interaction between, delivery from and analysis of supplier performance. Supplier association forums, supplier scorecards and structured performance reviews are entrenched. The quality of the processes is fair with variation for quality, cost and delivery performance known. A structured framework for the monitoring and correction of out of control supplier processes exists and has been able to reduce supplier variation in quality, cost and delivery. A risk analysis has been done on key supplier processes to identify error proofing opportunities and contingency plans. A fair portion of these have been realized. Key supplier teams have been trained process control techniques.	An overall supply chain strategy is well entrenched and is used to drive processes for the development, interaction between, delivery from and analysis of supplier performance. Supplier association forums, supplier scorecards and structured performance reviews have been in place for one year. The quality of the processes is fair with variation for quality, cost and delivery performance known. A structured framework for the monitoring and correction of out of control supplier processes exists and has been able to reduce supplier variation in quality, cost and delivery. A risk analysis has been done on key supplier processes to identify error proofing opportunities and contingency plans. Most of these have been realized. Key supplier teams are well practiced in process control techniques.
Quick Changeover	The supplier makes and delivers in large batches to support economic order quantity calculations and management accounting recoveries. There is lots of WIP in and around the supplier's facility. There have been little or no Single Minute Exchange of Die (SMED) activities to substantially reduce batch size within the supplier base.	The concept of making in smaller lots to improve lead time and flexibility is well understood by supplier management and key teams but SMED activities have not substantially reduced batch sizes. Key supplier teams have received training on quick changeover methods and where no major effort is required, batch sizes have been reduced (eg in warehousing, assembly, delivery and order processes).	Batch sizes made and delivered from suppliers are small relative to industry standards thanks to work done by quick changeover teams on implementing SMED for key equipment. Planning and scheduling in the supplier base is done to support small batch sizes and equipment is purposely modified to run in fixed, small batch sizes (eg long production lines have been segmented into smaller, more flexible production lines). There is relatively little WIP in and around a supplier's facility and where there is WIP, the WIP has been designated into fixed spaces (indicating batch sizing has been taken into account). Suppliers are delivering in smaller, more frequent batches rather than in large fixed deliveries made to support transport requirements.	Batch sizes made and delivered by suppliers are very small relative to industry standards thanks to work done by quick changeover teams on implementing SMED for key equipment. Planning and scheduling is done to support small batch sizes or single piece flow and equipment is purposely modified to run in fixed, small batch sizes (eg long production lines have been segmented into smaller, more flexible production lines). There is hardly any WIP in and around a supplier's facility and where there is WIP, the WIP has been designated into fixed spaces (indicating batch sizing has been taken into account). For processes that are closely linked (such as in manufacturing cells etc) single piece flow is clearly evident and this is widespread across the supply base. Suppliers make regular deliveries of small, mixed batches or single units.

Total Productive Maintenance	There is little or no understanding of critical process equipment in the supply base and suppliers have not communicated which equipment is key to their supply capability. Equipment breakdowns are regularly used as reasons for poor quality, cost and delivery performance.	Key process critical equipment has been identified and agreed upon among the supply base and the organization. Availability rates for this equipment are known and communicated on request from the organization. Contingency plans are in place among suppliers to ensure supply should key process critical equipment breakdown. Availability of equipment is less than 80% and little work has been done by the organization and suppliers to increase the availability, performance and quality of process critical machinery. Key supplier personal have been trained in the principals of Total Productive Maintenance (TPM). Key process critical machinery is generally utilized to such an extent that less than 5% reserve capacity is available to handle demand fluctuations.	Key process critical equipment (including delivery and transport equipment) has been well identified and agreed upon among the supply base and the organization (typically through the supplier association forum). Crises control plans are known and agreed among suppliers. The availability of this equipment has been improved to over 90% and through measures such as Overall Equipment Utilization (OEE) key reasons for poor process critical equipment availability, performance and quality are known and have been improved by well trained supplier and organization teams to produce a 15% reserve margin in capacity.	Key process critical equipment (including delivery and transport equipment) has been well identified and agreed upon among the supply base and the organization (typically through the supplier association forum). Crises control plans are well known and agreed among suppliers. The availability of this equipment has been improved to over 99% and through measures such as Overall Equipment Utilization (OEE) key reasons for poor process critical equipment availability, performance and quality are known and have been improved by well trained supplier and organization teams to produce a 20% reserve margin in capacity. The culture of ensuring continuous uninterrupted supply from key suppliers through TPM has been widely entrenched.
Material Control	Suppliers have not been trained in the principals of Pull systems. ERP orders generate supplier demand, Lead times are variable and there is no distinction between runner, repeater and stranger demand. There are no standard stocks of finished goods and the suppliers generally make to order.	Suppliers have received training on pull systems and understand the concepts of make to stock and make to order kanban systems. A long term contract of understanding (under the umbrella of a stable supply chain model) is in place for make to stock kanban suppliers and the organization to ensure a long term relationship and trust. An analysis has been conducted or Type A,B and C inventory (Cost) and Runners Repeaters and Strangers (Volume) to identify inventory suitable for kanban systems, 2-bin systems and make to order parts. A primary sole supplier has been dedicated for make to stock kanban for each item as well as a backup supplier. At least 20% of make to stock kanban items have been placed on a pull system and taken off the ERP ordering process, “Manual” kanbans in the form of electronic data exchange links etc are used to generate supplier demand. There is a clear line of traceability from the physical movement of stock generating a	Suppliers clearly understand the mechanisms and benefits of pull systems. Long term contracts are in place to ensure stability of make to stock kanban systems. Demand and capacity data is freely shared between suppliers and the organization and kanban teams from suppliers and the organization meet regularly in a structured process to discuss demand and capacity data. At least 60% of make to stock items have been placed on either kanban or 2 bin systems. Suppliers have required standard in process stocks (SIPS) in place to ensure consistent supply. Blanket orders are placed on suppliers to secure capacity and items are called off from suppliers as parts of the standard replenishment processes. Order times between the organization and the supplier have been analyzed and improved to dramatically shorten lead time. Orders on suppliers are placed based on point of use movement of the organizations inventory. Supplier performance is comprehensively managed	The system of supplier kanban management is well entrenched and suppliers have been operating on a kanban system for over one year. Long term kanban contacts are firmly in place and suppliers have well balanced and structured SIPS to maintain stock levels. Order times from the organization to the supplier have been reduced to almost nothing (they are almost instantaneous). Demand and capacity data is shared real time between suppliers and the organization and supplier representatives are on site regularly to receive and review kanban performance. All make to stock kanban’s have been implemented between the organization and the supplier. A large number of make to order kanban’s have been implemented between the organization and the suppliers. The organization and suppliers meet in a structured process to ensure dedicated capacity (though blanket ordering) and deliveries are regular and

		replenishment signal to the supplier getting that signal. Lead times for make to stock kanban items have been agreed and fixed. A system is in place for measuring and managing make to stock kanban supplier performance.	and joint programs are in place to improve performance. Large infrequent deliveries have been replaced by regular "milkrounds" where applicable.	structured through the use of milkrounds or other consistent processes.
Leveling	There is no leveling of demand from the organization to the suppliers. Demand is typically in the form of units and is released onto suppliers in batches of varying value or size. Regular capacity reviews with suppliers are not conducted to determine if scheduled demand exceeds supply capacity. Suppliers have not been trained on the concepts and benefits of leveling.	Suppliers have been trained on the concepts and benefits of leveling. For each supplier their short term capacity is known in available buckets of hours and orders released on suppliers are done so in terms of hour's worth of work. Excess order demand is leveled to ensure consistent supply.	The concepts of leveling and their benefits are well understood by suppliers. For each supplier a regular review of available hours is conducted and demand placed on suppliers is leveled to available hours. Furthermore the mix of product demand is also leveled as to ensure a consistent supply of runner, repeater and stranger products. The concepts of TAKT time and Total Actual Cycle Time (TACT) are understood and some suppliers have started producing a regular mix of products in a fix time cycle based on shared average usage data despite actual localized demand in order to bring consistency to their production (Every Part Every…(EPE) orders). There is a process in place to handle true demand spikes (wild card orders)	The process of leveling is firmly entrenched in the supply base. Suppliers understand the TAKT times for the mix of products they supply and strictly monitor the delivery of products to those TAKT times. There is regular focus on current TAKT times versus supplier average TACT times and processes are re-balanced or leveled to ensure adherence to TAKT time. EPE orders are regularly used as a means of production. The wild card process is firmly entrenched to handle true demand spikes.

Design for Simplicity	Suppliers are not involved in any product development or design decisions. They typically receive manufacturing drawings and are asked to quote for manufacture. They have no input into drawing or manufacturing method. There is no capability for either methoding or product design within the supplier base	Suppliers are involved in a basic process to review the method of manufacture of products but are not involved in the design of products. They receive manufacturing drawings of components and are asked to quote based on their own method of manufacture. Suppliers possess rudimentary engineering staff to assist with designing the best method of manufacture.	Suppliers are involved with the organization in both the product and design and manufacturing method. They receive a basic functional description of the part and work with in-house manufacturing teams to come up with a suitable design and method of manufacture. So called "black box" engineering is used and for products with complex BOM's, sub assemblies are typically outsourced to suppliers for redesign and manufacture. Suppliers have design teams with a fair amount of capability to work with in-house teams on product designs. Legal agreements are in place to facilitate supplier and organization design relationships.	Suppliers are deeply involved with the organization in the design and manufacture of sub assemblies and products. Supplier design teams work actively with the organization to develop designs and manufacturing methods. Supplier design teams have access to organization BOM's to ensure no new part numbers are created unless there is no alternative. Suppliers have sophisticated design teams able to take complete control of product design and manufacture. Legal agreements and mutual understandings are used to enable and foster an environment where suppliers are actively involved in the design and manufacture of products.
Specific Best practice	Insert industry or company specific best practice guides here	Insert industry or company specific best practice guides here	Insert industry or company specific best practice guides here	Insert industry or company specific best practice guides here

Scope 4: Branch distribution networks and customers

Lean Characteristic	Level 1	Level 2	Level 3	Level 4
Policy Deployment	No customer involvement in the Policy deployment process. Policy deployment and organizational objectives are inward looking only. There are no projects linked specifically to interacting with customers	No customer or distribution network involvement in the Policy deployment process. Policy deployment and organizational objectives are inward looking only. There are no projects linked specifically to interacting with customers or distribution networks	Projects mentioned in the organization's Policy Deployment process are specific to customer and distribution network, scope and objective. The distribution network (Branches, Dealerships etc) have formalised Policy deployment processes that are directly linked to the organization's Policy deployment objectives. Project tracking data is shared and recourses are agreed between the Distribution network and the organization. Customers are aware of the organization's policy deployment process and have been involved in setting objectives through either a survey or some other form of customer feedback.	Policy Deployment has been active in the branch distribution and customer network for at least two years. Projects mentioned in the organization's Policy Deployment process are specific to customer and distribution network, scope and objective. The distribution network (Branches, Dealerships etc) have formalized Policy deployment processes that are directly linked to the organization's Policy deployment objectives and improvement can be shown for previous Policy Deployment Objectives. Project tracking data is shared and recourses are agreed between the Distribution network, the organization and selected customer teams. Customers are actively involved in projects with the organization and in the policy deployment process
Cultural Awereness	Customers and sales representative from the branch distribution network are not aware of the organizational structure, their objectives and how they can contribute to those objectives. There is little interaction with customers and distribution network team outside of the sales department and customers as well as branch distribution network teams are not commonly known to organizational employees. There is no attempt from the organization to understand the structure, management and improvements taking place at customers and the branch distribution network.	There are regular meetings in place with customers and branch distribution network teams and infrequent meetings outside of the sales office. Often only key customers and branch distribution network personal visit the organization. Customers and branch distribution network teams have an understanding of the organizational objectives but little understanding of how they can contribute to those objectives. Higher level employees understand who the customers and branch distribution network teams are and a fair amount of middle managers understand the structure, management and improvements taking place at customers and branch distribution networks.	There are regular meetings in place outside of the sales department and customers and branch distribution network personal have the ability to view and understand the organizational daily accountability process. Customers and branch distribution network teams are clear on the company objectives and how they contribute to those objectives. Customers and branch distribution network teams have some access to company demand and capacity data on request. A fair amount of employees (both office and manufacturing based) understand the customer and branch distribution network s structure, management and improvement. Some lower level customer and branch distribution network teams are part of the daily accountability process at the organization.	Customer and branch distribution network team's involvement in the daily accountability process of the organization is entrenched and understood by all. Selected customers and branch distribution network teams have a semi-permanent presence at the organization with the sole function of sharing demand and capacity data and to solve cross functional problems. Senior management for both the customers, branch distribution network teams and the organization share a common set of objectives and actively work to build cross functional bridges between the customers, the distribution network and the organization.

Visual Management and housekeeping	First impressions of a branch or distribution network facility are that of disorder and chaos. For area's that have a direct impact on the organization, there is no identification of territory, no visual way to understand how the territory is being managed and no visual way to understand how it is being improved. The shop floor is cluttered and it is hard to move about. This applies to consignment stores located on customer's premises as well.	For a branch or distribution network facility there is evidence that clutter has been removed from the shop floor and only parts needed are on the floor. Basic team communication boards are in place with graphs that show actual performance against target. Walkways and isles are demarcated and generally clear of waste. There are signs identifying the area and operators are involved in the daily housekeeping process.	For a branch or distribution network facility, the shop floor is neat, identified and ordered. There is a visual display of how the area is managed (tracking charts etc) and being improved (tally charts showing defects etc). The area team is identified and there is a clear green area for all main visual boards, showing relevant KPI's in a structured manor (typically with heading like quality, cost, delivery, improvements, the team etc). A formal 5S program is in place and the area is neat, with demarcations for tools, equipment and WIP. Tools are ordered through the use of Shadow boards or a similar process of identifying them. The area is generally well lit and well kept (equipment, floors, workbenches etc all shine and look well maintained). Work has been done with customers and the organization to visually manage and order drop off and delivery locations.	For a branch or distribution network facility, a formal 5S program has been in place for at least one year. All area's have green areas with well kept and up to date KPI boards showing clear visual management of the area in terms of quality, cost and delivery. Shop floor personal are responsible for updating and maintaining the green area. Work cells or stations have mini communication boards to display local signals (Job cards, tally charting of local problems, area status etc). There is a place for everything and everything is in its place. It is clear on first impressions that the shop floor is well identified, well ordered, well lit and clean. The shop floor is has a clear method of showing how it is managed and a clear method for showing improvements. There is evidence of extensive work with customers and the organization to visually manage and order drop off and delivery locations.
Standardized work	There is no evidence of standardized work anywhere on the shop floor of a distribution network branch. Operators and supervisors mostly follow their own method of working. On the Job skills are typically gained informally through loose mentorships with experienced operators	For a distribution network branch standardized work templates and Standard Operating Procedures (SOP) have been developed. These are largely up to date and kept active. When starting a new Job Operators will use the SOP to receive training through the facilitation of a fully trained Operator. SOP's cover key tasks only and not out of production work such as changeovers, housekeeping and emergency escalation procedures. In-production work related SOP's do not contain standard cycle times. There is no system to regularly audit and update SOP's. SOP's show little evidence of revision and improvement.	For a distribution network branch SOP's have been developed, are up to date and show an active revision history. Operators and Supervisors alike use the SOP's as a basis for training and improvement. It is well understood that standardized methods are the only way for producing sustainable improvement. Standard times have been applied to key SOP's. The concept of Standardized work has also been developed for Supervisors and Managers, who known what standard tasks they must complete daily and what standardized work they need to complete. Training Matrices linked to SOP's are clearly in use. Customers have been involved in standardizing delivery, inspection and payment processes. Delivery and distribution processes between the organization and the distribution network branches have also been standardized.	For a distribution network branch the process of developing, publishing and revising SOP's is fully entrenched. The quality of the SOP's is such that they are clear to understand, have standard times (for key production processes) and show who must do what by when. The concept of standardized work is fully entrenched. Supervisors and Managers alike can all show their standard tasks for the day and there is a process to ensure that Leader standard work is being followed. Training matrices are in active use with development actions and timing for those not yet trained on key SOP's. Standardized processes have been developed for delivery and inspection of finished goods both between the branch network and customers and between the branch network and the organization. The branch distribution network has active access to all

				organization SOP's. Customers have been involved in revising customer related SOP's.
Process focus	Work tasks are grouped functionally at branch distribution networks. There is no control of WIP or partially completed Jobs. Operators are specialized and no cross training exists. Targets and Metrics are results centered. Jobs are processes in large batches based on availability of components or labour. Branch structures are based on functions rather than customer orientation.	For repair, exchange and delivery with the branch distribution network, a product, process grouping has been conducted and a few work centers have been reorganized around value streams. This also applies for the subcontracting of service and repair processes. Where possible equipment has been right sized and operators have begun cross training on a variety of operations across value streams. Management is still results centered but there are actual versus target graphs for repetitive operations. It can also been shown that an analysis on the location and service map of distribution networks has been done with involvement of key customers in order to reduce (rationalize) the variety and number of branch distribution centers. There has been work on the creation of regional hubs to service and hold inventory for smaller, more mobile service centers.	For repair, exchange and delivery with the branch distribution network processes are largely grouped by value stream. This includes administrative functions within the branch distribution network. For functions that are grouped into a cluster due to rationalization of personal and equipment (such as the grouping of communal administrative tasks into a regional hub to increase labour utilization) it can be shown that the cluster is divided by value stream or that the principals of Heijunka are applied to the cluster in order to bring consistency into the process. The branch distribution network has been largely rationalized, with regional hubs feeding small light service centers. It can be shown that logistics have been simplified and travel distances have been substantially reduced through the process.	For repair, exchange and delivery with the branch distribution network processes are mainly grouped by value stream. This includes administrative functions within the branch distribution network. The idea of value stream clusters is entrenched within the branch distribution network. Operators are mostly cross trained and there is a formal development program in place to encourage cross training. Branch networks have been fully rationalized and the creation of value stream centered distribution networks has been in place for over 1 year. Management of service repair jobs is processes focused with TAKT times determining the pace of operations. Variations from TAKT time are reported and reduced through management of the process. Equipment and Operators are fully flexible. There is a significant amount of interaction with customers to tailor distribution and repair process to specific customer needs across value streams.

Continuous Improvement	Branch and distribution networks and customer teams are not involved in any kaizen activity. Improvements made with Branches and key customers are handled either by process specialists or by regular management teams through meeting minutes etc. Branch and distribution networks and customer team kaizen projects are not part of any kaizen plan.	A few branch and distribution networks and key customer kaizens have been included in the organization's kaizen plan. A small number of branch and distribution networks and customer based kaizen activities have been conducted involving key personal from the organization and branch distribution teams. Kaizens are not well structured and little feedback is given either to the organization or to branch and distribution networks and customers. Relatively few branch and distribution networks and customer personal that interact with the organization on a regular basis have participated in continuous improvement training or kaizen events.	Branch and distribution networks and key customers kaizen events feature significantly in the organization's kaizen plan. There is significant involvement from key customers and not just employees from branch distribution networks. Branch and distribution networks and customers based kaizens are well planned, structured and clearly link to the organizations critical success factors. A large amount of branch and distribution networks and key customers personal that interact with the organization on a regular basis have been trained in continuous improvement methods. Feedback from branch and distribution networks and customers kiazens is formal and attended by management of both the branch network, customers and of the organization.	Branch and distribution networks and key customers kaizen events have been entrenched in the organization's kaizen plan for over 1 year. Branch and distribution networks and customers kaizens are well planned, executed and involve a diverse range of cross functional teams from the branch network, the customer and the organization. Branch and distribution networks and customers kiazen is actively driven by management of branch networks, the customer and the organization and feedback is formally presented to all management teams on a regular basis. Most employees from the branch networks and a fair amount from key customers that interact with the organization on a regular basis have received training in continuous improvement methods. It can be shown that branch and distribution networks and customer kaizens have significantly improved organization critical success factors.
Process control	There is no clear distribution strategy in place, which is used to drive sustainable processes for development, interaction, delivery to and analysis of branch distribution networks and customer performance. Orders are shipped erratically and distribution network and branch location decisions are made based on short term planning. Communal branch and customer problems are not assessed or known. No process control techniques have been applied to branch distribution networks to ensure consistency in quality, cost and delivery to the customer. There has been no risk analysis done on key distribution processes to identify error proofing opportunities and contingency plans. Key branch teams have had no exposure to process control techniques.	An overall distribution strategy exists and is used to drive processes for the development, interaction between, delivery to and analysis of branch distribution networks and customer performance. This takes the form of a branch and distribution association forum, branch performance scorecards and structured performance reviews. The quality of the processes is not high though and most processes are new to the distribution network base. Quality, cost and delivery performance is still inconsistent and there is little structured understating of root causes for variation within the branch distribution network or programs in place to improve control. A risk analysis has been done on key branch distribution processes to identify error proofing opportunities and contingency plans but	An overall distribution strategy exists and is used to drive processes for the development, interaction between, delivery to and analysis of branch distribution networks and customer performance. Branch association forums, branch performance scorecards and structured performance reviews are entrenched. The quality of the processes is fair with variation for quality, cost and delivery performance known. A structured framework for the monitoring and correction of out of control branch and distribution processes exists and has been able to reduce variation in quality, cost and delivery throughout the distribution network. A risk analysis has been done on key distribution processes to identify error proofing opportunities and contingency plans. A fair portion of these have been realized. Key branch teams	An overall distribution strategy exists and is well entrenched and is used to drive processes for the development, interaction between, delivery to and analysis of branch distribution network performance. Branch network association forums, branch network scorecards and structured performance reviews have been in place for one year. The quality of the processes is fair with variation for quality, cost and delivery performance known. A structured framework for the monitoring and correction of out of control supplier processes exists and has been able to reduce supplier variation in quality, cost and delivery. A risk analysis has been done on key supplier processes to identify error proofing opportunities and contingency plans. Most of these have been realized.

		these have not been realized yet. Key branch teams have been introduced to process control techniques through examples etc.	have been trained process control techniques.	Key branch teams are well practiced in process control techniques.
Quick Changeover	Dispatch through the branch and distribution network is in large batches to support economic order quantity calculations and management accounting recoveries. There is lots of WIP in and around the a branches facility or distribution node. There have been little or no Single Minute Exchange of Die (SMED) activities to substantially reduce batch size within the supplier base.	The concept of making in smaller lots to improve lead time and flexibility is well understood by branch and distribution network management and key teams but SMED activities have not substantially reduced batch sizes. Key branch teams have received training on quick changeover methods and where no major effort is required, batch sizes have been reduced (eg in warehousing, delivery and order processes).	Batch sizes made and delivered within the branch and distribution network are small relative to industry standards thanks to work done by quick changeover teams on implementing SMED for key equipment. Planning and scheduling in the branch and distribution network is done to support small batch sizes and equipment is purposely modified to run in fixed, small batch sizes. There is relatively little WIP in and around a branch or distribution facility and where there is WIP, the WIP has been designated into fixed spaces (indicating batch sizing has been taken into account). Deliveries to branches and the customer are in smaller, more frequent batches rather than in large fixed deliveries made to support transport requirements.	Batch sizes made and delivered throughout the branch and distribution network are very small relative to industry standards thanks to work done by quick changeover teams on implementing SMED for key equipment. Planning and scheduling is done to support small batch sizes or single piece flow and equipment is purposely modified to run in fixed, small batch sizes. There is hardly any WIP in and around a branch or distribution facility and where there is WIP, the WIP has been designated into fixed spaces (indicating batch sizing has been taken into account). For processes that are closely linked, single piece flow is clearly evident and this is widespread across the supply base. In most cases there are regular deliveries of small, mixed batches or single units to the distribution network and the customer.

Total Productive Maintenance	There is little or no understanding of critical process equipment in the branch and distribution network and branches or distribution network nodes have not communicated which equipment is key to their delivery capability. Equipment breakdowns are regularly used as reasons for poor quality, cost and delivery performance to the customer.	Key process critical equipment has been identified and agreed upon among the branch and distribution network and the organization. Availability rates for this equipment are known and communicated on request from the organization. Contingency plans are in place among branches and distribution networks to ensure supply should key process critical equipment breakdown. Availability of equipment is less than 80% and little work has been done by the organization and the branch distribution network to increase the availability, performance and quality of process critical machinery. Key branch or distribution network personal have been trained in the principals of Total Productive Maintenance (TPM). Key process critical machinery is generally utilized to such an extent that less than 5% reserve capacity is available to handle demand fluctuations.	Key process critical equipment (including delivery and transport equipment) has been well identified and agreed upon among the branch and distribution networks and the organization (typically through the branch association forum). Crises control plans are known and agreed among branches and distribution networks. The availability of this equipment has been improved to over 90% and through measures such as Overall Equipment Utilization (OEE) key reasons for poor process critical equipment availability, performance and quality are known and have been improved by well trained branch distribution network and organization teams to produce a 15% reserve margin in capacity.	Key process critical equipment (including delivery and transport equipment) has been well identified and agreed upon among the branch and distribution networks and the organization (typically through the branch association forum). Crises control plans are well known and agreed among branches and distribution networks. The availability of this equipment has been improved to over 99% and through measures such as Overall Equipment Utilization (OEE) key reasons for poor process critical equipment availability, performance and quality are known and have been improved by well trained branch distribution network and organization teams to produce a 20% reserve margin in capacity. The culture of ensuring continuous uninterrupted distribution of products and services to customers through TPM has been widely entrenched.
Material Control	Branch and distribution networks have not been trained in the principals of Pull systems. ERP orders generate demand from branch and distribution networks, Lead times are variable and there is no distinction between runner, repeater and stranger demand. There are no standard stocks of finished goods in the branch and distribution networks.	Branch and distribution networks have received training on pull systems and understand the concepts of make to stock and make to order kanban systems. An analysis has been conducted or Type A,B and C inventory (Cost) and Runners Repeaters and Strangers (Volume) to identify inventory suitable for kanban systems, 2-bin systems and make to order parts. At least 20% of make to stock kanban items have been placed on a pull system and taken off the ERP ordering process, “Manual” kanbans in the form of electronic data exchange links etc are used to generate demand from the branch and distribution networks. There is a clear line of traceability from the physical movement of stock generating a replenishment signal to the organization getting that signal. Lead times for make to stock kanban items have been agreed and fixed. A system is in	Branch and distribution networks clearly understand the mechanisms and benefits of pull systems. Demand and capacity data is freely shared between the branch and distribution networks and the organization and kanban teams from the branch and distribution networks and the organization meet regularly in a structured process to discuss demand and capacity data. At least 60% of make to stock items have been placed on either kanban or 2 bin systems. Branch and distribution networks have required standard in process stocks (SIPS) in place to ensure consistent supply. Order times between the organization and branch and distribution networks have been analyzed and improved to dramatically shorten lead time. Orders on the organization from the branch and distribution networks are placed based on point of use movement of inventory within the branch and distribution	The system of supplier kanban management is well entrenched and branch and distribution networks have been operating on a kanban system for over one year. Order times fro the branch and distribution networks to the organization have been reduced to almost nothing (they are almost instantaneous). The branch and distribution networks keep good control over their SIPS. Demand and capacity data is shared real time between the branch and distribution networks and the organization. Branch and distribution network representatives are on site regularly to receive and review kanban performance. All make to stock kanban’s have been implemented between the organization and branch and distribution networks. A large number of make to order kanban’s have been implemented between the organization and the branch and distribution

		place for measuring and managing make to stock kanban performance throughout branch and distribution networks.	networks. Delivery performance is comprehensively managed and joint programs are in place to improve performance. Large infrequent deliveries have been replaced by regular "milkrounds" where applicable. The organization has set in place standard finished goods areas where branch and distribution network milkrounds can call off stock.	networks. The organization and suppliers meet in a structured process to ensure dedicated capacity (through blanket ordering) and deliveries are regular and structured through the use of milkrounds or other consistent processes.
Leveling	There is no leveling of demand from the branch and distribution networks to the organization. Demand is typically in the form of units and is released onto the organization in batches of varying value or size. Regular capacity reviews with the organization and the branch and distribution network are not conducted to determine if scheduled demand exceeds supply capacity. Branch or distribution networks have not been trained on the concepts and benefits of leveling. Customers are not involved in the leveling process at all.	Branch and distribution networks have been trained on the concepts and benefits of leveling. For each Branch or distribution node their short term capacity is known in available buckets of hours and orders released onto the organization from them are done so in terms of hour's worth of work. Excess order demand is leveled to ensure consistent supply. Branches involve customers in the leveling process and there are basic reviews of current customer demand and supply capability held with customers.	The concepts of leveling and their benefits are well understood by the branch and distribution network. For each branch or distribution node a regular review of available hours is conducted and demand placed onto the organization from branch and distribution networks is leveled to available hours. Furthermore the mix of product demand is also leveled as to ensure a consistent supply of runner, repeater and stranger products to the branches and distribution networks. The concepts of TAKT time and Total Actual Cycle Time (TACT) are understood and some branches and distribution nodes have started ordering a regular mix of products in a fix time cycle based on shared average usage data despite actual localized demand in order to bring consistency to their supply to the customer (Every Part Every…(EPE) orders). There is a process in place to handle true demand spikes (wild card orders). Branches and distribution networks work the customer to try level demand.	The process of leveling is firmly entrenched in the branch and distribution networks. Branches and distribution nodes understand the TAKT times for the mix of products they order and strictly monitor the delivery of products to those TAKT times. There is regular focus on current TAKT times versus average TACT times from the organization and order processes are re-balanced or leveled to ensure adherence to TAKT time. EPE orders are regularly used as a means of order and supply throughout the branches and distribution networks. The wild card process is firmly entrenched to handle true demand spikes. Branches and distribution nodes work regularly with the customer to ensure consistency of demand and joint supply planning.

Design for Simplicity	Customers are allowed to order what they want through sales teams that are motivated by little other than commission. There is no consideration for what the organization is able to manufacture and for adding items onto the list of live part numbers available. The majority of products are made to order and contain specific customer customizations.	Basic rules are in place to prevent excessive customization of products by sales teams. Sales personal tendering on special projects requiring a large degree of customization are required to submit a comprehensive business plan in order to justify the additional complexity their products will provide.	There are well structured rules and control points in the order process to prevent and control orders so that there is little or no chance of uncontrolled customization in the order process. Special projects requiring customization undergo a special business review for approval or rejection. Sales personal are measured not only on commission. Sales personal are involved with the organization in identifying market opportunities for simplification and rationalization of products	There is a comprehensive set of order rules preventing uncontrolled customization in the order process. Special projects requiring customization undergo a special business review for approval or rejection. Sales personal are reviewed mainly on the amount of standard products they can sell. There is a well structured and regular review with sales personal to identify opportunities for simplification and rationalization of products and a significant number of products have been rationalized.
Specific Best practice	Insert industry or company specific best practice guides here	Insert industry or company specific best practice guides here	Insert industry or company specific best practice guides here	Insert industry or company specific best practice guides here

Sample of Lean Audit results

Lean Characteristic	Manufacturing Operations	Office environments	Supplier Networks	Customer and Distribution networks
Policy Deployment	Level 4	Level 2	Level 2	Level 3
Cultural Awareness	Level 1	Level 1	Level 4	Level 4
Visual Management and housekeeping	Level 4	Level 2	Level 4	Level 4
Standardized work	Level 3	Level 2	Level 1	Level 4
Process focus	Level 3	Level 2	Level 2	Level 1
Continuous Improvement	Level 2	Level 1	Level 1	Level 3
Process control	Level 1	Level 3	Level 4	Level 2
Quick Changeover	Level 3	Level 2	Level 1	Level 3
Total Productive Maintenance	Level 4	Level 3	Level 4	Level 4
Material Control	Level 2	Level 4	Level 2	Level 4
Level Production	Level 4	Level 2	Level 2	Level 1
Design for Simplicity	Level 2	Level 4	Level 1	Level 4
Specific Best practice	Level 1	Level 2	Level 2	Level 4